DOCKET 70-1151

NR-FM-013

ENVIRONMENTAL IMPACT APPRAISAL

of the

WESTINGHOUSE NUCLEAR FUEL COLUMBIA SITE (NFCS) COMMERCIAL NUCLEAR FUEL FABRICATION PLANT

COLUMBIA, SOUTH CAROLINA

APRIL 1977

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
DIVISION OF FUEL CYCLE AND MATERIAL SAFETY
WASHINGTON, D.C.

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1. INTRODUCTION

By letter dated August 28, 1974, Westinghouse requested renewal of their Special Nuclear Material License No. SNM-1107 covering the operations of the Westinghouse Nuclear Fuel Fabrication Plant at Columbia, South Carolina. In connection with the application for license renewal, the applicant submitted an Environmental Report (ER) titled "Environmental Evaluation for Westinghouse Nuclear Fuel Division, Columbia, South Carolina" on March 1975,[1] supplemented by further information submitted on October 12, 1976.

In connection with such license renewals, Part 51 of Title 10 of the Code of Federal Regulations requires that an environmental impact appraisal be performed to determine whether an environmental impact statement or a negative declaration will be prepared. Part 51 further states that the determination shall be guided by the Council on Environmental Quality Guidelines, 40 CFR 1500.6. In accordance with these regulations, the Division of Fuel Cycle and Material Safety (the staff) of the NRC initiated an assessment of the environmental impact of the proposed licensing action. Upon completion of the environmental impact assessment and evaluation of the findings, the staff independently prepared this appraisal on environmental considerations associated with the proposed licensing action in accordance with 10 CFR Part 51.5(b), implementing the requirements of the National Environmental Policy Act of 1969 and the President's Council of Environmental Quality Guidelines.

Because the facility is an operating plant and actual plant effluent releases have been monitored and are documented, this evaluation has addressed the most significant environmental indices. These relate to land use, demography, control of effluents, environmental monitoring, and accident potential.

1.1 DESCRIPTION OF THE PROPOSED ACTION

The proposed action for which this Environmental Impact Appraisal is performed is the routine renewal of the Commercial Nuclear Fuel Fabrication Plant operating license to provide for continuing operation and to evaluate environmental impacts of the proposed plant capacity expansion from 400 MTU/year to 1600 MTU/year. The facility has been an operating plant since September 1969 and was designed and constructed to fabricate low ($\leq$5.0 wt %)-enriched uranium fuel assemblies for use in light-water commercial power reactors. The operations of the plant include (1) conversion of uranium hexafluoride (UF_6) to uranium dioxide powder (UO_2), (2) processing the UO_2 powder into pellets, (3) encapsulation of the pellets into fuel rods, (4) fabrication of fuel rods into final assemblies, and (5) shipment of final assemblies to the customers' reactor sites. The license also authorizes the assembly of encapsulated mixed oxides (plutonium and uranium oxides, with $PuO_2 \leq 6.6$ wt % of the total oxide weight) fuel pins into fuel bundles. These sealed fuel pins are fabricated at another facility and shipped to the Columbia plant for final assembly. Because the mixed oxides are received as sealed sources, the fuel pins present no hazard to the environment.

The 400-MTU/year capacity described in the applicant's Environmental Evaluation Report as the present capacity refers to the situation up to the time when the preparation of the evaluation document was undertaken, that is, until about mid-1974. The various data presented in the evaluation are consistent with that time and that capacity. The production capacity of the plant has been increasing somewhat since then. According to the Environmental Evaluation Report, Westinghouse takes the position that since the existing fuel fabricating activities result in minimal environmental impact, and the environmental impacts extrapolated to this increased capacity of 1600 MTU/year are still conservatively small, continuing efforts to update the document are not warranted.

1.2 SUMMARY OF CURRENT STATUS

The original plant (including auxiliary facilities), with a design capacity of 400 MTU/year, was constructed on a 1158-acre site in 1969. Approximately 60 acres of the site have been developed, with the remainder composed of lake, woodland, swamp, and field.

There are plans to construct a separate 50,000-ft^2 building near the main plant to accommodate the fabrication of machined components for the 1600-MTU/year capacity. To facilitate this increase in capacity, additional chemical-conversion lines will be added within the confines of the existing 240,000-ft^2 main plant. The land that the expansion will occupy is presently covered with grass. Therefore, clearing and excavation of this land will have a negligible effect on the surrounding area.

The present liquid discharges from the plant of approximately 0.2 cfs to the Congaree River will increase to approximately 0.3 cfs with increased production to 1600 MTU/year. The average flow of the Congaree River is 9100 cfs, and the minimum seven-day average low flow to be expected in a ten-year period is 1590 cfs. The Congaree River meets applicable State and Federal water quality standards, except for ammonia. NFCS discharges into the Congaree currently are diluted sufficiently so that they constitute no significant effect on water quality, as quantified in Sect. 4.2.2.4. Allowable ammonia discharge waste limits are being reevaluated in cooperation with the regional Environmental Protection Agency, and corrective actions are being implemented.

REFERENCES FOR SECTION 1

1. Westinghouse Electric Corporation, Environmental Systems Department, *Environmental Evaluation for Westinghouse Nuclear Fuel Division, Columbia, South Carolina,* Docket No. 70-1151, Pittsburgh, Pa., Mar. 1, 1975. (This document is cited extensively throughout this Appraisal; however, its full title is given only in the list of references for Sect. 1. Elsewhere in this report, reference to this document will appear as ER, followed by a specific section, page, table, figure, or appendix.)

2. DESCRIPTION OF SITE ENVIRONMENT

This section presents basic information concerning the physical, biological, and human characteristics of the regional environment that might be affected by the operation of the Westinghouse Nuclear Fuel Division manufacturing plant near Columbia, South Carolina.

2.1 SITE LOCATION

The Nuclear Fuel Columbia Site (NFCS) is located in central South Carolina in Richland County. It is approximately 8 miles southeast of the Columbia city limits and is reached by South Carolina Highway 48. Nearby towns, industrial plants, public facilities, the Congaree River, and transportation links are shown in Fig. 2.1.

The site is bounded by Route 48 to the north, the Vestal Lumber Manufacturing Company property to the east, the Liberty Life Insurance Company property to the south, and the Burrel Manning property to the west.

The manufacturing plant facilities are located in the center of approximately 1158 acres of The fuel fabrication facilities, holding ponds, parking lot, and landscaped grounds occupy approximately 60 acres. Figure 2.2 shows the plant boundary and adjacent properties.

Figure 2.2 also depicts the elevations of the site. The plant floor is 142 ft above mean sea level (MSL). Plant-site-drainage flow follows original drainage patterns to Sunset Lake, Mill Creek, and the Congaree River.

The area around the site is primarily flat to the north and flat and swampy in other directions. Most of the unused portions of the site (approximately 1098 acres) will be left in its natural state.

2.2 DEMOGRAPHY

2.2.1 Resident population within 50 miles

A detailed breakdown of the 1970 population within a 50-mile radius of the NFCS plant is presented in Table 2.1. The population densities are summarized from Census Bureau tape records.

2.2.2 Resident population within 5 miles

The local population can be affected by plant operations and/or expansion through its exposure to the atmospheric effluents from the plant and to the negative effects of possible accidents at the plant.

A detailed analysis of the resident population distribution within a 5-mile radius of the plant was performed (ER, Figs. 2.2-2 through 2.2-5). The 1960 and 1970 population densities were estimated from census data[1-3] and from U.S. Geological Survey (USGS) topographic maps and projected through 1980 and 1990.

The total 1960 and 1970 populations within a 5-mile radius of the plant are 4116 and 5310 respectively. The maximum population densities occur in areas northwest and east-southeast of the plant site.

Population densities within the area under study were also projected for 1980 and 1990. These projections, based on data published by the Central Midlands Regional Planning Council,[4] are 6953 for 1980 and 16,501 for 1990. These projections indicate an estimated 30.9% increase in population from 1970 to 1980 and a 211% increase from 1970 to 1990 for the 78.5-sq-mile area under consideration.

In the northeast sector, population density increases with distance from the NFCS. In 1970, the population density was 26 per sq mile, 77 per sq mile, 126 per sq mile, 140 per sq mile,

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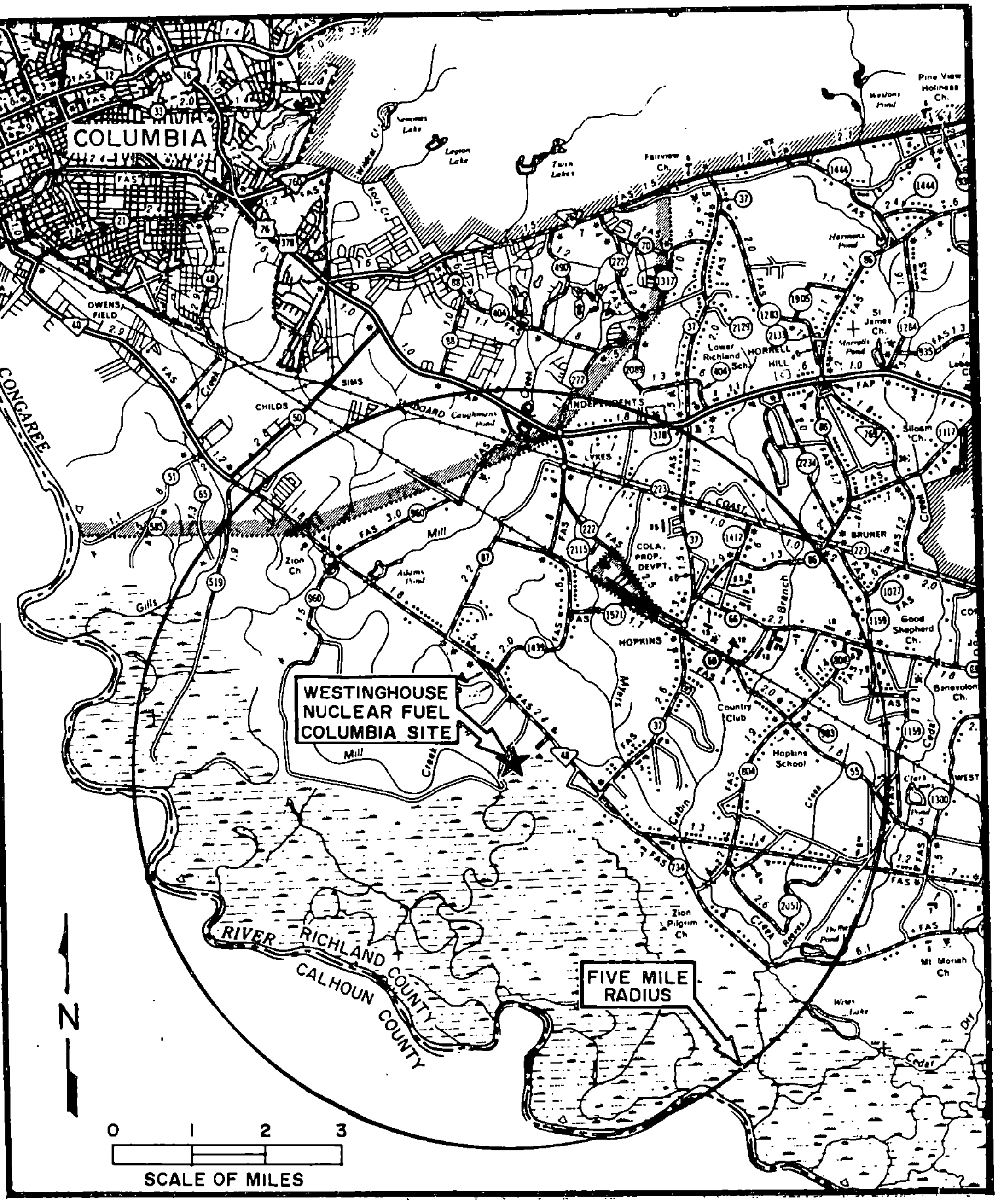

Fig. 2.1. NFCS location. Source: ER, Fig. 2.1-1.

and 158 per sq mile within the 180° sector covered by the 0- to 1-mile, 1- to 2-mile, 2- to 3-mile, 3- to 4-mile, and 4- to 5-mile radii, respectively, from the plant site. Comparable 1980 and 1990 projections indicate population growth will continue to be greater at increasing distance from the NCFS.

The transient population is similarly sparse and favorably distributed in the same 180° compass sector. All schools are over 3 miles away, and only one of 13 businesses with more than 5 employees is less than 3 miles from the NFCS. Based on the assumptions presented in the ER, p. 2.2-7, the total student body and school staff from the three public schools in the study

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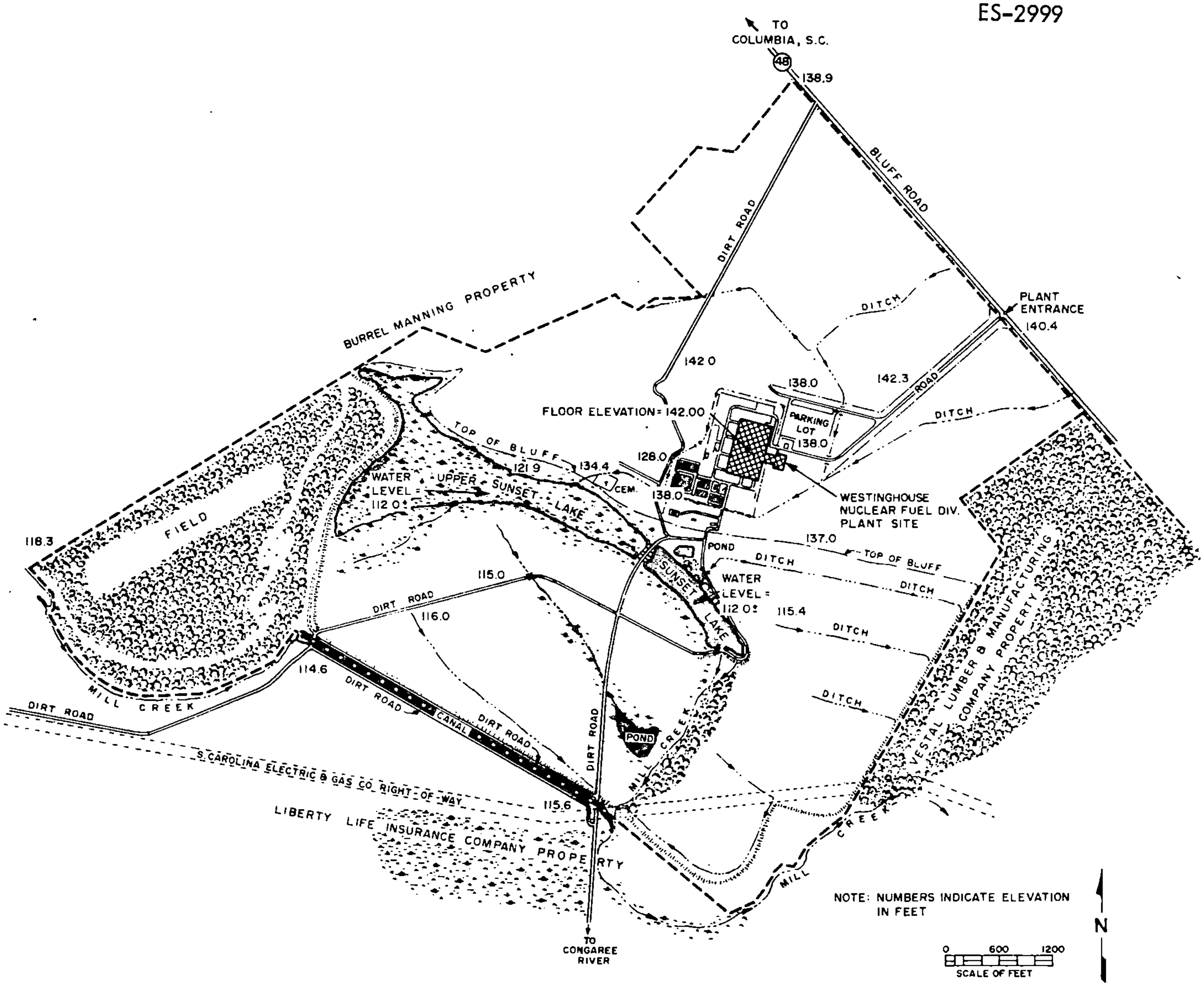

Fig. 2.2. NFCS property. Source: ER, Fig. 2.1-2.

Table 2.1. Population distribution surrounding Westinghouse Nuclear Fuel Site, Columbia, South Carolina (1970 Census)

Sector	Distance (miles)									
	0–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
N	0	0	0	0	137	28,547	19,986	4,490	722	6,433
NNE	0	0	0	0	0	1,315	1,680	5,498	4,738	5,201
NE	0	0	0	1,329	0	1,604	0	2,505	14,979	5,224
ENE	0	0	0	0	0	0	961	13,770	6,273	10,634
E	0	0	0	0	0	2,558	2,384	9,913	43,901	6,165
ESE	0	0	0	0	0	1,363	1,395	2,834	6,823	8,628
SE	0	0	0	0	0	0	848	1,815	5,107	10,960
SSE	0	0	0	0	0	0	4,750	2,543	6,826	4,085
S	0	0	0	0	0	0	2,024	28,263	6,455	6,459
SSW	0	0	0	0	0	965	954	4,751	4,153	10,253
SW	0	0	0	0	0	0	2,539	2,111	3,791	5,100
WSW	0	0	0	0	0	0	1,754	924	3,340	5,950
W	0	0	0	0	0	2,769	3,535	3,818	10,753	7,456
WNW	0	0	0	0	0	1,994	25,231	5,189	3,477	7,143
NW	0	0	0	0	1,263	24,138	58,227	5,503	5,803	9,679
NNW	0	0	0	454	372	31,683	74,612	2,460	9,382	3,868
Total	0	0	0	1,783	1,772	96,936	200,880	96,387	136,523	113,238

area increases the overall population by 17% (898 school personnel in addition to 5310 area residents) each day school is in session. Two out of three school persons are permanent residents of the study area.

There are no hospitals in the study area. Industrial and business facilities with more than five employees add 2026 (38% of resident population) persons to the total population of the study area during work days, assuming that all employees reside outside the area (ER, p. 2.2-7).

Annual attendance at the two parks in the area (Bluff Road County Park, 3.8 miles northwest of the NFCS; Hopkins County Park, 1.75 miles east of the NFCS) totaled 109,592 persons to July 1, 1974. Because the year-round climate is favorable and both parks provide indoor facilities, daily attendance was assumed to be 1/365 of the annual attendance (300 persons per day or 6% of area resident population; ER, p. 2.2-11). In the unlikely event that none of the park attendees were local residents, the total daily transient population would add about 61% (3224 persons) to the population of the area. Overall, the low resident and transient population density and its favorable distribution away from the NFCS are positive aspects of the site situation.

2.2.3 Industries and businesses

The major industries and businesses within a 5-mile radius of the plant are concentrated within a 160° sector between the west and the east-northeast. Table 2.2 lists all facilities within the study area that employ more than five persons. The combined work force of these 13 facilities is 2026.

2.2.4 Recreational and sports facilities

The recreational parks and sports facilities within the study area are listed in Table 2.3. There are no state parks or commercial sports stadiums within a 5-mile radius of the plant.

Table 2.2. Industries and businesses within 5 miles of the Westinghouse Nuclear Fuel Columbia Site[a]

Name	Type of business	Employees	Distance and direction from plant
Columbia Container Co.	Garbage containers	20	4-3/4 miles NW
Columbia Plastering Co.	Plastering	70	4-1/2 miles NW
Dan Dee Specialties	Picture frames	30	4-1/5 miles NW
Southco	Supplies for gift shops	10	4-1/5 miles NW
Roadway Express Inc.	General freight handling	24	4-1/5 miles NW
Power's Dairy	Milk	10	2-1/4 miles NNW
Richman and Associates (field office)	Construction of extra-high-voltage lines	100	3 miles NE
Columbia Eggs Division of Farmers Cooperative Exchange	Egg grading and packaging	35	3 miles ENE
Square D Company	Manufacture heavy industrial motor controls	930	4-2/3 miles NNE
Palmetto Metal Products, Inc.	Steel door frames, window walls, louvers	15	4-4/5 miles NNW
Wallace Concrete Products, Manhole Division	Manholes	12	4-4/5 miles NNW
McGregor's Dairy	Milk	7	4-4/5 miles NNE
Carolina Eastman	Man-made fibers	763	4-3/4 miles W
Total		2026	

[a]Only industries and businesses with more than five employees are included.
Source: ER, Table 2.2-3.

Table 2.3. Recreational parks and sports facilities within a 5-mile radius of the plant

Name	Distance and direction from plant	Total annual attendance[a]
Bluff Road County Park	3-4/5 miles NW	63,380[b]
Hopkins County Park	1-3/4 miles E	46,212
Total		109,592

[a]For the period July 1, 1973, to June 30, 1974.

[b]Bluff Road County Park did not open until Jan. 1, 1974. Therefore, attendance figures for Jan. 1, 1974, to June 30, 1974 were doubled to give an estimate of total annual attendance.
Source: ER, Table 2.2-4.

2.3 LAND USE

This portion of the Appraisal describes characteristics of local (within a 5-mile radius of the NFCS) land use that are important in the environmental assessment of the NFCS operation and/or expansion. Here, the staff evaluates the distribution and nature of agriculture, the important historic and prehistoric landmarks, and the distribution of undeveloped nonagricultural land.

2.3.1 Land-use distribution

The nature, extent, and distribution of local land uses are important in the environmental assessment of NFCS operations and/or expansion. The primary interaction to evaluate is that of NFCS radiological and chemical atmospheric effluents with local human and biological populations and with farming and manufacturing activities. Interactions involving water supplies to these populaitons and activities are of equal importance but are treated elsewhere in this assessment.

Approximately 5% of the land within 5 miles of the NFCS is residential; less than 1% (exclusive of the NFCS) is industrial and about 20% is agricultural. Seventy percent of the land is uninhabited forest or swamp forest (ER, p. 2.2-13).

2.3.1.1 Manufacturing

Except for the Carolina Eastman plant that lies 4.75 miles directly west of the NFCS (38% of the business work force), all firms with five or more employees are within the 180° sector (west-east-northeast). Those plants with potentially significant atmospheric or aquatic effluent loads with which the NFCS effluents could interact include the Carolina Eastman plant (man-made production fibers), Wallace Concrete Products (man-hole production), Square D Company (industrial motor control production), and Richman and Associates (extra-high-voltage line construction). Effluent loadings from these industries were requested from the NFCS but were not available.

However, information obtained by the staff on the Santee-Cooper River Basin water quality management plan[5] lists only Carolina Eastman as a water user, and there, only cooling water (3.2×10^6 gal/day) is indicated. Other point sources of effluent water are described for the nearby drainage systems (ref. 5, Table 6), but only volume and BOD estimates are given for the facilities producing effluents.

2.3.1.2 Agriculture

Agricultural land occupies about 20% of the land area, primarily in the northern and eastern portions of the study area. Crops include soybeans, corn, hay, cotton, wheat, and oats. Pecan orchards are present to the east. Data on acres of land devoted to each of these crops, including fruits and pastureland, and the cash importance of these crops were not available from the NFCS. In general, the cultivation is neither extensive nor does it appear to be economically important.

There are only two dairy farms within the study area; Power's Dairy, 2.2 miles northwest of the NFCS, has 400 milk cows (with capacity for 700). McGregor's Dairy, 4.8 miles north-northeast of the NFCS, has 150 milk cows (ER, p. 2.2-14). No other important crop or livestock production appears to occur in the study area. Light agricultural production and its possible decreasing frequency with greater proximity to the NFCS plant are positive aspects of the Columbia site.

2.3.1.3 Undeveloped nonagricultural land and landmarks

Seventy percent of the land in the study area is covered by forest or swamp forest (ER, p. 2.2-13). Forest and swamp land is more frequent to the north and less frequent toward the south. The distribution of the three forest communities identified by Westinghouse Environmental Systems Department (WESD) personnel seems to be controlled by drainage. Water tupelo-sweet gum dominated forests occur in swamps and on wet alluvial substrates along the Congaree River. A more mesic oak forest dominates the better-drained sites, whereas the driest sites in the area may be dominated by loblolly pine and hardwoods (oak species, red maple, yellow poplar, etc.). The distribution of vegetation and the biotic relationships existing within them are discussed in Sect. 2.8.1.

Presently there are no important logging activities in the forests (ER, p. 2.2-14); however, the swamp-forest communities to the south of the NCFS may be significant in another context. Although NFCS personnel state that the swamp forest on the site has regenerated from Civil War-aged plantations, the nearby swamp forests may be comparable with those about 4.5 miles to the southeast. This southeast area of some 21,000 acres is under consideration as a national monument. Its forests have been largely undisturbed for 200 years. Not only is this area a rare remnant of previously extensive southern-river floodplain forests (ER, p. 2.2-16), but it also contains several of the largest trees of their species (ref. 6; ER, Appendix 12a). The status of this forest and its boundaries are presently undecided.

There are numerous known and probably many more undiscovered archaeological sites in the Congaree Swamp and along S.C. Highway 48. The potential damage to an undiscovered site by excavation during proposed plant expansion is unlikely because development substrate was disturbed during original construction.

Other historical, cultural, and natural landmarks occur in the study area. According to correspondence from the South Carolina Department of Archives and History (ER, p. 2.A-2), the following historical sites, listed in the Central Midlands Survey of 1974, are potentially eligible for *National Register*, but none are presently of high priority for nomination. All sites are within a 5-mile radius of the plant.

1. Raiford's Mill Creek (Mill Creek) — 18th century
   The first settlements in the county were made along Mill Creek in the 1740's. Hopewell Ferry, across the Congaree River below the creek's mouth, was used in 1756 and throughout the Revolution. The creek was named for Philip Raiford, who settled on the creek below Adams' Mill Pond. The creek was later called Hays' Creek for William Hays, who built a mill there in 1748-1750. Known by 1800 simply as Mill Creek.

2. Cabin Branch (John Hopkins, Jr., Plantation House) — 1796
   Off County Road 1159, one-fourth mile south of intersection with Road 223, near Congaree Community. An 18th century house with two large front rooms, a center hall, and an open loggia. About 1835, two large rooms were added at the rear, and the loggia was extended into a hall. Still owned by the Hopkins.

3. Claytor House — 1887
   On Highway 37 at Hopkins, wooden cottage built by Dr. Hubert Claytor, with porch and fish-scale gable; architecturally distinctive.

4. Chappell Cabin Branch (Hicks Plantation House and Garden) — 1781
   On a dirt road off County Road 37, one-half mile south of Hopkins; a two-story rectangular frame house with a single-story front porch; recent alterations; a garden with original plantings remains; still occupied by Chappell family.

5. Hopkins Overseers Dwelling — 19th century
   In the Hopkins Community on County Road 37, one-fourth mile south of intersection of County Roads 37 and 55; center section is pedimented frame cottage; the Hopkins family cemetery is nearby.

2.3.2 Summary — local population and land-use characteristics

The present NFCS facility seems propitiously located with respect to land use. Resident and transient population density is low, particularly near the site. Gathering places (schools, recreational areas, business and manufacturing sites) are sparse, and agricultural activities are quite limited. According to the ER, commercial logging of nearby forests is nonexistent.

2.4 GEOLOGY

The features of underlying rocks pertinent to the NFCS environmental assessment include stability with respect to possible land subsidence, structure and seismicity with respect to potential for earthquake damage, and stratigraphy with respect to surface drainage and subsurface movement of water through aquifers. The surface expression of geological parameters (topography, soil thickness, etc.) controls other parameters such as vegetation composition, land use, and microclimate. Each of these characteristics will be discussed below.

2.4.1 Physiography — local and regional siting

The following discussion of physiography provides the conceptual framework for understanding specific subdisciplinary topics.

Like Washington, D.C., Raleigh, N.C., and Augusta, Ga., Columbia, S.C., is located along the zone of small waterfalls and river rapids known as the fall line. Here the Paleozoic (270 to 600 million years old) metamorphic rocks of the Piedmont physiographic province on the west dip beneath Cretaceous (135 million years old) sedimentary rocks of the Coastal Plain physiographic province on the east. The vertical gradient that produces the fall zone is due to the difference in erosion resistance of the adjacent metamorphic (hard) and sedimentary (soft) surface rocks.[7]

Northwest of Columbia, the Piedmont materials include those composing the Carolina slate belt, aa zone of rocks that are somewhat less erosion-resistant than the neighboring Piedmont metamorphics. Consequently, they form wider valleys and are favored for reservoirs on the Saluda River (Lake Murray, Lake Greenwood) above Columbia. A granitic pluton originating in the Piedmont slate belt occurs within Coastal Plain sediments and crops out of the north edge of Columbia. It is radiometrically dated as Mississippian (350 million years old) and includes metargillites, tuffs, and volcanic breccias. The southeastern contact of the pluton is covered by Coastal Plain sediments, so its location is unknown (ER, p. 2.B-5).

The Coastal Plain on which the NFCS is located extends from Cape Cod, Massachusetts, south to Mexico, and from the fall line eastward beneath the Atlantic Ocean to the edge of the continental shelf. It is characterized by gently rolling hills and generally well-drained, mature valleys. River systems are presently incising their beds and migrating headward in the vicinity of Columbia. "It is thought that this rejuvenation is more likely related to the impact of man and the clearing of the land in downstream directions, than to changes in base level initiated by tectonic activity" (ER, p. 2.B-10). Drainage headward of the incisement is dendritic and mature, whereas below this point the major creeks draining into the Congaree have developed in an adverted fashion as a response to former topography.

The Coastal Plain sediments pinch out at the fall-line area some 10 miles northwest of the NFCS. Beneath the NFCS, the sediments are some 165 ft thick (25 ft below MSL), whereas at the Atlantic coast, they are between 1100 ft (North Carolina coast) and 3700 ft (Georgia coast). Beneath these unconsolidated or semiconsolidated sediments, the Paleozoic metamorphic rocks of the Piedmont are found (ER, p. 2.4-5).

The bottommost Coastal Plain sediments of late Cretaceous age (approximately 100 million years old) are part of the Tuscaloosa Formation. The lower units are alluvial (deltaic) in nature and consist of quartz gravel, with lenses of sandy clay (Kaolin), coarse sands, and pure clays that are nonporous and of low permeability. At the point of outcrop, these lower units are marked by standing water or small springs that reflect perched water tables. The upper Tuscaloosa marine phase occurs only to the east of the NFCS, being eroded locally. Where the phase does occur, its fine sands lack clay lenses, thus it is highly permeable and quite porous (ER, p. 2.B-6).

The lower Tuscaloosa sediments are some 35 ft thick below the NFCS and dip toward the southeast at 20 to 30 ft/mile. Thus, the aquifers they contain similarly dip away from the NFCS and toward the Congaree River (ER, p. 2.4-6).

Unconsolidated sediments of more recent alluvial origin cover the nonporous Tuscaloosa materials at the NFCS. The sediments consist of medium-to-coarse clayey sand and fine gravel beds that form the Okefenokee terrace (upon which the NFCS rests) at about 140 ft above MSL. The Wicomico terrace below the NFCS on the southeast contains the Congaree River floodplain at about 120 ft above MSL, whereas above the NFCS on the northwest, the Sunderland terrace occurs at about 150 ft above MSL. These terraces are overlain by sandy soils (ER, p. 2.B-9).

2.4.2 Seismology

Most of the seismology information in the ER (pp. 2.4-6 to 2.4-11) is based on the Colquhoun report,[8] which was in turn based on recent work by Bollinger.[9,10] Bollinger is responsible for much of the current literature on seismology of the southeast generally, and of South Carolina in particular. He suggests that "broadly viewed, the region is a minor seismic zone, characterized by a low level of seismic energy release."[10] He also suggests that "earthquake frequency per unit time per unit area in this region is about one-tenth that of the west coast, but the seismograph station density that exists even today is inadequate."[10] However, he notes from other research that areas affected by shocks east of the Rocky Mountains may be felt over a wider area than those from equal magnitude events in the western United States.

According to the ER (pp. 2.4-7), earthquake activity in the NFCS area is probably associated with tensional faulting and apparently does not affect the Paleozoic and Cretaceous rocks below the NFCS. Instead, the Oligocene, early Miocene, and perhaps middle Miocene sediments (40, 25, and 15 million years old respectively) that are so affected occur some 30 miles southeast of the site.

The most intense shock in South Carolina cited by Bollinger[9] was the August 1886 event at Charleston. The quake was felt as far west as Missouri and as far north as Vermont. The quake intensity in the Charleston area corresponded to a Modified Mercalli Index (MMI) scale (ER, Table 2.C-1) of X, while most of the remainder of South Carolina, including the NFCS area,

underwent a quake intensity of MMI-VII (ref. 10, Fig. 15). The expected damage at an MMI value of VII includes cracked masonry, broken chimneys, falling plaster, loose bricks and cornices, damage to concrete irrigation ditches, and caving in along sand and gravel banks. Table 1 of ref. 8 indicates that at least 14 quakes of MMI-VII or greater intensity have occurred in the southeast since 1754.

The distribution of quakes from 1754 to 1974 is shown in Fig. 2.3. Recent seismic activity within 50 miles of the NFCS include two MMI-III and IV intensity shocks in 1971; an MMI-V shock near Bowman (43 miles south of the NFCS) in 1972; a quake (magnitude not noted) March 28, 1973, in the Pelion-Gaston area (18 miles west of the NFCS); and a MMI-V shock August 2, 1974, near Edgefield County (50 miles west of the NFCS).

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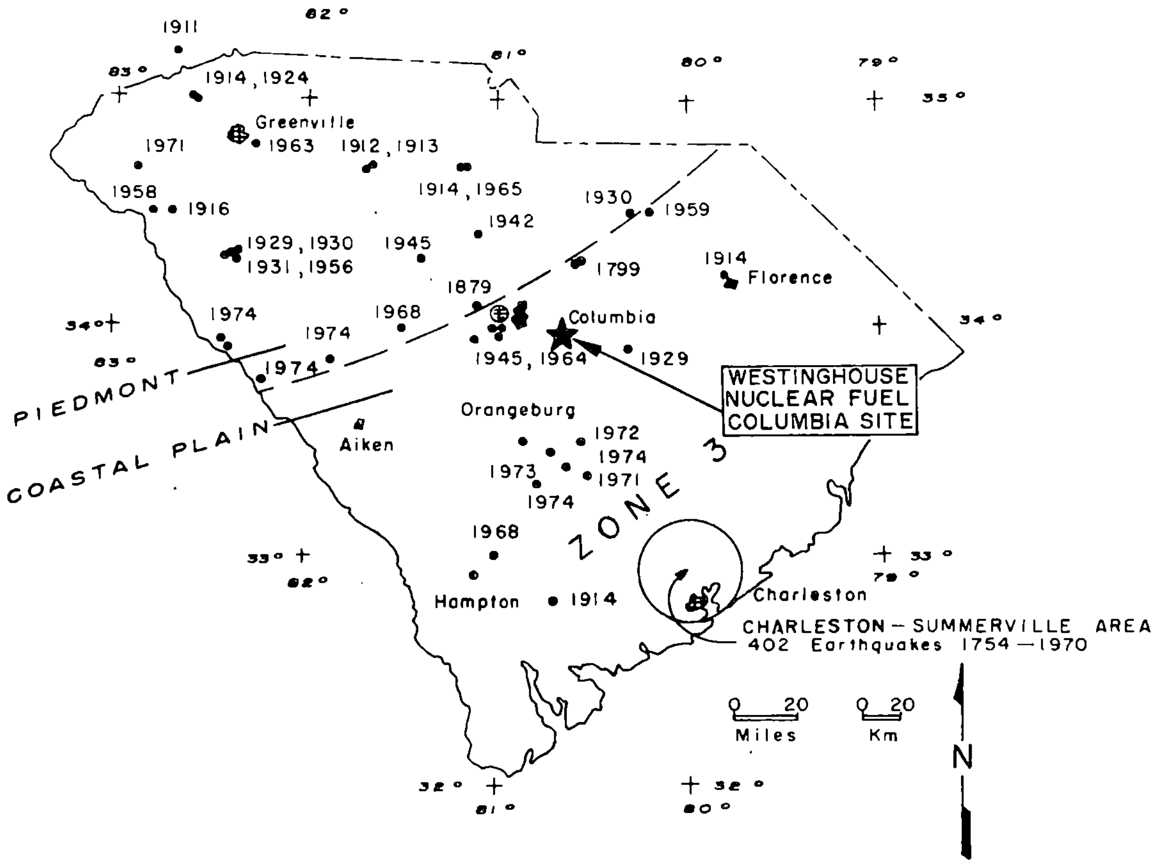

Fig. 2.3. Seismicity map of South Carolina; year is given by each epicenter. Map is updated to include earthquakes through 1974 and seismic risk zone 3. Source: ER, Fig. 2.4-3.

Bollinger[9] suggests that "up to 1950, the seismic activity within the state is seen to be concentrated in the Charleston-Summerville area, but subsequent to that time has been primarily outside that locale... unexplained is the apparent shift, during the past two decades, of seismic activity away from the coastal Charleston-Summerville area to the interior portions of the state. This apparent shift now includes three shocks in the central part that has been historically free of earthquake epicenters." Apparently, this suggested trend of Coastal Plain seismicity is quite localized, for Bollinger[10] notes that "appreciable earthquake activity in the Coastal Plain province appears only in South Carolina." The uncertainty of the suggested trend is magnified by the sparse and often unreliable data upon which it is based. "The southeastern region has seismic monitoring inadequate to specify completely its seismicity. This in turn implies the possibility of missing any buildup or decline in that activity."[10]

2.4.3 Soils

The nature of soils in the area is important in the assessment of NFCS operations or in its expansion. Problems occur if soils will not support structures or lagoons, if soil permeability allows effluents to escape into aquifers, or if the engineering limitations of soils (swelling, shrinking, corrosibility to concrete and soil, and flooding potential) cannot be overcome.

Soils groups for the NFCS region are mapped in Fig. 2.4. From this figure it is apparent that the plant site occurs on the Craven-Leaf-Johns association. Craven series soils are moderately well-drained level or sloping Coastal Plain soils. The surface layer is loam, with a clay subsoil that is very firm and slowly permeable. Clayey sediments interfinger with sand lenses below. The Leaf association is poorly drained, with a silt-loam surface and silty-clay subsoil (ER, p. 2.4-14).

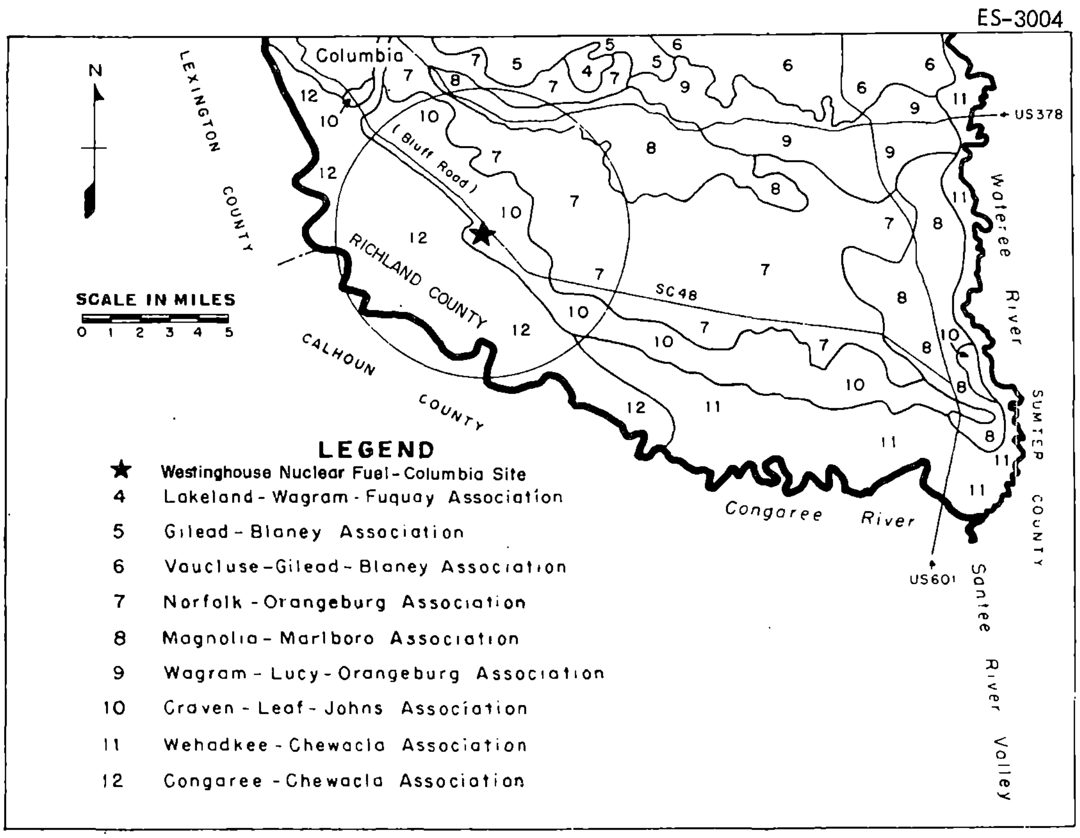

Fig. 2.4. Generalized soil associations of southern Richland County, South Carolina. Source: ER, Fig. 2.4-4.

Both soil series in the association have certain limitations. They are highly corrosive to both concrete and steel, and they have severe shrink-swell potential and severe wetness and flooding potential because of seasonal-high water tables. The latter characteristic also decreases their suitability for septic tanks. The wetness of the soils also limits sewage lagoons and sanitary landfills (ER, p. 2.4-14).

These soils are developed on the Okefenokee Formation, which is the principal aquifer in this portion of Richland County. Groundwater movement within the aquifer should parallel the impermeable surface of the Tuscaloosa alluvial beds about 30 ft below the ground surface at the NFCS (ER, p. 2.4-15) and then follow the expected southwest dip toward either Mill Creek or onto the Congaree River floodplain. Migration updip toward the northeast or north is unlikely (ER, p. 2.4-15).

2.4.4 Summary of geological characteristics

The information obtained from the NFCS indicates that the geological characteristics of the site are favorable both for current operations and for the proposed expansion. The bed-rock geology is relatively stable and structurally sound. Although tectonic activity exists, no earthquakes have been recorded within 6 miles of the site.

2.5 HYDROLOGY

2.5.1 Groundwater

2.5.1.1 Surficial terrace aquifers

The principal shallow aquifers in the region of the NFCS plant lie within three terrace formations, including the Okefenokee, the Sunderland, and the Coharie. Production from shallow holes is possible within any of these terrace formations. Most of the wells in the vicinity of the NFCS plant produce water within 25 to 40 ft of the surface (ER, p. 2.5-11).

The NFCS is underlain by the Okefenokee surficial aquifer. The static water level in all holes drilled into the surficial aquifer on the NFCS property lies within 10 to 15 ft of the surface (ER, p. 2.5-13). The lower boundary to the surficial aquifer is at a depth of 20 to 30 ft and dips riverward. A survey conducted in April 1974 by the South Carolina Health Department reported that more than 700 wells used for domestic and agricultural purposes are located within 5 miles of the NFCS plant (ER, p. 2.2-18). All wells are located updip of the NFCS plant (ER, p. 2.2-18). Since there are no wells that draw groundwater from the surface aquifer downdip of the plant, substances entering the aquifer from the plant would probably discharge toward the river into Mill Creek without entering any wells that are in use (ER, p. 2.5-18).

2.5.1.2 Upper Tuscaloosa Formation aquifers

The principal deep aquifers in this region of Richland County are limited to the upper, marine phase of the Tuscaloosa Formation. The nearest subcrop of these aquifers (Kti and Ktm aquifers) is approximately 14 miles to the east of the NFCS plant (Fig. 2.5). The piezometric surface of these aquifers indicates flow to the southeast, away from the NFCS (ER, p. 2.4-5). Since the aquifer is eroded, the NFCS plant is not connected hydrologically with land areas toward the northeast and east in Richland County (ER, p. 2.4-5).

2.5.1.3 Lower Tuscaloosa Formation aquifers

In the NFCS vicinity, a deep aquifer of unknown regional nature is present in the lower beds of the Tuscaloosa Formation (alluvial phase) about 70 ft below the surface (ER, p. 2.5-16). The number of wells penetrating this deep aquifer is limited and confined to that portion of Richland County lying west of the Ktm aquifer subcrop (Fig. 2.5). Production from these lower Tuscaloosa beds is unpredictable. Of five wells drilled into the lower Tuscaloosa Formation in the vicinity of the NFCS plant, four produced water (ER, p. 2.5-14). In all cases, production from the alluvial phase occurred very low in the stratigraphic sequence, and there was no production from the higher beds because of the occurrence of impermeable to low-permeability clays (ER, p. 2.5-14). In the vicinity of the NFCS plant, the upper beds of the alluvial phase of the Tuscaloosa Formation may be regarded as an aquiclude with regard to deeper aquifers and the overlying Okefenokee terrace aquifer. Therefore, accidental discharge of industrial wastes into the surficial aquifer underlying the NFCS holding ponds would be confined to the surficial aquifer and would not migrate to the lower aquifer as long as present casings in the deep holes remain effective (ER, p. 2.5-18).

2.5.2 Surface water

Figure 2.6 shows the surface-water features in the vicinity of the NFCS facility. The major stream near the plant is the Congaree River. Principal tributaries to the Congaree include Gills Creek at Columbia, Mill Creek near the NFCS plant, and Beaver Creek near Hopkins. Sunset Lake is a shallow, artificial impoundment on Mill Creek on the NFCS property (Fig. 2.6).

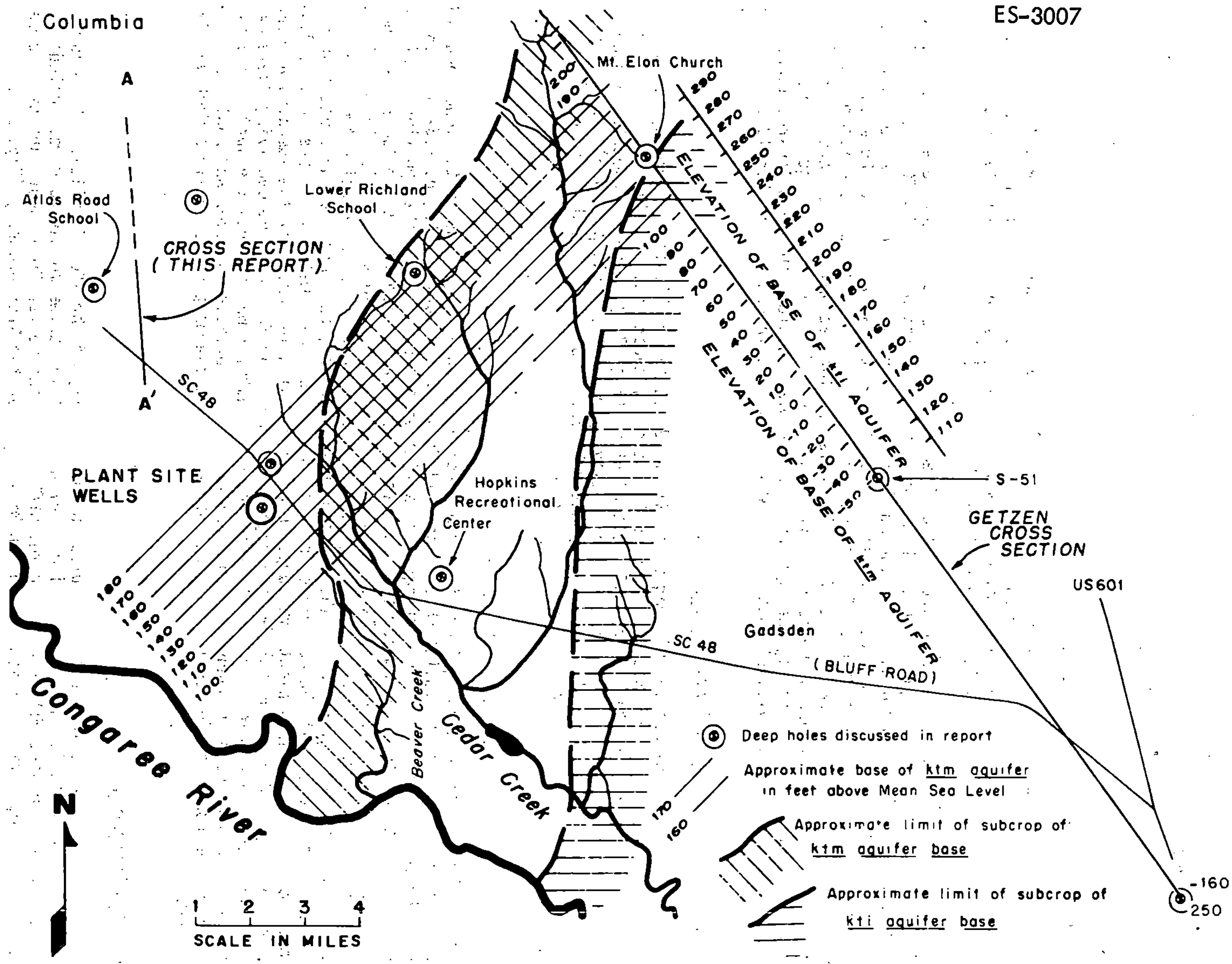

Fig. 2.5. Principal deep aquifer in the vicinity of the NFCS. Source: ER, Fig. 2.5-3.

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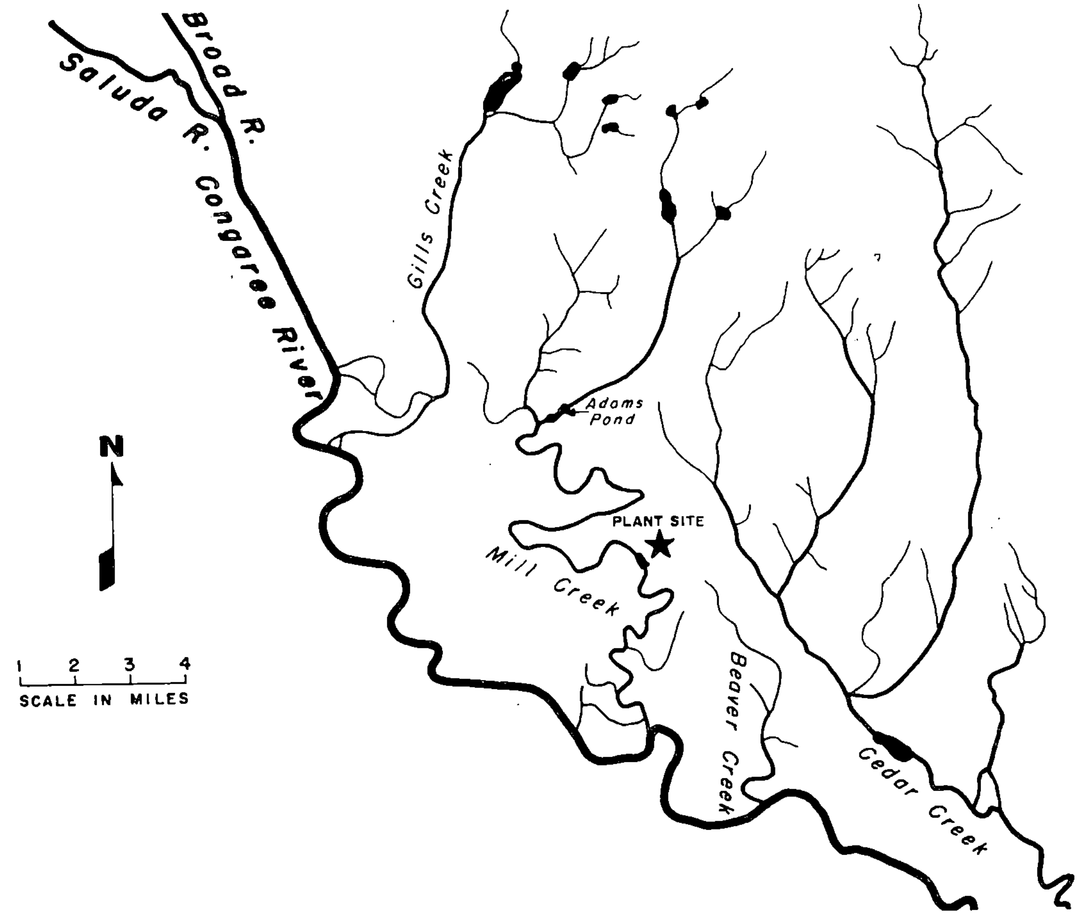


Fig. 2.6. General surface-water features in the vicinity of the NFCS. Source: ER, Fig. 2.5-1.

2.5.2.1 Congaree River

The Congaree River is a typical South Atlantic Piedmont stream that is characterized by high levels of suspended solids, sandy bottoms, and sand beaches (ER, p. 2.7-8). The Congaree is formed by the confluence of the Broad and Saluda Rivers, 10 miles north of the NFCS at Columbia, and flows southeast for approximately 60 miles to its confluence with the Wateree River and ultimate discharge into Lake Marion near Fort Motte, South Carolina. The flow of the Congaree River is regulated by Lake Murray and Lake Greenwood on the Saluda River and, to some extent, by power plants on the Broad River.[8] For approximately 1 mile below the confluence at Columbia, the river flows over Piedmont granites and schists before jossing sediments of the Coastal Plain province. The river valley within the Coastal Plain province is exceptionally wide, extending over 8 miles from the terraced northeastern to the scarped southwestern valley walls. The Congaree River generally occupies the southwestern part of the floodplain, flowing in a meandering pattern.[8] At the NFCS discharge point, the Congaree is about 500 ft wide and 9 ft or less deep.

The flow of the Congaree River at Columbia averages 9166 cfs (ER, p. 2.2-17). The average flow of the Congaree River was calculated from computer printouts available from the U.S. Geological Survey, Office of Water Data Coordination, and shows approximately 9400 cfs for the period 1959 to 1972. The lowest seven-day average flow that might be expected in a ten-year period is 1590 cfs (ER, p. 4.2-38). The minimum daily flow for the period 1939 to 1971 is 664 cfs (ER, p. 4.2-16). The lowest flows are generally during the summer months.[5]

Peak stages and discharges for the Congaree River have been recorded from 1892 to the present and are reported in the ER, Appendix 2.D. Since 1892, the highest stage of the Congaree River attained at Columbia, South Carolina, was the flood of August 27, 1908, when the stage reached 35.8 ft and the discharge was 364,000 cfs.[8] Since the flow of the Congaree has been regulated by lakes on the Saluda River, the maximum flow was 231,000 cfs on April 10, 1964, when the gage height attained was 33.34 ft.[8] The NFCS plant is about 17 ft above the level reached by the 1908 flood waters of the Congaree (ER, p. 2.5-4). On the 100-year flood-line maps of the Congaree River valley constructed by the U.S. Army Corps of Engineers, the line separating flood-prone and proximate areas occasionally flooded from higher land areas is drawn at 130 ft above MSL in the vicinity of the NFCS (ER, p. 2.5-4), which is 140 ft above MSL.

2.5.2.2 Mill Creek and Sunset Lake

Mill Creek is a tributary of the Congaree River, entering the river approximately 3 miles south of the NFCS, downstream of the plant's discharge point. Sunset Lake is a shallow (6 ft maximum depth) artificial impoundment on Mill Creek one-fourth mile south of the NFCS plant (Fig. 2.7). The lake originally consisted of two open-water areas, an Upper Lake with a surface area of 44 acres and a Lower Lake of 8 acres (ER, p. 2.7-8). Mill Creek enters the Upper Lake from the north and exits the Lower Lake by passing over a small dam located at the south end of the lake. Mill Creek then meanders through swamplands until discharging into the Congaree River 2.5 miles downstream from the NFCS waste discharge. The flow from Upper Sunset Lake to Lower Sunset Lake is by way of a narrow channel passing under a causeway. Water from the meander of Mill Creek that fed Upper Sunset Lake has been partially diverted from the lake by means of a canal (Fig. 2.7). The area that was originally the Upper Lake is now a swamp (ER, p. 2.7-9). Lower Sunset Lake still maintains an open-water area. A small dam separates Upper and Lower Sunset Lakes, and flow to the lower lake may be controlled by this dam.

Both Sunset Lake and Mill Creek are of interest because they could receive accidental spillage from the holding ponds at the NFCS facility. These spills could enter the swampy region of the former Upper Lake through a storm drain and subsequently enter the Lower Lake and Mill Creek.

2.5.3 Water use

2.5.3.1 Groundwater

Of the 700 wells in use within a 5-mile radius of the NFCS facility, none are located downdip of the plant. Because of the erosion of the upper Tuscaloosa aquifers, the NFCS plant is not connected hydrologically with wells that draw from these aquifers to the east and northeast of the plant. Groundwater quality will be discussed in Sect. 2.7.

2.5.3.2 Surface water

The city of Columbia uses 42 cfs (27 Mgd) of the Broad River waters for municipal uses (ER, p. 2.2-17). If the population of Columbia increases 29% by 1985, which is the predicted rate of increase for the Congaree subbasin,[5] water use will increase to 54 cfs (34.8 Mgd). There are no industrial or municipal water users of the Congaree River along its course from its confluence with the Saluda and Broad Rivers to its joining with the Wateree River to form the Santee River. The NFCS plant receives its water from the Columbia Municipal Water System. Projected water consumption by the NFCS plant at the expanded capacity of 1600 MTU/year is 10.6 million gallons per month (0.5 cfs).

The Congaree River receives discharges directly from the cities of Columbia, Cayce, and West Columbia, and from the NFCS plant. Since the ER was written, the city of Columbia has installed a waste-treatment plant, which consists of a trickling-filter and activated-sludge process. Columbia discharges currently average 31 cfs (20 Mgd) and peak at 93 cfs (60 Mgd).[5] Cayce and West Columbia together discharge 3 cfs (1.9 Mgd) of raw sewage into the Congaree.[5] NFCS currently discharges 0.2 cfs of process and sanitary wastes into the river. At 1600-MTU capacity, discharges will increase to 0.3 cfs (ER, p. 2.2-17). The only other major industrial discharge to the Congaree subbasin is from Carolina Eastman, which discharges 49 cfs (32 Mgd) of cooling-tower water into the Congaree via Hale's Branch, upstream from the NFCS.[5] Water quality of the river will be discussed in Sect. 2.7.

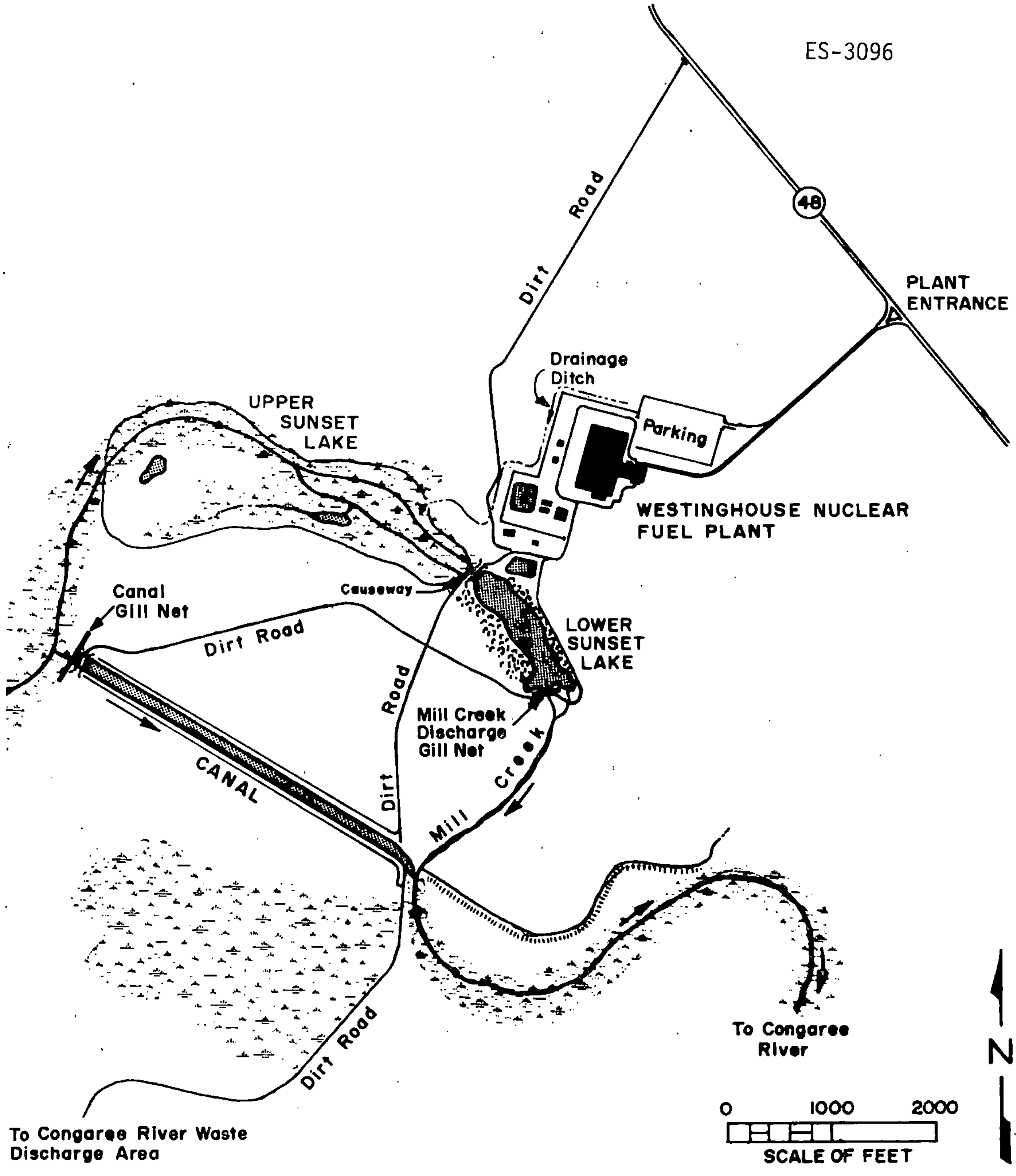


Fig. 2.7. Sunset Lake in the area of the NFCS plant. Source: ER, Fig. 2.G-2.

2.6 METEOROLOGY AND CLIMATOLOGY

This section describes the climatological features and the severe weather potential for the NFCS. The atmospheric dispersion characteristics relevant to the transport of gaseous effluents from the facility are also evaluated.

A summary of local climatological features for the U.S. Weather Bureau Station at Columbia Metropolitan Airport,[11] located about 16 miles northeast of the site, is given in Table 2.4, which includes temperature, relative humidity, wind, precipitation, and mean annual number of days of climatological events.

Table 2.4. Climatological data from Columbia Metropolitan Airport[a]

Parameter	Data
Temperature, °C	
Annual average	17.5
Maximum	24.1
Minimum	10.8
Record high	41.7
Record low	-18.9
Degree days	2598
Relative Humidity, %	
Annual average	73
Wind	
Annual average speed, mph	7.0
Prevailing direction	SW
Fastest mile	
Speed, mph	60
Direction	W
Precipitation, in.	
Annual average	46.36
Monthly maximum	16.72
Monthly minimum	Trace
24-hr maximum	7.66
Snowfall, in.	
Annual average	1.9
Monthly maximum	16.0
24-hr maximum	15.7
Mean Annual (No. of Days)	
Precipitation ⩾ 0.1 in.	110
Snow, sleet, hail ⩾ 1.0 in.	1
Thunderstorms	53
Heavy fog	27
Maximum temperature ⩾ 32.2°C	65
Minimum temperature ⩽ 0°C	65

[a]Data based on 7 to 30 years of record.
Source: ER, Table 2.6-1.

The weather in the region of the Columbia site reflects a temperate climate, with high relative humidity, moderate rainfall throughout the year, moderate winds, and normal diurnal temperature changes. Winters are mild, with rare cold waves accompanied by temperatures of zero or below. Freezing temperatures (32°F) occur on an average of 65 days per year, generally during the months of November through March.

2.6.1 Winds, tornadoes, and hurricanes

In South Carolina, severe tornadoes occur almost every year, most often in the spring. During the interval 1956 through 1973, 172 tornadoes were reported in this State. Data from Richland County, where the site is located, shows that over the past 24 years (1950-1973), nine tornadoes have been reported. Thom[12] developed an empirical formula to compute the mean recurrence interval for a tornado striking any location by approximating the location with a geometrical point. Based on the mean path area of a tornado, the number of tornadoes per year, and the area over which tornadoes may occur (Richland County), the probability of a tornado striking any location within Richland County, which includes the site, is once in more than 700 years.

During a 30-year period (1941-1970), four to five North Atlantic hurricanes out of a total of 31 penetrated into the central part of South Carolina. There was no severe damage due to winds; however, flash floods caused damage to farmlands and public utilities in the Columbia region.[13,14] The fastest wind recorded in the Columbia region is 60 mph; the calculated fastest mile of wind expected to occur in a 100-year period is 100 mph.[15]

2.6.2 Atmospheric dispersion

High air pollution potential is caused by low mixing heights and light winds.[16] Holzworth's data on the frequency of high air pollution potential (designated HAPP) indicated that from 1960 to 1965 the Columbia region experienced no HAPP cases of low mixing heights and light winds. Mixing heights of less than 1000 m coupled with winds of less than 4 m/sec lasting two days or more occurred only once in autumn during the five-year period. Similar conditions lasting five days or more did not occur. These data indicate that central South Carolina is in a region of extremely favorable dispersion.

2.6.3 Diffusion climatology

The annual and seasonal summary of the joint wind stability frequency is obtained from onsite meteorological data collected at the NFCS from August 1, 1972, through July 31, 1973, using the STAR program.[17] The results are presented in the ER, Table 2.E-18. The data indicate that stable conditions exist 47% of the time, neutral conditions occur about 43% of the time, and unstable atmospheric conditions prevail about 10% of the time.

Seasonal stability distribution for the various stability classes indicates that spring experiences the greatest number of hours (310) of unstable conditions as well as slightly stable conditions (412 hours); winter, the greatest number of hours (1047) of neutral conditions; and summer, the greatest number of hours (984) of stable conditions.

The annual wind rose from NFCS (Aug. 1, 1972 to July 31, 1973) is shown in Fig. 2.8.

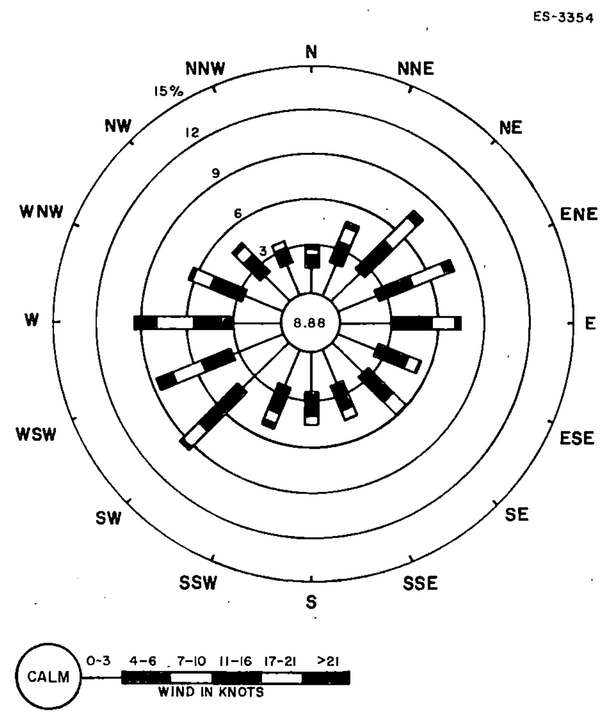


Fig. 2.8. Annual wind rose from NFCS for August 1, 1972 to July 31, 1973.

2.6.4 Short-term (accident) diffusion estimates

Estimates of atmospheric dilution factors (χ/Q) representative of post-accident time periods up to 30 days for the 50% and 95% confidence levels are given in Table 2.5 for downwind distances as far as 20 miles from the proposed site, assuming a ground-level release. The basis for estimating χ/Q representative of post-accident time periods up to 30 days is given in Appendix 2.E of the ER.

Table 2.5. Atmospheric dilution factors (χ/Q) for accident conditions[a]
(Data in sec/m^3)

Distance (miles)	Hours		Days	
	0.8[b]	8 to 24	1 to 4	4 to 30
0.07[c]	4.539E-2[d]	4.55E-3	1.940E-3	2.320E-4
0.1	1.255E-2	3.429E-3	1.479E-3	1.802E-4
0.2	3.760E-3	1.099E-3	4.190E-4	5.538E-5
0.3	1.916E-3	5.287E-4	2.020E-4	2.662E-5
0.5	8.400E-4	2.163E-4	8.290E-5	1.089E-5
0.568	7.71E-4	1.816E-4	6.910E-5	8.880E-6
0.7	5.74E-4	1.251E-4	4.798E-5	6.273E-6
1.0	4.23E-4	6.926E-5	2.655E-5	3.467E-6
2.0	2.07E-4	2.329E-5	8.790E-6	1.149E-6
5.0	7.48E-5	6.146E-6	2.310E-6	3.171E-7
10.0	3.28E-5	2.314E-6	8.670E-7	1.101E-7
20.0	1.509E-5	9.351E-7	3.488E-7	4.378E-8

[a]Data taken at NFCS from August 1, 1972 through July 31, 1973.

[b]Includes building wake factors given in Table 2.6-24.

[c]Exclusion distance, 114 m (374 ft).

[d]Read as 4.539×10^{-2}.

2.6.5 Long-term (routine) diffusion estimates

Estimates of atmospheric dilution factors (χ/Q) on an annual basis at downwind distances up to 50 miles in 16 compass directions at the 50-ft level are provided in Table 2.6, assuming ground-level release. The basis for estimating these dilution factors is presented in Appendix 2.E of the ER, "Basis for Estimates." The highest χ/Q values occur in the northeast sector, whereas the lowest values occur in the southern sector.

2.7 BACKGROUND CHARACTERISTICS

2.7.1 Radiological characteristics

To evaluate the significance of future releases of radioactive and nonradioactive materials to the environment from expanded operations at the NFCS, present background characteristics of the environs must be determined. The background radiological characteristics presented in this section were developed from selected data from numerous published reports and from the plant's environmental monitoring program. Where available, these data include uranium and gross alpha and beta levels as measured in air, water, fallout deposition, soil, and vegetation.

2.7.1.1 Total-body dose rates

Based on *Estimates of Ionizing Radiation Doses in the U.S. 1960-2000*,[18] the total-body dose rate from natural background radiation in the vicinity of Columbia is expected to be similar to that for South Carolina in general, that is, about 135 millirems/year (70 millirems/year from

Table 2.6. Estimates of atmospheric dilution factors for NFCS annual average χ/Q values (Data in sec/m^3)

Distance downwind (miles)	Direction from plant location															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.07[a]			3.61E-4													
0.1	1.11E-4	1.21E-4	2.62E-4	2.18E-4	1.90E-4	1.46E-4	1.11E-4	9.83E-5	8.99E-5	1.15E-4	1.57E-4	1.72E-4	1.86E-4	1.49E-4	1.46E-4	1.17E-4
0.2	3.18E-5	3.44E-5	7.51E-5	6.27E-5	5.47E-5	4.21E-5	3.19E-5	2.84E-5	2.60E-5	3.33E-5	4.54E-5	5.00E-5	5.39E-5	4.32E-5	4.21E-5	3.36E-5
0.3	1.54E-5	1.66E-5	3.62E-5	3.03E-5	2.65E-5	2.04E-5	1.55E-5	1.38E-5	1.26E-5	1.62E-5	2.20E-5	2.43E-5	2.62E-5	2.10E-5	2.05E-5	1.63E-5
0.5	6.22E-6	6.71E-6	1.47E-5	1.23E-5	1.08E-5	8.32E-6	6.32E-6	5.63E-6	5.15E-6	6.59E-6	8.97E-6	9.90E-6	1.07E-5	8.58E-6	8.35E-6	6.64E-6
0.8	2.76E-6	2.97E-6	6.52E-6	5.48E-6	4.80E-6	3.70E-6	2.81E-6	2.51E-6	2.29E-6	2.93E-6	3.99E-6	4.41E-6	4.77E-6	3.83E-6	3.72E-6	2.95E-6
1.0	1.89E-6	2.04E-6	4.49E-7	3.78E-6	3.31E-6	2.55E-6	1.94E-6	1.73E-6	1.58E-6	2.02E-6	2.75E-6	3.04E-6	3.29E-6	2.64E-6	2.56E-6	2.03E-6
1.5	9.80E-7	1.05E-6	2.34E-6	1.97E-6	1.72E-6	1.33E-7	1.01E-6	9.00E-7	8.24E-7	1.05E-6	1.43E-6	1.59E-6	1.72E-6	1.38E-6	1.33E-6	1.06E-6
2.5	4.42E-7	4.76E-7	1.07E-6	9.03E-7	7.87E-7	6.03E-7	4.58E-7	4.10E-7	3.76E-7	4.79E-7	6.53E-7	7.28E-7	7.87E-7	6.30E-7	6.07E-7	4.80E-7
3.5	2.65E-7	2.85E-7	6.49E-7	5.47E-7	4.76E-7	3.64E-7	2.76E-7	2.47E-7	2.27E-7	2.89E-7	3.94E-7	4.41E-7	4.77E-7	3.82E-7	3.67E-7	2.90E-7
4.5	1.82E-7	1.96E-7	4.49E-7	3.79E-7	3.29E-7	2.51E-7	1.90E-7	1.71E-7	1.57E-7	1.99E-7	2.72E-7	3.06E-7	3.31E-7	2.64E-7	2.53E-7	1.99E-7
7.5	8.69E-8	9.38E-8	2.19E-7	1.84E-7	1.59E-7	1.21E-7	9.12E-7	8.21E-8	7.55E-8	9.59E-8	1.31E-7	1.48E-7	1.61E-7	1.28E-7	1.22E-7	9.55E-8
10.0	5.78E-8	6.25E-8	1.47E-7	1.24E-7	1.07E-7	8.07E-8	6.08E-8	5.48E-8	5.05E-8	6.41E-8	8.77E-8	9.97E-8	1.08E-7	8.60E-8	8.14E-8	6.36E-8
15.0	3.16E-8	3.41E-8	8.07E-8	6.80E-8	5.85E-8	4.44E-8	3.34E-8	3.01E-8	2.78E-8	3.52E-8	4.82E-8	5.49E-8	5.95E-8	4.74E-8	4.49E-8	3.50E-8
20.0	2.20E-8	2.39E-8	5.79E-8	4.86E-8	4.14E-8	3.10E-8	2.32E-8	2.11E-8	1.95E-8	2.47E-8	3.38E-8	3.98E-8	4.21E-8	3.34E-8	3.13E-8	2.43E-8
25.0	1.66E-8	1.82E-8	4.48E-8	3.75E-8	3.17E-8	2.36E-8	1.76E-8	1.60E-8	1.49E-8	1.88E-8	2.58E-8	2.99E-8	3.23E-8	2.55E-8	2.37E-8	1.84E-8
30.0	1.32E-8	1.46E-8	3.64E-8	3.04E-8	2.56E-8	1.89E-8	1.40E-8	1.28E-8	1.19E-8	1.50E-8	2.07E-8	2.41E-8	2.60E-8	2.05E-8	1.90E-8	1.47E-8
35.0	1.09E-8	1.21E-8	3.06E-8	2.54E-8	2.13E-8	1.56E-8	1.16E-8	1.06E-8	9.91E-9	1.25E-8	1.72E-8	2.01E-8	2.17E-8	1.71E-8	1.57E-8	1.21E-8
40.0	9.28E-9	1.03E-8	2.63E-8	2.18E-8	1.82E-8	1.33E-8	9.82E-9	9.02E-9	8.44E-9	1.06E-8	1.47E-8	1.72E-8	1.85E-8	1.46E-8	1.33E-8	1.03E-8

Table 2.6 (continued)

Distance downwind (miles)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	Direction from plant location															
45.0	8.03E-9	8.93E-9	2.30E-8	1.91E-8	1.59E-8	1.15E-8	8.50E-9	7.82E-9	7.34E-9	9.22E-9	1.27E-8	1.50E-8	1.61E-8	1.27E-8	1.15E-8	8.89E-9
50.0	7.06E-9	7.88E-9	2.04E-8	1.69E-8	1.41E-8	1.02E-8	7.47E-9	6.88E-9	6.47E-9	8.13E-9	1.12E-8	1.32E-8	1.43E-8	1.12E-8	1.01E-8	7.82E-9
0.568[b]			1.21E-5													

[a]Exclusion distance, 114 m (374 ft).

[b]900 m (3000 ft).

external terrestrial radiation, 40 millirems/year from cosmic rays, and 25 millirems/year from internal terrestrial radiation). This value compares favorably with an average of 0.32 millirem/day (117 millirems/year) reported by the State[19] for areas in South Carolina where there are no nuclear facilities.

The above dose rates can be compared with those measured at six locations[19] in the vicinity of the plant. These data, listed in Table 2.7, indicate an average dose rate of 0.31 to 0.45 millirem/day, or 113 to 164 millirems/year.

2.7.1.2 Summary

A summary of present background radiological characteristics typical of the NFCS environs is presented in Table 2.8. Because of the variations in reported data, typical ranges rather than specific values are given for some of the parameters. These parameters are discussed and additional data are presented in the ER, pp. 2.8-1 through 2.8-2.

2.7.2 Nonradiological characteristics

2.7.2.1 Atmospheric effluents

Fluorides and ammonia are the main atmospheric chemicals discharged from the NFCS plant (ER, p. 4.2-31). NO_x emissions from the nickle-plating-room stack were measured at 2 ppm and were undetectable from the scrap-recovery-area stack (ER, p. 4.2-31).

No data were available to describe ambient atmospheric concentration values for either ammonia or fluorides or to describe deposition values for ammonia. Average annual fluoride deposition was 0.3 $\mu g\ cm^{-2}\ year^{-1}$. The average ambient atmospheric concentration for SO_2 was 32 $\mu g/m^3$. A maximum 1-hr value of 100 $\mu g/m^3$ was recorded (ER, pp. 2.8-24 and 2.8-25).

2.7.2.2 Background nonradiological characteristics of water

Groundwater quality

Table 2.9 lists groundwater quality for the surface aquifer within 5 miles of the NFCS plant. It is the only aquifer likely to receive accidental discharge of industrial wastes from the NFCS plant (ER, p. 2.5-18). The only constituent to exceed the recommended limit for public water supplies is fluorine. For regions in which the average daily maximum temperature is between 72° and 79°F, the recommended maximum fluoride concentration should not exceed 1.6 mg/liter.[20] The average daily maximum temperature at Columbia, South Carolina, is 75.4°F (ER, p. 2.6-2).

Congaree River

Tables 2.10 through 2.13, taken from the ER (pp. 2.5-6 through 2.5-9), list water quality records from 1969 to 1974 for the Congaree River, calculated from data obtained from the South Carolina Water Pollution Control Authority. No seasonal trends or yearly maximums for the values in the tables were obtainable. Two of the stations are above the NFCS discharge and two are below.

Effects of municipal dishcarges of raw sewage from the city of Columbia and other communities upstream are reflected in high bacteria counts in the Congaree River. Both coliform and fecal coliform counts exceed the South Carolina water quality standards and the Federally recommended levels for public water supplies.[20] The high ammonia levels are probably a result of the presence of raw sewage in the river. A number of constituents, among them cadmium, ammonia, chromium, and lead, exceed recommended limits for public water supplies listed in Table 2.14.

2.8 ECOLOGY

2.8.1 Terrestrial biota

2.8.1.1 General features

Characteristics of the terrestrial biota that are important in the assessment of the current operations or proposed expansion of the NFCS relate primarily to atmospheric effluent loads derived from the facility. The kinds of biotic problems that occur in association with long

Table 2.7. Average direct radiation measurements (millirem/day) with TLDs

Sample period	Location of stations relevant to plant					
	10 miles northwest	3000 ft northeast	2250 ft east	2250 ft northwest	7 miles northeast	9 miles north-northwest
1/7/71 to 4/4/71	0.51					
3/4/71 to 6/8/71	0.37					
6/8/71 to 8/16/71	0.64					
8/16/71 to 12/22/71	0.42					
12/22/71 to 3/21/72	0.16	0.20				
3/21/72 to 6/26/72	0.25	0.34				
6/26/72 to 9/19/72	0.25	0.33				
9/19/72 to 12/7/72	0.14	1.11				
12/7/72 to 3/1/73	0.24	0.23				
3/1/73 to 6/16/73	0.18	0.18				
Average millirem/day	0.31	0.45				
Average millirems/year	113	164				
9/22/72 to 12/11/72			0.60	0.49	0.51	0.55
12/11/72 to 3/2/73			0.27	0.28	0.25	0.40
3/2/73 to 6/6/73			0.26	0.25	0.21	0.23
Average millirem/day			0.37	0.34	0.32	0.39
Average millirems/year			135	124	117	142

Source: ER, Table 2.8-13.

Table 2.8. Summary of background radiological characteristics typical of the NFCS environs

Measured parameter	Typical values and ranges[a]		
	Gross alpha	Gross beta	Total uranium
Air	$\leq 1.0 \times 10^{-15}$ to 5.8×10^{-14} μCi/ml	$(1.6$ to $6.5) \times 10^{-14}$ μCi/ml	
Surface water			
Congaree River	$(0.5$ to $2) \times 10^{-9}$ μCi/ml	$(4.4$ to $5.6) \times 10^{-9}$ μCi/ml	$(0.06 \pm 0.29$ to $0.40 \pm 0.31) \times 10^{-9}$ μCi/ml
Sunset Lake	$(7.6$ to $55) \times 10^{-9}$ μCi/ml	$(18.3$ to $108) \times 10^{-9}$ μCi/ml	
Well water			
Onsite	$(8.2$ to $26) \times 10^{-9}$ μCi/ml	$(24$ to $103) \times 10^{-9}$ μCi/ml	
Offsite	$\sim 0.6 \times 10^{-9}$ μCi/ml	$\sim 2.8 \times 10^{-9}$ μCi/ml	
Drinking water	$(<0.5$ to $1.4) \times 10^{-9}$ μCi/ml	$(2.2$ to $5.3) \times 10^{-9}$ μCi/ml	
Precipitation	$(1.5$ to $2.1) \times 10^{-9}$ μCi/ml	$(9.0$ to $50) \times 10^{-9}$ μCi/ml	
Fallout deposition	0.5 to 2.0 nCi m^{-2} $month^{-1}$	0.35 to 18 nCi m^{-2} $month^{-1}$	
Vegetation			<1 pCi/g
Soil	1 to 5 pCi/g	1 to 4.5 pCi/g	<1 pCi/g
TLD's — Whole body dose: 110 to 160 millirems/year			

[a]Based on data presented in Sect. 2.8.1 to 2.8.1.7 of the ER.
Source: ER, Table 2.8-14.

Table 2.9. Groundwater quality of the surface aquifer within 5 miles of the NFCS plant

(Concentrations in mg/liter or as indicated)

Date	Dec. 12, 1962
Depth to top of sample (ft)	
Depth to bottom of sample (ft)	
Color (platinum-cobalt units)	33
Specific conductance (μΩ/cm)	399
pH	4.4
CO_2	
HCO_3	
Alkalinity (as $CaCO_3$)	
Hardness (calcium, manganese)	112
Noncarbonate hardness	112
Calcium	20
Magnesium	12
Sodium	21
Potassium	6.6
Cerium	36
SO_4	118
Fluorine	2.6
PO_4	
Dissolved NO_3–N	1.8
Dissolved NO_3	8.0
Total NO_3	8.0
SiO_2	18
Dissolved iron	1.1
Dissolved manganese	0.5
Total manganese	
Aluminum	1.9
Total dissolved solids (TDS)	258

Source: ER, Table 2.5-7.

linear structures or with disturbance of large land areas need not be considered here because the plant is compact and covers only 60 acres. Instead, biotic relationships must be evaluated with respect to atmospheric contaminant concentrations, their downwind diminution, and their gradual accumulation in plant and animal tissues and in soils. Therefore the nature and composition of the plant and animal communities at increasing distances from the NFCS will be discussed in the following paragraphs.

The potential vegetation of the area is classified by Küchler[21] as southern floodplain forest along the Congaree River, with oak-hickory-pine forest on the uplands and southern mixed forest immediately west of Columbia. Table 2.15 lists dominant and associated species in each of these plant associations. Species common to all three associations and those found in any two of the three communities are footnoted.

That so few important species are common to the three associations indicates that physical environmental limiting factors exert strong control on the composition and character of the plant communities. This is particularly apparent in the case of the swamp forest, which shares only 11% of its major species with the southern mixed forest and 18% with the oak-hickory-pine forest. The second two are more similar to each other, but they still share only 43% of their important species.

Table 2.10. Yearly water quality averages of Congaree River above Lexington-Calhoun county line about 6 river miles upstream from the NFCS discharge point

(Concentration in mg/liter or as indicated)

Constituent or characteristic	1971	1972	1973
Water temperature (°C)	23.5	17.4	22.5
Turbidity (Jtu)	90.6	29.0	
Turbidity (as SiO_2)	13.75	9.0	23.0
Color (platinum-cobalt units)	120.0	69.2	50.0
Dissolved oxygen probe			8.0
Dissolved oxygen	7.4	8.86	
Dissolved oxygen percent of saturation	86.6	89.3	
Biological oxygen demand	1.23	2.10	7.0
pH			6.8
Lab pH	6.84	6.05	6.10
Total $CaCO_3$	23.5	21.7	22
Total nitrogen	0.04		
NO_3-N	0.05	0.346	
NO_2 and NO_3-N, total	0.05	0.32	0.4
Ortho PO_4	0.043	0.063	0.15
Total hardness as $CaCO_3$	27.0		
Chloride	6.0		
Cadmium			0.030
Chromium			0.100
Copper			0.050
Iron, total			0.484
Lead			0.100
Total coliform MFI-M-ENDO per 100 ml[a]	60,333		
Fecal coliform MPN-EC-MED per 100 ml[b]	16,475	1030	
Fecal coliform MPN-MFCBR per 100 ml[c]	16,475	2398	1000
Total coliform MPN-PRES per 100 ml[d]	60,333		
Ammonia	13		
Mercury (μg/liter)		0.05	0.05

[a]MFI-M-ENDO = Membrane filter incubation procedure using M-ENDO medium.

[b]MPN-EC-MED = Most probable number using EC medium.

[c]MPN-MFCBR = Most probable number using M-FC broth.

[d]MPN-PRES = Most probable number, presumptive test.

Source: ER, Table 2.5-1.

Table 2.11. Yearly water quality averages of Congaree River 2-1/4 miles below Lexington-Calhoun county line and about 3.75 river miles upstream from the NFCS discharge point

(Concentration in mg/liter or as indicated)

Constituent or characteristic	1971	1972	1973
Water temperature (°C)	22.75	23.66	21.0
Turbidity (Jtu)	69.0	26.0	
Turbidity (as SiO_2)	19.0	10.5	15.0
Color (platinum-cobalt units)	160.0	56.0	50.0
Dissolved oxygen probe			7.9
Dissolved oxygen	7.23	8.68	
Dissolved oxygen percent of saturation	83.66	86.0	
Biological oxygen demand	0.9	1.62	2.8
pH			6.5
Lab pH	6.95	6.38	6.2
Total $CaCO_3$	24.0	21.1	26.0
Total nitrogen	0.06		
NO_3-N	0.05	0.32	
NO_2 and NO_3-N, total	0.05	0.34	0.4
Ortho PO_4	0.06	0.15	0.06
Total hardness as $CaCO_3$	24.5		
Chloride	5.6		
Cadmium			0.030
Chromium, total			0.100
Copper			0.050
Iron, total			0.870
Lead			0.100
Total coliform MFI-M-ENDO per 100 ml[a]	106,333		
Fecal coliform MPN-EC-MED per 100 ml[b]	49,250	946.6	
Fecal coliform MPN-MFCBR per 100 ml[c]	49,250	3088	1000
Total coliform MPN-PRES per 100 ml[d]	109,666		
Ammonia	0.66		
Mercury (μg/liter)		0.04	0.5

[a]MFI-M-ENDO = Membrane filter incubation procedure using M-ENDO medium.

[b]MPN-EC-MED = Most probable number using EC medium.

[c]MPN-MFCBR = Most probable number using M-FC broth.

[d]MPN-PRES = Most probable number, presumptive test.

Source: ER, Table 2.5-2.

Table 2.12. Yearly water quality averages of Congaree River at mouth of Mill Creek about 2.6 river miles downstream from the NFCS discharge point

(Concentration in mg/liter or as indicated)

Constituent or characteristic	1971	1972	1973
Water temperature (°C)	22.0	16.25	21.0
Turbidity (Jtu)	72.5	33.0	
Turbidity (as SiO_2)	17.0	11.25	11.0
Color (platinum-cobalt units)	152.5	56.0	50.0
Dissolved oxygen	7.2	8.61	
Dissolved oxygen percent of saturation	82.1	84.8	
Biological oxygen demand	0.95	1.7	2.4
pH			6.5
Lab pH	6.85	6.45	6.1
Total $CaCO_3$	24.0	20.8	20.0
Total nitrogen	0.04		
NO_3-N	0.05	0.41	
NO_2 and NO_3-N, total	0.05	0.38	0.4
Ortho PO_4	0.04	0.096	0.10
Total hardness as $CaCO_3$	22		
Chloride	6.0		
Cadmium			0.030
Chromium, total			0.100
Copper			0.050
Iron			0.232
Lead			0.100
Total coliform MFI-M-ENDO per 100 ml[a]	43,000		
Fecal coliform MPN-EC-MED per 100 ml[b]	40,250	1650	
Fecal coliform MPN-MFCBR per 100 ml[c]	40,250	6473.0	1000
Total coliform MPN-PRES per 100 ml[d]	43,000		
Ammonia	0.11	0.36	
Mercury (μg/liter)		0.03	0.5

[a]MFI-M-ENDO = Membrane filter incubation procedure using M-ENDO medium.
[b]MPN-EC-MED = Most probable number using EC medium.
[c]MPN-MFCBR = Most probable number using M-FC broth.
[d]MPN-PRES = Most probable number, presumptive test.

Source: ER, Table 2.5-3.

Table 2.13. Yearly water quality averages of Congaree River at mouth of Beaver Creek about 9.7 river miles downstream from the NFCS discharge point

(Concentration in mg/liter or as indicated)

Constituent or characteristic	1971	1972	1973
Water temperature (°C)	21.25	15.83	20.0
Turbidity (Jtu)	74.5	33.0	
Turbidity (as SiO_2)	15.0	9.0	11.0
Color (platinum-cobalt units)	132.5	55.0	50.0
Dissolved oxygen probe			8.1
Dissolved oxygen	7.6	8.7	
Dissolved oxygen percent of saturation	83.66	84.83	
Biological oxygen demand	0.725	1.64	2.2
pH			6.2
Lab pH	6.875	6.316	6.1
Total $CaCO_3$	23.5	21.83	20
Total nitrogen	0.035		
NO_3-N	0.060	0.396	
NO_2 and NO_3-N, total	0.01	0.38	0.4
Ortho PO_4	0.035	0.103	0.0
Total hardness as $CaCO_3$	40.5		
Chloride	6.0		
Cadmium			0.030
Chromium, total			0.100
Copper			0.050
Iron			0.374
Lead			0.100
Total coliform MFI-M-ENDO per 100 ml[a]	118,666		
Fecal coliform MPN-EC-MED per 100 ml[b]	24,050	2193	
Fecal coliform MPN-MFCBR per 100 ml[c]	24,050	3596	1000
Total coliform MPN-PRES per 100 ml[d]	118,666		
Ammonia			
Mercury (μg/liter)		0.03	0.05

[a]MFI-M-ENDO = Membrane filter incubation procedure using M-ENDO medium.

[b]MPN-EC-MED = Most probable number using EC medium.

[c]MPN-MFCBR = Most probable number using M-FC broth.

[d]MPN-PRES = Most probable number, presumptive test.

Source: ER, Table 2.5-4.

Table 2.14. Recommended surface water criteria for public water supplies

Constituent or characteristic	Permissible criteria (mg/liter)	Desirable criteria (mg/liter)
Ammonia	0.5 (as nitrogen)	<0.01
Arsenic	0.10	Absent
Barium	1.0	Absent
Boron	1.0	Absent
Cadmium	0.01	Absent
Chloride	250	<25
Chromium (hexavalent)	0.05	Absent
Copper	1.0	Virtually absent
Dissolved oxygen		
Monthly mean	≥4	Near saturation
Individual sample	≥3	
Iron (filterable)	0.3	Virtually absent
Lead	0.05	Absent
Manganese (filterable)	0.05	Absent
Nitrates plus nitrites	10 (as N)	Virtually absent
pH (range)	6.0–8.5	
Selenium	0.01	Absent
Silver	0.05	Absent
Sulfate	250	<50
Total dissolved solids (filterable residue)	500	<200
Zinc	5	Virtually absent
Cyanide	0.2	Absent
Oil and grease	Virtually absent	Absent
Total carbon	0.15	<0.04
DDT	0.042	Absent
Dieldrin	0.017	Absent
Heptaepoxide	0.018	Absent
2-4-D	0.1	Absent
Total coliform	20,000 per 100 ml	
Fecal coliform	2,000 per 100 ml	
Mercury	0.002	Absent

Sources: Committee on Water Quality Criteria, *Water Quality Criteria, 1972*, National Academy of Sciences — National Academy of Engineering, Washington, D.C., 1972: ER, Table 4.2-16.

Table 2.15. Potential natural vegetation of the Columbia, South Carolina, area

SOUTHERN FLOODPLAIN FOREST (*Quercus-Nyssa-Taxodium*)	
Physiognomy:	Dense, medium tall to tall forest of broadleaf deciduous and evergreen trees and shrubs and needleleaf deciduous trees
Dominants:	Tupelo (*Nyssa aquatica*) Oak (*Quercus* spp.) Bald cypress (*Taxodium distichum*)
Other components:	*Acer rubrum* var. *drummondii*, *Ampelopsis arborea*, *Berchemia scandens*, *Campsis radicans*, *Carya aquatica*, *C. illinoensis*, *Celtis laevigata*, *Forestiera acuminata*, *Fraxinus caroliniana*, *F. profunda*, *Gleditsia aquatica*, *Ilex decidua*, *Liquidambar styraciflua*,[a] *Nyssa silvatica*,[b] *N. silvatica* var. *biflora*, *Persea borbonia*,[a] *Planera aquatica*, *Platanus occidentalis*, *Populus deltoides*, *P. heterophylla*, *Quercus falcata*[a] var. *pagodaefolia*, *Q. lyrata*, *Q. michauxii*, *Q. nigra*, *Q. shumardii*,[b] *Salix nigra*, *Ulmus americana*, *Vitis* spp.
OAK-HICKORY-PINE FOREST (*Quercus-Carya-Pinus*)	
Physiognomy:	Medium tall to tall forest of broadleaf deciduous and needleleaf evergreen trees
Dominants:	Hickory (*Carya* spp.) Shortleaf pine (*Pinus echinata*)[b] Loblolly pine (*P. taeda*)[b] White oak (*Quercus alba*)[b] Post oak (*Q. stellata*)[b]
Other components:	*Carya cordiformis*, *C. glabra*,[b] *C. ovata*, *C. tomentosa*,[b] *Cornus florida*,[b] *Diospyros virginiana*, *Liquidambar styraciflua*,[a] *Liriodendron tulipifera*,[b] *Nyssa sylvatica*,[b] *Oxydendrum arboreum*, *Persea borbonia* (lower elevations),[a] *Pinus virginiana*, *Quercus coccinea*, *Q. falcata*,[a] *Q. marilandica*,[b] *Q. prinus*, *Q. rubra*, *Q. shumardii*,[b] *Q. velutina*
SOUTHERN MIXED FOREST (*Fagus-Liquidambar-Magnolia-Pinus-Quercus*)	
Physiognomy	Tall forest of broadleaf deciduous and evergreen and needleleaf evergreen trees
Dominants:	Beech (*Fagus grandifolia*) Sweet gum (*Liquidambar styraciflua*)[a] Southern magnolia (*Magnolia grandiflora*) Slash pine (*Pinus elliottii*) (especially in Florida) Loblolly pine (*P. taeda*)[b] White oak (*Quercus alba*)[b] Laurel oak (*Q. laurifolia*)
Other components:	*Acer barbatum*, *Carpinus caroliniana*, *Carya glabra* (northern part),[b] *C. tomentosa* (northern part),[b] *Cornus florida*,[b] *Ilex glabra*, *I. opaca*, *Liriodendron tulipifera*,[b] *Myrica cerifera*, *Ostrya virginiana*, *Persea borbonia*,[a] *Pinus echinata* (northern part),[b] *P. palustris*, *Quercus falcata*,[a] *Q. incana*, *Q. laevis*, *Q. marilandica*,[b] *Q. stellata*,[b] var. *margaretta*, *Q. virginiana* (Florida and coastal regions), *Sabal palmetto* (eastern part), *Serenoa repens*

[a]Species common to all three plant associations.

[b]Species found in any two of the plant associations.

Source: From A. W. Küchler, *Potential Natural Vegetation of the Conterminous United States*, Special Publication 36, American Geographical Society, New York, 1964, 156 pp.

The physical parameters that control plant community composition near the NFCS may be a function of soils and the associated water drainage. For example, specialized morphological adaptations are required for survival of trees that grow in the permanently standing water of swampland. The well-drained sandy soils of the Orangeburg soil series are distinctly zeric (dry) in comparison to the wet, poorly drained clays and silty clays of the Leaf and Craven soil series. Unfortunately, data were not available from the NFCS to demonstrate that these specific soils and soil moisture conditions produce the distinct community boundaries as described in the data mentioned above.

The nature of the parameters that control plant community composition, structure, and density are important when the impact of proposed land uses is considered. If the vegetation is primarily under biological control (i.e., competition, predation, parasitism, etc.), the impact of a minor change in physical or chemical parameters may induce significant community-wide changes in species composition, structure, and density. Thus the environmental change is translated via the intricate dependent relationships among the organisms into responses by a large number of species.

On the other hand, if a larger portion of the control upon vegetation is exerted by physical parameters (i.e., depth to water table, soil structure, drainage characteristics, etc.), the impact of a minor change in physical or chemical parameters may induce little significant change in species composition, structure, and density. In this case, the environmental change is translated more independently into responses by individual species rather than into responses by groups of interdependent species.

Because the animal populations depend either directly or indirectly upon characteristics of the plant communities, they change similarly to the plant communities. Hypothetically, greater impact from changes in physical and chemical parameters may occur among animal populations that are associated with plant communities controlled by biological parameters rather than those controlled by physical parameters.

It seems likely that the latter situation occurs in the biotic communities surrounding the NFCS, that is, physical parameters control biotic composition and density. Supportive data would be helpful. Plant species lists are incomplete, and data on plant distribution are unavailable. Similar data on animal populations are insufficient. The data available are presented in Appendices A.1 through A.11 (ER, pp. 2.F-4 through 2.F-15). Nevertheless, it seems unlikely that single-parameter environmental changes at NFCS would be translated into responses by a large number of species.

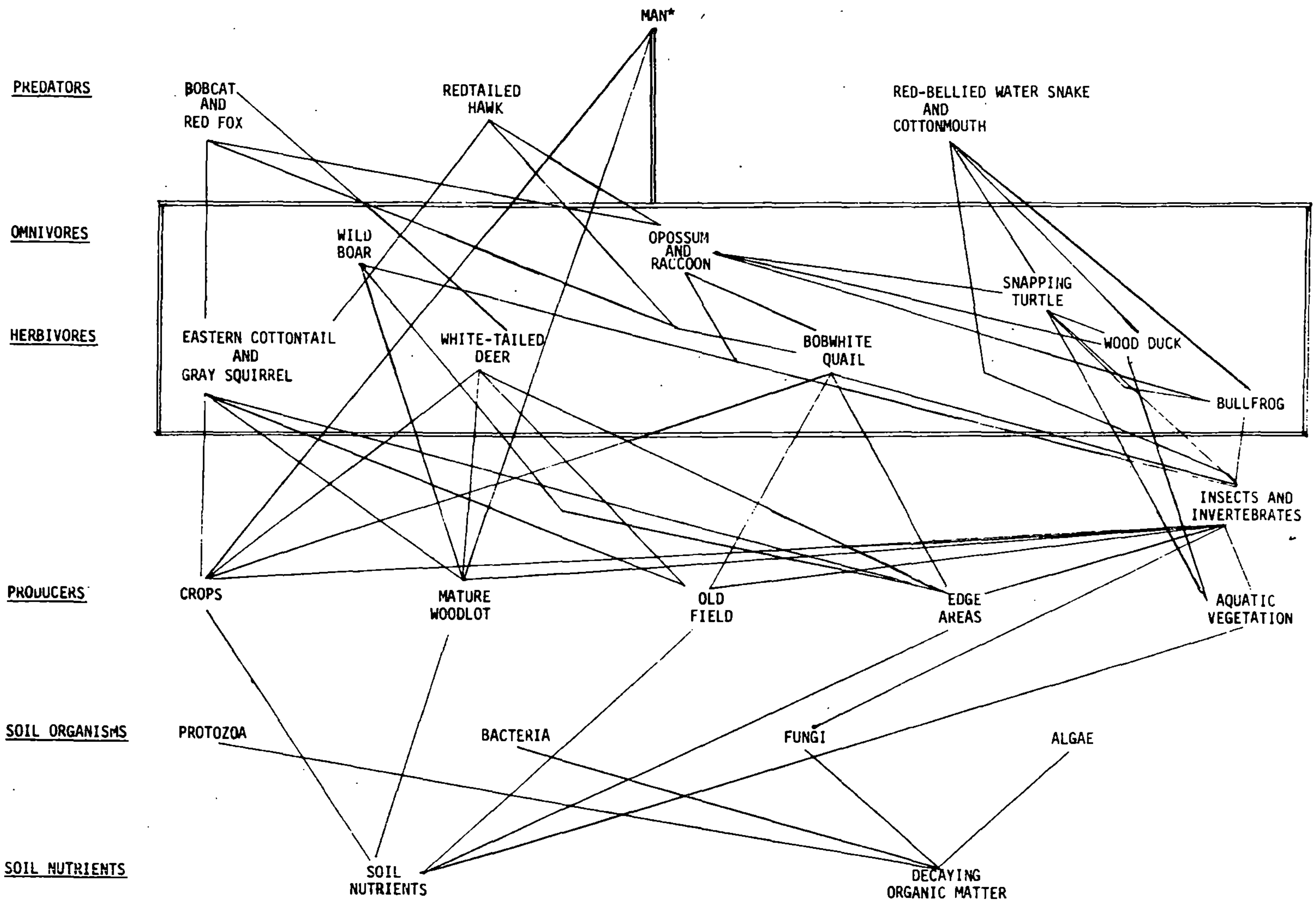
2.8.1.2 Food web relationships

A food web was constructed by the applicant to show the relationships between some of the common species on the site. The web illustrates possible pathways for uptake and concentration of pollutants in the food chain. This food web includes man as a consumer of several species that could be harvested primarily by hunting (Fig. 2.9).

2.8.1.3 Threatened and endangered species

Although several threatened or endangered vertebrate species are known to exist in South Carolina,[22] according to NFCS personnel, few are likely to be found in the immediate site area. The ER (p. 2.7-16) suggests that visits to the site by the endangered Southern bald eagle (*Haliaeltus leucocephalus*) and American peregrine falcon (*Falco peregrinus anatum*) are rare. The endangered red-cocaded woodpecker (*Dendrocopus borealis*) and threatened Eastern brown pelican (*Pelicanus occidentalis*), both present in South Carolina, are birds of restricted habitats, and their presence onsite is unlikely.[23] The endangered Bachman's warbler (*Vermivora bachmanii*) may occur in the swampy river bottom habitat on the site, but its presence was not detected. No Eastern cougars (*Felis concolor*), either resident or transient, are expected onsite. American alligators (*Alligator mississippiensis*) may have occurred onsite at one time but it is believed they have been exterminated in recent years.

There are nine endangered and 35 threatened plant species[24] that occur in South Carolina. None of the nine endangered species are known to occur in Richland County or the six immediately adjacent counties.[25] The nine threatened species occurring in this area are listed in Appendix A.12. Of these, three occur in Richland County (*Isoetes melanospora, Nestronia umbellula,* and *Sarracenia rubra*). Two of the species are restricted to habitats or physiographic areas that do not exist at the NFCS (Appendix A.12). The lone exception is *Isoetes melanospora,* which prefers stream edges. *Isoetes melanospora* therefore may occur along Mill Creek. Even if other threatened species listed in Appendix A.12 occurred at the NFCS in the past, disturbance for farming, then for plant construction, would have eliminated them.



*All animals within double line may be consumed by man.

Fig. 2.9. Generalized food web of the NFCS. Source: ER, Fig. 2.7-1.

2.8.2 Aquatic biota

2.8.2.1 Introduction

Aquatic habitats occurring in the vicinity of the NFCS plant include the Congaree River, Mill Creek, and Sunset Lake. The Congaree River is a typical South Atlantic Piedmont stream characterized by high levels of suspended solids, a sandy bottom, and sand beaches (ER, p. 2.7-9). River flow averages 9166 cfs. At the NFCS discharge point, the river is approximately 500 ft wide and 9 ft deep. Water quality has been described in the preceding section.

Sunset Lake is a shallow, artificial impoundment on Mill Creek. Upper Sunset Lake is now a swamp supporting a mixed stand of swamp tupelo (*Nyssa aquatica*) and Carolina ash (*Fraxinus caroliniana*). The water surface is covered by a dense duckweed mat (*Spirodela polyrihiza* and *Lemna minor*). Lower Sunset Lake still maintains an open-water area, although the encroachment of swamp tupelo and macrophyte growth is evident. This small lake exhibits a brown coloration, probably due to the presence of humic substances (ER, p. 2.7-10).

2.8.2.2 Available environmental data

A review of information available on the Congaree River indicates that very little biological survey work has been done in the area. Contacts with State and Federal agencies and the University of South Carolina provided minimal information. According to the South Carolina Division of Game and Freshwater Fishes, there have been no creel censuses of the Congaree River. The list of fish species collected from the Congaree River Basin in 1957, presented in Table 2.G-3 of Appendix 2.G in the ER, is too general and is outdated. Most of the specimens collected during the 1957 survey were not from the river itself, but from small tributary streams and ponds. Tables 2.G-4 through 2.G-6 of the ER, listing fish collected in Richland, Lexington, and Calhoun counties, are even more general.

All recent available information on aquatic biota in the Congaree River and Sunset Lake is from five days of sampling in 1974 (September 30 through October 4) by Westinghouse Environmental Systems Department (WESD) (ER, pp. 2.7-10 through 2.7-15). Since this was the only time sampling was conducted, it is not possible to discuss seasonal trends or population fluctuations. Because quantitative data was based on five days of sampling, it is possible to deduce only a rough relative abundance of the organisms. Sampling was conducted during a period of relatively high river flow (ER, p. 2.7-11); therefore, results may not be representative of the populations throughout most of the year. Species lists of the aquatic biota collected during the WESD environmental survey may be found in the ER, Appendix 2.G.

2.8.2.3 Congaree River

The Congaree River, near the NFCS, is close enough to the sea that its flow is relatively slow, the waters are warm (+20°C), and the bottom is generally composed of muds and sands. Fauna of such warm, slow rivers are either adapted to warm water or are tolerant to a wide range of temperatures; there is often a rich plankton fauna.[26] Detritus and plant debris washed into the river from the surrounding lands makes up a large part of the nutrients at the base of the food web. The food web of rivers is a complex structure, with organisms often feeding at two or more trophic levels. For example, benthic invertebrates may feed on submerged vegetation as primary consumers or on zooplankton as secondary consumers. Fish may function as primary consumers on plants, as secondary consumers on invertebrates, and as tertiary consumers on other fish.

In the past, the Congaree River has received a large amount of raw sewage. At the time WESD conducted the biological survey, the City of Columbia was still discharging some raw sewage into the river. Many of the organisms collected from the Congaree River, such as tubificid worms, midge larvae (Chironomidae), and phytoplankton of the genera *Nitzchia, Melospira,* and *Pteromonas*, are representative of waters rich in organic matter with little dissolved oxygen.

Phytoplankton collected by tow samples from the river in the vicinity of the NFCS discharge in October 1974 were predominately the colonial green algae, *Eudorina elegans* (ER, Appendix 2.G). Twenty-two species of phytoplankton were identified. Of the total number of individuals collected, 73% were members of Chorophyta, 14% of Chrysophyta, 12% of Cyanophyta, and 1% of Euglenophya and Pyrrophyta. Average cell numbers in the river were 500 cells per milliliter. Some of the phytoplankton present may have been washed down from the lakes on the Saluda River.

Zooplankton collected from tow samples were very sparse. Thirty-three species were identified. The larval stage of bivalve mollusks (glochidia), copepods, oligochaete worms, nematods, and the protozoan *Epistilis plicatilis* were most frequently encountered (ER, Appendix 2.G). Glochidia comprised 21% of the individuals collected. Rotifers, cladeocerans, and insects were also collected.

Samples from a variety of substrates (logs, leaves, and rocks) in the river yielded 112 species of periphyton. Ninety-seven percent of the species were diatoms (ER, Appendix 2.G). Some of the more abundant diatoms observed were *Achnanthes deflexa, Navicula minima, Navicula mutica,* and *Navicula cryptocephala.* Green algae, mostly *Ulothrix* sp., and blue-green algae, *Microcoleus vaginatus* and *Oscillatoria* sp., were observed infrequently.

Benthic invertebrates were collected by ponar dredge samples from the river above and below the NFCS discharge. Of the four phyla collected, 43% were mollusks, 29% were annelids, 27% were arthropods (insects), and 1% were nematodes. Fingernail clams, *Sphaerium* sp., were the most numerous organisms. Corbiculid clams occurred only below the NFCS discharge. Midge larvae (Chironomidae) and tubificid worms were numerous both above and below the discharge.

Electroshocking (for 3 hr) and gill netting (for 23 hr) in the river near the NFCS discharge (by WESD) yielded only one channel catfish, *Ictalurus punctatus*. High flows during sampling may have been responsible for the small catch (ER, p. 2.7-10). Major fish species that presently occur in the Congaree River, according to the South Carolina Department of Fish and Wildlife, are listed in Table 2.16 (ER, p. 2.7-10). Bass, crappies, bluegill, and catfish are all popular game species.

Table 2.16. Major fish species that presently occur in the Congaree River

Scientific name	Common names
Lepisosteidae	
Lepisosteus osseus	Long-nose gar
Amiidae	
Amia calva	Bowfin
Clupeidae	
Dorosoma cepedianum	Gizzard shad
Cyprinidae	
Cyprinus carpio	Carp
Ictaluridae	
Ictalurus natalis	Yellow bullhead
I. nebulosus	Brown bullhead
I. punctatus	Channel catfish
Serranidae	
Morone saxatilis	Striped bass
M. chrysops	White bass
Centrarchidae	
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth bass
M. salmoides	Largemouth bass
Pomoxis annularis	White crappie
P. nigromaculatus	Black crappie

Source: ER, p. 2.7-11 (South Carolina Fish and Wildlife Department).

Fish are generally at the top levels of the food web in aquatic ecosystems. However, because many species will eat a variety of foods, including plants, detritus, and invertebrates, it is impossible to assign a definite position in the food web to a large proportion of the species. The most widespread and important food for river fishes is invertebrates, which form the major part of the diet of a wide range of types of fishes. The majority of the fish likely to be found in the Congaree River, such as bass, bluegill, and crappies, feed on invertebrates. The range of invertebrates eaten is wide, and fish generally eat whatever is available.[26] Largemouth bass and large catfish may eat other fishes as well as other vertebrates such as frogs,

salamanders, and young ducklings. Carp, gar, and catfish are bottom feeders and often function as scavengers. Detritus and plant debris washed into the river may make up a large part of the diet of some fishes, especially gizzard shad.[26]

2.8.2.4 Sunset Lake and Mill Creek

Sunset Lake is a shallow, humic lake with abundant decomposing organic matter and stands of emergent vegetation such as yellow water lily (*Nuphar advena*), lizard tails (*Saururus cernus*), and St. John's wort (*Hypericum spathulatum*). Dissolved oxygen levels in the lake were low (less than 4 ppm) due to high temperatures, low flow, and decomposing organic matter. The only benthic invertebrate collected was the abundant phantom-midge (*Chaobor s punctipennis*), which is tolerant of low dissolved oxygen levels.

The plankton fauna of Sunset Lake were abundant. Phytoplankton densities averaged 60,000 plankters per milliliter. Predominant phytoplankters in the lake were the colonial green algae *Eudorina elegans*. In general, green algae constituted the majority of the phytoplankton community, although diatoms, euglenoids, bluegreens, and dinoflagellates were also represented. Zooplankton species were predominately protozoans (*Difflugia lobostoma* and *Difflugia oblonga*) and the rotifer *Asplanchna priodonta*. Both zooplankton and phytoplankton were more abundant at the inflow end of the lake, probably as a result of the inflow of swamp water from Upper Sunset Lake.

Table 2.17 lists fish species collected from Sunset Lake and Mill Creek. Bluegill and golden shiners (*Notemigonus crysoleucas*) were the most abundant species. According to the applicant, fishing is allowed on Lower Sunset Lake and on Mill Creek on the NFCS property.

2.8.2.5 Threatened and endangered aquatic species

The only threatened and endangered aquatic species that might occur in the region of South Carolina near the NFCS plant is the American alligator, *Alligator mississippiensis*.[22] The staff is not aware of any studies on NFCS property to determine the presence or absence of alligators on the site.

Table 2.17. Enumeration of fish species collected from the Congaree River and Sunset Lake from Oct. 1-3, 1974

Scientific name	Common name	No. collected by gill nets	No. collected by electroshocking	Total No. collected
Lepisosteidae				
Lepisosteus osseus	Long-nose gar	3	0	3
Amiidae				
Amia calva	Bowfin	1	0	1
Cyprinidae				
Notemigonus crysoleucas	Golden shiner	18	0	18
Catostomidae				
Minytrema melanops	Spotted sucker	2	0	2
Ictaluridae				
Ictalurus natalis	Yellow bullhead catfish	1	0	1
Ictalurus mebulosus	Brown bullhead catfish	1	0	1
Ictalurus punctatus[a]	Channel catfish	0	1	1
	Unidentified catfish	4	0	4
Centrarchidae				
Centrarchus macropterus	Flier	1	1	2
Chaenobryttus gulosus	Warmouth	6	0	6
Lepomis machrochirus	Bluegill	68	1	69
Pomoxis nigromaculatus	Black crappie	8	0	8
Unidentified fish		2	0	2
Totals		115	3	118

[a]This was the only fish of its kind collected from the Congaree River.

Source: ER, Appendix 2.G.

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3. THE FACILITY

3.1 EXTERNAL APPEARANCE

The main plant building utilizes approximately 240,000 ft^2 of floor space for the administration and manufacture of nuclear fuel assemblies. There are plans to construct a separate 50,000 ft^2 building on a concrete slab floor to accommodate the fabrication of machined components for the 1600-MTU/year capacity. The following information also includes the description, evaluation, and the extrapolated effects of a projected plant capacity expansion. Based on such extrapolations, it is not expected that in the future when Westinghouse applies for license amendments authorizing such increased capacity, an extensive additional environmental consideration will be conducted.

Major site facilities consist of the main plant building, the chemical storage area, and the waste treatment area, which consists of four chemical settling ponds and one sanitary stabilization pond, as shown in Fig. 3.1. The main plant building contains manufacturing facilities, administration offices, laboratories, and other service-related facilities. The main building floor plan and location of the various operations performed therein are shown in Fig. 3.2. Approximately 700 people are currently employed. With the ultimate facility production rate of 1600 MTU/year, approximately 1850 people will be employed.

3.2 SUMMARY OF OPERATION PROCESSES

The NFCS was designed and constructed to fabricate low ($\leq$5.0 wt %)-enriched-uranium fuel assemblies for use in light-water, commercial power reactors and includes: (1) conversion of uranium hexafluoride (UF_6) to uranium dioxide powder (UO_2), (2) processing the UO_2 powder into pellets, (3) encapsulation of the pellets into fuel rods, (4) fabrication of fuel rods into final assemblies, and (5) shipment of final assemblies to the customers' reactor sites. The operation also includes the assembly of encapsulated mixed oxides (plutonium and uranium oxides, with $PuO_2 \leqslant 6.6$ wt % of the total oxide weight) shipped to this plant from other Westinghouse plants. Construction of the facility was begun in 1968 and completed in 1969. Commercial operation subsequently began in 1969 following authorization granted by the U.S. Atomic Energy Commission in Special Nuclear Materials License No. SNM-1107. Figure 3.3 schematically describes the general sequence of operations (nuclear fuel cycle) involved, from mining uranium ore to the production of electrical energy, including the uranium and plutonium recycle. The boxed-in area depicts the role of the NFCS in this cycle.

The NFCS is operated under the regulations of the Nuclear Regulatory Commission, the Environmental Protection Agency, the South Carolina regulatory agencies, and the Westinghouse environmental and safety policies and procedures. The techniques and processes incorporated into the NFCS are generally typical of uranium fuel fabrication and have been successfully demonstrated during five years of operation.

Several operations are performed at the NFCS in the fabrication of nuclear fuel assemblies for shipment to nuclear power plant customers. Fuel assembly fabrication consists of both chemical and mechanical operations. During these operations, solid, liquid, and gaseous wastes are generated. Plant equipment is designed and operated to keep hazardous chemicals and radioactive discharges to the environment as low as practicable. Figure 3.2-1 of the ER presents a general flow diagram of the processing operations. This figure also schematically shows the gaseous- , liquid- , and solid (baled)-waste release points. A description of the plant processes and complementary service operations follows.

3.2.1 Chemical conversion — ammonium diuranate process

The ammonium diuranate (ADU) process is currently used at the NFCS for making uranium dioxide (UO_2). This process is well established and is generally accepted in the industry as representing the current state of applied technology. The ADU process consists of hydrolyzing UF_6 in water to form UO_2F_2 + HF, then reacting the UO_2F_2 with ammonium hydroxide to form ammonium diuranate, $(NH_4)_2U_2O_7$ (ADU). The ADU is then heated in the presence of steam and hydrogen to form UO_2.

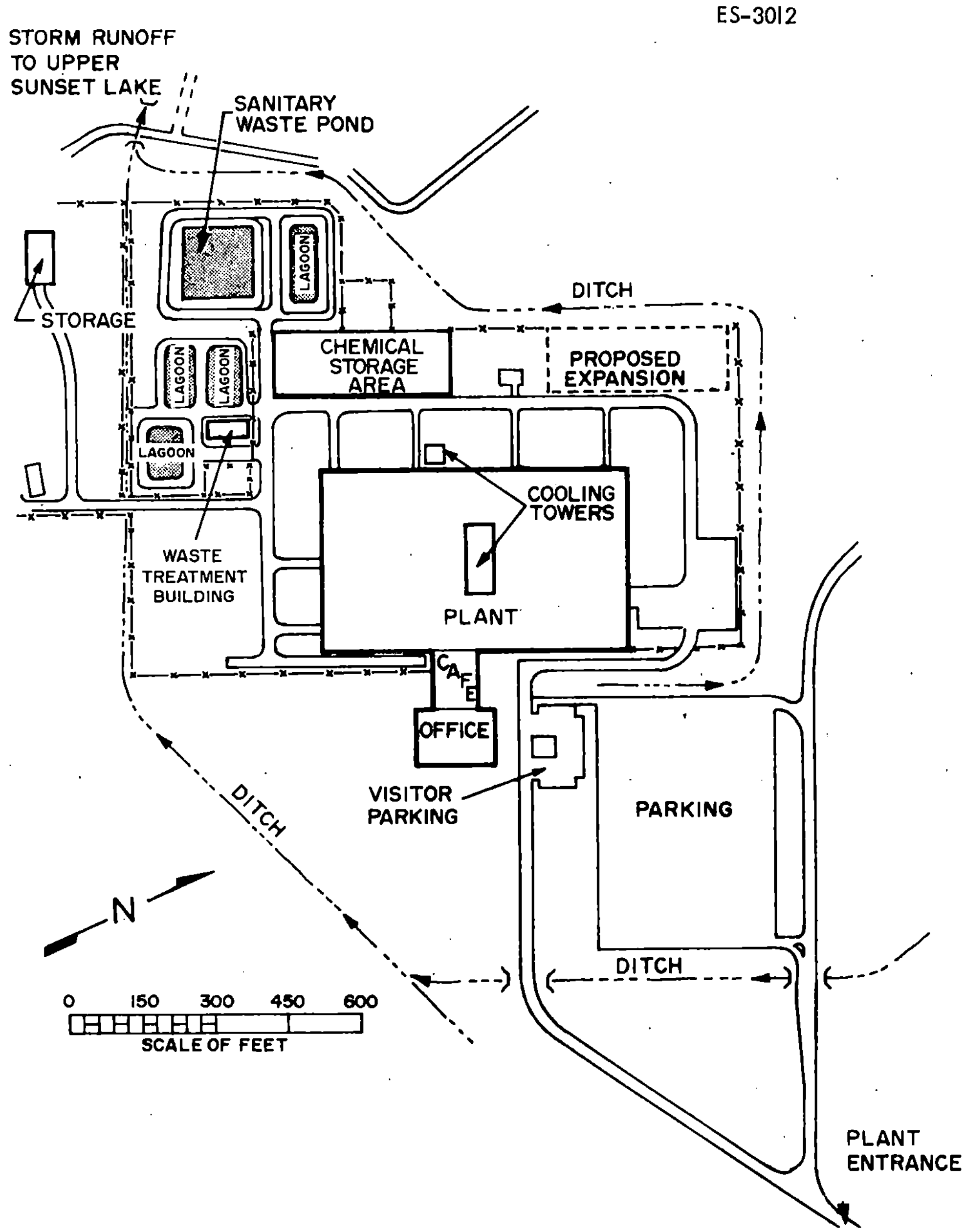
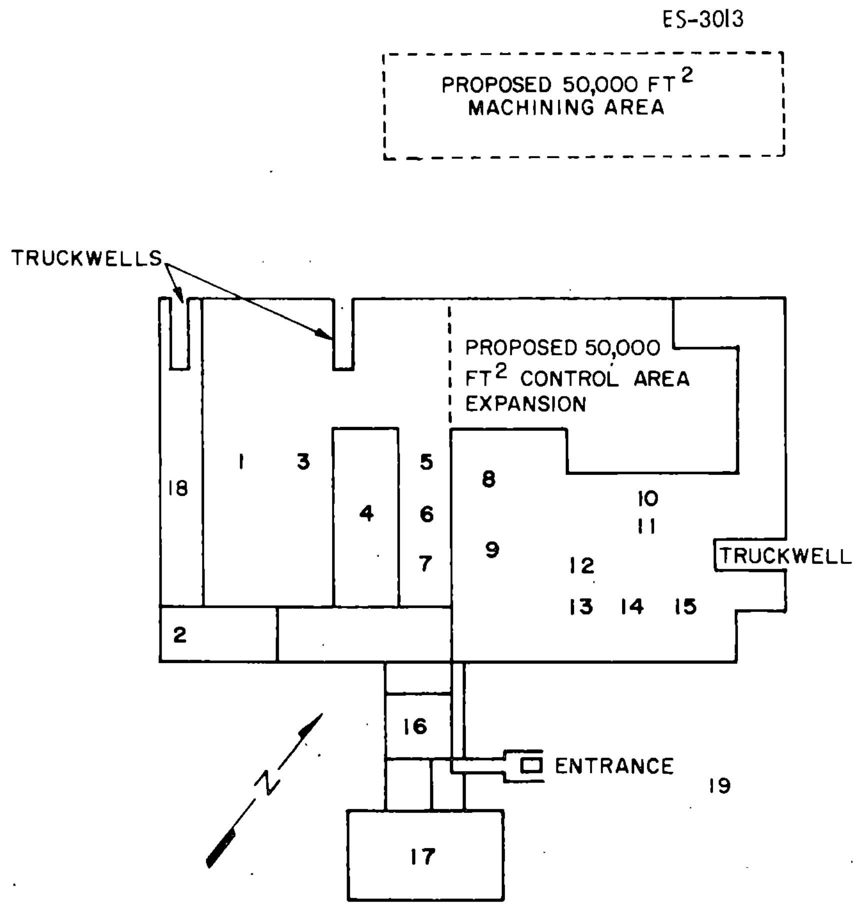


Fig. 3.1. NFCS plot plan. Source: ER, Fig. 3.1-1.

Five ADU conversion lines are currently available to process five different isotopic enrichments simultaneously. It is anticipated that seven to eight ADU conversion lines will be able to produce the new design capacity of 1600 MTU/year. Enrichment control is maintained throughout each conversion line. The important steps that take place in a typical ADU conversion line are described in the following headings.

3.2.2 UF_6 vaporization and hydrolysis

Uranium hexafluoride (UF_6) is received from suppliers in a solid form. The UF_6 is vaporized by heating and fed as a gas to the ADU line. Water is mixed with the gaseous UF_6 to (1) form an



LEGEND

1 CHEMICAL PROCESSING	10 11 GRID AREA
2 CHEMICAL LABORATORY AREA	12 13 14 15 ASSEMBLY AREA
3 PELLETIZING	16 CAFETERIA
4 SINTERING FURNACES	17 OFFICE AREA
5 6 7 ROD LOADING	18 UF_6 RECEIVING
8 9 X-RAY	19 PARKING

Fig. 3.2. Building floor plan. Source: ER, Fig. 3.1-2.

aqueous solution of uranyl fluoride and hydrofluoric acid, (2) convert the gas into a more manageable form (a liquid), and (3) control very precisely the mass flow of uranium to the next operation.

$$\underset{\text{Uranium Hexafluoride}}{UF_6} + \underset{\text{Water}}{2H_2O} \rightarrow \underset{\text{Uranyl Fluoride}}{UO_2F_2} + \underset{\text{Hydrofluoric Acid}}{4HF}$$

3.2.3 Precipitation

Ammonium hydroxide is added to the uranyl fluoride to cause formation of solid precipitated particles of ADU. The ADU particles are suspended in the excess ammonium hydroxide solution; this solution is called a slurry. It is here, in the precipitation step, that the basic physical

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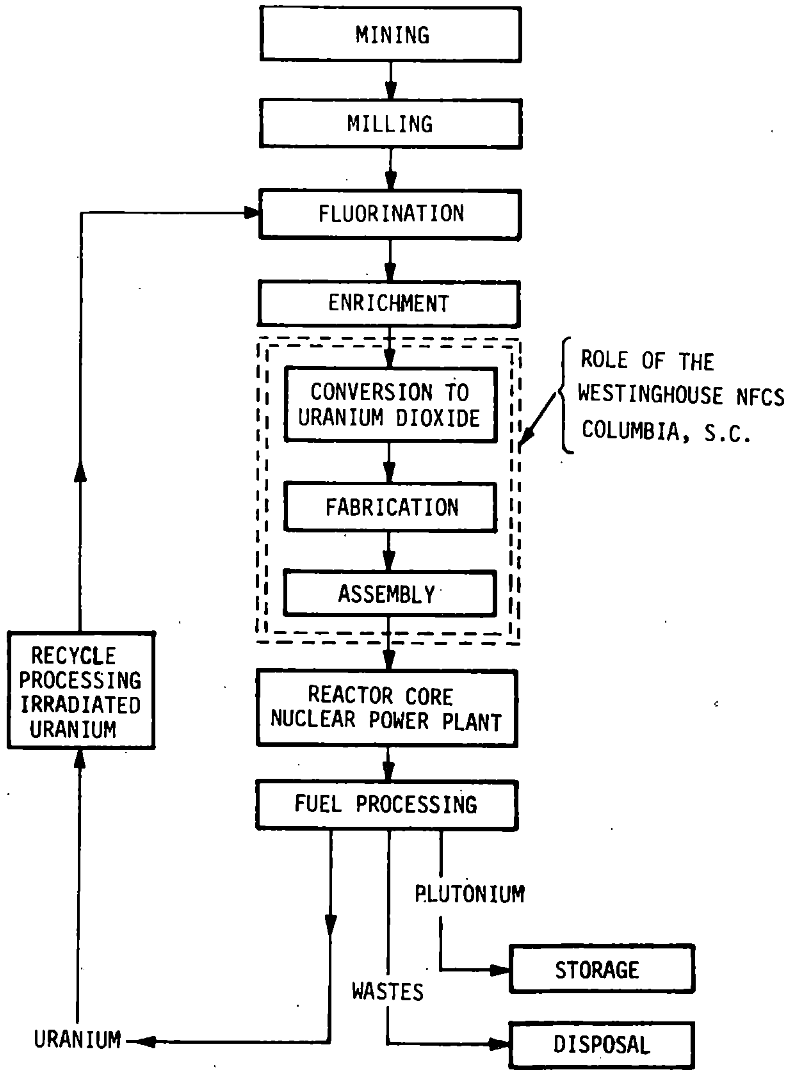

Fig. 3.3. Nuclear fuel cycle. Source: ER, Fig. 1.2-3.

properties of the final nuclear fuel are formed. Great care is taken to maintain close process control over the reactant streams and the product flow to the next operation.

$2UO_2F_2$	+	$6NH_4OH$	→	$(NH_4)_2U_2O_7$	+	$4NH_4F + 3H_2O$
Uranyl Fluoride		Ammonium Hydroxide		Ammonium Diuranate		Ammonium Fluoride

3.2.4 Calcination (kiln drying)

After passing through a centrifuge, where the slurry is dewatered, the ADU is fed into a rotary calciner where the ADU is converted by heat and hydrogen to uranium dioxide. The calciner is externally fired with natural gas. The calcining step is very important since it affects the chemical and physical properties of the uranium dioxide.

The calciner reaction can be described in the following chemical equation:

$(NH_4)_2U_2O_7$	+	$2H_2$	$\xrightarrow{\text{Heat}}$	$2UO_2$	+	$2NH_3$	+	$3H_2O$
ADU		Hydrogen		Uranium Dioxide		Ammonia		Water

The calciner reaction gases are passed through a water scrubber where ammonia gas is absorbed. This exhaust is then filtered through a high-efficiency particulate air (HEPA) filter assembly unit before it is discharged to the atmosphere. It is continuously monitored and counted for gross alpha. The scrubber solution is mixed with the liquid waste from the ADU process (quarantine solutions). This waste is analyzed for gross alpha. If the total uranium concentration in the solution is found to be less than 3.0×10^{-5} μCi/ml, the solution is discharged to the waste treatment facility. If the uranium concentration is greater than the discharge limits, the solution is reprocessed to reduce the concentration to acceptable levels before being discharged to the waste treatment facility.

The bulk of the ammonia absorbed by the water scrubber is recovered for reuse in the ammonia recovery system, which is described in further detail in Sect. 3.3 of the ER.

3.2.5 Direct-conversion fluidized-bed (DCFB) process

The DCFB process employs technology that is currently beyond the advanced development stage but has not yet attained sufficient commercial operating experience to represent the applied technology currently available. This process is presently under evaluation at the NFCS and could be expected to be a candidate process for the installation of additional conversion capacity. The most important waste stream generated by this process is hydrofluoric acid (HF), which has the potential of being a salable by-product. Because the process does not employ ammonia in intermediate chemical conversion steps, but rather converts the feed directly to the desired oxide, other waste streams, such as ammonia, are not generated by this process. The DCFB process offers both advantages and disadvantages in terms of waste generation. An evaluation of waste treatment requirements constitutes a portion of the evaluation of expansion planning.

The DCFB process is a continuous-flow process for converting uranium hexafluoride (UF_6) to uranium dioxide (UO_2). This alternate direct-conversion process is in an advanced development stage, with plans for implementation geared to Westinghouse management evaluations and decisions. Figure 3.2-2 in the ER shows a flow diagram of the DCFB process.

The overall DCFB reaction can be described by the chemical equation

$$UF_6(g) + 2H_2O(g) + H_2(g) \longrightarrow UO_2(s) + 6HF(g) .$$

Processing is carried out at elevated temperatures (550° to 630°C) and at slightly positive pressures in three gas-solid reactors in series — primary converter, fluoride stripper, and cleanup reactor. The uranium dioxide product is recovered from a cooler-blender as a free-flowing granular product and is milled, packaged, and stored until further processing.

Cooler-blender product is discharged into an isolation hopper, purged with an inert gas, and transported in dilute-phase fluo-solids flow to the comminution system by a suitable carrier gas. The comminution system consists of a mill feed hopper, mill, and discharge bin. Milling, packaging, and storage of the uranium dioxide product is very similar to that described for the ADU (ammonium diuranate) process.

A wet-scrubber system is used to control pollutants to the waste off-gas stream to the lowest practicable levels. Each off-gas stream passes through a 5-μ sintered-Monel filter with a timed blow back to keep the filter clean. A similar backup filter is also supplied in the main exhaust line to the scrubber. The gases are then passed through a direct-contact, recirculating, venturi scrubber, through a tangential demister or disengaging plenum, and through a 10-in.-diam packed column where the off-gases are scrubbed with water. The scrubber liquid and resulting overflow to the process-liquid-waste quarantine tanks are maintained at a pH of about 7 by introducing aqueous ammonia to the scrubber reservoir.

Prior to release to the atmosphere, the gases pass through a demister and through HEPA filters. Filtered gases discharged to the atmosphere are continuously sampled and analyzed on a daily basis for airborne particulate radioactivity. Fluorides will be analyzed on a periodic basis.

The tangential demister or disengaging plenum and scrubber reservoir alternately overflow into one of three quarantine tanks. The contents of each quarantine tank are sampled and analyzed to ensure that the concentration is below maximum permissible concentration (MPC) before release to the waste treatment facility for fluoride removal. A recirculating filter system with provision for pH adjustment and precipitation to remove the residual radioactivity is available if the concentration exceeds MPC.

3.2.6 Scrap recovery

Scrap recovery process operations are characterized as batch operations involving a variety of input forms. The preliminary operations concentrate the material and convert it to forms readily processed into U_3O_8 powder. Not all materials require processing through the entire sequence of operations. The basic processing sequence includes dissolution of solid forms, conversion to slurry form by precipitating ADU from the solution, dewatering the slurry form by wet mechanical separation, calcining the resulting sludge in regular or controlled atmosphere furnaces, and packaging and storing the resulting product. The product is sampled and analyzed in essentially the same manner as any other incoming powder supplies before release to manufacturing.

Before being released through the HEPA-filtered exhaust system to the atmosphere, off-gases from the dissolution tank are routed through a reflux condenser and a scrubber to remove entrained particles and condensible vapors. The reflux condenser is mounted vertically and directly above the dissolution tank so that any condensation formed can drain back into the tank.

3.2.7 Pellet and rod area

The uranium dioxide powder from the chemical conversion or scrap recovery areas is received in the pellet and rod area and is densified in a slug-pressing operation. The slugs are granulated, and the resultant material is transferred to a nearby operation where a binder-lubricant is added.

3.2.8 Quality assurance operations

Finished fuel rods are subjected to a variety of inspection operations to ensure the quality of the final product. These operations include dimensional inspection, radiography, gamma scanning, and leak testing. Following these operations, finished fuel rods are transferred to storage racks to await further processing in the final assembly area.

3.2.9 Shipping

Completed fuel assemblies are shipped to customers in Government (DOT and/or NRC)-approved containers for insertion into their reactors. Waste shipments to an approved burial ground are also made from the shipping area. Before any waste is sent out for disposal, it is measured for uranium content.

3.2.10 Liquid-waste treatment

Westinghouse Nuclear Fuel Division (Sect. 1, ref. 1) has continued to meet all discharge limitation parameters. Phase III limits have been achieved through effective distillation operations, through the use of caustic addition (to supplement pH adjustment with lime and disassociate complexed ammonia), through the use of supplemental lime treatment following the heat exchange, through increasing the frequency of chemical process analyses, and by holding extensive operator training sessions. All Phase III limitations are being met.

The major waste generated in converting uranium hexafluoride into uranium dioxide is ammonium fluoride. The basic reaction involved in the treatment of process waste is:

$$2\ NH_4F + Ca\ (OH)_2 \longrightarrow 2\ NH_4OH + CaF_2\ .$$

After the process waste stream is treated with slaked lime for pH adjustment and fluoride removal, it is then pumped through a heat exchanger to the ammonia still. The stripping of free ammonia from the waste stream for recycle to the ADU process is a pH-dependent reaction. If an excess quantity of lime is used for the pH adjustment, the heat exchanger will become plugged with excess solids. Phase III development consisted of adding NaOH so that almost all bound ammonia is converted to free ammonia in accordance with the following equation:

$$NH_4^+ + OH^- \longrightarrow NH_3 + H_2O\ .$$

This reaction effectively reduces ammonia complexed either as ammonium fluoride or ammonium nitrate. Thus, the maximum theoretical stripping efficiency is achieved. The feed is injected into a still. Stripped ammonium hydroxide (30%) is stored for reuse in the ADU conversion process, and CaF_2 bottoms are further treated.

The addition of supplemental lime following the heat exchange has increased the efficiency of fluoride removal and has provided the process control necessary to meet Phase III limits. The additions of supplemental caustic and lime are controlled manually after the operator's review of continuous, on-line specific ion and pH electrodes.

Process operational control levels are NH_3 — 100-500 ppm (depending on volume); F^- — 20-3,000 ppm (depending on volume); and pH — 8.0-9.0.

In addition to the ADU process waste stream, ammonia originates from other low-concentration waste streams or from those which contain foaming or corrosive impurities. By discontinuing the use of ammonia in areas such as the DCFB scrubbers, the waste-incinerator scrubbers, and the scrap recovery area, a resultant decrease in final-effluent ammonia has been achieved. Also, by reducing makeup water in the final-air-effluent scrubber stream (thereby increasing the ammonia concentration), the stream was made suitable for treatment using the ammonia still.

After the ammonia is removed, the still bottoms containing the CaF_2 waste are further treated by one of the two following methods:

1. Pumping the still bottoms directly to the west lagoon for solids and fluoride removal using quiescent settling. Following settling, the clarified liquid is transferred to either the north or south lagoon for discharge via the plant outfall. Chemical analyses of the lagoon contents dictate daily discharge rates.

2. Mechanical separation of the CaF_2 solids using a centrifuge. The CaF_2 solids are pumped as a 50% slurry to the west lagoon for dewatering. The liquid portion is handled as above. The clarified supernate can be discharged either directly to the river or to the lagoon system if it is high in fluorides.

Research and engineering evaluations by Westinghouse have indicated that certain actions can be taken in Phase IV to increase the removal efficiency of the waste treatment process. These are:

1. The addition of capacity to the sanitary waste treatment system.

2. Rerouting of piping network so that plating room process waste goes directly to the river sump rather than through the west lagoon.

3. Addition of a final aerator to ensure sufficient dissolved oxygen in the effluent.

4. Use of a computerized effluent discharge system to ensure that discharge limitations are met.

5. Installation of a nickel removal system for the dragout in the plating process.

3.2.11 Sanitary waste system

At 1600 MTU/year capacity, approximately 23,500 items per month (socks, underwear, towels, etc.) will be sent to an approved cleaning company for reuse in the plant. Soiled clothes are packed in 55-gal drums and then scanned for activity before release from the plant. A single-channel analyzer, sodium-iodide-crystal scanner is used for this monitoring.

Wastes generated in the washroom and in other sanitary facilities are routed to a single-cell oxidation stabilization pond with a holding capacity of 1,500,000 gal. The process involves treatment through an extended aeration package plant, followed by solids settling with anaerobic and aerobic decomposition of the organic matter. The treated sanitary waste leaves the system via a lift pump, is mixed with treated process wastes, and is discharged to the Congaree River.

3.2.12 Industrial wastes

At design capacity, water will be obtained from the Columbia Municipal Water System at a rate of approximately 10,600,000 gal/month. This water will be used for potable and process cooling requirements. About 45% of the incoming water will be returned to the atmosphere in the form of water vapor from the lagoon ponds and the cooling towers. The balance of water, approximately 5,700,000 gal/month, will be discharged to the Congaree River in the form of process and sanitary-treated water, 2,850,000 gal for each stream. A 4-in.-diam pipeline transfers these wastes to the Congaree River about 3.5 miles south of the facility. The pipe submerges into the river and discharges directly into the river current, near the bottom and about 20 ft from the shoreline.

3.3 WASTE CONFINEMENT AND EFFLUENT CONTROL

Effluents from the various processes occur in three forms: gaseous, liquid, and solid. The effluents may contain small quantities of the radioisotopes U-234, U-235, U-236, and U-238. The composition of the mixture will vary depending upon the enrichment of the material being processed; however, in all cases, the bulk of the material will be U-238 (∿95% by weight or more), whereas the predominant activity will be U-234 (up to ∿86% of the total activity). For this study, the reference mixture given in Table 3.1 will be used.

Table 3.1. Reference isotopic mixture

Isotope	Mass fraction (%)	Activity fraction (%)	Activity (μCi/g)
U-234	0.04	85.38	2.48
U-235	4.15	3.07	0.09
U-236	0.025	0.55	0.016
U-238	95.78	11.00	0.32

The process effluents consist primarily of ammonia (NH_3) and fluorides such as NH_4F, CaF, and a very small amount of gaseous HF.

3.3.1 Gaseous effluents

3.3.1.1 Ventilation systems — radioactive material areas

Operations involving the use of radioactive materials in unsealed physical forms are limited to low-enrichment (≤5% U-235) uranium in the fuel manufacturing facilities or in the associated analytical laboratory. No plutonium will be airborne in the NFCS plant and in the assembly areas because the pellets containing plutonium are hermetically sealed in tubular fuel rods received from other Westinghouse facilities. The ventilation systems installed in these facilities are designed so that all air from zones used to handle or process uranium is treated to remove essentially all uranium prior to its release to the atmosphere. At the design capacity of 1600 MTU/year, the maximum air flow from the plant is estimated not to exceed 160,000 cfm.

The normal gaseous radioactive effluent from the plant operating at 1600 MTU has been estimated to be about three times that of the present 400-MTU operation. These effluents are released from a number of short stacks and roof vents, as shown in Fig. 3.4 and listed in Table 3.2.

3.3.1.2 Nonradioactive process gases

Process gases are also vented through several short stacks and vents on the roof of the manufacturing building, as shown in Fig. 3.4. Prior to discharge to the atmosphere, process gases that may affect the environment are scrubbed for chemical removal (Fig. 3.5). The process gas scrubbers are listed in Table 3.3.

Based upon an extrapolation of data obtained by the applicant during 400-MTU/year operation, the average and maximum release rates for ammonia and fluorides during normal operation at 1600 MTU have been estimated. They are listed in Table 3.4.

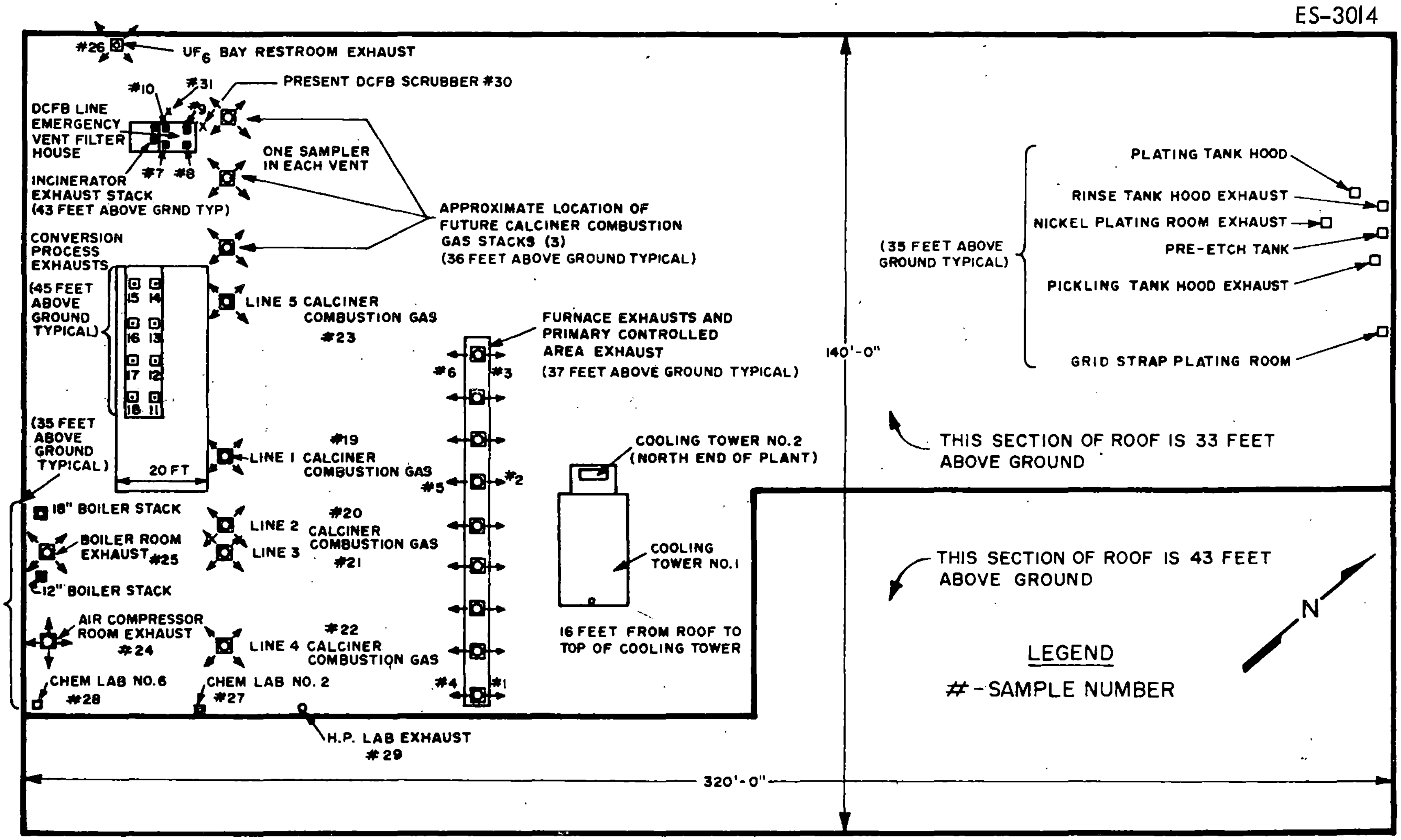

Fig. 3.4. Process stack locations — roof plan. Source: ER, Fig. 3.3-1.

Table 3.2. Estimated airborne uranium releases

Effluent release point	Release rate (μCi/sec) at 400 MTU	Release rate (μCi/sec) at 1600 MTU
Furnace exhausts	1.76×10^{-5}	3.87×10^{-5}
DCFB[a] emergency exhausts	5.35×10^{-6}	2.14×10^{-5}
Conversion process exhausts	1.01×10^{-5}	4.05×10^{-5}
Calciner combustion gas	2.18×10^{-6}	3.49×10^{-6}
Air compressor room	2.74×10^{-6}	2.74×10^{-6}
Boiler room exhaust	4.70×10^{-6}	4.70×10^{-6}
UF_6 bay rest room exhaust	3.30×10^{-8}	3.30×10^{-8}
Chem lab exhaust 2	2.98×10^{-7}	1.19×10^{-6}
Chem lab exhaust 6	9.58×10^{-7}	3.83×10^{-6}
HP lab exhaust	2.15×10^{-7}	8.59×10^{-7}
Incinerator exhaust	3.65×10^{-7}	1.46×10^{-6}
Totals	4.45×10^{-5}	1.19×10^{-4}

[a]Direct-conversion fluidized-bed. Source: ER, Table 3.3-3.

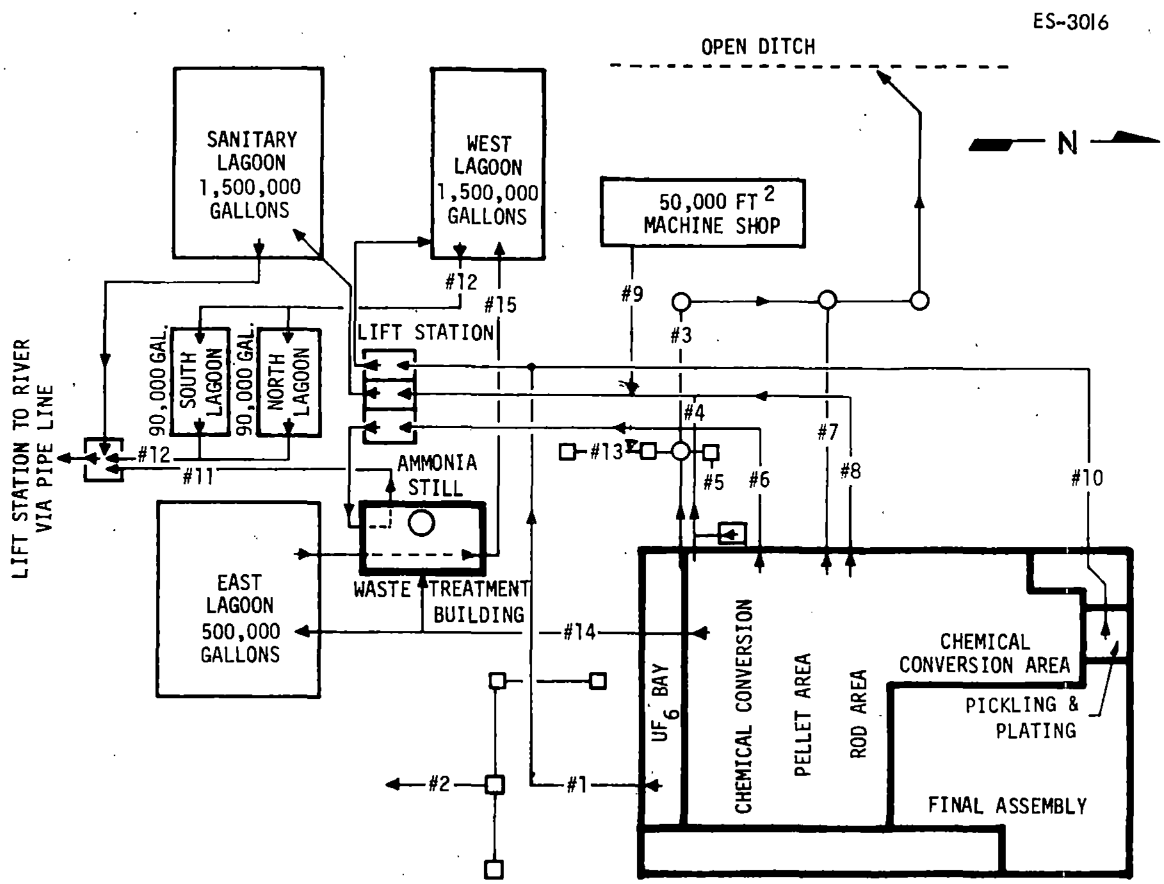

Fig. 3.5. Building and liquid-waste-treatment flow sheet. Source: ER, Fig. 3.3-2.

Table 3.3. Process gas scrubbers

Scrubber	Quantity	Location	Type	Efficiency: Chemical (%)	Efficiency: Particulate (wt %)
S-2A S-2B	2	Plant air effluent	High-energy venturi cyclone	70-85 (NH_3, HF)	90
S-3	1	Vessel vent header	Packed tower	90 (NH_3, HF)	
S-1	2	Scrap recovery	Venturi	90 (NH_4F)	
Calciner reaction gas effluent	10	Calciners	Venturi	75-80 (NH_3) 75-90 (HF)	90
Incinerator effluent	1	Incinerator	Impingement	75-85 Acids	95
DCFB[a]	1	DCFB off-gas	Venturi	98 (HF)	
	1	DCFB off-gas scrubber	Packed tower	97 (NH_3) 99 (HF)	

[a]Direct-conversion fluidized-bed. Source: ER, Table 3.3-2.

Table 3.4. Average and maximum emission rates (g/sec) of process gases

Chemical	Average at		Maximum at	
	400 MTU	1600 MTU	400 MTU	1600 MTU
Ammonia (NH_3)	6.49	25.96	7.80	31.18
Fluorides (F^-)	0.006	0.0238	0.0072	0.0286

The DCFB process does not require the use of ammonia; therefore, should this process, which is an advanced development, be adopted to replace the ADU process, the ammonia effluent would be discontinued.

3.3.1.3 Monitoring procedures

Each release stack monitored is equipped with a device that continuously draws a sample through a low-porosity filter. The filter paper is then removed periodically and analyzed for uranium. The past analysis of air concentrations and flow rates have been utilized to give the total release rate at the present capacity (400 MTU). These calculations were then extrapolated to estimate the releases at the projected capacity of 1600 MTU. A scaling factor of 4 was used for the chemical process areas. Lower values (2.2 and 1.6 respectively) were used for the furnace exhausts and calciner combustion gases. The emissions from the air compressor room, boiler room, and UF_6 bay rest room are assumed to remain unchanged. Waste gases from chemical processing are also periodically analyzed for ammonia and fluorides. Using a scaling factor of 4, the average and maximum ammonia and fluoride gaseous effluent releases for the present operating load of 400 MTU have been utilized to estimate the values to be expected at the projected capacity of 1600 MTU.

3.3.2 Liquid effluents

Liquid wastes consist of two components: sanitary wastewater generated by plant employees and industrial wastewater generated by the manufacturing process. Both ADU and DCFB process wastes, which may contain uranium, are processed through ion-exchange columns and circulated through cartridge filters. The fluoride-containing wastes are treated with lime to form a slurry of CaF_2, which is then distilled to remove the ammonia for reuse. The slurry is then discharged to the east or west lagoon for settling of the solids.

The total annual flow rates are 47 million gallons for the 400-MTU capacity and are estimated to be 69 million gallons for the 1600-MTU-capacity plant. A schematic diagram of the waste system is shown in Fig. 3.5; the components are identified in Table 3.5.

3.3.2.1 Radioactive liquid effluents

The raw waste streams are monitored for radioactivity before leaving the plant conversion area. If the uranium concentration exceeds a specified level, the stream is diverted for additional processing. Liquid wastes from the process scrubbers, the scrap-recovery line, and the DCFB process are stored in quarantine tanks on a batch basis and then sampled before release. Only uranium concentrations in liquid-waste streams below the specified level of 30 pCi/ml (the MPC for U-234 given in 10 CFR Part 20) are permitted to leave the plant area.

In addition to the isotopes of uranium, the liquid-waste streams contain small amounts of the daughter products Th-231, Th-234, and Pa-234*m*. These radionuclides account for the presence of some beta-gamma activity in the liquid-waste stream.

The average discharge concentrations and the total annual release of radioactivity to the river for the present 400-MTU operation, in addition to estimated values for the projected 1600-MTU operation, are given in Table 3.6.

Table 3.5. Identification of transfer lines for the building and waste treatment system[a]

Line No.	Identity
1	— Process waste Water UO_2 NH_4F NH_4OH
2	— Groundwater
3	— Roof drain to storm sewer
4	— Sanitary drain
5	— Closed-cooling-tower loop overflow and blowdown of system to storm sewer (Note: Line No. 5 stream deleted because of EPA requirements and now reports to line No. 4) Water Nalco 39 Nalpac 8241 Nalco 918 Nalpac 8240 Nalco 7313 Nalco 82
6	— Contaminated waste Water UO_2 powder
7	— Roof drain to storm sewer
8	— Sanitary drain Has boiler blowdown Nalco 19 Nalco 711 Nalco 356 Nalco 752 Has deionizer flush and backwash Sulfuric acid (H_2SO_4) Caustic NaOH Serves as waste drain for x-ray film development chemicals Gevaert fixer and developer is used in automatic developing equipment Contains wastes from cafeteria and kitchen
9	— Roof drain to storm sewer
10	— Process waste drain Has pickling and plating wastewater Nitric acid Nitric acid, iron salts, and nickel salts Hydrofluoric acid Hydrofluoric acid, iron salts, and nickel salts Sulfuric acid Sulfuric acid, iron salts, and nickel salts Hydrochloric acid Hydrochloric acid, iron salts, and nickel salts Boric acid Enthone Corporation L-90 Conversion Corporation Kenvert No. 183 Sodium hydroxide Sodium carbonate Trisodium phosphate Nickel chloride Nickel sulfate Nickel nitrate Nickel fluoride
11	— Contaminated waste (filtered) Water

Table 3.5 (continued)

Line No.	Identity
12	— Process waste (treated) Water NH_4F NH_4NO_3 NH_4OH CaF_2 CaOH Contains lab-drain wastes (individual pickup points not shown)
13	— Storm sewer groundwater
14	— Process waste Water HF (from DCFB process)
15	— Treated (unclarified waste) H_2O CaOH NH_4F NH_4OH CaF_2 UO_2

[a]See Fig. 3.5. Source: ER, Table 3.3-5.

Table 3.6. Discharge concentrations and total annual release of radioactivity in NFCS liquid wastes

Radiation component	At 400 MTU/year			At 1600 MTU/year		
	Concentration (pCi/ml)	Percentage of MPC	Total release rate (mCi/year)	Concentration (pCi/ml)	Percentage of MPC	Total release rate (mCi/year)
Alpha	0.884	2.9[a]	157	1.22	4.1[a]	319
Beta	2.94	15.3[b]	523	3.64	20.2[b]	951
Gamma	0.112		20	0.14		37

[a]Based on U-234, 10 CFR Part 20.

[b]Based on Th-234, 10 CFR Part 20.

Source: ER, Table 3.3-6.

3.3.2.2 Nonradioactive liquid effluents

After precipitation of the fluorides with lime and the removal of the ammonia in the stripping still, the treated effluent is discharged to the east or west lagoon to permit settling of the solids. The liquid is drained out on a batch basis to the north or south lagoon where additional settling takes place. After a one- to three-day settling time, the supernate is pumped to the Congaree River, usually together with overflow from the sanitary stabilization pond. The average annual total quantities discharged at the 400-MTU/year level are given in Table 3.7.

The projected values at 1600-MTU/year capacity are given in Table 3.8.

3.3.2.3 Monitoring procedures

A continuous recorder measures the flow and pH of waste discharged to the river. Twenty-four-hour composite samples are obtained and measured on a daily basis for ammonia and fluoride. Also, 24-hr composite samples are obtained and measured on a weekly basis for BOD_5, for total

Table 3.7. Average water-chemical-effluent data for 400-MTU/year operation

Parameter	Discharged to river	
	Quantity (lb/day)	(Concentration, mg/liter)
Silver (Ag)	0.075	0.15
Iron (Fe)	0.52	1.03
Sodium (Na)	30	60
Calcium (Ca)	293	584
Magnesium (Mg)	1.38	2.75
Manganese (Mn)	0.035	0.07
Molybdenum (Mo)	0.095	0.19
Nickel (Ni)	0.5	1
Boron (B)	0.22	0.43
Chloride (Cl)	24.8	49.5
Phosphorus as -P	0.75	1.5
Kjeldahl (nitrogen)	244	488
Ammonia (NH_3)[a]	200[b]	399
Fluoride (F)	122.8	61.5
Sulfate (SO_4)	42.6	85
Sulfite (SO_3)	0.63	1.26
Sulfide (S)	trace	trace
COD	58	116
BOD_5	10.9	21.5
Phenols	trace	trace
Surfactants	0.035	0.07
Oil and grease	4.3	8.67
Hardness (as $CaCO_3$)	293	583.5
Total suspended solids	8.0	15.8
Total volatile solids	310	619
Total solids	281	560.8
Total dissolved solids	273	544
pH (units)		8.9

[a]Ammonia discharges were for May 1974.

[b]This value is believed to be much lower than that for other months; however, it is in compliance with the May 1, 1974, permit of an average and maximum discharge of 231 lb/day. Westinghouse Columbia has applied for a variance to this NPDES permit for an average of 1700 lb/day and a maximum of 4000 lb/day until June 30, 1975.

Source: ER, Table 6.2-1.

suspended solids, and for nickel. Grab samples are taken from the lift pump station once a week and once a month, respectively, and analyzed for grease and oil and fecal coliform. A monthly composite sample is also analyzed for gross alpha, beta, and gamma activity. In addition, total uranium is analyzed on a weekly basis.

Table 3.8. Calculated average and maximum quantities and concentrations of chemicals to be discharged for 1600-MTU/year operation

Parameter	Discharged to Congaree River			
	Average (lb/day)	Maximum (lb/day)	Average concentration (mg/liter)	Maximum concentration (mg/liter)
pH (units)			6.0	9.0
B	2.04	2.22	1.68	3.64
Na	170	240	141	1199
Ag	0.34	0.45	0.34	0.37
Mo	0.53	1.88	0.43	1.54
Mn	0.13	0.32	0.11	0.27
Mg	6.54	12.3	5.37	10.1
Fe	2.60	10.3	2.13	8.49
Hardness, $CaCO_3$	1222	3213	1005	2645
Ca	1212	3190	2328	2626
$SO_3{}^{2-}$	2.79	3.01	2.29	2.47
$SO_4{}^{2-}$	218	356	178	293
S^{2-}				
P	3.38	3.8	2.80	4.23
NO_3 (nitrogen)	220	281	138	176
Cl	130	221	106	181
F	25	25	15.6	15.6
NH_3	15	15	9.4	9.4
BOD_5	18.7	40	11.8	11.8
COD	300	558	247	460
Oil and grease	12.5	18.7	7.81	7.81
Total suspended solids	25	50	15.6	15.6
Total dissolved solids			1093	2032
Total volatile solids			1466	1734
Total solids			1122	2113
Kjeldahl nitrogen			534	787

Source: ER, Table 3.3-5.

A monthly composite sample of plant discharges is sent to Control for Environmental Pollution, Inc., at Santa Fe, New Mexico, for a complete chemical analysis to determine the amounts of major, minor, and trace elements as well as organic compounds, algicides, and coliform.

3.3.3 Solid wastes

3.3.3.1 Manufacturing waste

Materials such as used packaging, worn-out clothing, paper, wood-floor sweepings, discarded tools, etc., are collected and stored prior to disposal, which is made according to two primary classifications: uranium contaminated or contamination free and combustible or noncombustible.

Waste materials that are or could be contaminated are collected in suitable containers according to combustible or noncombustible categories. Noncombustible waste is examined to determine the

feasibility of recovery and is then either processed chemically or collected in boxes for ultimate disposal at a Government-licensed waste disposal site. Combustible items are reduced to ash in a specially designed incinerator.

The incinerator off-gas is treated by water scrubbing and has been found to contain about 4×10^{-13} $\mu Ci/cm^3$ of uranium. The ash is sampled, analyzed for uranium, and either reprocessed or disposed of by burial.

Approximately 40 to 60 bales of combustible contaminated waste and 4 bales of noncombustible waste will be generated per day at the 1600-MTU level.

3.3.3.2 Calcium fluoride

The west lagoon is presently full and contains approximately 1.5 million gallons of partially dewatered CaF_2. This material contains 4 to 10 μCi of uranium per pound, and there are no current plans concerning the ultimate disposal of this material. Accordingly, the staff recommends that Westinghouse be requested to submit their plans for permanent disposition.

4. ENVIRONMENTAL IMPACTS OF FACILITY OPERATIONS

4.1 RADIOLOGICAL IMPACTS

The radiological impacts of the NFCS plant were assessed by calculating the maximum dose to the individual living at the site boundary closest to the highest concentration of airborne radionuclides released from a 1600-MTU/year plant. In addition, the dose to an individual from drinking water and eating fish from the nearest water supply was also assessed. The doses are actually 50-year dose commitments, that is, the total dose to a reference organ, resulting from one year of intake, that will accrue during the remaining lifetime (50 years) of the individual. Site-specific data were used where available.

4.1.1 Terrestrial

4.1.1.1 Individual dose

The doses from airborne radioactive effluents released from the plant stack are calculated for an individual living at the property line, 1800 ft north-northwest of the plant, where the maximum offsite ground-level concentration of radionuclides occurs. The average annual χ/Q value at this location was estimated to be 1.63×10^{-5} sec/m^3. It is assumed that the individual spends all of his time at this location and that all of the food consumed is produced at the point of reference.

The highest dose received, 1.1 millirems/year, was to the bone. The total-body dose (0.07 millirem/year) and doses to the kidney, GI tract, and lungs were all less than 1 millirem/year. These doses are well below the allowable limit of 25 millirems/year to the total body, 75 millirems to the thyroid, and 25 millirems to any other organ.[1] The annual average total-body dose from natural radiation in the State of South Carolina is about 135 millirems/year (ref. 2) and may be compared with the maximum total-body dose of 0.07 millirem/year resulting from the plant airborne releases.

4.1.1.2 Population dose

The annual total-body dose to the population within 50 miles of the plant (see Sect. 2.2) is 2.4×10^{-2} man-rem and is due primarily to U-234 (46%) and U-235 (39%). The population total-body dose may be compared with the similar population dose resulting from the area natural background of 8.75×10^4 man-rems. The average total-body dose resulting from the plant airborne effluents to the 6.48×10^5 persons within a 50-mile radius is only 3.7×10^{-5} millirem/year.

The highest annual population organ doses are to the bone, 1.8×10^{-1} man-rem, due primarily to U-234 (77%); lungs, 1.1×10^{-1} man-rem, due primarily to U-234 (79%); and kidney, 4.7×10^{-2} man-rem, due primarily to U-234 (72%) and U-235(16%). The dose to all other organs is less than that of the total body.

4.1.2 Aquatic

The doses resulting from the release of liquid effluents into the Congaree River are based on the estimated measurements in the river for a projected 1600-MTU/year plant capacity.[3] The bone received the highest combined dose from eating fish and drinking water (1.0 millirem/year), based on an intake of 50 g/day and 1.2 liters/day respectively. The dose to the total body from aquatic sources was only 0.06 millirem/year and, similarly, doses to the kidney and GI tract were less than 1 millirem/year. These annual doses are well below the allowable limits of 25 millirems/year to the total body, 75 millirems to the thyroid, and 25 millirems to any other organ.[1]

4.2 NONRADIOLOGICAL IMPACTS

4.2.1 Terrestrial impacts

The staff believes that the primary potential impact of the NFCS plant operation on terrestrial biotic communities will result from the atmospheric effluents emitted from the plant. The only measurable effluents are ammonia and fluorine. Under certain conditions, the concentrations and duration of ammonia and fluorine are toxic to terrestrial biota.

4.2.1.1 Impact on plants

All plants require a source of nitrogen, especially for protein synthesis. Ammonia is a form of already-fixed nitrogen that can be used by plants. However, very high concentrations of ammonia in the atmosphere can cause collapse of foliar tissue without loss of chlorophyll. Bioassay tests (5-min exposures) of 10 plant species indicated that a concentration of 1000 $\mu g/m^3$ of atmospheric ammonia decreased photosynthesis by about 10%.[4] The staff calculated the average annual ground-level concentration of ammonia at the closest NFCS boundary (1800 ft NNW), for 1600 MTU/year production, to be 119 to 270 $\mu g/m^3$, with maximum annual values of 142 to 324 $\mu g/m^3$ (Table 4.1). Offsite vegetation would not undergo ammonia concentrations great enough (1000 $\mu g/m^3$) to reduce photosynthesis even under extended Pasquill type F or G stability conditions.

During the current 400-MTU/year production, no vegetation damage attributable to atmospheric ammonia was observed by Westinghouse Environmental Systems Department personnel who surveyed plants within 3 miles of the NFCS (ER, p. 4.2-34). Because ammonia and other nitrogen compounds are common products of microbial decomposition of dead plant debris, ammonia accumulation in soils from the NFCS is not likely to be measurable.

The processes and problems involved with atmospheric fluoride concentrations are more complex than those concerning ammonia. Fluorides are highly soluble in biological systems, where they may accumulate to toxic levels.[5] The effects of atmospheric fluorides on plants are generally induced through fluoride absorption by leaves rather than through absorption by roots.[6] Although root uptake of fluorides can be important in acid soils,[7] even that is of little consequence in toxicity.[8]

The effect of atmospheric fluoride absorbed by leaves varies with the continuity of the exposure. Plants appear to respond least to intermittent fluoride exposure, especially when nonexposure periods cover single or multiple days.[9] Intermittent exposure is more characteristic of areas that surround a point source of atmospheric fluoride such as the NFCS. Shifts in wind direction may reduce otherwise toxic concentrations to harmless levels at a given locale several times a day.

Low fluoride levels in leaf tissue may merely reduce photosynthesis, thereby reducing growth.[5] They may also cause death of plants, which symptomatically appears first as chlorosis (loss of chlorophyll) then as necrosis (death) of leaves in broad-leafed species or tip-burn of conifer needles.[8]

McCune[10] has synthesized the literature on plant responses to atmospheric fluoride. In all plants, the cumulative nature of the fluoride damage is apparent from the gradual reduction in fluoride concentrations necessary to induce toxicity with increased time of exposure. None of the experiments on which the work is based exceeded 100 days. Therefore, actual long-term toxic values may be lower, especially for perennials. Among perennials, conifers in particular should be affected because they carry their needles for several years. On the other hand, most of McCune's data are based on continual exposure to fluorides rather than to the intermittent exposure expected to occur at the NFCS. Boundary fluoride concentration values from the NFCS (Table 4.1) and suggested air quality criteria for fluorides[10] are given in Table 4.2.

Table 4.1. Ground-level concentrations of ammonia and fluoride at a plant capacity of 1600-MTU/year at nearest site border (1800 ft NNW, or about 0.3 mile)

	Annual average[a] release (μg/m³) at —			Annual maximum[b] release (μg/m³) at —		
	13.7 m (staff)[c]	1 m (staff)[c]	Ground (NFCS)[d]	13.7 m (staff)[c]	1 m (staff)[c]	Ground (NFCS)[d]
Ammonia	118.64	269.98		142.50	324.27	210.20
Fluoride	0.11	0.25		0.13	0.30	0.16

[a]From annual average emission rates (Table 3.4).

[b]From annual maximum emission rates (Table 3.4).

[c]The staff calculated concentration values for a point 1800 ft NNW of the site (closest boundary), at release points of 13.7 m (height of stack) and 1 m (conservative correction for wake effects), by multiplying emission rate values by χ/Q values (4.57×10^{-6} sec/m³ at 13.7 m; 1.04×10^{-5} sec/m³ at 1 m), which were generated from R. E. Moore, *AIRDOS — A Computer Code for Estimating Population and Individual Doses Resulting from Atmospheric Releases of Radionuclides from Nuclear Facilities,* ORNL/TM-4687, Oak Ridge National Laboratory, Oak Ridge, Tenn., January 1975.

[d]The NFCS staff used maximum emission rate values (ER, Table 4.2-10) to calculate concentration values for a point 0.3 mile (1584 ft) NNW of the site (closest boundary), with a ground-level release point, by multiplying emission rate values by the χ/Q value (1.63×10^{-5} sec/m³) from ER, Table 2.6-3. Emission rate values for fluorine (ER, Table 4.2-10) are four times greater than the values the NFCS intended and used here (from R. Fischer, WNFCS, letter to E. Y. Shum, NRC, Washington, D.C., Oct. 26, 1976, Docket No. 70-1151).

Table 4.2. Atmospheric fluoride levels (at the plant boundary expected from NFCS operation at 1600 MTU/year), air quality standards, and levels at which symptoms appear and toxic conditions prevail among selected plants[a]

	Exposure period	Average concentration of (μg/m³)	Maximum concentration of (μg/m³)
NFCS fluoride concentrations at plant boundary	Yearly	0.109	0.131
Washington state HF ambient air standards[b]	Yearly Monthly	0.500 0.800	

	Exposure period (days)	Appearance of symptoms (μg/m³)	Toxicity (μg/m³)
Fluoride concentrations			
Tree fruits	70	1.5	4.0
Corn	10	1.5	2.0
Alfalfa	12	1.0	100.0
Larch	5		1.0
Western conifers	8		1.0
one- to two-month-old pine needles	10		0.6

[a]Toxic levels are those at which reduced productivity or yield have been measured.

[b]Washington maintains the most restrictive fluoride air quality standards; South Carolina has none.

Source: D. C. McCune, "On the Establishment of Air Quality Criteria, with Reference to the Effects of Atmospheric Fluorine on Vegetation," American Petroleum Institute, *Air Qual. Monogr.* 69(3) (1969).

From the calculated levels of fluoride concentrations (0.11 to 0.25 μg/m³ average, 0.13 to 0.30 μg/m³ maximum) expected at the NFCS boundary at 1600-MTU/year operation and from the toxic levels of atmospheric fluorine shown for various plant species in Table 4.2, little, if any, plant damage can be expected near the NFCS.

The most important natural biotic community is the Congaree swamp forest under consideration for national monument status (Sect. 2.5). It is unlikely that fluoride emissions from the NFCS would reach the swamp 4-1/2 miles distant.

The loblolly pines (*Pinus taeda*) and other pine species near the NFCS would also be unlikely to undergo fluoride damage as would those on the plant site. However, if damage were to occur and were great enough to actually kill trees, some changes in forest composition would follow.

Effects of fluorine concentrations on agricultural activities could also occur. The pecan orchards near the eastern border of the study area (ER, p. 2.2-14) are probably too far from the NFCS to be affected. Examination of cultivated and native species within 3 miles of the NFCS, by WESD field ecologists, indicated no fluoride damage. This field study was conducted in the spring of 1974 after approximately five years of plant operation.

4.2.1.2 Impact on animals (including man)

There is generally no direct effect of ammonia on animals or humans at the concentrations calculated for the NFCS boundary conditions (119 to 324 μg/m³). The lowest ammonia concentrations found to affect experimental animals was 2000 μg/m³; ammonia concentrations two orders of magnitude greater are generally required to produce measurable damage.[11] The indirect effects of ammonia on humans and animals via food ingestion is also not expected because this compound is a plant nutrient (Sect. 4.2.1.1).

Atmospheric fluorides cannot be evaluated as simply as ammonia. Direct inhalation of atmospheric fluoride contributes a negligible amount to total fluoride intake by man or animals.[12] Instead, effects are felt through food chains that contain fluorides accumulated by plants being ingested by cattle that are, in turn, ingested by man.

Although soil fluoride concentrations are irrelevant (Sect. 4.2.1.1), the relationship of atmospheric fluoride concentrations (usually in micrograms per cubic meter) to levels of fluoride in plant tissue (usually in parts per million per gram of dry weight) is complex. Natural fluoride accumulation rates differ among plant species, and within a species, rates differ among different climatic and edaphic conditions.[13] However, certain important conclusions can be drawn.

First, a direct (if not linear) relationship between atmospheric exposure to fluorides and plant accumulation of fluorides does exist. Second, the relationship can be used to translate one variable into the other. For example, Benedict et al. and Guderian et al.[14] used a 1.1-$\mu g/m^3$ concentration of fluorine with a 47-day exposure period to test fluoride accumulation in forage plants. Fluoride levels in orchard grass and alfalfa were raised 125 ppm/g in both species.[15] Under exposure periods of two months, plant fluoride concentrations of 40 ppm in these two species would be supplied by a concentration of 0.5 μg of fluoride per cubic meter.[16] Other forage crop fluoride accumulation values are similar.[17] Because maximum concentration values of fluoride at NFCS (Table 4.2) are little different, similar plant tissue fluoride values may be expected at the NFCS boundary.

The concentrations of fluoride in plant tissue that can affect cattle are >50 ppm, sheep and pigs, >100 ppm; and chickens, >300 ppm.[18] At plant tissue fluoride concentrations greater than 50 ppm, for example, chronic fluorosis may develop in dairy and beef cattle, producing lameness, loss of appetite with a resulting weight loss, and decreased milk production.[19] Dietary intake of fluorides by humans is not a problem[20] because contaminated plant and/or animal foods that humans ingest do not constitute a large enough portion of the total human diet.

From the data given above, it is apparent that chronic fluorosis in livestock that consume forage produced on and near the NFCS may occur at the 1600-MTU/year operation. Data are insufficient to make a more specific determination at this time. Therefore, monitoring programs to assess this possibility are proposed (p. 5.6).

4.2.1.3 Summary of impacts on terrestrial biota

No deleterious effects of ammonia generated at the NFCS have been identified. At the present 400-MTU/year production level or at the projected 1600-MTU/year level, it is unlikely that fluoride emissions will damage native plants and livestock off the NFCS property.

Potential damage to onsite needle-leafed trees, with accompanying potential changes in forest composition, and subsequent changes in animal species composition and population densities may occur. Forage and hay crops grown on the NFCS property are in some danger of fluorine accumulation. These effects are serious enough to warrant the biotic monitoring procedures as recommended in the following section on environmental monitoring programs.

No other significant impact of the NFCS plant operation or expansion upon agricultural or natural biota is foreseen.

4.2.2 Aquatic impacts

4.2.2.1 Impacts of the NFCS facility on water use

The NFCS plant receives its water from the Columbia Municipal Water system. The projected water consumption at the expanded capacity of 1600 MTU/year is 0.5 cfs (10.6 million gallons per month), which represents 1% of the city's current water use (ER, pp. 2.2-17 and 3.2-13). The effect of the NFCS on the city's water availability will be negligible.

At the expanded 1600-MTU capacity, the NFCS will return 0.3 cfs of combined process and sanitary wastes to the Congaree River, resulting in a consumptive water use of 0.2 cfs (ER, p. 3.2-13). Since the lowest seven-day average flow of the Congaree River to be expected in a ten-year period is 1590 cfs, the staff concludes that water use by the NFCS plant will have a negligible effect on the quantity of water available from the river for downstream use.

4.2.2.2 Impacts of NFCS liquid effluents

Liquid effluents and the waste treatment system are described in detail in Sect. 3.3 of this appraisal. Liquid wastes consist of two waste streams: sanitary wastewater generated by plant employees and industrial wastewater generated by both the ADU and DCFB processes. At the expanded 1600-MTU capacity, the applicant predicts each waste stream will consist of 0.15 cfs, totaling 0.3 cfs of liquid effluent (ER, p. 3.2-13).

The major wastes generated by the manufacturing processes are fluoride and ammonia. Some nickel is released in the plating room wastes, which are treated before joining the process waste stream. The treatment of process wastes consists of the precipitation of fluorides with lime and removal of ammonia by distillation. Treated process effluent is then discharged to the east lagoon to permit settling. The clarified liquid is then pumped to either the north or south lagoon for further settling before being discharged along with sanitary-waste effluents.

The treatment of sanitary wastes consists of an extended aeration package plant and polishing lagoon. The NFCS presently chlorinates the sanitary-waste stream using calcium hypochlorite. Residual chlorine concentrations in the sanitary effluent are 2 ppm.[21]

4.2.2.3 Compliance with Federal and State water quality regulations

Federal

The NFCS plant operates under National Pollution Discharge Elimination System (NPDES) Permit No. SC 0001848, enforced by the U.S. Environmental Protection Agency (EPA). Phase III and Phase IV limitations for effluents covered by the permit are listed in Table 4.3. The NFCS plant has complied with Phase III levels for all limited parameters. Table 4.4 lists the results of NFCS effluent monitoring for the past year (Sept. 1, 1975, to Aug. 30, 1976). It is evident from Table 4.4 that current ammonia and fluoride levels exceed Phase IV limitations. The NFCS has requested and received from the EPA an informal extension of the Phase III limitations until mid-November 1976. The EPA cannot grant another extension of Phase III limitations without a formal hearing.[22]

Table 4.3. Daily Phase III, current Phase IV, and requested revised Phase IV limits for NFCS NPDES permit No. SC 0001848

(Values are lb/day except where indicated)

Effluent parameter	Phase III limits		Current Phase IV limits		Requested revised Phase IV limits	
	Av	Max	Av	Max	Av	Max
BOD_5	23	50	18.7	40	23	50
Total suspended solids	25	50	25	50	50	50
Ammonia	231	231	15	15	75	150
Fluoride	100	100	25	25	50	100
Nickel	1.5	1.5	1.25	1.5		
Oil and grease	15	22	12.5	18.7		
Fecal coliform (No./100 ml)	100	200	N/A[a]	N/A		
pH range	6-10.5		6.8-10.5			

[a]N/A — not applicable.

Source: R. Fischer, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, D.C., Oct. 12, 1976, Docket No. 70-1151.

The NFCS has further requested an EPA revision of the Phase IV limitations for ammonia, fluorides, total suspended solids, and BOD_5. Requested Phase-IV limits for these parameters are listed in Table 4.3. The NFCS believes that compliance with the original Phase-IV limits is not feasible with currently available technology. The EPA has asked the NFCS to undertake an engineering and economic study of all currently available methods for ammonia and fluoride removal to determine if any of the methods could be applied to the NFCS wastes to further minimize discharges. The EPA is reserving any decision on revision of Phase IV limits pending completion of an engineering study now being conducted by Metcalf and Eddy, Inc., at the request of NFCS. This study will address the practicability of available treatment alternatives for application to NFCS

Table 4.4. NFCS monitoring of NPDES-limited effluents
(Values are lb/day except where otherwise noted)

Month	Ammonia, N		Fluoride		Nickel		Fecal coliform as No./100 ml		pH		Total suspended solids		Oil and grease		BOD_5		Flow (Mgd)	
	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max
Sept. 1975	49.7	101	33	48	0.40	0.58	<5	<5	8.8	9.5	17	23	5	6	15.4	23.0	0.1367	0.2129
Oct. 1975	43.0	93	21	76	0.41	0.84	<5	<5	8.7	9.6	12	15	9	18	4.2	7.5	0.1402	0.1690
Nov. 1975	78.0	223	20	52	0.48	0.62	131	356	8.8	9.9	16	24	6	8	5.1	10.4	0.1362	0.2059
Dec. 1975	56.9	181	15	50	0.72	1.34	<5	<5	8.6	9.2	10	17	6	8	10.5	17.8	0.0673	0.1360
Jan. 1976	113.8	224	19	49	0.91	1.43	<5	<5	8.7	9.4	22	32	6	10	9.6	17.4	0.1026	0.1969
Feb. 1976	96.3	207	13	47	1.03	1.35	<5	<5	8.9	9.8	17	19	5	6	4.6	6.5	0.0907	0.1651
Mar. 1976	40.6	153	11	36	0.43	0.58	<5	<5	8.9	10.4	21	37	3	4	2.3	4.2	0.0749	0.0889
Apr. 1976	65.4	148	19	75	0.57	0.70	<5	<5	8.9	9.9	22	50	6	13	3.3	6.4	0.0802	0.1441
May 1976	62.2	142	21	100	0.33	0.69	31	56	8.2	8.9	9	17	6	6	7.3	12.8	0.1054	0.1630
June 1976	38.2	102	27	92	0.37	0.88	<5	<5	8.4	9.2	14	21	5	6	5.1	7.4	0.0376	0.2001
July 1976	24.2	54	14	43	0.61	1.45	<5	<5	7.5	8.9	12	21	5	7	1.7	3.2	0.1166	0.1743
Aug. 1976	39.7	114	25	78	0.32	0.74	39	100	7.1	7.8	9	13	5	6	8.0	9.4	0.1168	0.1957
Mean	59.0	145	19.8	62.2	0.55	0.93	<20	<45	8.5	9.4	16	24	6	9	6.4	10.5	0.1004	0.1710
Highest for 12 months	113.8	224	33	100	1.03	1.45	39	100	8.9	10.4	22	50	9	18	15.4	23.0	0.1402	0.2129

Source: R. Fisher, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, D.C., Oct. 12, 1976, Docket No. 70-1151.

wastewaters. A test plan was submitted in December 1976, and results of the bench-scale tests will be available in April. Until such time as EPA decides on any revision of Phase IV limits, based on the results of the test, the NFCS will remain in noncompliance with its NPDES permit and will be subject to enforcement action under the provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1319).[22]

State regulations

The EPA has recently transferred the regulation of most industrial discharges to the State of South Carolina's Pollution Control Authority. Because of the pending decision on the NFCS permit, the regulation of NFCS effluents has not yet been transferred to the State. NFCS liquid discharges do not come under any state jurisdiction.

Table 4.5 lists State water quality standards for Class B waters, which apply to the Congaree River. Pertaining to State-regulated parameters of pH and fecal coliform, NFCS releases are negligible when diluted in the large flow of the Congaree River.

Table 4.5. Quality standards for Class B waters[a]

Items	Specifications
Fecal coliform	Not to exceed a log mean of 1000/100 ml based on five consecutive samples during any 30-day period; nor to exceed 2000/100 ml in more than 20% of the samples examined during such period (not applicable during or following periods of rainfall)
pH	Range between 6.0 and 8.5, except that swamp waters may range from 5.0 to 8.5
Dissolved oxygen	Daily average not less than 5 mg/liter with a low of 4 mg/liter, except that swamp waters may have an average of 4 mg/liter
Phenolic compounds	Not greater than 1 μg/liter unless caused by natural conditions

[a]Waters suitable for domestic supply after complete treatment in accordance with requirements of the South Carolina Department of Health and Environmental Control. Suitable also for propagation of fish, industrial and agricultural uses, and other uses requiring water of lesser quality.

Source: ER, Table 4.2-17.

4.2.2.4 Impacts of liquid effluents on the Congaree River

Effluents not limited by the NPDES permit

Table 3.8 in Sect. 3.3 lists the average and maximum amount of effluents expected at 1600-MTU capacity. For the non-NPDES-limited parameters, the values in Table 3.8 represent approximately four times the current amounts being released at 400 MTU, listed in Table 3.7 of Sect. 3.3. Table 4.6 contains a conservative (often called worst-case) estimate of the increase in concentration of non-NPDES-limited parameters in the Congaree River due to NFCS discharges. To obtain the numbers in column 2 of Table 4.6, the maximum release (at 1600 MTU) of each non-NPDES-limited parameter in Table 3.8 was assumed to be diluted in a flow of 1590 cfs, which is the lowest seven-day average flow to be expected for the Congaree River in a given ten-year period. Since no data were available from the NFCS on the plume characteristics of discharges into the Congaree River, one may only assume complete mixing with the Congaree River waters. Since the effluent does not contain heated water, the assumption may be close to the real situation.

Since background concentrations of many of these substances in the river were not available, it was not possible to estimate the resultant concentrations after the addition of NFCS effluents. Most non-NPDES-limited parameters in the effluent are released in small-enough amounts to be negligible after dilution in the river. Hardness ($CaCO_3$) of the Congaree River will be raised 0.38 mg/liter, which represents approximately 1% of the present background hardness ($CaCO_3$) of

Table 4.6. Worst-case estimates of increase in concentrations of non-NPDES-limited parameters in the Congaree River due to NFCS discharges (1600-MTU capacity)

(Dilutions assume complete mixing in river)

Parameter	Maximum daily discharge at 1600 MTU (lb/day)	Increase in concentration of Congaree River at a flow of 1590 cfs (mg/liter)
Boron (B)	2.22	0.0003
Sodium (Na)	240.0	0.03
Silver (Ag)	0.45	0.00005
Molybdenum (Mo)	1.88	0.0002
Manganese (Mn)	0.32	0.00004
Manganese (Mn)	12.3	0.001
Iron (Fe)	10.3	0.001
$CaCO_3$ hardness	3213	0.38
Calcium (Ca^{2+})	3190	0.37
Sulfate (SO_4^{2-})	356	0.04
Sulfite (SO_3^{2-})	3.01	0.0004
Sulfide (S^{2+})	trace	
Phosphorus (P)	3.8	0.0004
Nitrate nitrogen (NO_3^-(N)	281	0.03
Chloride (Cl)	221	0.03

Source: ER, Table 4.2-15.

the river (Tables 2.10 through 2.13 of Sect. 2.7.2). The other non-NPDES-limited effluents will have a negligible effect on the Congaree River. The staff concludes that the non-NPDES-limited parameters in Table 4.6 will have no impact on the aquatic biota in the Congaree River.

The applicant estimates that the sanitary-waste stream will have an initial concentration of 2 ppm residual chlorine following treatment.[21] After dilution with the process waste stream, the final effluent could have a concentration of 1 ppm residual chlorine. Assuming the mixing of the discharge into a flow of 1590 cfs, the resultant rise in residual chlorine concentration in the river would be 0.0002 mg/liter, which is less than 8% of the recommended maximum concentration of 0.003 mg/liter residual chlorine.[23] At average river flows of 9166 cfs, the increase in chlorine concentration will be 0.00003, or 1% of the recommended concentration.

The staff recognizes that complete mixing will not be instantaneous and that residual chlorine concentration directly at the outfall could reach toxic levels. If this were the case, aquatic life such as relatively immobile benthic invertebrates and periphyton, which could not avoid the chlorine at the outfall, would be killed. Since no information on plume characteristics is available, no estimate can be made of how far from the outfall lethal concentrations of chlorine could exist. Most fish would in all likelihood avoid the high chlorine concentrations at the outfall. Avoidance response of rainbow trout has been reported at concentrations of 0.001 mg/liter of free chlorine.[23]

Considering that the worst case of low flow is unlikely and that the lethal effects of residual chlorine would probably involve relatively few aquatic organisms directly at the outfall, the staff concludes that the impact of NFCS residual chlorine on Congaree River biota will be negligible.

Impact of NPDES — Limited Parameters

Predicted discharges of the NPDES-limited parameters (ammonia, BOD_5, fluoride, total suspended solids, nickel, and oil and grease) at a 1600-MTU/year plant capacity are listed in Table 3.8. The predictions are based on the applicant's expectation of meeting current Phase IV limitations.

Since NFCS has expressed doubts about achieving current Phase IV limits, even at their present 400-MTU capacity, the predicted discharges in Table 3.8 for NPDES-limited parameters at 1600 MTU are probably not realistic. The requested higher Phase IV limits in Table 4.3 may be a more reasonable prediction of discharges at 1600 MTU than those in Table 3.8. Table 4.7 lists the increase in concentration of NPDES-limited parameters in the Congaree River as a result of NFCS effluents. The discharge levels in Sect. A of Table 4.7 are based on the requested higher maximum Phase IV limits in Table 4.3.

Table 4.7. Estimation of increase in concentration of NPDES-limited parameters in the Congaree River as a result of maximum NFCS discharges expected for 1600-MTU/year capacity

(Dilutions assume complete mixing in river)

Discharge (lb/day)	Increase in concentration of effluents (mg/liter)	
	River flow of 1590 cfs[a]	Average annual flow of 9166 cfs
A. Based on maximum requested revised Phase IV limits		
Ammonia, total NH_3(N), 150	0.02	0.003
Fluoride, 100	0.01	0.002
BOD_5, 50	0.01	0.001
Total suspended solids, 50	0.01	0.001
Nickel, 1.5	0.0002	0.00003
Oil and grease, 18.7	0.002	0.0004
B. Based on average mean monthly discharge for past year multiplied by a factor of 4		
Ammonia, total NH_3(N), 236	0.03	0.005
Fluoride, 79.2	0.01	0.002
BOD_5, 25.6	0.003	0.0005
Total suspended solids, 64	0.01	0.001
Nickel, 2.2	0.0003	0.00005
Oil and grease, 24	0.003	0.0005
C. Maximum discharge at 400 MTU for the past year multiplied by a factor of 4		
Ammonia, total [NH_3(N)], 896	0.10	0.02
Fluoride, 400	0.05	0.01
BOD_5, 92	0.01	0.002
Total suspended solids, 200	0.02	0.004
Nickel, 5.8	0.0007	0.0001
Oil and grease, 72	0.008	0.002

[a]Lowest seven-day average for a ten-year period.

However, discharges of ammonia and fluoride at 400-MTU capacity, as recently as August 1976, are very near the requested higher Phase IV limits (Table 4.4) and would certainly exceed these limits at the expected quadrupled plant capacity. Probably the most reasonable prediction of NFCS discharges of NPDES-limited parameters at 1600-MTU capacity would be obtained by multiplying the mean monthly discharges of each effluent for the past year (in Table 4.4) by four, which is how the discharge levels in Sect. B of Table 4.7 were obtained.

To make an adequate assessment of potential environmental impacts, it is not sufficient to consider only the average case of mean monthly discharges. A worst case of maximum discharges and low river flow must also be considered. Accordingly Sect. C of Table 4.7 represents a worst-case estimate of maximum NFCS discharges at 1600-MTU capacity. Discharge levels in Sect. C were calculated by multiplying the greatest maximum monthly discharge of each effluent for the past year (in Table 4.4) by four. The center column of Table 4.7 represents the worst case of NFCS effluents diluted in a ten-year low river flow. The last column of Table 4.7 assumes dilution in an average river flow.

To summarize Table 4.7, the middle column of Sect. C may be thought of as the very worst case of a high effluent discharge diluted in a low flow that may be statistically expected once in ten years. Assuming NFCS discharges continue in proportion to their discharge over the past year, the last column of Sect. B would represent the case that would most often occur. However, assuming NFCS is able to meet the higher Phase IV limits, the last column of Sect. A would represent the case that would occur most frequently.

The increases in concentration of BOD_5, total suspended solids, nickel, and oil and grease, even at the very worst case, are negligible. Tables 2.7 through 2.10 show that dissolved oxygen in the Congaree River averages about 80% saturation; therefore, an increase in BOD_5 of 0.01 ppm (Table 4.7) is negligible. Aquatic systems are considered to be afforded a high level of protection at 25 mg/liter of total suspended solids.[23] An increase in concentration of 0.02 mg/liter of total suspended solids (Table 4.7) represents only 0.08% of the recommended level. The increases in concentration of nickel of 0.0007 ppm and of oil and grease of 0.008 ppm (Table 4.7) are negligible.

The two major NFCS effluents are ammonia and fluoride. At the very worst case (second column of Sect. C of Table 4.7), concentrations of ammonia and fluoride would be increased by 0.1 mg/liter and 0.05 mg/liter respectively. A 0.1 of 1 ppm increase in ammonia and a 0.05 of 1 ppm increase in fluoride are relatively minor increases and would occur very infrequently. The very worst case would occur only if a large NFCS discharge coincided with a low flow that may be statistically expected only once in ten years. Normally, NFCS discharges will cause an increase in fluoride concentrations of approximately 0.002 ppm and an increase in ammonia concentrations between 0.003 and 0.005 ppm (Table 4.7). The increase in concentration of fluoride and ammonia due to NFCS discharges, then, would normally be very low. Even at the very worst case, the increases in concentration of ammonia and fluoride in the river are minimal.

An adequate discussion of the impact of the major NFCS effluents should include the existing background river concentrations of these effluents. The water quality data presented in the ER, pp. 2.5-6 through 2.5-10, are not adequate for a discussion of ammonia and fluoride background concentrations. However, the NFCS has monitored the Congaree River for ammonia, fluoride, and pH. Table 4.8 presents the results of the last 13 months of NFCS monitoring of the river, both above and below the discharge point. Some recommended maximum concentrations of ammonia and fluoride and a recommended pH range considered safe for aquatic systems are also included in Table 4.8.

The pH of the Congaree River is well within recommended safe limits for aquatic systems (Table 4.8). The maximum pH recorded in the past 13 months was 7.55 at one station above the NFCS plant. Fluoride concentrations in the river are also well within safe limits. The maximum fluoride concentration recorded in the past 13 months (0.83 mg/liter) is little more than half the recommended safe limit of 1.5 mg/liter (Table 4.8). The addition of a worst case (0.05 mg/liter) of fluoride (Sect. C, Table 4.7) to the river will still result in a concentration well below 1.5 mg/liter.

Ammonia concentrations in the Congaree River, however, do at times exceed the recommended 0.9 mg/liter of total ammonia concentration considered safe for aquatic biota. The EPA recommendation of 0.9 mg/liter of total ammonia is based on a maximum safe level of 0.02 mg/liter of undissociated ammonia. At 25°C and a pH of 7.6, 0.9 mg/liter of total ammonia would result in 0.02 mg/liter of undissociated ammonia.[24] The recommended safe level of 0.9 mg/liter of total ammonia was exceeded two months out of 13 at the Blossom Street and NFCS stations, three months at the Mill Creek Station, and four months at the 601 Bridge station.

Table 4.8. Results of 13 months (July 1, 1975, to July 30, 1976) of NFCS monitoring of the Congaree River at two stations above the discharge point and two below

Station	Ammonia, $NH_3(N)$ (mg/liter)		Fluoride (mg/liter)		pH	
	Av	Max	Av	Max	Av	Max
Ten miles above NFCS discharge at Blossom Street Bridge, Columbia, S.C.	0.45	1.50	0.41	0.83	7.38	7.55
NFCS discharge point	0.63	1.30	0.38	0.78	7.20	7.31
Mouth of Mill Creek, less than one mile below discharge	0.62	1.00	0.36	0.66	6.80	7.39
601 Bridge, 35 miles below NFCS discharge point	0.67	1.20	0.37	0.72	7.02	7.12
Recommended maximum safe concentration for aquatic biota	0.9[a]		1.5[b]		6.5–8.5[c]	

[a]The recommended safe level is 0.02 mg/liter of undissociated ammonia. At a temperature of 25°C, which would be expected in the Congaree River in summer, and at a pH of 7.6, the maximum recorded pH above, a total ammonia concentration of 0.9 mg/liter would yield a concentration of 0.02 mg/liter of undissociated ammonia. (From Environmental Protection Agency, Offices of Water and Hazardous Material, *Quality Criteria for Water*, Washington, D.C., 1976.)

[b]From Resource Agency of California, State Water Quality Control Board, *Water Quality Criteria*, 2nd ed., J. E. McKee and H. W. Wolf (Eds.), 1963.

[c]From Environmental Protection Agency, Offices of Water and Hazardous Material, *Quality Criteria for Water*, Washington, D.C., 1976.

Source: R. Fischer, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, D.C., Oct. 12, 1976, Docket No. 70-1151.

The Congaree River is considered a public water supply. The EPA-recommended maximum ammonia concentration for a public water supply is 0.5 mg/liter (Table 2.14). The recommended level is based on the fact that ammonia indicates pollution and ammonia interferes with the proper chlorination of water.[23] The average concentration of ammonia in the Congaree River exceeds the recommended 0.5-mg/liter level (Table 4.8).

In conclusion, the impact of NFCS discharges of fluoride, BOD_5, total suspended solids, nickel, and oil and grease are negligible. The increase in concentration of ammonia in the Congaree River as a result of NFCS discharges is minimal. The maximum increase of ammonia at the very worst case is 0.1 mg/liter (Table 4.7). However, because the concentration of ammonia in the river already exceeds the recommended public water supply level and occasionally exceeds levels considered safe for aquatic life, the addition of more ammonia to the river is a cause for concern. The staff recommends that the NFCS make every effort to further reduce ammonia discharges, so that the addition of ammonia to an already overloaded system can be held to the barest minimum.

4.2.2.5 Impacts of NFCS discharges on Sunset Lake and Mill Creek

The major source of contamination of surface water bodies on the NFCS property is from the process waste settling lagoons. The east and west lagoons, where initial settling takes place, are lined with 1/2-in.-thick asphalt. The north and south lagoons, where secondary settling

takes place, are lined with butyl rubber. French drains, located under the lagoons, carry any leakage to a ditch that conveys storm runoff from the NFCS plant to Upper Sunset Lake. Ammonia and fluoride are the major effluents that would occur in lagoon leaks. The NFCS plant currently monitors Sunset Lake and Mill Creek monthly for concentrations of ammonia and fluorides and for pH levels at five stations: (1) at the entrance to the NFCS property where Mill Creek enters Sunset Lake; (2) at the road station where the drainage culvert from the plant storm sewer enters Upper Sunset Lake; (3) at the causeway station where the dam separates the upper and lower portions of Sunset Lake; (4) at the spillway station where Sunset Lake enters Mill Creek; and (5) at the exit from NFCS property, the point on Mill Creek where water from Sunset Lake mixes with water diverted through the canal. Table 4.9 gives the results of the monitoring from July 1, 1975, to July 30, 1976.

Table 4.9. Results of NFCS monitoring of surface water bodies from July 1, 1975, to July 30, 1976

Station	Ammonia (mg/liter)		Fluoride (mg/liter)		pH	
	Av	Max	Av	Max	Av	Max
Entrance to NFCS property[a]	<1	<1	<0.2	<0.2	6.4	8.3
Road station where drain enters Upper Sunset Lake	13.6	43	10.9	97	7.4	8.9
Dam causeway between upper and lower lake	0.1	1.9	0.5	1.8	6.6	7.3
Spillway of lower lake into Mill Creek	1.0	1.3	0.7	2.5	6.6	7.2
Point on Mill Creek where water from lower lake joins diversion canal water[a]	1.0	3.1	0.2	0.4	6.5	7.7

[a]Based on five months of sampling during July 1975 and April 1976 to July 1976.

Source: R. Fischer, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, D.C., Oct. 12, 1976, Docket No. 70-1151.

The road station, where the drain containing lagoon leakage enters Upper Sunset Lake, is the only point at which relatively high concentrations of fluoride and ammonia occur. Because the storm drain is not an aquatic habitat, the staff believes that concentrations at the road station are not of concern. Water from the upper lake flows over the causeway to Lower Sunset Lake and then out to Mill Creek. Since ammonia and fluoride concentrations in these waters are low (Table 4.9), dilution of the storm drain effluents occurs sufficiently enough to protect aquatic life in the lower lake. Lower Sunset Lake and Mill Creek are small warm-water fisheries and contain mostly golden shiners and bluegill (Sect. 2.8.2). The staff concludes that the low concentrations of ammonia and fluorides in Lower Sunset Lake and Mill Creek pose no threat to aquatic life in these waters.

A possible adverse impact on aquatic biota in Lower Sunset Lake and Mill Creek could result from a settling-lagoon failure. Such a failure occurred on October 20, 1971, when the wall of the west lagoon collapsed, emptying its entire contents of 1.5 million gal into the storm drain and thus to Upper Sunset Lake (ER, p. 5.3-8). Drainage from the upper lake to the lower lake was cut off at the causeway station, and water from Mill Creek was allowed to enter and dilute the upper lake. Approximately 7 bbl (55 gal each) of fish, primarily carp, were killed in the upper lake (ER, p. 5.3-8).

Since the 1971 lagoon failure, a system of dikes and holding tanks have been installed to contain leaks. The lagoon walls have been strengthened, and pollution abatement equipment installed since 1971 has reduced the level of contaminants in the lagoons (ER, p. 5.3-9). For these reasons, the consequences of another massive lagoon failure would not be as severe as the 1971 failure. However, a lagoon failure would probably result in a fish kill in the upper lake. Since the contaminants could be contained in the upper lake and released only after dilution, fish kills in the lower lake and in the river would probably not result.

Once toxicants reach the upper lake, it is impossible to recover them, so they must eventually enter the Congaree River. While toxicants can be diluted below harmful levels before discharge to the river, a lagoon failure will still result in a large amount of ammonia and fluoride being released to the Congaree River over a period of time. Because the ammonia concentration in the river already exceeds the recommended level for public water supplies (Tables 2.14 and 4.8), and sometimes exceeds the recommended level considered safe for aquatic life (Table 4.8), the addition of a large amount of ammonia resulting from a lagoon failure would be serious. The staff recommends that the NFCS consider upgrading the present system of dikes and holding tanks to contain the entire contents of a major lagoon spill.

4.2.3 Impacts of NFCS liquid effluent on groundwater supplies

Settling lagoons are the major sources of substances entering the groundwater at the NFCS plant. The liners and drains beneath the process lagoons minimize the likelihood that any leakage will enter the surface aquifer. However, the storm ditch and sanitary lagoon are not lined and could be a source of groundwater contamination. Three surface wells on the NFCS property are monitored for fluorides, ammonia, and pH. The concentrations of ammonia and fluorides in the well are generally low (1 ppm ammonia and 0.2 ppm fluorides). However, from July 1975 to December 1975, concentrations of ammonia in one well averaged 8.5 ppm; therefore, it is possible that the wells are occasionally contaminated. Contamination of the surface aquifer by effluents from the NFCS plant would have little or no adverse impact on groundwater use in the vicinity of the plant, since no wells are located downdip (Sect. 2.5, Hydrology). Substances entering the surface aquifer would probably not enter lower aquifers for reasons discussed in Sect. 2.5. The staff concludes that minimal leakage to the surface aquifer from the NFCS plant would have no impact on groundwater usage as long as wells downdip of the plant are not used for drinking water. The staff recommends that the NFCS should make every effort to eliminate leakage to the groundwater.

4.2.4 Impacts of solid waste

Noncontaminated solid waste generated in the cafeteria and offices at the NFCS is picked up by a local disposal company. Solids produced by precipitation in the east and west lagoons are mainly CaF_2. The west lagoon is presently full of CaF_2 slurry. All solids produced over the last six years of operation are in the west lagoon. There are no plans to dispose of the lagoon contents.

4.2.5 Noise

During the site visit, the staff heard no mechanical noise emanating from the NFCS plant. From the description of current and proposed activities at the NFCS (ER, pp. 3.2-1 to 3.3-21), no mechanical noise problem is anticipated.

4.2.6 Appearance — visual impact

According to the ER (p. 3.1-4), the NFCS plant was designed to complement its flat, rural surroundings. This statement was confirmed on the staff site visit. The structure is no taller than two stories (ER, Fig. 1.2-1), without extremely tall chimneys or similar structures to mar its simple lines. The grounds are landscaped with shrubs and wide expanses of lawn and are in sharp contrast to neighboring land uses, particularly to the property adjacent to the NFCS (S.C. Rte. 48), which is littered with rusted automobiles.

4.2.7 Local employment and economics

The present work force of over 700 is expected to grow gradually to approximately 1850 during the proposed five-year expansion period, which significantly reduces the influx during any given year. Most of the demand for labor can be met within the local labor area.

The plant currently generates approximately $7.5 million of income annually. Based on present salary levels, this amount should increase to over $19 million per year at the end of the expansion period.

Total gross tax revenues are expected to increase throughout the five-year expansion period. The local community will receive about $300,000 in property taxes, with $110,000 going to the State government each year as sales and use taxes.

Another source of revenue results from expenditures made by the plant to maintain normal operation. The purchase of local goods and services will increase from the current level of \$1.5 million to a future expenditure of \$3.75 million, for an annual increase of \$2.25 million. In addition, costs for operation and maintenance combined with research and development are estimated at nearly \$13 million per year after expansion. Construction of the expanded facility will further stimulate the local economy through the purchase of material and equipment (about \$17.8 million) and labor costs (about \$7.6 million).

The degree of adverse impact a community experiences from any given project is generally proportional to the number of new employees that must be imported. This impact may occur during a new expansion phase as well as during the operation period. Although the increase in permanent employment will be considerable, only the new workers (less than 300) from outside the Columbia SMSA need be considered for the purpose of evaluating potential impact.

The housing market should also expand at a rate sufficient to accommodate the NFCS-related influx of workers. The number of households projected for the Columbia SMSA by 1980 reflect an increase of about 11,000 units over 1975 levels, with another substantial increase of nearly 24,000 by 1985.

A community relations file maintained by the NFCS personnel department reveals that there has been no significant adverse public reaction to the NFCS plant since its establishment. The Speakers Bureau entertains an average of approximately two requests per month from schools and civic groups for speeches related to operations at the NFCS. The managers and professionals of the bureau also conduct about the same number of plant tours. According to Westinghouse, the plant has been well accepted and is considered a favorable addition to the community.

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14. Ref. 12, pp. 124-25.

15. Ref. 12, Tables 7-3 and 7-4.

16. Ref. 12, p. 128.

17. Ref. 12, Table 7-5.

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5. ENVIRONMENTAL MONITORING PROGRAM

5.1 RADIOLOGICAL

The purpose of the environmental radiation surveillance program at the Columbia plant is (1) to ensure compliance with State and Federal regulations and standards, (2) to evaluate possible buildup or radioactivity in the environment, and (3) to provide information for public distribution.

The operational surveillance program includes sampling sites considered to be beyond the influence of plant discharges. The program emphasizes sampling and measurements of environmental media with the greatest potential for contributing to the dose to man.

5.1.1 Air monitoring

Air-sampling stations for air-particulate monitoring are located (1) at the nearest site boundary in the prevailing wind direction (3000 ft northeast of the plant), (2) at the nearest site boundary (1800 ft north-northwest), (3) near the meteorological tower (1950 ft west-northwest), (4) in the town of Hopkins (2.9 miles northeast, the nearest town and the nearest town in the direction of the prevailing winds), and (5) at the employee front parking lot (450 ft northeast) where concentration is expected to be maximum. Locations are shown in Fig. 5.1.

The air monitors will continuously accumulate air particulates with an air sampler that pumps air through a filter. The filters will be analyzed with the following frequencies: monthly for gross alpha and beta activity and quarterly for isotopic uranium activity.

5.1.2 Water monitoring

Well water is taken from three onsite wells. The well locations are shown in Fig. 5.2. Well water will be analyzed monthly for gross alpha and beta activity and quarterly for isotopic uranium activity.

Surface water samples will be taken monthly by collecting 1-liter grab samples from the five locations shown in Fig. 5.2. A comparison of samples from the downstream location [500 yd from the discharge (2)] with upstream samples (1 and 3) will provide a measurement of possible contamination to the river from plant discharges. Locations 4 and 5 will indicate possible contamination from accidental releases from the holdup pond.

Analysis should be performed with the following frequencies: monthly for gross alpha and beta activity and quarterly for isotopic uranium activity.

5.1.3 Area monitoring (fallout, vegetation, soil, and fish)

Monitoring for wet fallout is performed at six stations (Fig. 5.1). Analyses are monthly for gross alpha and quarterly for isotopic uranium. Composite aliquot samples are used for uranium analysis.

Sampling and analyses of vegetation samples are performed at four locations (Fig. 5.2). Either grass (hay) or another agricultural crop appropriate to the growing season will be collected and analyzed on a semiannual basis for gross alpha and beta activity and for isotopic uranium activity. Sediment samples taken annually from the Congaree River at approximately 500 ft downstream of the discharge will be similarly analyzed.

Samples of fish from the Congaree River downstream of the plant discharge and from Sunset Lake will be analyzed annually for gross alpha and beta activity and for isotopic uranium activity.

5.1.4 Conclusions

The radiological monitoring program proposed for the plant appears adequate to measure the impact of plant effluents on the environment during normal operation or following an accident situation.

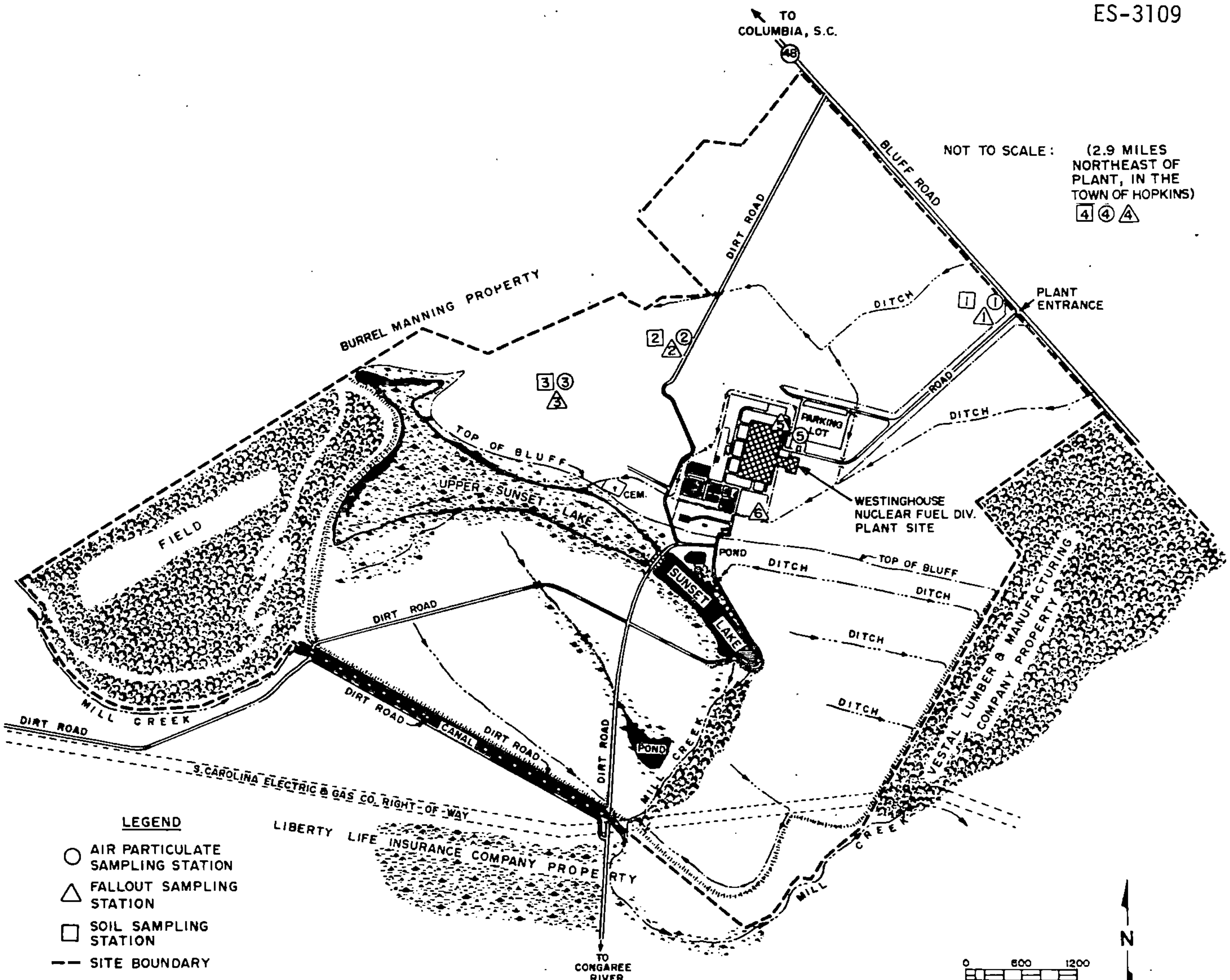

Fig. 5.1. Locations of proposed air-, fallout-, and soil-monitoring stations. Source: ER, Fig. 6.1-1.

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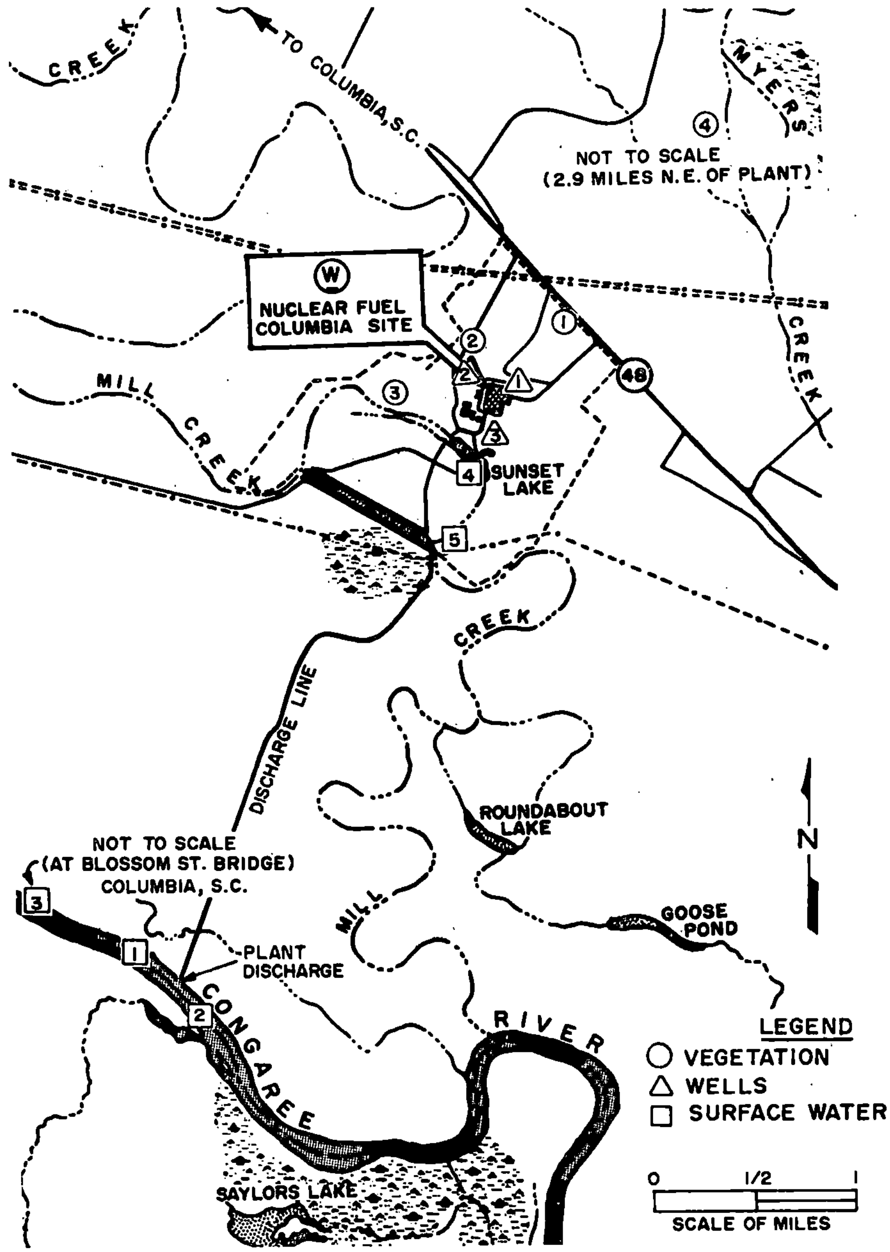

Fig. 5.2. Locations of proposed vegetation-, well-, and surface water-monitoring stations. Source: ER, Fig. 6.1-2.

5.2 NONRADIOLOGICAL

5.2.1 Atmospheric monitoring

According to the ER (p. 6.2-1), particulate fluoride concentrations inside process-gas-effluent stacks are monitored daily with glass suction filters. Periodically (no period given), gas-impinger samples from effluent stacks are collected and analyzed for both particulate and gaseous fluoride emissions. Fluoride deposition is monitored periodically at the site boundary with calcium oxide fallout papers.

Ammonia concentrations in process-gas-effluent stacks are monitored occasionally with gas impingers. The ammonia concentration in the atmosphere at the site boundary is measured at unspecified time intervals with a universal sampling pump and detector tube (ER, p. 6.2-1).

5.2.2 Monitoring of surface waters

The NFCS is required to monitor effluents in accordance with the schedule and methods described in the NPDES permit. A copy of the permit appears in Appendix 3.A of the ER.

5.2.2.1 Congaree River

The NFCS monitors the Congaree River at four staitons: (1) at Blossom Street bridge in Columbia; (2) at the NFCS discharge; (3) downstream of the discharge at the mouth of Mill Creek; and (4) at 601 bridge, 35 miles downstream of the NFCS facility. Ammonia, fluoride, and pH are monitored monthly.

5.2.2.2 Sunset Lake and Mill Creek

Sunset Lake and Mill Creek are monitored monthly for ammonia, fluorides, and pH at five stations: (1) at the entrance to the NFCS property where Mill Creek enters Sunset Lake, (2) at the road station where the drainage culvert from the plant storm sewer enters upper Sunset Lake, (3) at the causeway station where the dam separates the upper and lower portions of Sunset Lake, (4) at the spillway station where Sunset Lake enters Mill Creek, and (5) at the exit from the NFCS property, the point on Mill Creek where water from Sunset Lake mixes with water diverted through the canal.

5.2.3 Groundwater monitoring

Three onsite wells are monitored monthly for fluoride, ammonia, and pH (Fig. 5.2). The wells were at the site as part of an existing irrigation program before the NFCS plant was constructed.

5.2.4 Monitoring of biota

5.2.4.1 Terrestrial

According to the ER (p. 6.6-2), there is no known terrestrial monitoring program for biota in the vicinity of the NFCS. However, it was also stated (ER, p. 6.5-1) that ". . . a program has been established to monitor the extent of pollutants, radiological and chemical, that may enter the food chain. . . This program consists of analyzing samples of common browse leaf and/or twig tissue for fluoride content. If no significant accumulations are detected during the first year of sampling, the monitoring program will be discontinued until plant capacity reaches 1600 MTU/year." The staff assumes that this sampling program was among those that NFCS personnel reported as being discontinued.

5.2.4.2 Aquatic

Currently, there is no nonradiological monitoring program for aquatic biota at the NFCS.

5.2.5 Staff recommendations for future NFCS nonradiological monitoring

5.2.5.1 Atmospheric monitoring

The staff believes that the applicant's unscheduled atmospheric sampling program should be more regular to supplement the vegetation sampling recommended below (Sect. 5.2.5.4). Specifically, the staff recommends that ammonia and fluorides in process-gas-effluent stacks and at the site boundary be measured quarterly by the methods presently in use at the NFCS (ER, p. 6.2-1). The spring and fall season samples should be collected at the same time vegetation is sampled (Sect. 5.2.5.4). The atmospheric sampling program should be operational before the NFCS increases its production capacity so that variation in values from current production will be established.

5.2.5.2 Surface waters

The staff concludes that the monitoring of Sunset Lake and Mill Creek by the NFCS is adequate and should be continued. The staff recommends that the NFCS continue monitoring the Congaree River for ammonia, fluoride, and pH. Because NFCS has requested higher Phase IV limits for BOD_5 and total suspended solids, they should perform additional monitoring of the river for these two parameters. The staff recommends that the monitoring stations on the Congaree River be changed

to the following: (1) 1500 yd above the NFCS discharge, (2) directly at the outfall of the discharge, (3) 1500 yd below the discharge, and (4) 1500 yd below the mouth of Mill Creek. With the suggested change in stations the NFCS would still be monitoring four stations, and the staff believes that the recommended stations would be better situated to assess the effects of the NFCS discharge to the Congaree River. Finally, because sanitary effluent will increase when the plant expands to a capacity of 1600 MTU/year, the staff recommends that the NFCS institute a monthly monitoring program for residual chlorine at the outfall of the discharge.

5.2.5.3 Groundwater

The staff concludes that the present system of groundwater monitoring would be adequate if the program included fecal coliform counts to determine if leakage from the sanitary waste system was entering the water table.

5.2.5.4 Biota

Considering the relatively low concentrations of ammonia and fluoride (the major effluents) in both the Congaree River and the surface water bodies on the NFCS property, the staff concludes that nonradiological monitoring of the aquatic biota is not necessary as long as liquid effluents from the NFCS do not exceed Phase IV limits.

The staff strongly recommends the implementation of a vegetation monitoring program to assess the extent of onsite contamination resulting from atmospheric fluorine emissions.

Samples from forage plants in pastures or croplands at the site should be analyzed for fluoride content at least twice yearly, preferably in the spring (May) and early fall (September). The same plant species should be analyzed each time, and the sampling program should be operational before the NFCS increases its production capacity so that background value variation might be established.

The above recommendations are to be incorporated in the applicant's monitoring program as a condition for the renewal of its license.

6. IMPACT OF ACCIDENTS

For the purposes of analysis, the applicant has identified three categories of accidents. These include:

Category 1 events

Category 1 events would include plant accidents most likely to occur in the course of plant operations. These accidents would have the least severe consequences of the three categories considered. Although some adverse onsite effects could occur as a result of these accidents, the effects on the offsite environment would be minimal and not likely to exceed those from normal effluent releases.

Category 2 events

Category 2 events are accidents that may occur infrequently during the operating life of the plant. These accidents could release to the environment amounts of uranium or harmful chemicals that would be several times greater than those from normal effluent releases.

Category 3 events

Category 3 events include postulated accidents that are not expected to occur during the life of the plant; however, these accidents are considered because their consequences would include the potential for release to the environment of significant amounts of radioactive or otherwise harmful chemical materials. Thus, these accidents represent limiting-design conditions and are known as design-basis accidents.

The applicant has analyzed both the radiological and chemical consequences of a number of possible accidents in each of these categories, both for occurrences within the confines of the manufacturing building and in adjacent areas. In those cases where atmospheric transport is of interest, the analysis has been done using the 50% confidence short-term values of χ/Q listed in Table 2.6-2 of the ER, as is customary in evaluating the environmental effects of reactor accidents.

In all cases, the analysis has been carried out on the basis of a 400-MTU/year capacity. An increase in capacity to 1600 MTU/year would not significantly alter the consequences of the accidents analyzed but would slightly increase their probability of occurrence.

6.1 RADIOLOGICAL ACCIDENT EVALUATION

The radiological and, where applicable, the chemical consequences of radiological accidents in all three categories both within and outside the manufacturing plant have been summarized in Table 6.1.

For evaluation purposes, the radiological consequences have also been presented in terms of the equivalent time of exposure to occupational MPC values given in 10 CFR Part 20, Appendix B.[1] These are based on an annual dose commitment of 5 rems to the whole body, bone, or gonads, 30 rems to the skin and thyroid, and 15 rems to other organs.[2]

The applicant has established the uranium chemical toxicity guide, shown below in Table 6.2, based on recommendations of the Federal Water Pollution Control Administration;[3] the percentage of the concentrations given in this guide are shown in Table 6.1.

In accident category 1, the event evaluated as having the greatest effect on the environment and to humans results from a postulated spill of solid radioactive wastes in combination with a fire. This accident results in an airborne concentration of uranium at the site boundary that results in an exposure to the lung equivalent to about 2.6 hr at occupational MPC, assuming that all of the uranium is converted to the insoluble oxide form. The accident with the next highest effect is a minor leak in a holding lagoon equivalent to 12.5 gal/min remaining undetected for a 24-hr period. This release to Upper Sunset Lake results in uranium concentrations equivalent to only a 30-sec exposure at nonoccupational MPC and 1.6×10^{-2}% of the chemical toxicity guide.

Table 6.1. Summary of radiological plant accident evaluation (400-MTU/year capacity)

Accident category	Accident description	Radiological dose (rems/occurrence)	Uranium chemical toxicity (mg/day)	Equivalent time at occupational MPC	Percentage of chemical toxicity guide
INSIDE					
1	Break in transfer line	≤ normal releases		≤ normal releases	
1	Solution spill	≤ normal releases		≤ normal releases	
1	UO_2 powder spill	≤ normal releases		≤ normal releases	
1	UF_6 release within vaporizer area	4.4×10^{-8} (bone)	1×10^{-6} (kidney)	<1 sec (bone)	1.7×10^{-3} (kidney)
1	Loss of electric or water supply	≤ normal releases		≤ normal releases	
1	Spill of radioactive wastes	1.9×10^{-2} (lung)		2.6 hr (lung)	
1	Localized fire and/or explosion	1.9×10^{-2} (lung)		2.6 hr (lung)	
1	Failure of HVAC system	≤ normal releases		≤ normal releases	
OUTSIDE					
1	Leak of a UF_6 container	≤ normal releases		≤ normal releases	
1	Leak in a lagoon	6.3×10^{-5} (GI tract)	8.0×10^{-4} (kidney)	30 sec (GI tract)	1.6×10^{-2} (kidney)
INSIDE					
2	Cracked calciner tube	4.1×10^{-1} (lung)		2.4 days (lung)	
2	Failure of a single HEPA filter	3.0×10^{-2} (lung) 1.1×10^{-2} (bone)	1.4×10^{-1} (kidney)	4.2 hr (lung) 4.7 hr (bone)	5.8×10^{0} (kidney)
2	Rupture of a UO_2 fuel rod	≤ normal releases		≤ normal releases	
2	Rupture of a mixed oxide fuel rod	1.2×10^{-2} (lung)		1.7 hr (lung)	
2	Massive failure of a UF_6 shipping container	2.6×10^{-3} (lung) 1.0×10^{-3} (bone)	2.4×10^{-2} (kidney)	22 min (lung) 17 min (bone)	1.0×10^{0} (kidney)
OUTSIDE					
2	Complete failure of UO_2 shipping container	9.0×10^{-1} (lung)		5.2 days (lung)	
2	Breach of a uranyl nitrate drum	1.6×10^{-3} (GI tract)	4.1×10^{-2} (kidney)	13 min (GI tract)	4.1×10^{-1} (kidney)
2	Massive failure of lagoon	7.3×10^{-3} (GI tract)	9.0×10^{-2}	1 hr (GI tract)	9.0×10^{-1}
INSIDE					
3	Criticality	3.4×10^{0} (thyroid) 1.4×10^{-1} (whole body)		9.8 days (thyroid) 2.4 days (whole body)	
3	Sintering furnace explosion	2.4×10^{-3} (lung)		20 min (lung)	
3	Calciner explosion	1.1×10^{-3} (lung) 8.1×10^{-5} (bone)	2.0×10^{-3} (kidney)	9 min (lung) 2 min (bone)	8.0×10^{-2} (kidney)
3	Fires in bank of filters	8.2×10^{0} (lung)		47 days (lung)	

[a]See Table 5.1-1 in the ER for radiological-dose release guide values and Table 5.1-2 in the ER for uranium-toxicity release guide values.
Source: ER, Table 5.1-4.

Table 6.2. Uranium chemical toxicity release guide on air and water intake limits (in mg/day) for humans

Accident category	Description	Air	Water
1	Minor faults and operational transients (accidents of moderate frequency)	0.06	5
2	Infrequent faults	2.5	10
3	Limiting faults (design basis accidents)	2.5	10

Source: ER, p. 5.1-4.

An accident in category 1 with the third largest effect is a UF_6 release in the vaporizer area. The UF_6 leak is calculated to result in a uranium concentration at the site boundary that is equivalent to less than a 1-sec exposure at MPC and 1.7×10^{-3}% of the chemical-toxicity-guide value. All other accidents in category 1 are expected to be equal to or less than the allowable releases for normal operation. Thus, the consequences of the most frequent category 1-type accidents are calculated to be so far below the safe guide limits that they are expected to result in negligible effects to offsite residents or transients and to have virtually no other environmental effects.

Category 2 accidents within the manufacturing building that are evaluated as having the greatest effect on an individual located at the nearest site boundary include a cracked calciner tube, failure of a single HEPA filter, or a massive failure of a UF_6 container. These accidents result in calculated radiological doses that are equivalent to 2.4 days, 4.2 hr, and 22 min, respectively, at nonoccupational MPC. Additionally, a single HEPA filter failure and a massive failure of a UF_6 container are also calculated to result in inhaled concentrations of soluble uranium that are 5.8% and 1.0%, respectively, of the applicable chemical-toxicity-guide values.

Other category 2 accidents outside the manufacturing building that lead to similar radiological and/or chemical-toxicity effects include a complete failure of a UO_2 shipping container, a breach of a uranyl nitrate drum, and a massive failure of a lagoon. For the latter two events, the uranium is assumed to have contaminated all drains into Upper Sunset Lake and is diluted there by 43 million gallons of water. Since none of the category 2 accident consequences exceed 10% of the guide-value limits, these accidents were evaluated using conservative and/or realistic parameters; because such accidents would be expected to take place infrequently, no measurable effect on individuals living in the vicinity of the plant would be expected.

In category 3, the events leading to the largest effects on an individual located at the site boundary were postulated as a criticality event or a fire in the bank of HEPA filters controlling the furnance exhausts. These two events, should they occur, would be expected to result in concentrations of airborne radioactive materials to the environment such that an individual located at the nearest site boundary would receive a thyroid dose commitment equivalent to 9.8 days exposure at nonoccupational MPC in the former case and a lung exposure equivalent to about 47 days at MPC in the latter case. No effects from chemical toxicity would be expected to result from these accidents. Some decontamination in the downwind direction would probably be required.

A calciner explosion, however, could result in an individual offsite receiving the equivalent of a 9-min exposure to the lung and 0.08% of the chemical-toxicity-guide value for the kidney.

Thus, these events, should they happen, would not be expected to result in measurable effects on residents or transients located nearby. Furthermore, as mentioned previously, category 3 events would not be expected to happen during the life of the plant.

6.2 NONRADIOLOGICAL ACCIDENT EVALUATION

The most significant environmental problems that may occur at a low-level-enrichment nuclear fuel fabrication plant would most likely result from possible accidents associated with potentially harmful chemicals rather than from radioactive materials. Thus, the NFCS can be considered in the same class as any other manufacturing plant in which significant quantities of nonradioactive chemicals are processed.

The chemicals presently stored onsite are listed in Table 6.3; estimated quantities for 1600-MTU capacity are also included.

Table 6.3. Bulk chemical and gas storage[a]

Product	Location	At 400 MTU/year			At 1600 MTU/year (estimated)			
		Total gallons	Cubic feet	Pounds	Total gallons	Tank size (gal)	Cubic feet	Pounds
Liquid NH_4OH	Tank farm	15,700			20,700	5,700		
Anhydrous ammonia	Tank farm	30,000			60,000	18,000		
Nitric acid (68%)	Tank farm	5,000			10,000	5,000		
Hydrogen (liquid)	Tank farm	18,000	2,044,000		36,000	18,000	2,044,000	
Nitrogen (liquid)	Tank farm	6,000	541,000		12,000	6,000	541,000	
Argon (gas)	Tank farm	600	58,000		1,200	600	58,000	
Helium (liquid)	Tank farm		138,000				276,000	
Uranium hexafluoride	Outside pad			550,000				1,100,000
Uranyl nitrite (liquid)	Inside plant			25,000				80,000
Lime (CaO)	Waste treatment hopper			100,000				200,000
Zinc stearate	Inside plant			2,500				5,000
Miscellaneous								
Acetone	55-gal drums (oil house)	825			1,650			
Sulfuric acid (66 Baume + 45°)	55-gal drums (outside)	770			1,540			
Nitric acid (68%)	55-gal drums (outside)	275			550			
Muriatic acid (22% HCl)	55-gal drums (outside)			800				1,000
Sodium carbonate	Outside tent			800				1,600
Caustic soda (50% NaOH solution)	Outside tent (100-lb drums)			500				1,000
Nickel sulfate	Outside tent			500				1,000

[a]Other small amounts of miscellaneous chemicals (500 lb or 55 gal) are stored at the plant site.

Source: ER, Table 5.3-1.

The important chemical accidents would involve chemicals associated with uranium, anhydrous ammonia, aqueous ammonia, nitric acid, and hydrogen.

6.2.1 Category 1 accidents

An accident of this type within the manufacturing building in the chemical processing area would be typified by minor liquid spills (i.e., 10 gal or less) including acid, ammonium diuranate, uranyl nitrate, and oil spills. A leak of this nature would be quickly detected by operators, and corrective action (such as isolation of the leaking-line section) would be taken. The spilled liquids would be quickly cleaned up and transferred to appropriate waste containers or, if appropriate, returned to the process for recovery. No floor drains are installed in the processing area of the main plant building, and therefore, there would be no release to the environment through either airborne or liquid pathways.

Category 1 accidents (external to the manufacturing building) that are likely to happen during the life of the plant include minor process-equipment leaks (50 gal or less). A leak of this type would be located rapidly by operators, and corrective action would be implemented.

Another possible accident of this type could result from the release of chemicals due to a leak in the liner of a waste-holding pond. In previous spills that occurred before improvements in the waste treatment process (as required by the NPDES permit) were implemented, a chemical analysis of surface water indicated that fluoride concentrations increased from less than 1 mg/liter for all sampling stations to 120 mg/liter at the causeway station, to 108 mg/liter at the spillway station, and to 96 mg/liter at the exit station. Ammonia concentrations at the causeway station increased from less than 1 mg/liter to 40.1 mg/liter. Such concentrations can be hazardous to aquatic life.

6.2.2 Category 2 accidents

In general, category 2 accidents within the manufacturing building (leakages of approximately 50 gal) are of greater magnitude than category 1; however, category 2 accidents still could not result in releases that would be of concern to the external environment because of the reasons given for accidents of category 1.

Greater environmental consideration must be given to the case when the water spray to the plant gaseous effluent scrubber fails. In this case, ammonia and hydrogen fluoride would escape to the atmosphere unscrubbed. This condition could go undetected for a maximum of 8 hr since the scrubber is checked at least once each shift. This scrubber is 70% to 85% effective; therefore, when discounting the scrubber efficiency, the maximum concentration of ammonia and hydrogen fluoride that would escape to the environmental atmosphere during a maximum of 8 hr is estimated to be 36.28 mg/m^3 and 107 $\mu g/m^3$ respectively.

Category 2 accidents occurring in the chemical storage areas outside the manufacturing building could result in complete or partial emptying of a storage tank. The releases would flow through the storm drainage ditch to Upper Sunset Lake, where it would mix and flow into Lower Sunset Lake via a causeway. Lower Sunset Lake drains into Mills Creek, which eventually enters the Congaree River via a meandering route of about seven miles. Both Sunset Lakes are on Westinghouse property.

In the event of a major spill, the upper lake can be closed off at the causeway and then diluted by increasing the diverted flow of incoming Mill Creek water. The continuous chemical monitoring and prompt dilution of these waters can prevent significant liquid releases to the offsite environment. As part of the 1975 plan improvement program, protective dikes that could contain approximately 36,000 gal of liquid wastes in the event of complete tank failure were placed around the chemical tank farm. The largest bulk storage tank contains anhydrous ammonia, which has a capacity of 18,000 gal.

6.2.3 Category 3 accidents

Category 3 accidents are catastrophic in magnitude and are not expected in the plant's lifetime. All are extremely unlikely; they would involve either container rupture, failure, explosion, fire, natural disaster, or an extremely improbable criticality-type accident. Storage vessels are designed using good engineering practices and are filled according to safe operating procedures. To experience a rupture or failure, some unforeseen catastrophic disaster would have to occur, or all current safety systems would have to deteriorate simultaneously.

A category 3 accident in the chemical storage area would release no more potentially harmful chemicals than the contents of any industrial chemical storage tank or the overflow resulting from a massive lagoon break.

Another major accident could result from a hydrogen explosion, and as a result, tanks containing chemicals could be ruptured. Environmental hazards associated with such ruptures have been discussed in previous sections. To prevent such an accident, the hydrogen gas tanks are stored and handled according to OSHA regulation No. 1910.10 and maintained according to procedures recommended by the Linde Division of Union Carbide Corporation.

6.3 EVALUATION OF POTENTIAL ENVIRONMENTAL IMPACT OF ACCIDENTS

It is concluded that even the most severe accidents will have little or no radiological environmental effect outside the site boundary.

REFERENCES FOR SECTION 6

1. 10 CFR Part 20, Appendix B.
2. ICRP Publication 2, *Report of Committee II on Permissible Dose for Internal Radiation*, Pergamon Press, New York, 1959.
3. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Apr. 1, 1968, Washington, D.C., Federal Water Pollution Control Administration.

7. MATERIALS AND PLANT PROTECTION

7.1 PHYSICAL PROTECTION AND MATERIAL ACCOUNTING

Current safeguards are set forth in 10 CFR Parts 70 and 73. The regulations in Part 70 provide for material accounting and control requirements with respect to facility organization, material control arrangements, accountability measurements, statistical controls, inventory methods, shipping and receiving procedures, material storage practices, records and reports, and management control.

The Commission's current regulations in 10 CFR Part 73 provide requirements for the physical security and protection of fixed sites and for transportation involving strategic quantities of nuclear materials. Physical security requirements for protecting fixed sites include the establishment and training of a security organization (including armed guards), provision for physical barriers, and establishment of response plans.

The Commission's regulations in 10 CFR Parts 70 and 73, described briefly above, are applied in the reviews of individual license and permit applications. License conditions then are developed and imposed which translate the regulations into specific requirements and limitations that are tailored to fit the particular type of plant or facility involved.

The Westinghouse Columbia site is an existing licensed activity, and while experience and continuing study may indicate areas where revisions in the Commission's regulations applicable to the Columbia site should be made, the Commission has determined that for the kind of installation under review the safeguards framework of existing and proposed regulations discussed in their statement of November 14, 1965,[1] is adequate to enable the Commission to carry out its responsibilities to protect the public health and safety and the common defense and security. The licensee has an approved material control and accounting plan and an approved physical security plan which meet the current requirements of 10 CFR Parts 70 and 73. It is concluded that the safeguards-related environmental impact of the proposed action is insignificant.

REFERENCES FOR SECTION 7

1. 40 FR 53056.

8. SUMMARY AND CONCLUSION OF ENVIRONMENTAL IMPACTS OF OPERATION

The staff has analyzed the environmental impacts of operation of the Westinghouse Nuclear Fuel Columbia Site (WNFCS) fabrication plant. It is the staff's judgment that normal plant emissions or the possible effects of accidents do not constitute a significant addition of radioactive effluent to the environment. An analysis of nonradiological atmospheric emissions of fluorides and ammonia by the staff indicates that it is unlikely that there will be any significant offsite adverse impacts on native vegetation, agriculture, livestock, or humans. Some localized onsite impacts on native vegetation due to fluoride emissions under unusually stable and continuous exposure periods may occur (chlorosis and necrosis of leaf tissue, some plant mortality). The staff considers that this potential effect on vegetation will not have a significant adverse impact on the terrestrial ecosystem of the WNFCS.

The applicant has an NPDES permit from EPA to allow for the discharge of liquid effluent into receiving stations. The staff considers that aqueous effluents released to receiving waters will not have significant adverse impacts on aquatic biota. The staff has recommended modifications to existing environmental monitoring programs to provide additional information necessary to continually evaluate environmental quality at the WNFCS.

In connection with the renewal of the WNFCS license, the staff concludes that an environmental impact statement is not required under NRC regulations in 10 CFR 51.5(b), nor under CEQ guidelines in 40 CFR 1500.6. As shown in this appraisal, the environmental effects of continued plant operation are insignificant. As provided in 10 CFR 51.5C(1), a negative declaration is being prepared in accordance with the requirement of 10 CFR 51.7.

Appendix A

FLORA AND FAUNA OBSERVED ON AND NEAR THE NFCS

Table A.1. Plants observed onsite

Loblolly pine	*Pinus taeda*
Overcup oak	*Quercus lyrata*
Swamp chestnut oak	*Q. michauxii*
Southern red oak	*Q. falcata*
Cherrybark oak	*Q. falcata* var. *pagodaefolia*
Scarlet oak	*Q. coccinea*
Water oak	*Q. nigra*
White oak	*Q. alba*
Willow oak	*Q. phellos*
White ash	*Fraxinus americana*
Carolina ash	*F. caroniniana*
Shagbark hickory	*Carya ovata*
Mockernut hickory	*C. tomentosa*
Shellbark hickory	*C. laciniosa*
Bitternut hickory	*C. cordiformes*
Sweet gum	*Liquidambar styraciflua*
American elm	*Ulmus americana*
Winged elm	*U. alata*
Red maple	*Acer rubrum*
Yellow poplar	*Liriodendron tulipifera*
American beech	*Fagus grandifolia*
Black cherry	*Prunus serotina*
Water tupelo	*Nyssa aquatica*
Black locust	*Robinia pseudoacacia*
Redbud	*Cercis canadensis*
Poison ivy	*Rhus radicans*
Smooth sumac	*R. glabra*
Japanese honeysuckle	*Lonicera japonica*
Greenbrier	*Smilax bona-nox*
Trumpet vine	*Campsis radicans*
Virginia creeper	*Parthenocissus quinquefolia*
Common privet	*Ligustrum vulgare*
Cross vine	*Bignonia capreolata*
Blackberry	*Rubus* sp.
Lead bush	*Amorpha fruticosa*
Wild onion	*Allium* sp.
Smartweed	*Polygonum* sp.
Broomsedge	*Andropogon virginicus*
Great mullein	*Verbascum thapsus*
Sheep sorrel	*Rumex hastatulus*
Queen Anne's lace	*Daucus carota*
Water meal	*Spilodella* sp.
Duckweed	*Lemna* sp.

Source: ER, Table 2.F-1.

Table A.2. Avifauna observed in open-field areas

Turkey vulture	*Cathartes aura*
Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*B. lineatus*
Bobwhite	*Colinus virginianus*
Killdeer	*Charadrius vociferous*
Mourning dove	*Zenaidura macroura*
Chimney swift	*Chaetura pelagica*
Tree sparrow	*Iridoprocne bicolor*
English sparrow	*Passer domesticus*
Bobolink	*Dolichonyx oryzivorous*
Eastern meadowlark	*Sturnella magna*
Common grackle	*Quiscalus quiscula*
Brown-headed cowbird	*Molothrus ater*
Savannah sparrow	*Passerculus sandwichensis*
Vesper sparrow	*Pooecetes gramineus*
Field sparrow	*Spizella pusilla*
Chipping sparrow	*S. passerina*
Song sparrow	*Melospiza melodia*

Sources: Westinghouse Environmental Systems Department 1974 survey. ER, Table 2.F-2.

Table A.3. Avifauna observed in swamp-edge areas

Black duck	*Anas rubripes*
Wood duck	*Aix sponsa*
Marsh hawk	*Circus cyaneus*
Cattle egret	*Bubulcus ibis*
Great blue heron	*Ardea herodias*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Barred owl	*Strix varia*
Fish crow	*Corvus ossifragus*
Acadian flycatcher	*Empidonax virescens*
Carolina wren	*Thryothorus ludovicianus*
Gray catbird	*Dumetella carolinensis*
White-eyed vireo	*Vireo griseus*
Red-eyed vireo	*V. olivaceus*
Prothonotary warbler	*Protonotaria citrea*
Northern parula warbler	*Parula americana*
American redstart	*Setophaga ruticilla*
Red-winged blackbird	*Agelaius phoeniceus*
American goldfinch	*Spinus tristis*
Song sparrow	*Melospiza melodia*

Sources: Westinghouse Environmental Systems Department 1974 survey. ER, Table 2.F-3.

Table A.4. Avifauna observed along borders of old fields and woodlots

Turkey vulture	*Cathartes aura*
Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*B. lineatus*
Common flicker	*Colaptes auratus*
Red-bellied woodpecker	*Centurus carolinus*
Hairy woodpecker	*Dendrocopus villosus*
Ruby-throated hummingbird	*Archilochus colubris*
Eastern kingbird	*Tyrannus tyrannus*
Great crested flycatcher	*Myiarchus crinitus*
Acadian flycatcher	*Empidonax virescens*
Blue jay	*Cyanocitta cristata*
Fish crow	*Corvus ossifragus*
Tufted titmouse	*Parus bicolor*
White-breasted nuthatch	*Sitta carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Mockingbird	*Mimus polyglottos*
Gray catbird	*Dumetella carolinensis*
Robin	*Turdus migratorius*
Wood thrush	*Hylocichla mustelina*
Blue-gray gnatcatcher	*Polioptila caerulea*
Ruby-crowned kinglet	*Regulus calendula*
Cedar waxwing	*Bombycilla cedrorum*
Loggerhead shrike	*Lanius ludovicianus*
Starling	*Sturnus vulgaris*
Solitary vireo	*Vireo solitarius*
White-eyed vireo	*V. griseus*
Worm-eating warbler	*Helmitheros vermivorous*
Northern parula warbler	*Parula americana*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated green warbler	*D. virens*
Black-throated blue warbler	*D. caerulescens*
Prairie warbler	*D. discolor*
Yellowthroat	*Geothlypis trichas*
Yellow-breasted chat	*Icteria virens*
Summer tanager	*Piranga rubra*
Cardinal	*Richmondena cardinalis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Indigo bunting	*Passerina cyanea*
American goldfinch	*Spinus tristis*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Savannah sparrow	*Passerculus sandwichensis*
Vesper sparrow	*Pooecetes gramineus*
Field sparrow	*Spizella pusilla*
White-throated sparrow	*Zonotrichia albicollis*
Song sparrow	*Melospiza melodia*

Sources: Westinghouse Environmental Systems Department 1974 survey.
ER, Table 2.F-4.

Table A.5. Avifauna observed in all areas on and near the site

Black duck	*Anas rubripes*
Wood duck	*Aix sponsa*
Turkey vulture	*Cathartes aura*
Marsh hawk	*Circus cyaneus*
Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*B. lineatus*
Bobwhite	*Colinus virginianus*
Cattle egret	*Bubulcus ibis*
Great blue heron	*Ardea herodias*
Killdeer	*Charadrius vociferous*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Mourning dove	*Zenaidura macroura*
Barred owl	*Strix varia*
Chimney swift	*Chaetura pelagica*
Ruby-throated hummingbird	*Archilochus colubris*
Common flicker	*Colaptes auratus*
Red-bellied woodpecker	*Centurus carolinus*
Hairy woodpecker	*Dendrocopus villosus*
Eastern kingbird	*Tyrannus tyrannus*
Great crested flycatcher	*Myiarcus crinitus*
Acadian flycatcher	*Empidonax virescens*
Tree swallow	*Iridoprocne bicolor*
Blue jay	*Cyanocitta cristata*
Fish crow	*Corvus ossifragus*
Tufted titmouse	*Parus bicolor*
White-breasted nuthatch	*Sitta carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Mockingbird	*Minus polyglottos*
Gray catbird	*Dumetella carolinensis*
Robin	*Turdus migratorius*
Wood thrush	*Hylocichla mustelina*
Blue-gray gnatcatcher	*Polioptila caerulea*
Ruby-crowned kinglet	*Regulus calendula*
Cedar waxwing	*Bombycilla cedrorum*
Loggerhead shrike	*Lanius ludovicianus*
Starling	*Sturnus vulgaris*
Solitary vireo	*Vireo solitarius*
White-eyed vireo	*V. griseus*
Pronthonotary warbler	*Protonotaria citrea*
Worm-eating warbler	*Helmitheros vermivorous*
Parula warbler	*Parula americana*
Northern yellow-rumped warbler	*Dendroica coronata*
Black-throated green warbler	*D. virens*
Black-throated blue warbler	*D. caerulescens*
Prairie warbler	*D. discolor*
Yellowthroat	*Geothlypis trichas*
Yellow-breasted chat	*Icteria virens*
American redstart	*Setophaga ruticilla*
English sparrow	*Passer domesticus*
Bobolink	*Dolichonyx oryzivorous*
Eastern meadowlark	*Sturnella magna*
Red-winged blackbird	*Agelaius phoeniceus*
Common grackle	*Quiscalus quiscula*
Brown-headed cowbird	*Molothrus ater*
Summer tanager	*Piranga rubra*
Cardinal	*Richmondena cardinalis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Indigo bunting	*Passerina cyanea*
American goldfinch	*Spinus tristis*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Savannah sparrow	*Passerculus sandwichensis*
Vesper sparrow	*Pooecetes gramineus*
Chipping sparrow	*Spizella passerina*
Field sparrow	*S. pusilla*
White-throated sparrow	*Zonotrichia albicolis*
Song sparrow	*Melospiza melodia*

<u>Sources</u>: Westinghouse Environmental Systems Department 1974 survey.
ER, Table 2.F-5.

Table A.6. Mammals of the plant site and adjacent areas

Opossum[a]	*Didelphis marsupialis*
Shorttail shrew	*Blarina brevicauda*
Least shrew	*Cryptotis parva*
Eastern mole	*Scalopus aquaticus*
Little brown myotis	*Myotis lucifugus*
Raccoon[a]	*Procyon lotor*
River otter[a]	*Lutra canadensis*
Striped skunk	*Mephitis mephitis*
Red fox	*Vulpes fulva*
Gray fox[a]	*Urocyon cinereoargenteus*
Bobcat[a]	*Lynx rufus*
Woodchuck	*Marmota monax*
Eastern chipmunk	*Tamias striatus*
Eastern gray squirrel[a]	*Sciurus carolinensis*
Red squirrel[a]	*Tamiasciurus hudsonicus*
White-footed mouse[a]	*Peromyscus leucopus*
Golden mouse[a]	*P. nuttalli*
Meadow vole	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethica*
Meadow jumping mouse	*Zapus hudsonius*
Eastern cottontail[a]	*Sylvilagus floridanus*
Wild boar	*Sus scrofa*
Eastern whitetail deer[a]	*Odocoileus virginianus*

[a]Mammals observed onsite and in adjacent areas during Westinghouse Environmental Systems Department 1974 survey.

Source: ER, Table 2.F-6.

Table A.7. Mammals common to shore-line areas

Opossum	*Didelphis marsupialis*
Shorttail shrew	*Blarina brevicauda*
Least shrew	*Cryptotis parva*
Little brown myotis	*Myotis lucifugus*
Raccoon	*Procyon lotor*
River otter	*Lutra canadensis*
Striped skunk	*Mephites mephites*
Red fox	*Vulpes fulva*
Gray fox	*Urocyon cinereoargenteus*
Bobcat	*Lynx rufus*
Eastern chipmunk	*Tamias striatus*
White-footed mouse	*Peromyscus leucopus*
Muskrat	*Ondatra zibethica*
Eastern whitetail deer	*Odocoileus virginianus*

Source: ER, Table 2.F-7.

Table A.8. Mammals common to edge areas of old fields and woodlots

Opossum	*Didelphis marsupialis*
Shorttail shrew	*Blarina brevicauda*
Raccoon	*Procyon lotor*
Red fox	*Vulpes fulva*
Gray fox	*Urocyon cinereoargenteus*
Eastern chipmunk	*Tamias striatus*
Eastern gray squirrel	*Sciurus carolinensis*
Red squirrel	*Tamiasciurus hudsonicus*
White-footed mouse	*Peromyscus leucopus*
Eastern cottontail	*Sylvilagus floridanus*
Eastern whitetail deer	*Odocoileus virginianus*

Source: ER, Table 2.F-8.

Table A.9. Mammals common to grassy areas and open fields

Opossum	*Didelphis marsupialis*
Least shrew	*Cryptotis parva*
Eastern mole	*Scalopus aquaticus*
Striped skunk	*Mephites mephites*
Woodchuck	*Marmota monax*
Meadow vole	*Microtus pennsylvanicus*
Meadow jumping mouse	*Zapus hudsonius*

Source: ER, Table 2.F-9.

Table A.10. Herpetofauna observed onsite and in adjoining areas

Amphibians	
Green frog	*Rana clamitans melanota*
Bullfrog	*R. catesbeiana*
Southern cricket frog	*Acris gryllus gryllus*
Southern leopard frog	*Rana pipiens sphenocephala*
American toad	*Bufo americanus*
Reptiles	
Snapping turtle	*Chelydra serpentina*
Yellow-bellied turtle	*Pseudemys scripta scripta*
Eastern mud turtle	*Kinosternon subrubrum subrubrum*
Eastern painted turtle	*Chrysemys picta picta*
Eastern box turtle	*Terrapene carolina carolina*
Five-lined skink	*Eumeces fasciatus*
Banded water snake	*Natrix sipedon fasciata*
Red-bellied water snake	*N. erythrogaster erythrogaster*
Black rat snake	*Elaphe obsoleta obsoleta*
Eastern king snake	*Lampropeltis getulus*
Canebrake rattlesnake	*Crotalus horridus atricaudatus*

Source: ER, Table 2.F-10.

Table A.11. Threatened or endangered species in South Carolina, possibly occurring on the site

Eastern brown pelican	*Pelicanus occidentalis*
Southern bald eagle	*Haliaeetus l. leucocephalus*
American peregrine falcon	*Falco peregrinus aratum*
Red-cockaded woodpecker	*Dendrocopus borealis*
Bachman's warbler	*Vermivora bachmanii*
Eastern cougar	*Felis concolor*
American alligator	*Alligator mississippiensis*

Source: ER, Table 2.F-11.

Table A.12. Threatened plant species in Richland and adjacent counties, South Carolina

Family	Genus, species, variety	Habitat preference	County
Asteraceae	*Helianthus schweinitzii*	Upland wood, thickets, pastures on Piedmont	Lexington
Crassulaceae	*Sedum pussillum*	Vernal pools in granite on Piedmont	Fairfied, Kershaw
Fagaceae	*Quercus georgiana*	Granitic hills	Kershaw
Haloragaceae	*Myriophyllum laxum*	Sinks and pools	Kershaw
Isoetaceae	*Isoetes melanospora*	Ponds on granite, low wet fields, edges of sluggish streams on Piedmont and Coastal Plain	Richland
Liliaceae	*Trillium pusillum* var. pusillum	(var. not mentioned) alluvial woods, pocosins	Calhoun
Poaceae	*Sporobolus teretifolius*	Savannas on Coastal Plain	Kershaw
Santalaceae	*Nestronia umbellula*	Parasitic on pine roots, in woods primarily on Piedmont	Richland, Calhoun
Sarraceniaceae	*Sarracenia rubra*	Shrubby bogs, savannas on Coastal Plain	Richland, Calhoun, Lexington, Sumter

Source: Smithsonian Institution, *Report on Endangered and Threatened Plant Species of the United States*, Ser. No. 94-A, Washington, D.C., 1975; A. E. Radford, H. E. Ahles, and C. R. Bell, *Manual of the Vascular Flora of the Carolinas*, University of North Carolina Press, Chapel Hill, 1968.