CHAPTER 3

AFFECTED ENVIRONMENT

This chapter describes the environment of the Savannah River Plant (SRP) and the nearby region that would be affected by the cooling water alternatives associated with K- and C-Reactors and the D-Area powerhouse; it also describes the three affected onsite streams.

3.1 SAVANNAH RIVER PLANT SITE AND REGION

3.1.1 GEOGRAPHY

The Savannah River Plant is located in southwestern South Carolina. The SRP occupies an almost circular area of about 780 square kilometers (192,741 acres), bounded on its southwestern side by the Savannah River, which is also the border between the States of South Carolina and Georgia. Portions of Barnwell, Aiken, and Allendale Counties, South Carolina, lie inside the SRP boundary. The major population centers closest to the SRP site are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Figure 3-1 shows the location of the SRP site in relation to surrounding population centers within a 240-kilometer radius. TE

The SRP facilities include five nuclear production reactors (three currently operating and two in standby condition), two chemical separations areas, a fuel and target fabrication facility, and various supporting facilities (Figure 3-2). TC

The locations of the various Plant areas with reference to the five major stream systems that drain the site are shown in Figure 3-2. Most of the Plant areas drain toward the Savannah River, which ranges from 27 to 104 meters above sea level. C-Reactor is located near the middle of the SRP site. K-Reactor is about 5 kilometers southeast of C-Reactor. L- and P-Reactors are about 5 and 10 kilometers east of K-Reactor, respectively. R-Reactor is about 12 kilometers northeast of K-Reactor. The D-Area powerhouse is about 10 kilometers southwest of C-Reactor.

Almost all the SRP site is drained by tributaries of the Savannah River. Each tributary is fed by several small streams. One small stream in the northeastern sector of the site drains to the Salkehatchie River rather than the Savannah River.

The southwestern border of the Plant is the Savannah River Swamp System (SRSS). About 10,000 acres of the Savannah River swamp forest lie on the Plant from Upper Three Runs Creek to Steel Creek. The SRP swamp area borders the Savannah River for approximately 16 kilometers and averages about 2.4 kilometers in width (Figure 3-2). TE

A small embankment or natural levee has been built up along the north side of the river by sediments deposited during periods of flooding. Three breaches in the levee allow water from Steel Creek, Four Mile Creek, and Beaver Dam Creek to flow to the river. The combined discharges of Steel Creek and Pen

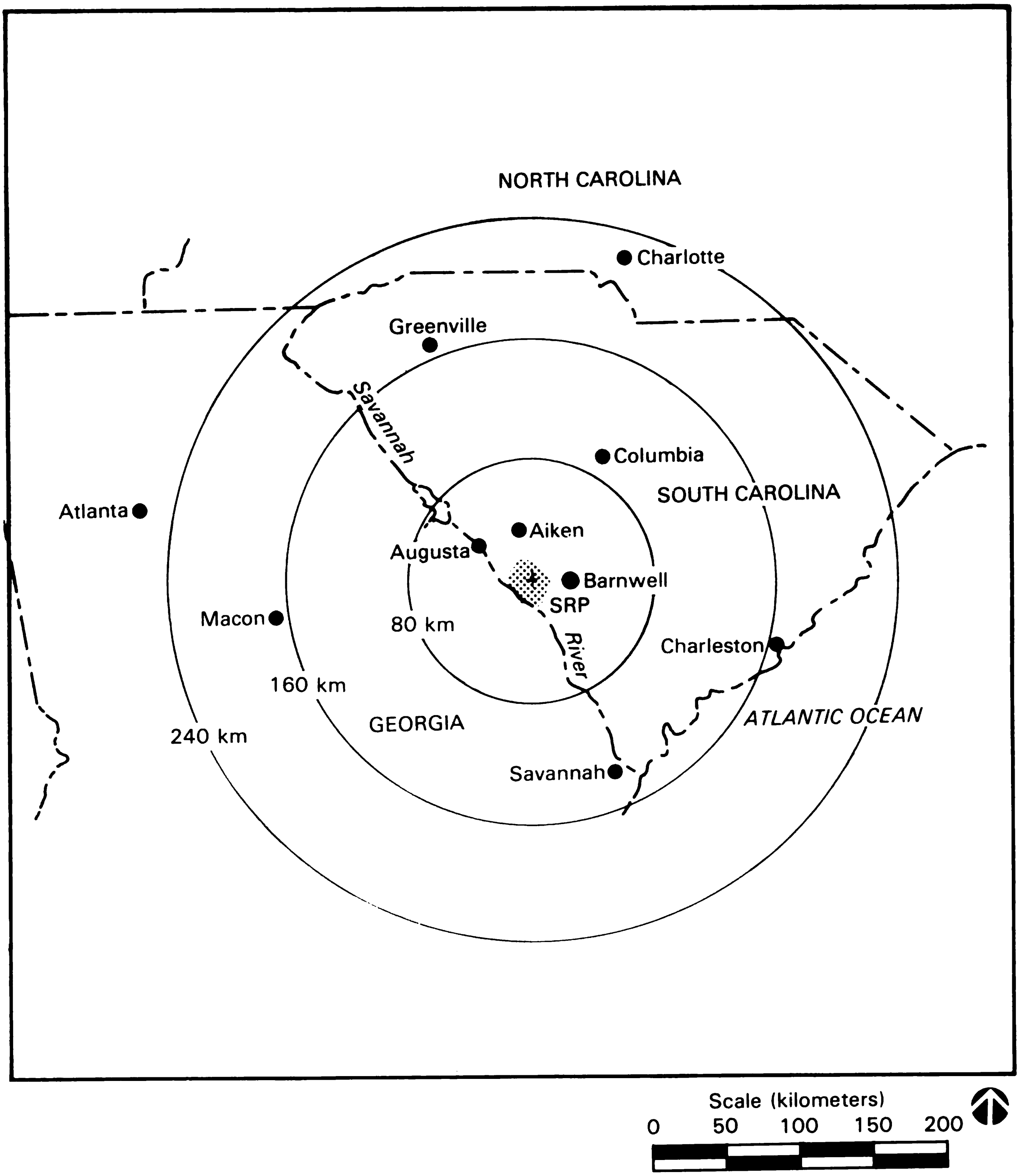


Figure 3-1. SRP Location in Relation to Surrounding Population Centers

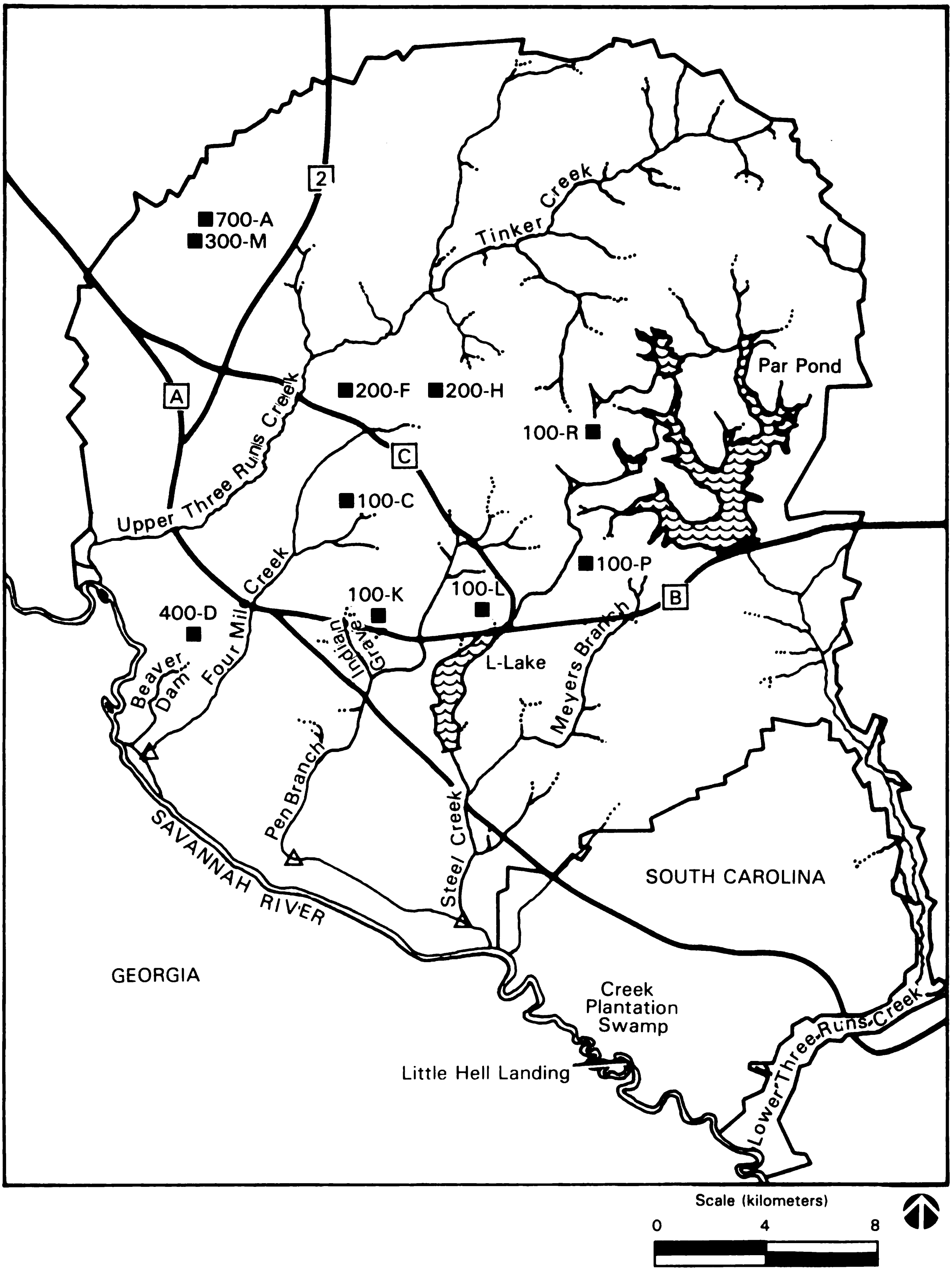


Figure 3-2. Savannah River Plant Site Map

Branch enter the river near the southeastern corner of the Plant. On the landward side of the levee, the ground elevation decreases to form the swamp system, which contains stands of cypress-tupelo forest, bottomland hardwoods, and some open marsh areas.

During periods of high river level, river water overflows the levee and stream mouths and floods the entire swamp area, leaving only isolated islands. The overflows occur when river elevations exceed 27 meters above mean sea level (MSL) as measured at the SRP boat dock. During flooding, the water from these streams flows through the swamp parallel to the river and enters the river southeast of the mouth of Steel Creek at Little Hell Landing after crossing an offsite swamp.

3.1.2 SOCIOECONOMIC AND COMMUNITY CHARACTERISTICS

A comprehensive description of socioeconomic and community characteristics for the area around the Savannah River Plant was presented in the report Socioeconomic Baseline Characterization for the Savannah River Plant Area, 1981 (ORNL, 1981). Information contained in the 1981 report was subsequently updated in the report Socioeconomic Data Base Report for Savannah River Plant (DOE, 1984a); additional information on the topics presented in this section can be found in the updated report.

3.1.2.1 Study Area

The permanent operating and construction force at the Savannah River Plant has averaged 7500, ranging from a low of 6000 in the 1960s to the current 14,957 (June, 1987). In 1980, approximately 97 percent of SRP employees resided in a 13-county area surrounding the Savannah River Plant (Table 3-1). Of these 13 counties, 9 are in South Carolina and 4 are in Georgia. The greatest percentage of employees now reside in the six-county area of Aiken, Allendale, Bamberg, and Barnwell Counties in South Carolina, and Columbia and Richmond Counties in Georgia (Figure 3-3). Together, these six counties house approximately 89 percent of the total SRP workforce. These six counties were chosen as the study area for the assessment of potential socioeconomic and community effects of the proposed cooling water alternatives because the percentage of employees residing in these counties has remained essentially the same since the early 1960s.

3.1.2.2 Demography

Table 3-2 lists the 1980 populations in the study area for counties and places of more than 1000 persons. The largest cities in the study area are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Of the 31 incorporated communities in the study area, 16 have populations under 1000 persons, and 11 have populations between 1000 and 5000 persons. Aiken, Columbia, and Richmond Counties, which comprise the Augusta Standard Metropolitan Statistical Area (SMSA), had a total population of about 327,400 in 1980; however, most of this population resides outside cities or towns. About two-thirds of the total six-county population resides in rural or unincorporated areas.

Over the last three decades, the rate of population growth has varied from county to county. From 1950 to 1980, the counties comprising the Augusta SMSA

Table 3-1. Distribution of June 1980 SRP Employees by Place of Residence

Location of residence	Percent of SRP labor force
South Carolina	80.0
Aiken County	58.8
Allendale County	1.8
Bamberg County	2.0
Barnwell County	8.8
Edgefield County	1.1
Hampton County	1.2
Lexington County	1.6
Orangeburg County	1.7
Saluda County	1.0
Other counties	2.0
Georgia	20.0
Columbia County	3.1
Richmond County	14.8
Burke County	0.3
Screven County	0.8
Other counties	0.9
Other states	0.1
Total	100.0

Source: DOE, 1984b.

TC

experienced a positive growth rate; the combined average annual rate was about 3 percent. The most significant population increases occurred in Columbia County, which experienced an average growth rate between 1960 and 1980 of about 10 percent per year. The rural counties - Allendale, Bamberg, and Barnwell - experienced population declines between 1950 and 1970; reversals of this decline occurred between 1970 and 1980 when population increases for these counties ranged from 9 to 16 percent. The population growth rate experienced in the study area during the last two decades was about equal to that experienced in the southern United States and slightly less than the growth rate experienced in the South Atlantic Region (Bureau of the Census, 1983).

In 1980 the estimated population in the 80-kilometer area around the Savannah River Plant was approximately 563,300 persons. The year 2000 population in this area is estimated at 852,000 persons. This estimate was calculated using the 1970-to-1980 growth rate of each county in the 80-kilometer area, assuming these growth rates would continue in the future. For counties that experienced a negative population growth rate between 1970 and 1980, the calculation assumed that no continued population decline would occur.

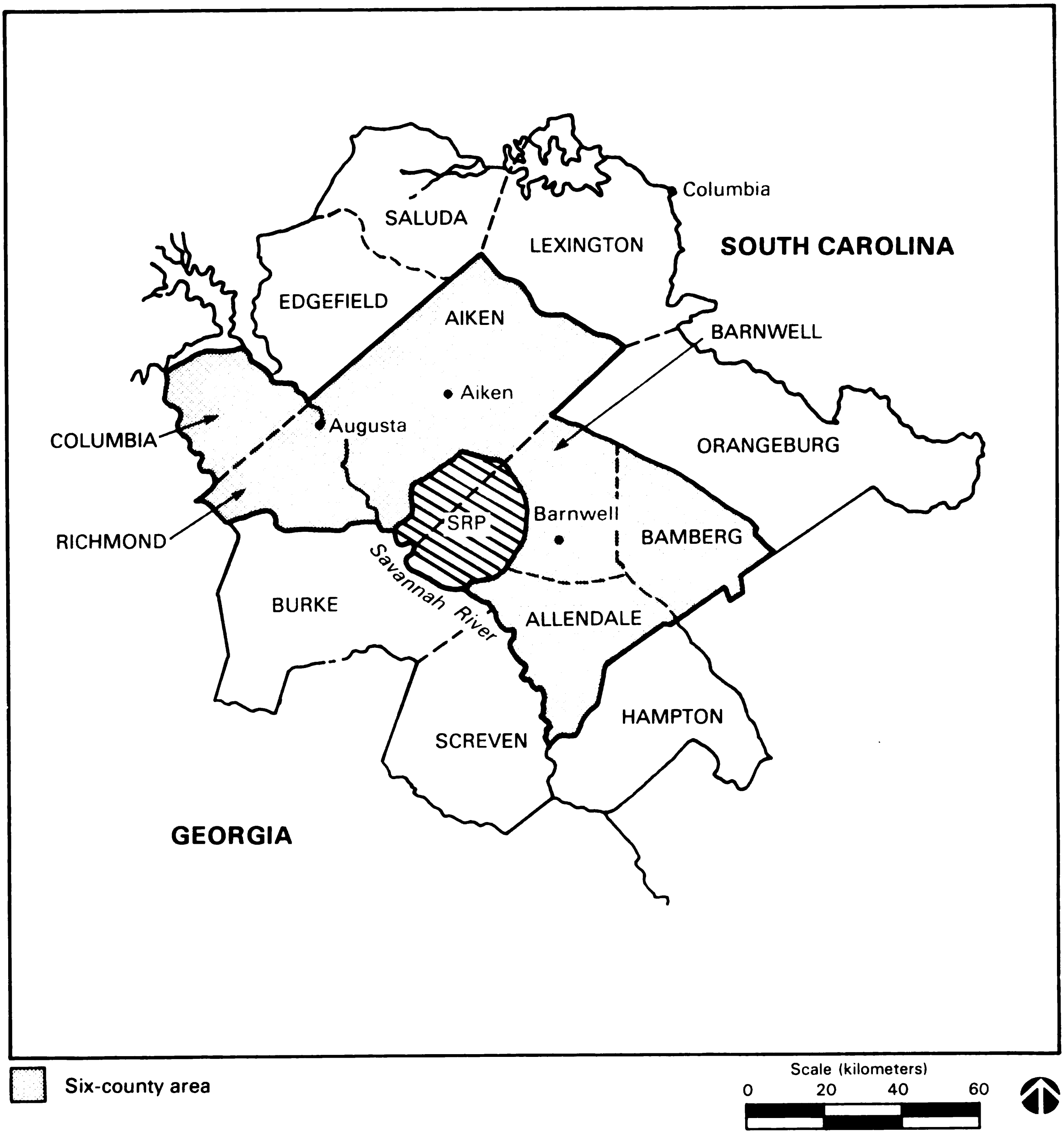


Figure 3-3. Counties in SRP Area

Table 3-2. 1980 Population for Counties and Places of 1000 Persons or Greater[a]

Location	1980 population
Aiken County, South Carolina	105,625
City of Aiken	14,978
Town of Jackson	1,771
City of North Augusta	3,593
City of New Ellenton	2,628
Allendale County, South Carolina	10,700
Town of Allendale	4,400
Town of Fairfax	2,154
Bamberg County, South Carolina	18,118
Town of Bamberg	3,672
City of Denmark	4,434
Barnwell County, South Carolina	19,868
City of Barnwell	5,572
Town of Blackville	2,840
Town of Williston	3,173
Columbia County, Georgia	40,118
City of Grovetown	3,384
City of Harlem	1,485
Richmond County, Georgia	181,629
City of Augusta	47,532
Town of Hephzibah	1,452
Study area total	376,058

a. Adapted from the Bureau of the Census (1982a,b).

3.1.2.3 Land Use

In the six-county study area, less than 8 percent of the existing land use is devoted to urban and developed uses. Most land uses of these types are in and around the Cities of Augusta and Aiken. Agriculture accounts for about 21 percent of total land use; forests, wetlands, water bodies, and unclassified lands that are predominantly rural account for about 70 percent of total land use.

All the counties in the study area have a land-use plan, and Columbia and Richmond Counties have zoning ordinances. The projected future land uses of the study area are very similar to the existing land-use patterns. Developed urban land is projected to increase by 2 percent in the next 20 years. The largest percentage of this growth is expected to occur in Aiken and Columbia Counties, as a result of the expansion of the Augusta metropolitan area.

Agricultural land throughout the study area is undergoing a transition from smaller operations to larger consolidated farms. This is especially true in the rural areas of Allendale, Bamberg, and Barnwell Counties.

3.1.2.4 Public Services and Facilities

There are nine public school systems in the study area. County-wide school districts are located in each county except Bamberg, which has two districts, and Barnwell, which has three. An estimated total of 3642 new students could have been accommodated in the study area school districts in 1982.

Of the 120 public water systems in the study area, 30 county and municipal systems serve about 75 percent of the population. All but four of the municipal and county water systems - the Cities of Aiken, Augusta, and North Augusta, and Columbia County - obtain their water from deep wells. Aiken obtains some of its water from Shaws Creek and Shiloh Springs, while Columbia County and the Cities of Augusta and North Augusta obtain water from the Savannah River. For those municipal and county water systems that use groundwater as their supply, restrictions in system capabilities are due primarily to storage and treatment capacity rather than availability of groundwater.

Most municipal and county wastewater-treatment systems have the capacity to treat additional sewage. Selected rural municipalities in Allendale, Bamberg, and Columbia Counties and the City of Augusta in Richmond County have experienced problems in treatment-plant capacities. Programs to upgrade facilities are under way or planned in most of these areas.

3.1.2.5 Housing

Since 1970, the largest increases in the number of housing units have occurred in Columbia, Richmond, and Aiken Counties. Columbia County has grown the fastest, more than doubling its number of housing units. Between 1970 and 1980, Aiken and Richmond Counties each experienced about a 36-percent increase in the number of housing units. In Aiken County, one-fourth of this increase resulted from the high growth rate in the number of mobile homes.

The vacancy rate for owner-occupied housing units for the six-county area in 1980 was 2.3 percent. Individual county rates ranged from 3.6 percent in Columbia County to 0.8 percent in Barnwell County. Vacancy rates for rental units in 1980 ranged from 14.8 percent in Columbia County to 7.1 percent in Bamberg County; the average for the study area was 10.5 percent.

3.1.2.6 Economy

The results of the 1980 Census of Population indicate that between 1970 and 1980 there was a 35-percent increase in total employment, from 75,732 to 102,326 employees, in establishments with payrolls in the six-county area. Service sector employment increased at these establishments by 65 percent, mirroring a national trend toward a service-based economy. Employment in manufacturing increased by 27 percent, adding more than 9000 employees. Most of the overall expansion in the number of employment positions occurred in Richmond and Aiken Counties.

About 31 percent of the workforce in the six-county area in 1980 was employed in the service sector, and 27 percent in the manufacturing sector. Retail trade was the third largest category, accounting for 15 percent of the workforce. The remaining 27 percent of the workforce was dispersed among the seven additional categories of employment reported by the Census. In 1980, fewer than 2 percent of workers in the study area were employed in the category of agriculture, forestry, and fishing, while nearly 4 percent were employed in that category in 1970.

3.1.3 HISTORIC AND ARCHAEOLOGICAL RESOURCES

In 1985, 69 sites in the study area were listed in the National Register of Historic Places (see Appendix E). Richmond County had the largest number of sites (27), most of which are in the City of Augusta. Approximately 25 more National Register sites are in Aiken and Allendale Counties. TC TC

In past years, the South Carolina Institute of Archaeology and Anthropology has conducted various archaeological surveys on the Savannah River Plant through the Savannah River Plant Archaeological Resource Program. An intensive archaeological and historic survey was conducted in 1984 in the Pen Branch and Four Mile Creek watersheds (Figure 3-4). As discussed in Appendix E, 65 sites were located, about two-thirds of which were not considered significant due to the lack of site integrity and limited research potential. Consultations with the State Historic Preservation Officer have determined that none of the potentially significant sites possess the necessary characteristics for nomination for inclusion in the National Register of Historic Places (see Appendix E). Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the survey areas. As discussed in Appendix E, site 38BR450 is considered a significant archaeological resource and has been recommended for eligibility for nomination to the National Register of Historic Places. AT-1 AT-2 AZ-1

3.1.4 GEOLOGY

3.1.4.1 Geologic Setting

The Savannah River Plant is located in the Aiken Plateau physiographic division of the Upper Atlantic Coastal Plain of South Carolina (Cooke, 1936). Figure 3-5 shows a generalized northwest-to-southeast geologic profile across the Savannah River Plant. The Aiken Plateau at the Plant is characterized by interfluvial areas with narrow, steep-sided valleys. Because of the Plant's proximity to the Piedmont region, it has somewhat more relief than the near coastal areas; onsite elevations range from 27 to 104 meters above mean sea level.

The center of the Plant is about 40 kilometers southeast of the Fall Line (Davis, 1902) that separates the Atlantic Coastal Plain physiographic province from the Piedmont physiographic province (Figure 3-5). Crystalline rocks of

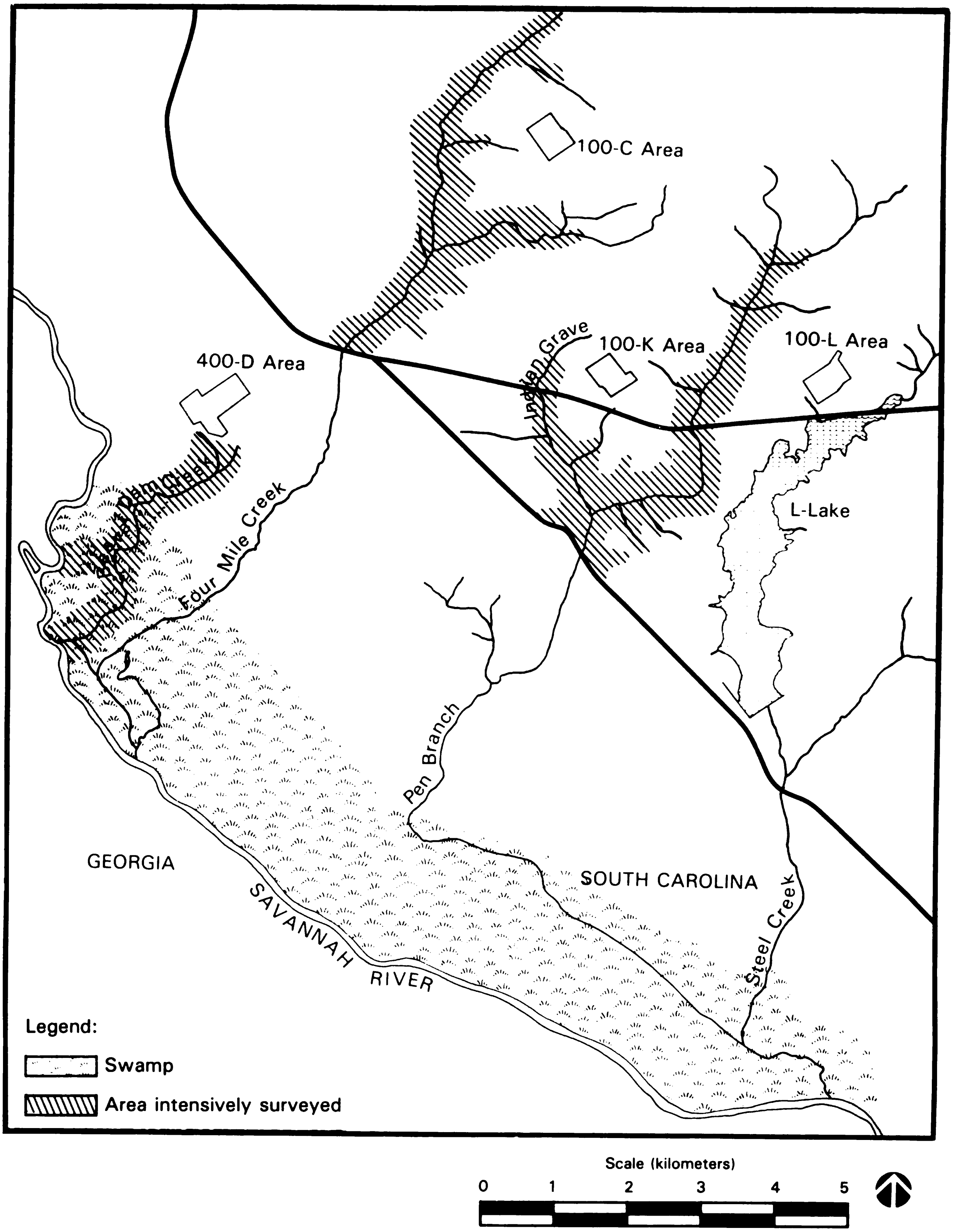
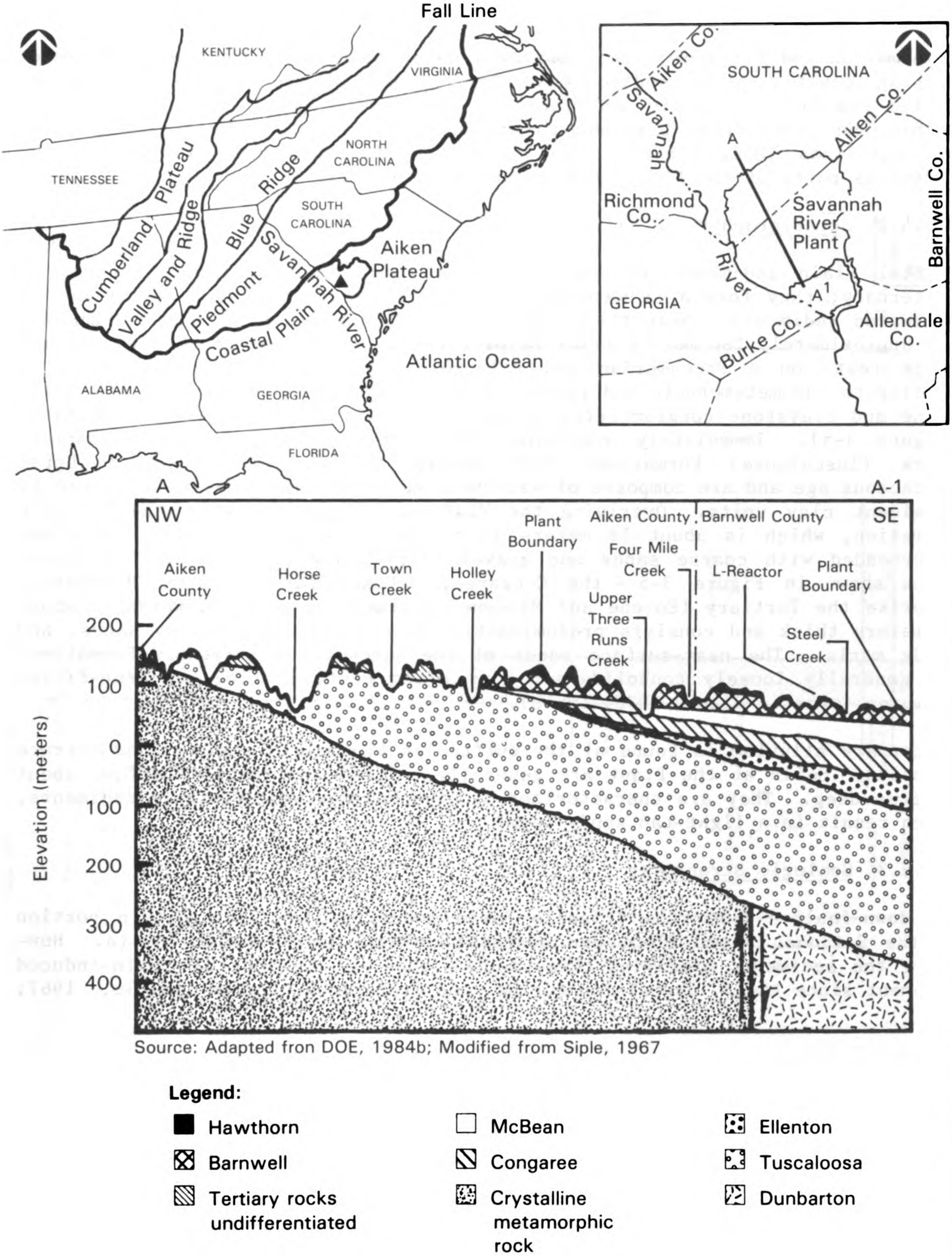


Figure 3-4. General Map of Archaeological Survey Area



Source: Adapted fron DOE, 1984b; Modified from Siple, 1967

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Figure 3-5. Generalized NW to SE Geologic Profile Across the Savannah River Plant

Precambrian and Paleozoic age underlie a major portion of the gently seaward-dipping coastal plain sediments of Cretaceous and younger age. Sediment-filled basins of Triassic and Jurassic age (exact age is uncertain) occur within the crystalline basement throughout the coastal plain of Georgia and the Carolinas (DOE, 1984b). One of these, the Dunbarton Triassic Basin, underlies parts of the Plant (Marine and Siple, 1974).

TC | 3.1.4.2 Stratigraphy*

Coastal Plain sediments in South Carolina range in age from Cretaceous to Quaternary; they form a seaward-dipping and thickening wedge of mostly unconsolidated sediments. Near the center of the Plant at H-Area, these sediments are approximately 280 meters thick (Siple, 1967). The base of the sedimentary wedge rests on a Precambrian and Paleozoic crystalline basement, which is similar to the metamorphic and igneous rocks of the Piedmont, and on the siltstone and claystone conglomerates of the down-faulted Dunbarton Triassic Basin (Figure 3-5). Immediately overlying the basement are the Middendorf-Black Creek (Tuscaloosa) Formations (175 meters thick), which are of Upper Cretaceous age and are composed of waterbearing sands and gravels separated by prominent clay units. Overlying the Middendorf/Black Creek is the Ellenton Formation, which is about 18 meters thick and consists of sands and clays interbedded with coarse sands and gravel (Siple, 1967). Four of the formations shown in Figure 3-5 - the Congaree, McBean, Barnwell, and Hawthorn - comprise the Tertiary (Eocene and Miocene) sedimentary section, which is about 85 meters thick and consists predominantly of clays, sands, clayey sands, and sandy marls. The near-surface sands of the Barnwell and Hawthorn Formations are generally loosely consolidated; they often contain thin, sediment-filled fissures (clastic dikes) (DOE, 1984b).

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Quaternary alluvium is found at the surface in floodplain areas and as terrace deposits. Soils at the Plant are generally uniform and rather shallow, about 1 meter deep. They are characterized by bleached Barnwell-Hawthorn sediments, which result in a light-tan sandy loam.

3.1.4.3 Geologic Structures

The down-faulted Dunbarton Triassic Basin underlies the southeastern portion of the Savannah River Plant and contains several interbasinal faults. However, the sediments overlying these faults show no evidence of basin-induced movement since their deposition during the Cretaceous Period (Siple, 1967;

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*The accepted names for stratigraphic units are continually evolving as additional information on the age of the units and their correlation with similar units in other areas has surfaced. This is reflected in the different names used by authors to identify subsurface units. The stratigraphic nomenclature used in this document is the same as the usage of the various authors whose works have been referenced. Therefore, different portions of the text might use different names for the same geologic units. Similarly, the same name might be used for geologic units or portions of units that are otherwise different. Figure 3-6 shows the correlation of the units used by the various authors. The terminology used in this document is largely that of Siple (1967).

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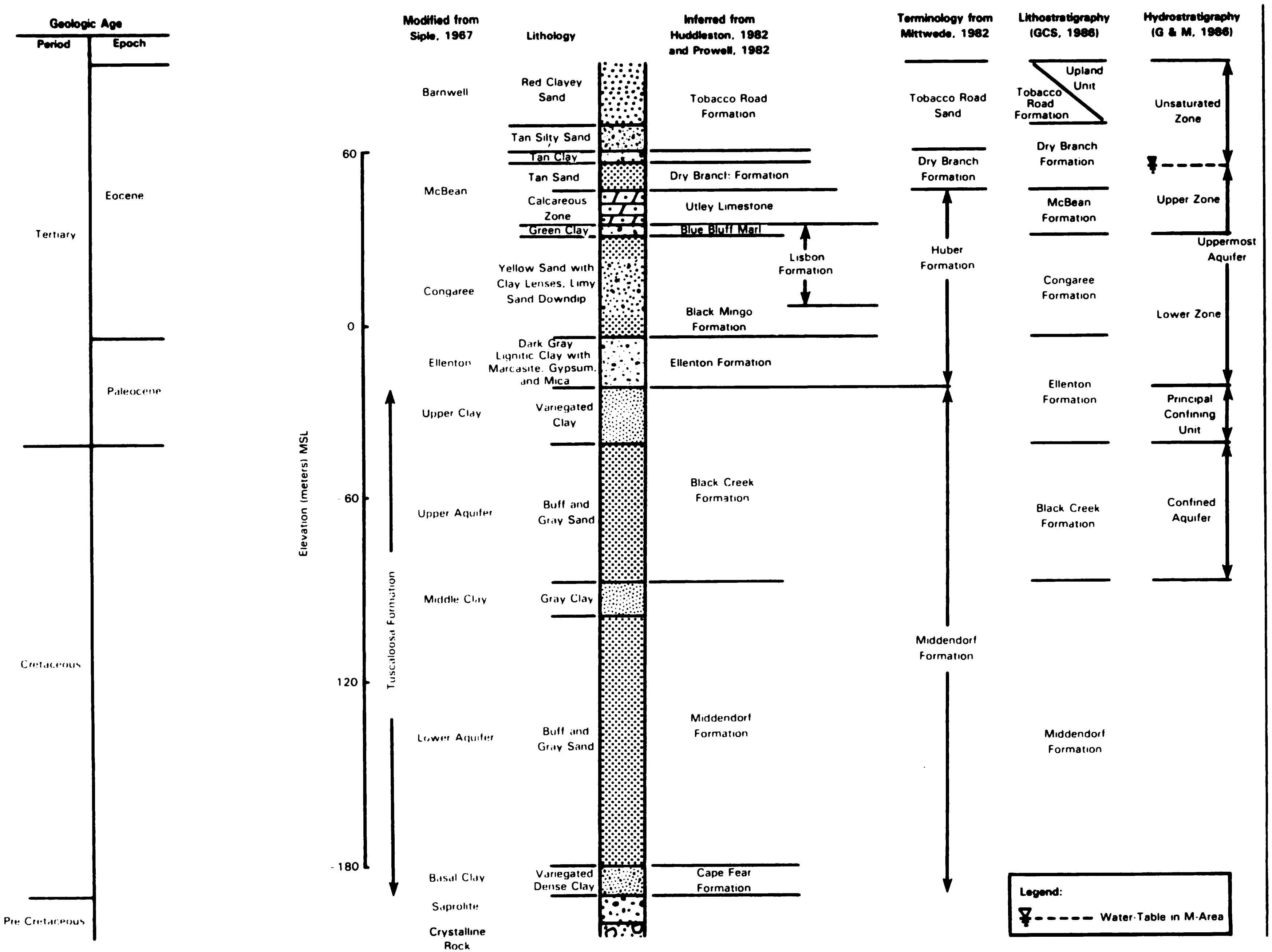


Figure 3-6. Tenative Correlation of Stratigraphic Terminology of Southwestern South Carolina Coastal Plain

Marine and Siple, 1974). Other Triassic-Jurassic basins have been identified in the Coastal Plain tectonic province of South Carolina and Georgia; these features can be associated with the South Georgia Rift (Marine and Siple, 1974; Popenoe and Zietz, 1977; Daniels, Popenoe, and Zietz, 1983). The Piedmont, Blue Ridge, and Valley and Ridge tectonic provinces, which are associated with Appalachian Mountain building, are northwest of the Fall Line (Figure 3-5). Several fault systems occur in and adjacent to the Piedmont and the Valley and Ridge tectonic provinces of the Appalachian system; the closest of these is the Belair Fault Zone, about 40 kilometers from the Plant, which is not capable of generating major earthquakes (Case, 1977).

Surface mapping, subsurface boring, and geophysical investigations at the Plant have not detected any faulting of the sedimentary strata or any other geologic hazards that would affect SRP facilities (DOE, 1984b).

3.1.4.4 Seismicity

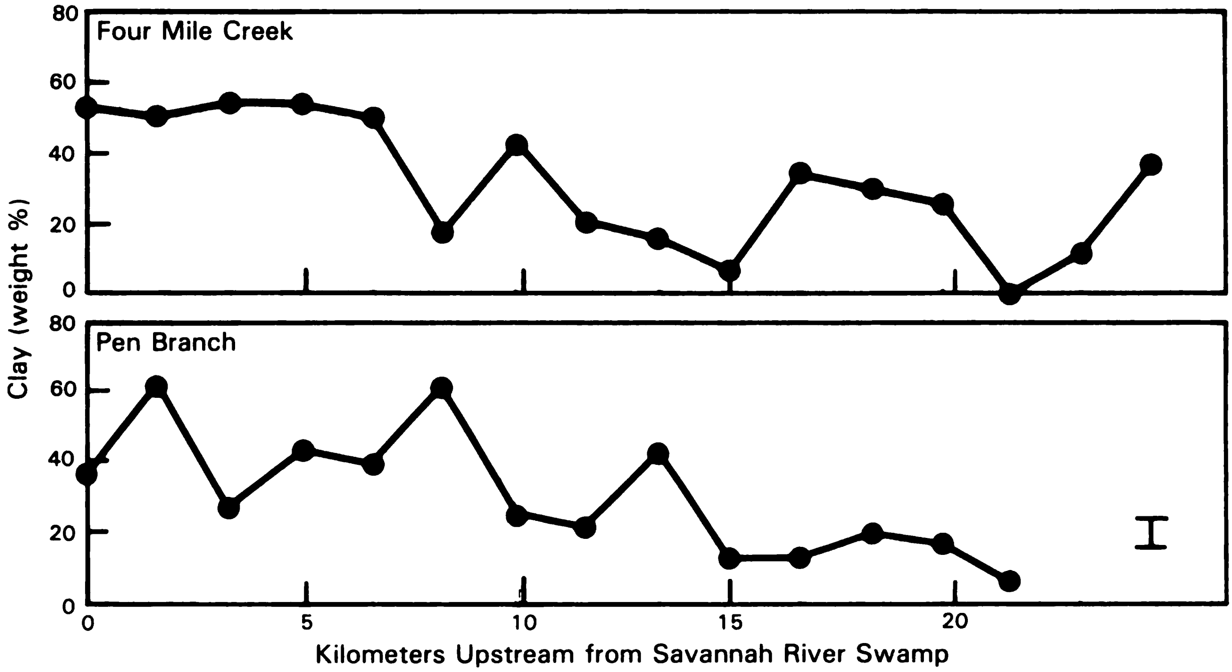
Two major earthquakes have occurred within 300 kilometers of the Savannah River Plant: the Charleston earthquake of 1886, which had an epicentral modified Mercalli intensity (MMI) of X, and was located about 145 kilometers away; and the Union County, South Carolina, earthquake of 1913, which had an epicentral shaking of MMI VII to VIII, and was located approximately 160 kilometers away (Langley and Marter, 1973). An estimated peak horizontal shaking of 8 percent of gravity (0.08g) was calculated for the site during the 1886 earthquake (Du Pont, 1982a). Site intensities and accelerations for other significant earthquakes have been published by DOE (1982, p. G-7). No reservoir induced seismicity is associated with Par Pond (see Figure 3-2).

On June 8, 1985, a minor earthquake of local magnitude 2.6 (maximum intensity: MM III), and focal depth of 0.96 kilometer occurred at the Plant near Aiken, South Carolina. The epicenter was just to the west of K- and C-Areas. The acceleration produced by the earthquake was estimated to be less than 0.002g (Stephenson, Talwani, and Rawlins, 1985).

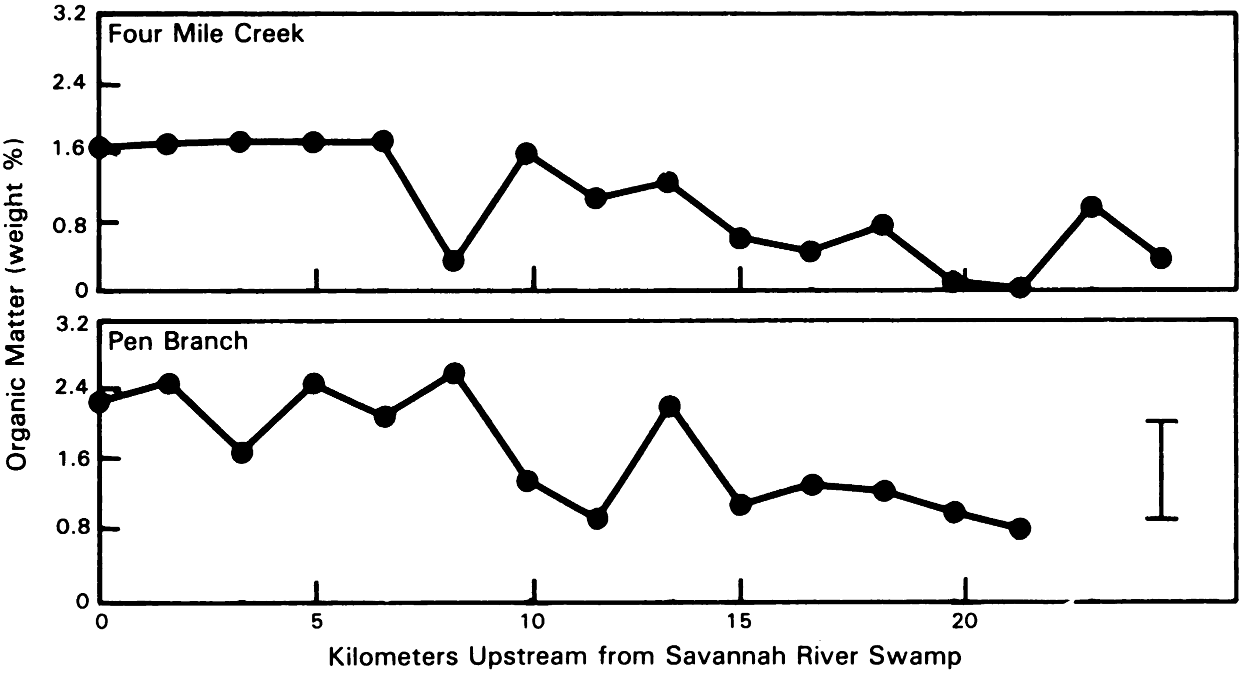
3.1.4.5 Streambed Sediments

Most of the cesium-137 that has been discharged to SRP creeks by Plant operations and by fallout from offsite weapons testing is associated with the silts and clays found in the streambed and with suspended solids. The principal mechanisms for this association are (1) cation exchange with kaolinite and gibbsite clay minerals; (2) sorption on minerals; and (3) chelation with naturally occurring organic material. Figure 3-7 shows the variation in ion-exchange capacity, clay content, and content of organic materials along the course of Four Mile Creek and Pen Branch. A distribution coefficient of K_d = 3960, measured for sediments from Four Mile Creek (Kiser, 1979), and the work by Prout (1958) demonstrate the affinity of cesium-137 for the sediments and suspended solids in the system.

The mineral composition of each particle-size fraction of the stream sediment was observed to be quite uniform. Quartz was found to account for 80 percent of the sand and 90 percent of the silt-size fraction; kaolinite dominated the clay-size fraction (Hawkins, 1971). Minor gibbsite was found in approximately half of the sediment and soil samples, regardless of location.



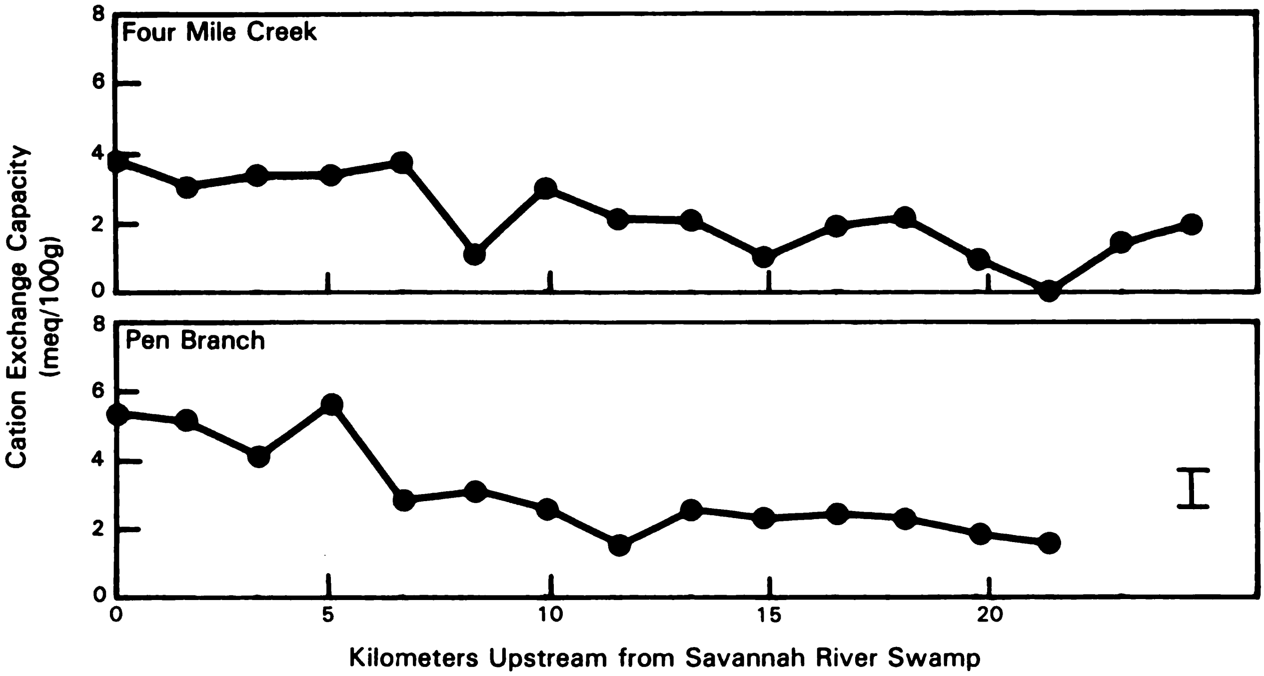
Clay Content of Streambed Sediments



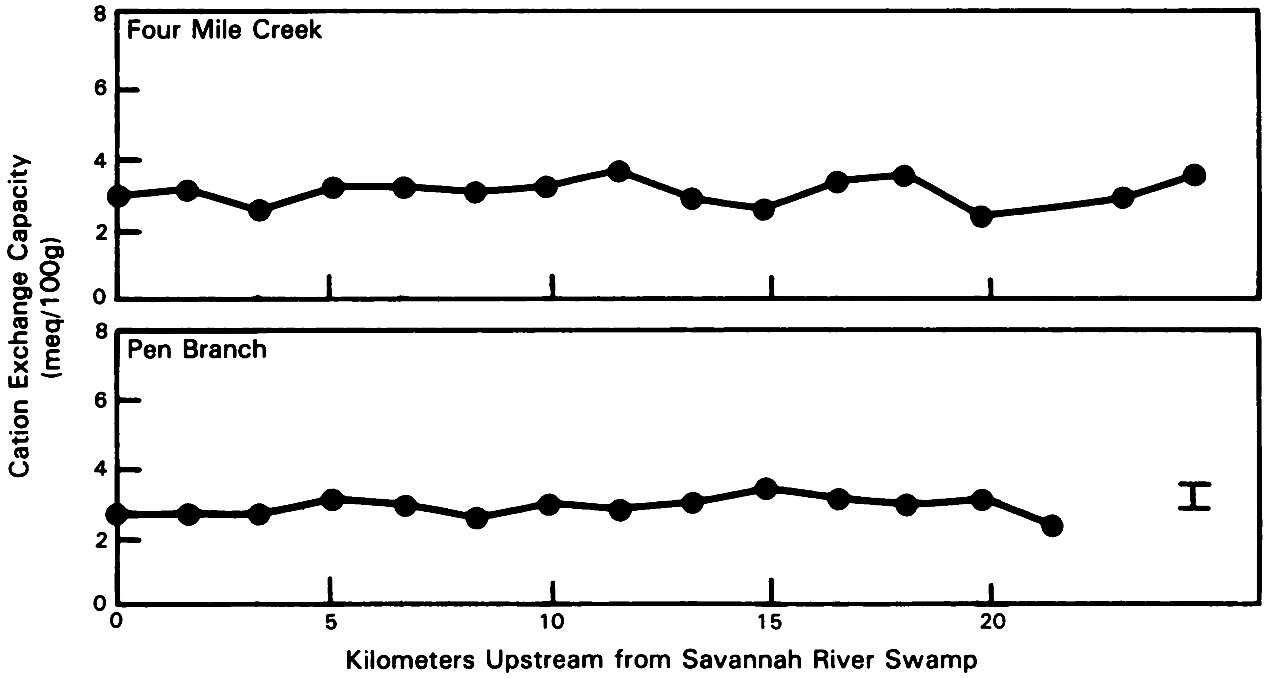
Organic Matter Contents of Streambed Sediments

Note: Range in 9 soils from source area of sediments
Source: Hawkins (1971)

Figure 3-7. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch



Cation Exchange Capacity of Streambed Sediments



Cation Exchange Capacity of the Clay Fractions of Streambed Sediments, Organic Matter Removed

Note: Range in 9 soils from source area of sediments

Source: Hawkins (1971)

Figure 3-7. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch (continued)

The cation-exchange capacity (CEC) of sediment generally increases as particle size decreases, because of an increase in organic matter, clay-mineral content, and surface area in the finer fractions. Upstream samples contain less clay and organic matter and have lower CEC values than those from near the Savannah River swamp. Overall, the CEC of all samples was very low because of the paucity of organic matter (1.26 percent sediments, 1.52 percent soils) and the predominance of kaolinite. Kaolinite has the lowest CEC of the common clay minerals; the CEC for SRP soils and sediment typically ranges from about 1.5 to 15.2 milliequivalents per 100 grams (Siple, 1967).

As a result of these affinities, sedimentation and sorption processes control the distribution of cesium-137. The resuspension, transport, and deposition of sediment are governed by the hydraulic properties of the sediment and streambed and by the creeks varied flow regime as a consequence of reactor operations. In addition, the finegrained creekbed and floodplain sediments (clay and silt) are usually associated with higher cesium-137 concentrations than are the coarser grained sediments.

Since the early 1950s, the flow regimes of Four Mile Creek and Pen Branch, including Indian Grave Branch, have been increased by the discharge of cooling water and process effluent directly into the creeks. The drainage patterns of the two creeks changed with erosion in the stream channels and deposition near the point of discharge to the swamp. Deltas developed in the swamp. Depositional environments in both creeks presently extend from their deltas to about 2.4 kilometers below SRP Road A, where near-neutral (neither erosion nor deposition) conditions exist (Ruby, Rinehart, and Reel, 1981).

3.1.4.6 Geotechnical Properties of Sediments and Subsurface Materials* TC

Near the center of the Savannah River Plant, the Congaree Formation (25 to 30 meters thick) consists of interfingered beds of very dense sands [SC and SM, according to the Unified Soil Classification System (Lambe and Whitman, 1969)] with stiff silts. Near its contact with the overlying McBean Formation, the Congaree is characterized by a silty to sandy marl. Exploratory drilling showed that penetration resistance [as measured by the standard penetration test (SPT) (Lambe and Whitman, 1969)] of the Congaree Formation is consistently very high, frequently greater than 50 blows per 30 centimeters of penetration. Geophysical surveys indicate a shear-wave velocity of about 470 meters per second over the entire thickness of the Congaree Formation.

A stiff to hard, glauconitic-clay to marl unit, which thickens from about 2 meters in the central portion of the Plant to about 18 meters in the south-southeast portion, separates the McBean Formation from the Congaree Formation. This clay is known locally as the "green clay." TE

The McBean Formation, about 18 to 21 meters thick in the central region of the Plant, is composed of sands (SM, SP), clay sands (SC), silts (ML, MH), and clays (CL, CH) in the upper section, and of impure calcareous sands (SM, SC) and silts (ML); indurated broken to slightly broken marl and fossiliferous limestone might be present in the lower section. Exploratory borings have

*Formation terminology after Siple, 1967. TC encountered very soft plastic-clay lenses within and immediately overlying the calcareous sediments. Portions of the calcareous zone, where present, have been subjected to the subsurface leaching of appreciable amounts of calcareous material. Thus, this zone is characterized by high penetration resistance where the material is competent, and very low penetration resistance, with drops of drilling rods of 2 to 3 meters and loss of drilling fluids, where dissolution and removal of material have occurred. The U.S. Army Corps of Engineers grouted the calcareous zone beneath major structures when the facilities on the Plant were constructed in the early 1950s (COE, 1952). The zone with dissolution characteristics immediately overlies an impure limestone that is characterized by high blow counts. The limestone units are discontinuous; where they are present, the upper surface of the limestone is generally irregular and undulatory. Above the basal calcareous zone, the sands of the McBean are medium-dense with penetration resistance typically in the range of 10 to 30 blows per centimeters. In some areas, such as stream valleys, the upper McBean sands can be in a very loose to loose state. Except in stream valleys, shear-wave velocities are expected to range from about 300 meters per second in the upper portion of the formation to 440 to 470 meters per second in the lower portion.

TE A discontinuous clay unit (approximately 3.5 meters thick) known locally as the "tan clay" separates the McBean Formation from the overlying Barnwell Formation. The total thickness of the Barnwell in the central portion of the Plant is about 25 meters, but it varies depending on the amount of erosion that has occurred. The sands of the Barnwell Formation are typically classified as SC and SM with some SP material, whereas the clayey material is usually classified as CL, ML, and MH. Penetration resistance in the Barnwell is frequently low, with the sandy material exhibiting loose to very loose densities and the clays soft to very soft consistencies. Two zones of loosely compacted material have been identified, one near the top of the formation and the other near its base. In these zones, the penetration resistance is usually less than 4 blows per 30 centimeters.

Undifferentiated floodplain alluvial sediments consist of interfingering lenses of inorganic, very loose to loose and medium-dense sands (SP), gravels (GM-GP), and clay-sand mixtures (SM and SC). The very soft and soft inorganic and organic silts (ML, MH, and OH) and clays (GC) of this zone have also been encountered in floodplain sediments. Typical deposits are about 5 meters thick in the center of the valley and pinch out toward the valley walls. Colluvial deposits are located on the flanks of the stream valleys and are partially mixed with the floodplain sediments. They are composed of reworked sediments of the McBean and Barnwell Formations and form a drape 3 or more meters thick over the valley slopes.

The potential for settlement and liquefaction exists beneath structures founded above areas with low penetration resistance.

3.1.5 HYDROLOGY

3.1.5.1 Surface-Water Hydrology

The principal surface-water body associated with the Plant is the Savannah River, which adjoins the site along its southwestern border. The total drainage area of the river, 27,388 square kilometers, encompasses all or parts of

41 counties in Georgia, South Carolina, and North Carolina. More than 77 percent of this drainage area lies upriver of the Plant (Lower, 1985). On the Plant, a swamp lies in the floodplain along the Savannah River for a distance of about 16 kilometers; the swamp is about 2.4 kilometers wide.

Six principal tributaries to the Savannah River are located on the SRP site: Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek (Figure 3-2). Five of these onsite streams have historically received thermal discharges from SRP cooling water operations. Currently, only Beaver Dam Creek, Four Mile Creek, and Pen Branch are receiving direct thermal discharges from the D-Area coal-fired powerhouse, C-Reactor, and K-Reactor, respectively. Both L-Reactor and P-Reactor discharge to cooling impoundments before the effluent is released to Steel Creek and Lower Three Runs Creek, respectively. The P-Reactor effluent is recirculated in Par Pond prior to discharge, whereas L-Reactor discharges its cooling effluent to a "once-through" cooling impoundment. No direct discharge of SRP cooling water is made to the Savannah River.

Streamflow Characteristics

Natural discharge patterns on the Savannah River are cyclic: the highest river levels are recorded in the winter and spring, and lowest levels are recorded in the summer and fall. Stream flow on the Savannah River near the Plant is regulated by a series of three upstream reservoirs: Clarks Hill, Russell, and Hartwell (DOE, 1984b). These reservoirs have stabilized average annual stream flow to 288.8 cubic meters per second near Augusta (Bloxham, 1979) and 295 cubic meters per second at the Savannah River Plant (DOE, 1984b).

The river overflows its channel and floods the swamps bordering the Plant when its elevation rises higher than 27 meters above mean sea level (which corresponds to flows equal to or greater than 438 cubic meters per second) (Marter, 1974). River-elevation measurements made at the SRP Boat Dock indicate that the swamp was flooded approximately 20 percent of the time (74 days per year on the average) during the period from 1958 through 1967.

The peak historic flood between the years 1976 and 1981 was estimated to be 10,190 cubic meters per second (DOE, 1984b). Since the construction of the upstream reservoirs, the maximum average monthly flow has been 1242 cubic meters per second for the month of April (1964-1981).

There are three significant breaches in the natural river levee at the SRP site; they are opposite the mouths of Beaver Dam Creek, Four Mile Creek, and Steel Creek. During periods of high river level (above 27 meters), river water overflows the levee and stream mouths and floods the entire swamp area. The water from these streams then flows through the swamp parallel to the river and combines with the Pen Branch flow. The flows of Steel Creek and Pen Branch converge 0.8 kilometer above the Steel Creek mouth. However, when the river level is high, the flows are diverted parallel to the river, across the offsite Creek Plantation Swamp; ultimately they join the Savannah River flow near Little Hell Landing (DOE, 1984b).

Water Quality

Historically, the Savannah River has been subjected to many factors that affect the water quality. Completion of the Clarks Hill Dam, located upstream from the Plant at River Mile 237.7, resulted in decreased silt loading and turbidity downstream. Because of the depth of withdrawal, the temperature of the water decreased by about 5°C (Neill and Babcock, 1971). From 1951 until 1956, downstream reaches of the Savannah River were dredged to improve channel alignment and navigability. This dredging temporarily increased suspended solids, turbidity, and dissolved nutrients.

Improved wastewater treatment by municipalities since the mid-1960s has reduced the nutrient loading and biochemical oxygen demand; however, industrialization of the river basin in the metropolitan Augusta, Georgia, area has increased total waste loading (DOE, 1982).

Variability of all water-quality parameters has diminished over the last 20 years, primarily because of flow stabilization by upstream dams. The pH of the river is generally slightly acid. The river water is relatively soft, well oxygenated, and low in chemical and biological oxygen demand (Lower, 1984). Table 3-3 compares the 10-year mean Savannah River water quality measurements upriver, at, and downriver of the Plant.

The annual average temperature of the Savannah River 3 kilometers upriver of the Plant, from 1979 to 1982, was 17.8°C with a range of individual sample analyses of 1.5° to 26.0°C. Similarly, below the Plant the average annual temperature was 18.4°C and the range was 6.5° to 26.0°C. Figure 3-8 shows monthly average daily-maximum temperatures above and below the Plant from 1971 to 1983. The river temperature increased by about 1.0°C on the average over the 18 river miles between Ellenton Landing and Millet, South Carolina, below Steel Creek. This increase was due, in part, to natural warming as the water tended toward its equilibrium temperature as the result of impoundments upstream.

As shown in Figure 3-8, June, July, August, and September are the warmest river-temperature months. The average river temperature during these months was about 25 percent higher than the annual average river temperature. From June 1955 through September 1982, the river temperature at Ellenton Landing equaled or exceeded 28°C three times and equaled or exceeded 28.3°C once (DOE, 1984b).

Water Usage

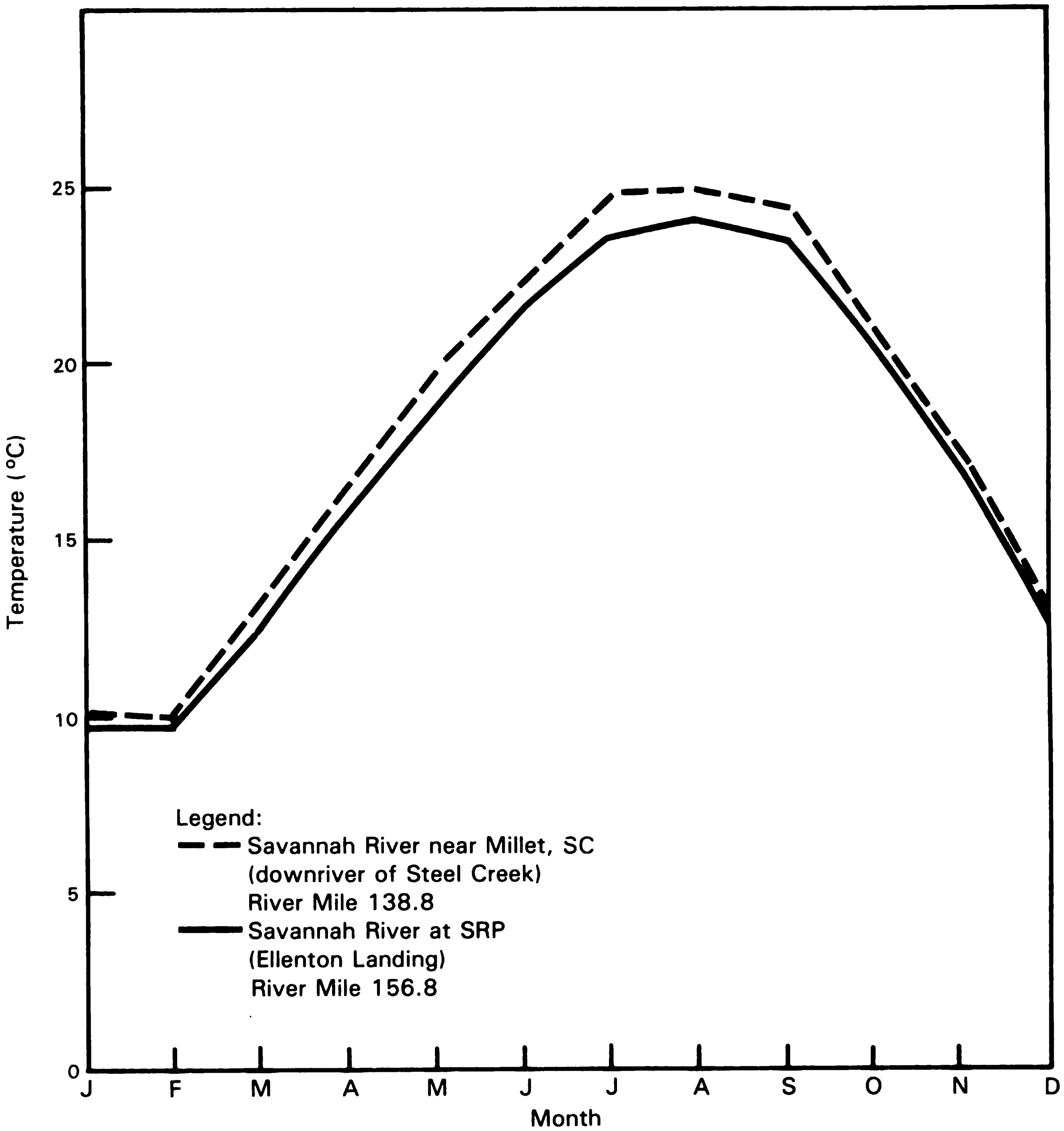
The Savannah River downstream from Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and - after treatment - domestic use. The river upstream from the Plant supplies municipal water for Augusta, Georgia (River Mile 187), and North Augusta, South Carolina (River Mile 201). Downstream, the Beaufort-Jasper Water Authority in South Carolina (River Mile 39.2) withdraws water to supply a population of about 51,000. The Cherokee Hill Water Treatment Plant at Port Wentworth, Georgia (River Mile 29.0), withdraws water to supply a business-industrial complex near Savannah, Georgia, that has an estimated consumer population of about 20,000 (Du Pont, 1982b). Plant expansions for both systems are planned for the future.

Table 3-3. Water Quality of the Savannah River, 1973 to 1982 Upriver of the SRP, at Pumphouse 3G and Downriver at the U.S. Highway 301 Bridge[a]

Parameter	Upstream of SRP mean concentration, 1973-1982 (mg/l[b]) RM 158.5	Pumphouse 3G mean concentration, 1973-1982 (mg/l[b]) RM 155.5	Hwy. 301 Bridge mean concentration, 1973-1982 (mg/l[b]) RM 118.7
Temperature (°C)	17.7	19.0	18.1
pH (units) (range)	5.3-7.6	5.3-8.0	5.5-7.3
Dissolved oxygen	9.6	9.7	9.5
Alkalinity	13.8	17.7	13.9
Conductivity (μm hos/cm)	66.8	NA	67.9
Suspended solids	17.1	24.1	16.2
Volatile solids	23.4	22.1	23.3
Total dissolved solids	47.9	58.6	48.2
Total solids	65.2	83.0	65.7
Biochemical oxygen demand	1.6	0.73	1.5
Chemical oxygen demand	NA[c]	10.7	NA
Chlorides	5.3	6.2	5.1
Kjeldahl nitrogen (N)	NA	1.0	NA
Nitrates + nitrites (N)	0.693	0.294	0.637
Sulfates (SO_4)	5.17	4.34	5.14
Total phosphates (PO_4)	0.464	0.098	0.421
Aluminum (Al)	0.382	0.97	0.443
Ammonia (N)	0.108	0.147	0.090
Calcium (Ca)	2.24	3.66	2.23
Sodium (Na)	7.66	9.33	7.24
Iron, total (Fe)	0.34	0.90	0.32
Lead (Pb)	NA	0.42	NA
Manganese (Mn)	NA	0.01	NA
Mercury (Hg)	0.002	0.001	0.002

a. Source: Du Pont, 1985b.
b. Except as noted.
c. NA - No analysis.

The Savannah River Plant currently withdraws a maximum of 37 cubic meters per second (about 90 percent of the maximum pumping rate of 41 cubic meters per second) from the river, primarily for use as cooling water in production reactors and coal-fired powerhouses (DOE, 1984b). Almost all this water returns to the river via SRP streams; consumptive water use is about 0.9 cubic



Source: Moyer, 1986

Figure 3-8. Savannah River Monthly Average Daily-Minimum Temperatures for 1971-1983

meter per second at K- and C-Reactors, 1.3 cubic meters per second at L- and P-Reactors, and about 0.3 cubic meter per second at the D-Area coal-fired powerhouse (DOE, 1984b).

The river also receives sewage treatment plant effluents from Augusta, Georgia; North Augusta, Aiken, and Horse Creek Valley, South Carolina; and other waste discharges along with the heated SRP cooling water via its tributaries. Withdrawal of an average of 1.3 cubic meters per second from the river for cooling and the return of an average of 0.35 cubic meter per second from unit one of the Vogtle Electric Generating Plant began in 1987. These withdrawal and return rates would double when both units were operating (NRC, 1985). The Urquhart Steam Generating Station at Beech Island withdraws approximately 7.4 cubic meters per second of once-through cooling water. Upstream, recreational use of impoundments on the Savannah River, including water contact recreation, is more extensive than it is near the Plant and downstream. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (Du Pont, 1982b). TC

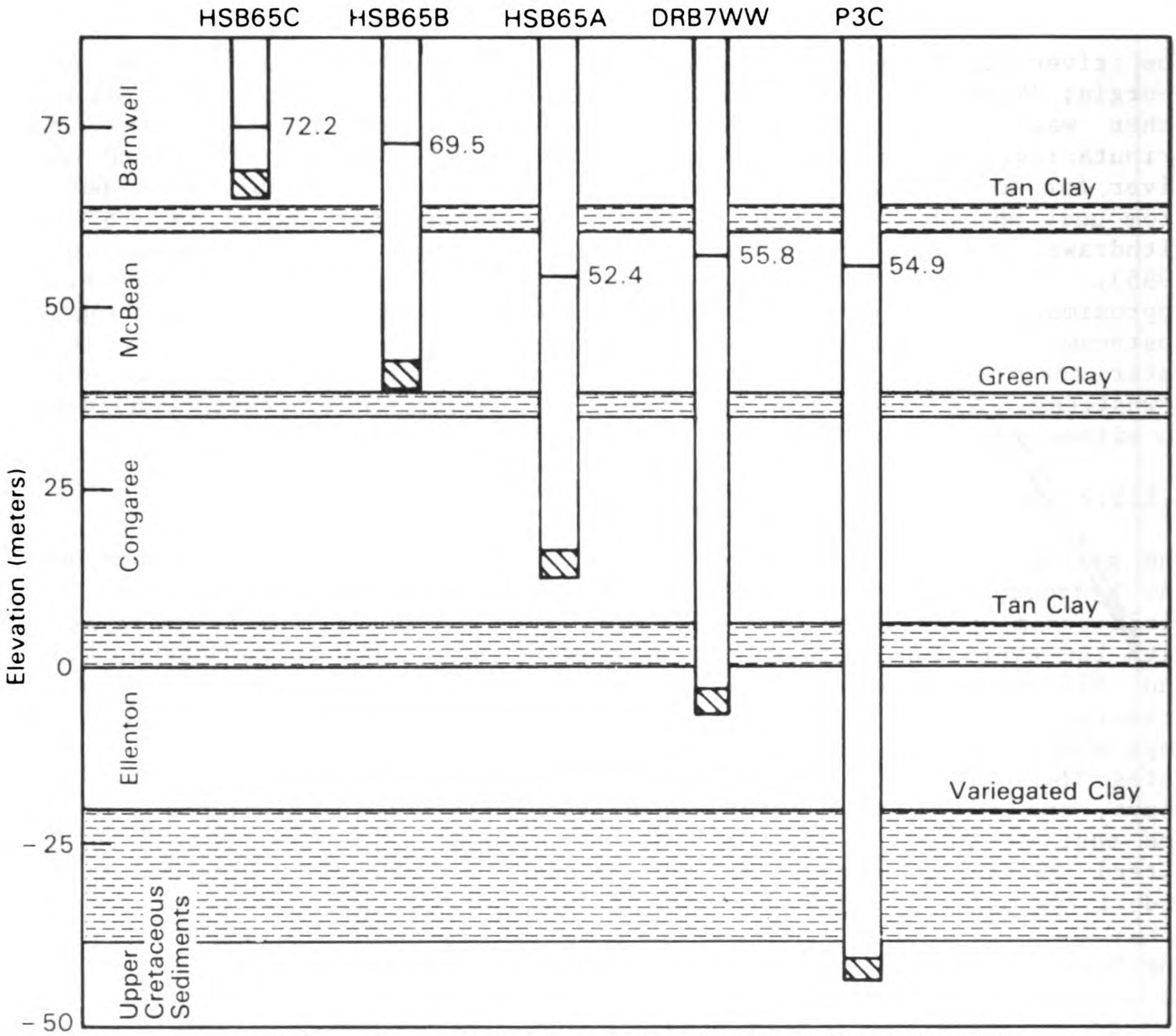
3.1.5.2 Subsurface Hydrology

The geologic units that underlie the Savannah River Plant are components of the hydrogeological system of the area (see Figure 3-6). Here the Coastal Plain sedimentary units that transmit water consist of the Barnwell (combined with the overlying Hawthorn as one mapping unit), McBean, Congaree, Ellenton, and Middendorf/Black Creek ("Tuscaloosa") Formations (Figure 3-6). The principal confining and semi-confining units include the "tan clay," which separates the Barnwell and McBean Formations, the "green clay," which separates the McBean and Congaree Formations, the basal Congaree and Ellenton clays, and the clay units in the Middendorf/Black Creek (Figure 3-9). South and east of Upper Three Runs Creek, the water table (or unconfined groundwater) generally occurs in the Barnwell Formation. Groundwater in the underlying units occurs under semiconfined and confined conditions. TE TE

The Barnwell Formation at the Plant is recharged by precipitation, which moves in a predominantly vertical direction to the water table at a rate of about 0.9 to 2.1 meters per year (Haskell and Hawkins, 1964). Natural discharge from the Barnwell Formation is to the perennial creeks and to the McBean Formation. From a water budget analysis for the central part of the Plant, Hubbard and Emslie (1984) estimated that the annual recharge to the Barnwell Formation is about 38 centimeters with about 13 centimeters of groundwater discharging to the creeks and 25 centimeters seeping through the "tan clay" to the McBean Formation.

The McBean Formation is recharged in offsite areas and by seepage from the Barnwell Formation. Natural discharge is toward Upper Three Runs Creek, Four Mile Creek, Pen Branch, and Indian Grave Branch, which is a tributary of Pen Branch. TC

The Congaree Formation is recharged in offsite areas and by seepage from the McBean Formation. Natural discharge is toward the wetlands along Upper Three Runs Creek and the Savannah River. There is no appreciable seepage downward through the Ellenton clay or upward through the "green clay." As a result of



Source: Du Pont, 1985a. Hydrostratigraphic unit terminology after Siple, 1967; see Figure A-2.

Legend:

Clay layer

Screen zone

Note: Water levels in HSB65A, B, and C measured 3/8/85
Water levels in DRB7WW and P3C measured 3/18/85

TC

Figure 3-9. Vertical Head Relationship Near the H-Area Seepage Basins

the natural discharge, the potentiometric head in the Congaree is lower than that in the Middendorf/Black Creek Formations in a broad area within about 10 kilometers of Upper Three Runs Creek and the Savannah River. | TE

The Middendorf/Black Creek Formations are recharged in offsite outcrop areas near the Fall Line in Aiken County, and through the overlying sediments north and west of Upper Three Runs Creek. Natural discharge is toward the wetlands along the Savannah River north of the Plant. Water is also lost from seepage into overlying formations. | TE | TC

The water in the Coastal Plain sediments tends to be of good quality, suitable for municipal and industrial use with minimal treatment. It is generally soft, slightly acid, and low in dissolved and suspended solids.

Most municipal and industrial water supplies in Aiken County are developed from the Middendorf/Black Creek ("Tuscaloosa") Formations. Domestic water supplies in Aiken County are developed primarily from the Barnwell, McBean, and Congaree Formations. In Barnwell and Allendale Counties, the Middendorf/Black Creek Formations occur at increasingly greater depths; some municipal users, therefore, are supplied from the shallower Congaree and McBean Formations or from their limestone equivalent. In these counties, domestic supplies are developed from the Barnwell and McBean Formations. | TE | TE

3.1.6 ECOLOGY

The United States Government acquired the 780-square-kilometer (192,741 acres) Savannah River Plant in 1951 (Du Pont, 1985b). At that time the land was approximately two-thirds forested and one-third cropland and pasture (Dukes, 1984). With the exception of the production and support areas, many previously disturbed areas and open fields have been reclaimed by natural succession or have been planted with trees; these areas are managed by the U.S. Forest Service. Today more than 90 percent of the Plant is forested. Table 3-4 lists recent SRP land utilization, other than the land used for chemical or nuclear processes and support facilities. The Plant, which was designated as a National Environmental Research Park in 1972, is one of the most extensively studied environments in this country (DOE, 1984b). | TC

This section describes the ecology of the Savannah River Plant and the surrounding region. Appendix C presents results of many studies conducted in the Savannah River, the Savannah River swamp, and the onsite streams.

3.1.6.1 Terrestrial Ecology

Soils

A general soils map of the Savannah River Plant (Adelott, 1977) grouped the soil types into 23 mapping units. The dominant types are Fuquay/Wagram Soils (27.3 percent), Dothan/Norfolk soils (9.6 percent), Savannah River Swamp and Lower Three Runs Corridor (9.4 percent), Troop Loamy Sand, Terrace phase (8.4 percent), Gunter Sand (7.5 percent), and Vaucluse/Blaney Soils (6.5 percent). Together these units account for approximately 70 percent of the soil types that occur on the Savannah River Plant.

Table 3-4. Land Utilization, 1983[a]

Land	Area (acres)
Open fields	650
Slash pine	35,000
Longleaf pine	37,500
Loblolly pine	48,000
Pine-hardwood (60% pine)	4,000
Hardwood-pine (60% hardwood)	6,300
Scrub oak	2,000
Upland hardwoods	4,500
Bottomland hardwoods	29,000
Other pine	100
Subtotal	167,050
Wetlands	
Creeks/floodplains	24,500
Savannah River Swamp	10,000
Par Pond	2,500
Carolina bays	1,000
Other	1,000
Subtotal	39,000
Total	206,050[b]

a. Adapted from Dukes, 1984.
b. Exceeds total acreage of the Savannah River Plant because of overlap in wetlands and bottomland hardwood acres.

Vegetation

The Savannah River Plant is near the line that divides the oak-hickory-pine forest and the southern mixed forest. Consequently, it has species representative of each forest association (DOE, 1984b). In addition, SRP vegetation has been influenced strongly by farming, fire, soil features, and topography. No virgin forest remains in the region. Except for the production areas and their support facilities, the U.S. Forest Service has reclaimed many previously disturbed areas through natural plant succession or by planting with pine (Du Pont, 1985b).

A variety of vascular plants (150 families, 1097 species) occur on the Savannah River Plant (Dukes, 1984). (See Appendix C for greater detail and Appendix F for a discussion of wetlands and floodplains.) Typically, scrub oak communities cover the drier sandy areas; longleaf pine, turkey oak, bluejack oak, blackjack oak, and dwarf post oak with ground cover of three awn grass and huckleberry dominate such communities. Oak-hickory hardwoods are prevalent on more fertile, dry uplands. The characteristic species are white oak, post oak, southern red oak, mockernut hickory, pignut hickory, and loblolly pine with an understory of sparkleberry, holly, greenbrier, and poison ivy.

The composition is more variable on moist soils found along small streams or on old floodplains. Characteristic species include tulip poplar, birch, sweet gum, willow oak, water oak, and loblolly pine. The understory can include dogwood, members of the honeysuckle family, holly, and red buckeye.

Bottomland hardwood forest borders the Savannah River swamp where it is subject to occasional flooding. Some common trees are sweet gum, swamp chestnut oak, red maple, hackberry, laurel, blue birch, river birch, water oak, willow, sycamore, winged elm, and loblolly pine. Palmetto, switch cane, greenbrier, grape, crossvine, and trumpet creeper are also common.

The swamp bordering the Savannah River is subjected to seasonal flooding with winter and early spring water levels 3 to 4.5 meters higher than those of summer and fall. Bald cypress and tupelo gum are the dominant trees in the Savannah River swamp, where standing water is present almost year-round. Black gum and water oak are also present.

The status of the smooth coneflower (Echinacea laevigata), which is found on the Savannah River Plant along the Burma Road, as a threatened and endangered species is currently under status review by the U.S. Fish and Wildlife Service (Currie, 1985). To date, the U.S. Fish and Wildlife Service has not identified any "critical habitat" on the Savannah River Plant. Commercially valuable plant biota on the Savannah River Plant include approximately 175,000 acres of timber managed by the U.S. Forest Service.

Wildlife

The diversity and abundance of wildlife that inhabit the Savannah River Plant reflect the interspersion and heterogeneity of the habitats occurring at the site. Because of its mild climate and the variety of aquatic and terrestrial habitats, the Savannah River Plant contains a varied and abundant herpetofauna (DOE, 1984b). Gibbons and Patterson (1978) provide a comprehensive description of the herpetofauna of the site, including taxonomy, distribution, and ecological information. The species on the Plant include 31 snakes, 26 frogs and toads, 17 salamanders, 10 turtles, 9 lizards, and 1 alligator (Dukes, 1984).

Species collected during intensive field studies on Steel Creek, particularly during 1981 and 1982, are considered to be representative of species occurring on similar creeks and wetland areas. Frogs and toads, turtles, and salamanders (in order of decreasing relative abundance) constituted more than 85 percent of the 65 species (69 percent of those on the Plant) found (DOE, 1984b).

Biologists have identified more than 213 species of resident and migrant birds on the Plant. Gamebirds such as quail and dove were initially abundant on the Plant but have declined since the 1960s because the conversion of agricultural fields to forests has reduced the carrying capacity for these species. The

South Carolina Wildlife and Marine Resource Department initiated a turkey-breeding program on the Plant in 1972. As of 1984, about 135 turkeys had been captured and used to restock other areas of the State (Dukes, 1984).

TC Waterfowl on the Plant are mainly winter migrants. Wood ducks are the only waterfowl species to breed consistently in the SRP region. An estimated 10,000 to 15,000 ducks and coots spend the winter on the site; most congregate on Par Pond and on other large ponds and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River (Dukes, 1984).

Commercially and Recreationally Valuable Biota

TC The ecosystems on the Savannah River Plant support many commercially and recreationally valuable game populations; however, DOE restricts recreational use to controlled hunts for white-tailed deer and feral hogs. Many species are highly mobile and travel offsite where activities such as hunting are allowed. Other resident species that are edible and that travel offsite include the ring-neck duck, wood duck, mallard, bullfrog, and various species of turtles. The slider turtle is the most abundant turtle known to migrate offsite; other common species that move offsite include the Florida cooter and the snapping turtle (DOE, 1984b).

Endangered and Threatened Species

TC Four species listed as either threatened due to similarity of appearance or endangered by the U.S. Fish and Wildlife Service - the American alligator, the bald eagle, the wood stork, and the red-cockaded woodpecker - have been identified on the SRP. As stated above for plant species, the U.S. Fish and Wildlife Service has not identified any "critical habitat" for animal species on the Savannah River Plant. (See Appendix C for more detail, especially concerning definition of "threatened due to similarity of appearance.")

TC Listed Federally as "threatened due to similarity of appearance," the American alligator is common locally and breeds in Par Pond, near D-Area, in the Savannah River Swamp, along Steel Creek, in Pond B, and in Lower Three Runs Creek. The ecology of this species on the Savannah River Plant has been examined intensively (Du Pont, 1985b).

TC The Federally endangered bald eagle is a fairly common permanent breeding resident in South Carolina. Bald eagles migrate from the southeast to the northern states and Canada in midsummer; they return south in the fall and early winter to nest and rear their young (Sprunt and Chamberlain, 1970). The first sighting of an active bald eagle nest on the SRP occurred in June 1986, below Par Pond dam in the Lower Three Runs Creek drainage area. Two eaglets were fledged from this nest in 1986 and 1987.

TE Endangered wood storks, which have been observed on the Savannah River Plant, originate from the Birdsville rookery near Millen, Georgia. The Steel Creek delta, Beaver Dam Creek area, and other sites in the Savannah River swamp provide important feeding habitat for storks from this rookery (Du Pont, 1985b).

The endangered red-cockaded woodpecker has a very restrictive requirement for nesting habitat; it nests only in old (more than 50 years) stands of pines. In 1987, the SRP had three active breeding pairs and a total population of 14 (A. B. Gould, U.S. Department of Energy, personal communication with J. L. Oliver, NUS Corporation, August 20, 1987). TC

3.1.6.2 Aquatic Ecology

Aquatic Flora

The Savannah River is the dominant water body associated with the Savannah River Plant. The river has experienced two significant alterations since the early 1950s: (1) dredging in the main channel as far as Augusta, Georgia, and (2) completion of upstream reservoirs (Clarks Hill in 1952; Hartwell in 1961; Russell in 1984). These changes have affected the aquatic community by reducing shallow habitat and reducing transport of sediment and allochthonous particulate organic material (Patrick et al., 1967). The microflora of the Savannah River is dominated by diatoms, although blue-green algae are sometimes common upstream from the Plant; their abundance is caused by organic loading from municipal sources. The abundance and species distribution of phytoplankton result, to some extent, from upstream reservoir overflow. Macrophytes, most of which are rooted, are limited to shallow areas of reduced current, such as oxbows, behind sandbars, in swamp areas, and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the Savannah River adjacent to the Plant; the most common are water milfoil, hornwort, alligatorweed, waterweed, and duck potato (DOE, 1984b).

Aquatic Fauna

Shallow areas and quiet backwaters and marshes of the Savannah River near the Plant support a diverse aquatic invertebrate fauna. However, the bottom substrate of most open portions of the river consists of shifting sand that does not provide optimum habitat for bottom-dwelling organisms. During the 1950s, TE the river experienced a decrease in the total number of invertebrate species; this decrease has been attributed primarily to the effects of dredging (Patrick et al., 1967). The stabilization of the river discharge and the elimination of habitat caused by the reduction in the flooding of backwater areas might have contributed to the decline. Some recovery occurred during the 1960s and 1970s, but complete recovery has not taken place. The groups most affected are those sensitive to the effects of siltation and substrate instability. Mayflies and dragonflies predominated among insect fauna in earlier surveys. In more recent surveys, dipterans (true-flies) have been dominant (DOE, 1984b; ECS, 1985).

Results of insect faunal studies conducted have indicated substantial organic loading to the river upstream from the Savannah River Plant. True-flies (particularly chironomids) dominated the drift communities, which is typical of a riverine system. Mollusks, such as snails and clams, are also an important component of the Savannah River invertebrate community. The Asiatic clam, Corbicula fluminea, is found in the river and larger tributary streams in the vicinity of the Plant (DOE, 1984b).

The Savannah River drainage is typical of southeastern coastal plain systems, exhibiting a diverse fish fauna represented by 102 species (Dahlberg and Scott, 1971). Eighty species have been found in the streams, swamp, and river near the SRP site (Paller and Osteen, 1985).

A study of certain biota in the Savannah River was initiated in July 1982 (Du Pont, 1985b). The focus of this study was to examine the occurrence, relative abundance, and distribution of adult and larval fishes in the river, the SRP intake canals, and lower reaches of tributary creeks. (See Appendix C for additional discussion.) Previous data and studies were reviewed, incorporated, or extended in this study.

Researchers collected 80 fish species as part of this study. The dominant small fishes (excluding minnows) were sunfishes (especially redbreast) and flat bullheads. The dominant large fishes were bowfin, spotted suckers, and channel catfish. Other important species were largemouth bass, American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker. The most abundant small forage species were shiners TC | and brook silverside (Du Pont, 1985b; Paller and Osteen, 1985).

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January. Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species (37) was captured during May, possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August (Du Pont, 1985b).

Thermal effluents affect the structure of fish communities in the streams and swamp on the Savannah River Plant. Studies of nonthermal, thermal, and postthermal areas in SRP stream and swamp systems indicate that the thermal streams have markedly reduced species richness and abundance in relation to ambient-temperature areas. In these ambient-temperature areas, habitat factors (cover type, water depth, water velocity) can strongly influence species composition. The greatest differences in fish community structure occurred between the swamp sites and areas sampled along the lower reaches of the Four Mile Creek corridor. Species richness declined substantially and mosquitofish clearly dominated collections. Mosquitofish were either absent or minor components of the community at ambient-temperature sites (Du Pont, 1985b).

The 1983 ichthyoplankton sampling program extended from February through July; it included 26 river transects, 2 intake canals, and 33 tributary creeks of the Savannah River between River Mile (RM) 29.6 and 187.1. During 1983, researchers collected and identified 43,294 fish larvae and 7138 fish eggs (Du Pont, 1985b).

Ichthyoplankton densities were highest downstream of the Plant during February, March, and April, highest near the Plant during May, and highest upstream of the Plant during June and July. These trends correlated with temperature and probably occurred because the lower river warmed to suitable spawning temperatures before the upper river (Du Pont, 1985b).

During March and April 1983, ichthyoplankton density decreased nearly five-fold near the Plant between RM 141.7 and RM 150.4. This phenomenon did not result from the destruction of larvae by thermal plumes from the Plant because river temperatures were not abnormally elevated in the region; nor was it due to entrainment, because only 6.6 percent of the river discharge was entrained during March and 4.2 percent in April. The marked increase in ichthyoplankton abundance below RM 150.4 probably resulted from an influx of larvae from spawning areas in the swamps bordering the Plant. When river levels are unusually high, as they were during the 1983 spawning season, SRP thermal effluents discharge into the swamp rather than directly into the main channels of the receiving streams. The resulting temperature increases in the swamp might have stimulated spawning.

Patterns in stream-swamp ichthyoplankton abundance on the Savannah River Plant were comparable with those of adult fish. Generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than those at creek stations upstream from the swamp. Results from sampling throughout the Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in the delta area. The deepwater, open-canopy areas were the most productive for ichthyoplankton; centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominated collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than those observed at creek mouth stations. Generally, anadromous species appear to make minimal use of swamp areas for spawning and restrict these activities to the creek mouths. No striped bass ichthyoplankton have been collected in swamp or creek mouth locations.

During 1984, 1938 fish were collected from impingement samples on 107 sampling dates. The number of fish impinged daily ranged from 0 to 190, with an average of 18 fish per day (Paller and Osteen, 1985). The average number of fish impinged during 1984 was approximately half of the 37 fish impinged daily during 1983 (Paller et al., 1984), but was similar to the average of 19 fish impinged during 1982 (ECS, 1983). These three years of data (1982 to 1984) indicate that more than twice as many fish are impinged as the 7 per day reported during 1977 (McFarlane, Frietsche and Miracle (1978). Generally, all researchers found that sunfishes were the most dominant fish impinged, followed by shad and herring. Highest rates of impingement generally occurred in the spring, associated with flood conditions (Du Pont, 1985b; Paller and Osteen, 1985).

Entrainment of larval fish and eggs at the SRP pumphouses during the 1984 spawning season totaled 23.4×10^6 ichthyoplankters (17.6×10^6 larvae and 5.8×10^6 eggs (Paller, O'Hara, and Osteen, 1985)), which was 37.0 percent less than the 37.2×10^6 larval and eggs entrained in 1983 (Paller et al., 1984). The 1983 and 1984 entrainment values represent 8.3 and 9.3 percent, respectively, of the total ichthyoplankton that passed by the intake canals and structures (Paller, O'Hara, and Osteen, 1985). (See Appendix C for more details concerning entrainment and impingement studies).

Endangered and Threatened Species

Recent fisheries surveys on the Savannah River revealed that the endangered shortnose sturgeon spawn in the vicinity of the Savannah River Plant (Du Pont, 1985b). Shortnose sturgeon larvae were collected in river water upstream, downstream, and adjacent to the Plant during 1982 (two larvae collected), 1983 (six collected), and 1984 (two collected). All of the sturgeon larvae collected during 1982 were taken from the section of river between RM 150.8 and RM 157.3, with none collected from the intake canals. One of the seven shortnose sturgeon larvae collected in 1983 was found in the 1G intake canal, one was found in the 3G intake canal, and the remaining five were found adjacent to or downstream of the Plant. During 1984, both shortnose sturgeon larvae were collected below the Plant. No larvae or juveniles were collected from any SRP tributary stream during 1982, 1983 (Du Pont, 1985b), or 1984 (Paller, O'Hara, and Osteen, 1985).

A biological assessment of the potential effects of SRP operations on the shortnose sturgeon in the Savannah River (Muska and Matthews, 1983) was submitted to the National Marine Fisheries Service (NMFS). The NMFS and DOE-SR have concurred that the population of the shortnose sturgeon in the Savannah River would not be jeopardized by SRP operations (Oravetz, 1983).

Commercially and Recreationally Valuable Biota

All thermal streams on the Savannah River Plant support depauperate fish populations, especially during periods of reactor operations. However, the Savannah River supports both commercial and sport fisheries (Appendix C). Most fishing is confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia. The only commercial fish of significance near the Plant are the American shad, the channel catfish, and the Atlantic sturgeon. (The commercial catch of American shad from the Savannah River during 1979 was 57,600 kilograms.) These species are exploited to a limited degree by local fishermen.

Sport fishermen are the principal consumers of river fishes, primarily sunfish and crappie. Striped bass are classified as game fish in South Carolina and Georgia (Ulrich et al., 1978).

The Fisheries Section of the Georgia Department of Natural Resources (GDNR) published the results of a fisheries study conducted on the Savannah River from July 1, 1981, to June 30, 1982 (Georgia Game and Fish Division, 1982). GDNR researchers collected data from sports fishermen on fishing effort, harvest, species sought, habitat or location fished, and angler origin. Approximately 4600 anglers fish in the freshwater section of the Savannah River. Georgia residents constitute 68.2 percent of these anglers. The anglers fish in both the mainstream (58.2 percent) and oxbows, creeks, and lakes (41.8 percent) of the river. Freshwater anglers fish (43.8 percent of their time) for bream (i.e., bluegill, redbreast sunfish, warmouth, redear sunfish, and spotted sunfish); bream account for 73 percent of the fish caught. Largemouth bass is the next most popular species (38 percent of the time); however, success is low (2.5 percent of the fish caught). About 90,000 kilograms of freshwater fish are harvested from the lower Savannah River annually.

3.1.7 METEOROLOGY AND CLIMATOLOGY

The description of the meteorology of the Savannah River Plant is based on data collected at the Plant and at Bush Field in Augusta, Georgia (Du Pont, 1980a, 1982b; NOAA, 1985). Additional information in the following sections was obtained from magnetic tapes containing data from the onsite meteorological program for the period 1975 through 1979.

3.1.7.1 Regional Climatology

The SRP area has a temperate climate, with mild winters and long summers. The region is subject to continental influences, but it is protected from the more severe winters in the Tennessee Valley by the Blue Ridge Mountains to the north and northwest. The SRP site and the surrounding area are characterized by gently rolling hills with no unusual topographical features that would have a significant influence on the general climate.

Winters are mild and, although cold weather usually lasts from late November to late March, less than one-third of the days have a minimum temperature below freezing.

3.1.7.2 Local Meteorology

SRP Meteorology Data System

Meteorological data are collected from a system of seven towers located adjacent to each production area on the Plant and from the WJBF-TV tower about 15 kilometers northwest of the SRP boundary. The seven towers are instrumented at the stack height of 61 meters with vector vanes designed for turbulence measurements (Kern and Mueller, 1979). The TV tower is instrumented at seven levels (Hoel, 1983) with bivanes and fast-response cup anemometers to provide the same type of information as that received from the SRP towers (Kern and Mueller, 1979). Platinum resistance thermometers at each of eight levels on the TV tower provide temperature information on the lowest 300 meters of the atmosphere.

The data measured by this tower system are received in the Weather Center Analysis Laboratory (WCAL) on the Plant. The data collected from the SRP tower system and the WJBF-TV tower are used for real-time emergency-response situations.

In addition to the tower data, extremes in daily temperature and rainfall are recorded, and continuous measurements of temperature, relative humidity, and pressure are kept. Rain gauges are located at various locations on the SRP site.

Temperature and Humidity

Table 3-5 lists the average and extreme temperatures recorded for the Plant. The annual average temperature at the Plant is 18°C. The monthly average ranges from 7°C in January to 27°C in July (see Table 3-5). The extreme temperatures observed are -16°C and 41°C. The Augusta, Georgia, long-term temperature data are in agreement with those for the Savannah River Plant.

The length of the growing season for the Augusta area is normally 241 days, with the first freeze on November 12, and the last on March 16. Freezing temperatures have been observed, however, as early as October 17, and as late as April 21.

Table 3-5. Average and Extreme Temperatures (°C) at Savannah River Plant, 1961-1981

	Average temperature			Extreme temperature	
Month	Daily maximum	Daily minimum	Monthly	Record maximum	Record minimum
Jan.	13	2	7	30	-16
Feb.	16	3	9	27	-16
Mar.	20	7	13	32	-12
Apr.	25	12	18	35	0
May	28	16	22	37	5
June	32	19	26	41	9
July	33	21	27	41	14
Aug.	32	21	27	40	13
Sept.	29	18	24	38	5
Oct.	24	12	18	33	-2
Nov.	19	7	13	32	-8
Dec.	15	3	9	28	-11
Year	24	12	18	41	-16

The annual average daily relative humidity for the Plant ranges from 43 to 90 percent.

Average Wind Speed and Direction

TE The average annual wind speed measured in Augusta from 1951 to 1981 was 3.0 meters per second (see Table 3-6). The average annual wind speed recorded at a height of 10 meters on the WJBF-TV tower near Beech Island, about 15 kilometers northwest of the Plant, was 2.5 meters per second from 1976 to 1977. The average monthly wind speed for Augusta, Georgia, is listed in Table 3-6 along with the prevailing wind direction for each month. This table also lists the monthly and annual average wind speeds for three levels of the television tower.

TE Annual wind-direction frequencies for the K-, C-, and D-Areas are shown in the transport plots (Figures 3-10 through 3-12). These figures show the percentage of time that the wind blows from each of 16 directions (22.5° sectors). The information presented in these figures was produced from data taken at the 61-meter level (the stack height in most SRP production areas). Seasonal transport is generally as follows: winter, northwest to southeast; spring, west to east; summer, toward the southeast through north to northeast; and autumn, toward the southwest and southeast. Because the pollutant dispersion depends on atmospheric stability, annual wind roses are available for each of the seven SRP towers for each of seven Pasquill-type stability classes; seasonal wind roses are also available (Hoel, 1983).

Table 3-6. Average Monthly Wind Speed for Bush Field, Augusta, Georgia, 1951-1981 and WJBF-TV Tower, 1976-1977

	Bush Field		WJBF-TV tower elevation (m)		
Month	Mean speed (m/sec)	Prevailing direction	10	36	91
Jan.	3.2	W	3.0	4.5	6.1
Feb.	3.4	WNW	2.9	4.6	5.8
Mar.	3.6	WNW	3.3	4.5	5.9
Apr.	3.4	SE	2.8	4.2	5.4
May	2.9	SE	2.5	3.7	5.0
June	2.8	SE	2.4	4.0	4.8
July	2.6	SE	2.0	3.1	4.4
Aug.	2.5	SE	2.1	3.2	4.3
Sept.	2.5	NE	2.1	3.3	4.7
Oct.	2.6	NW	2.4	4.1	5.6
Nov.	2.8	NW	2.4	4.1	5.6
Dec.	3.0	NW	2.7	4.4	6.3
Annual	3.0	SE	2.5	3.9	5.3

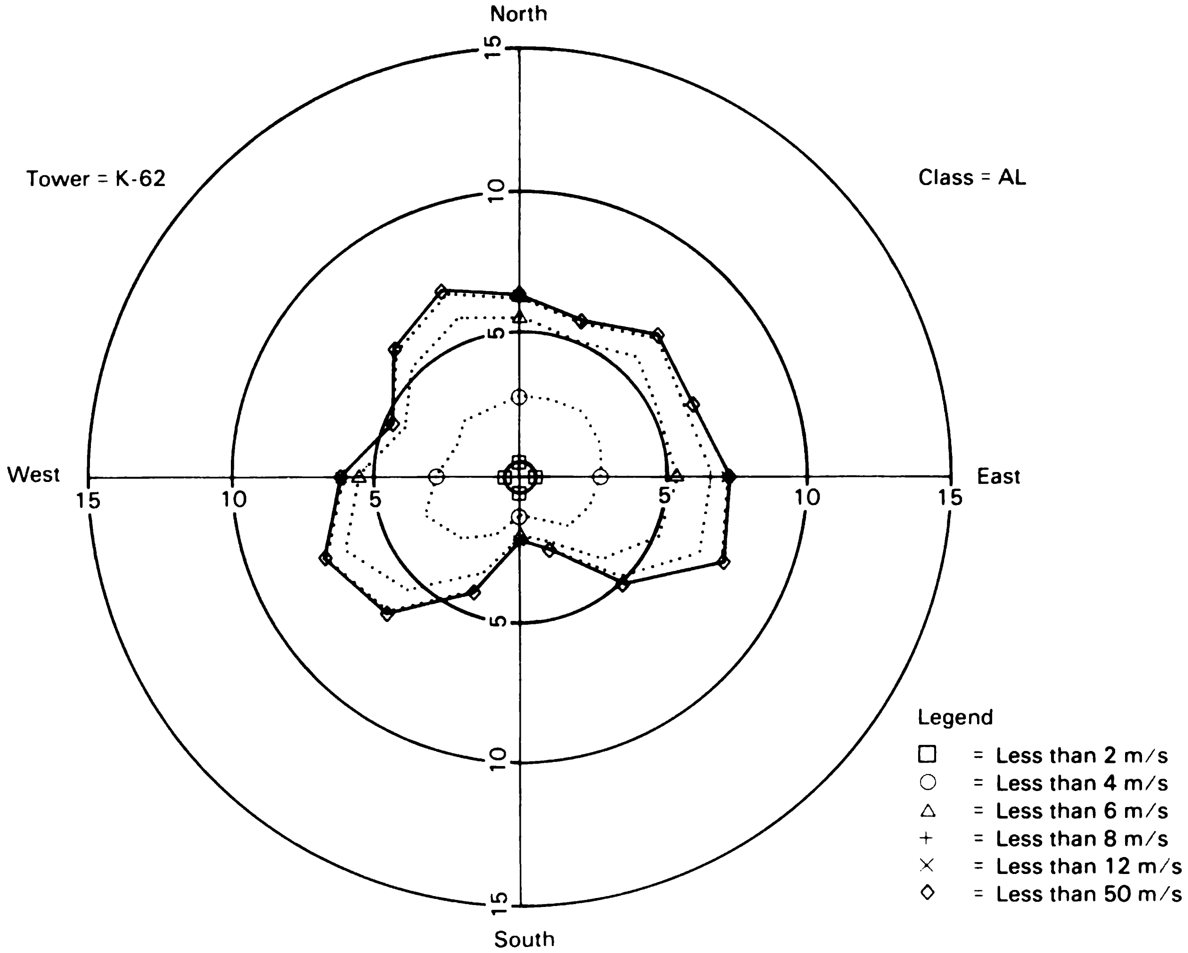
Precipitation

The average annual rainfall at the Savannah River Plant from 1952 through 1978, was about 120 centimeters (Du Pont, 1982b). The average at Augusta from 1951 to 1980 was about 113 centimeters (NOAA, 1985). Table 3-7 lists the means and extremes of precipitation for the Plant from 1952 to 1982. The maximum monthly precipitation was about 31.6 centimeters, recorded in August 1964. Hourly observations in Augusta show that the intensity of the rainfall is normally less than 1.3 centimeters per hour.

3.1.7.3 Severe Weather

Extreme Winds

The strongest winds in the SRP area occur in tornadoes, which can have wind speeds as high as 116 meters per second. The next strongest surface winds occur during hurricanes. During the history of the SRP, only Hurricane Gracie, in September 1959, had winds in excess of 34 meters per second. Winter storms with winds as high as 32 meters per second have been recorded occasionally (Du Pont, 1982b). Thunderstorms can generate winds as high as 18 meters per second and even stronger gusts. The highest 1-minute wind speed recorded at Augusta between 1951 and 1984 was 28 meters per second. Table 3-8 lists the extreme wind speeds for 50- and 100-year return periods for three locations about equally distant from the Plant (Simiu, Changery, and Filliben, 1979).

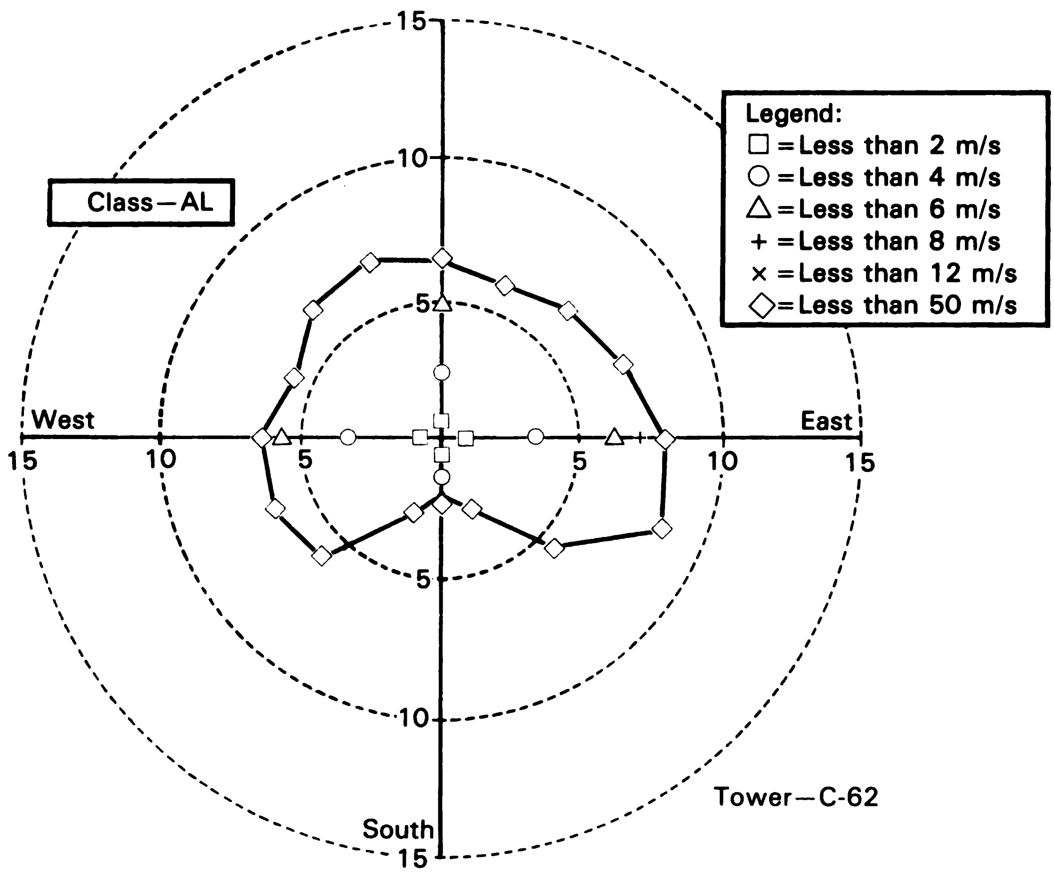


Windrose data

Minimum date	MMDDYY	10175		Maximum date	MMDDYY	123179
Minimum time	ZULU	0000		Maximum time	ZULU	2400
Entries all classes		113511		Entries this class		113511

	Speed in meters sec						Average		Percent time wind @ speed						
Direction	0-2	2-4	4-6	6-8	8-12	·12	speed	Total	0-2	2-4	4-6	6-8	8-12	·12	Total
N	469	1076	747	195	48	0	2 66	2535	41	95	66	17	04	0 00	2.23
NNE	634	1774	1696	691	168	12	3 11	4975	.56	1 56	1 49	.61	15	01	4.38
NE	563	2807	2922	1145	114	38	3 52	7589	50	2 47	2 57	1 01	10	.03	6 69
ENE	710	3336	3446	848	107	9	3 38	8456	63	2.94	3 04	.75	09	.00	7 45
E	569	2744	3069	613	83	26	3 42	7104	50	2.42	2 70	54	07	02	6 26
ESE	542	2173	2212	469	48	2	3.22	5446	48	1 91	1.95	41	04	.00	4 80
SE	644	2368	3013	815	97	4	3 41	6941	57	2 09	2 65	72	.08	00	6.11
SSE	496	2336	3755	1043	177	18	3 73	7825	44	2 06	3.31	92	16	.01	6 89
S	536	2569	3037	752	185	12	3 55	7091	.47	2.26	2.68	66	16	01	6.25
SSW	559	2600	2532	700	131	13	3 35	6535	.49	2.29	2 23	62	12	.01	5.76
SW	688	2828	3018	1072	167	18	3 42	7791	.61	2 49	2 66	.94	15	.01	6 86
WSW	608	2789	2606	1034	330	38	3 48	7405	.54	2.46	2 30	91	29	03	6 52
W	631	2588	2982	1391	675	56	3.71	8323	.56	2.28	2.63	1.23	.59	.04	7.33
WNW	614	2339	3011	1725	995	84	3 87	8768	.54	2.06	2 65	1 52	88	.07	7 72
NW	614	2090	1881	944	343	37	3 33	5909	54	1.84	1 66	83	30	.03	5 21
NNW	444	1315	951	324	74	1	2.89	3109	39	1 16	84	29	.06	00	2.74
No direct	2247	3071	1623	555	132	81	2 23	7709	1 98	2.71	1.43	49	12	.07	2.23
Avg speed	1 25	2 99	4.86	6 69	9.16	14 85	3 31								
Total entry	11568	40803	42501	14316	3874	449		113511							

Figure 3-10. K-Area Tower 1975-1979



Windrose Data

Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 114938

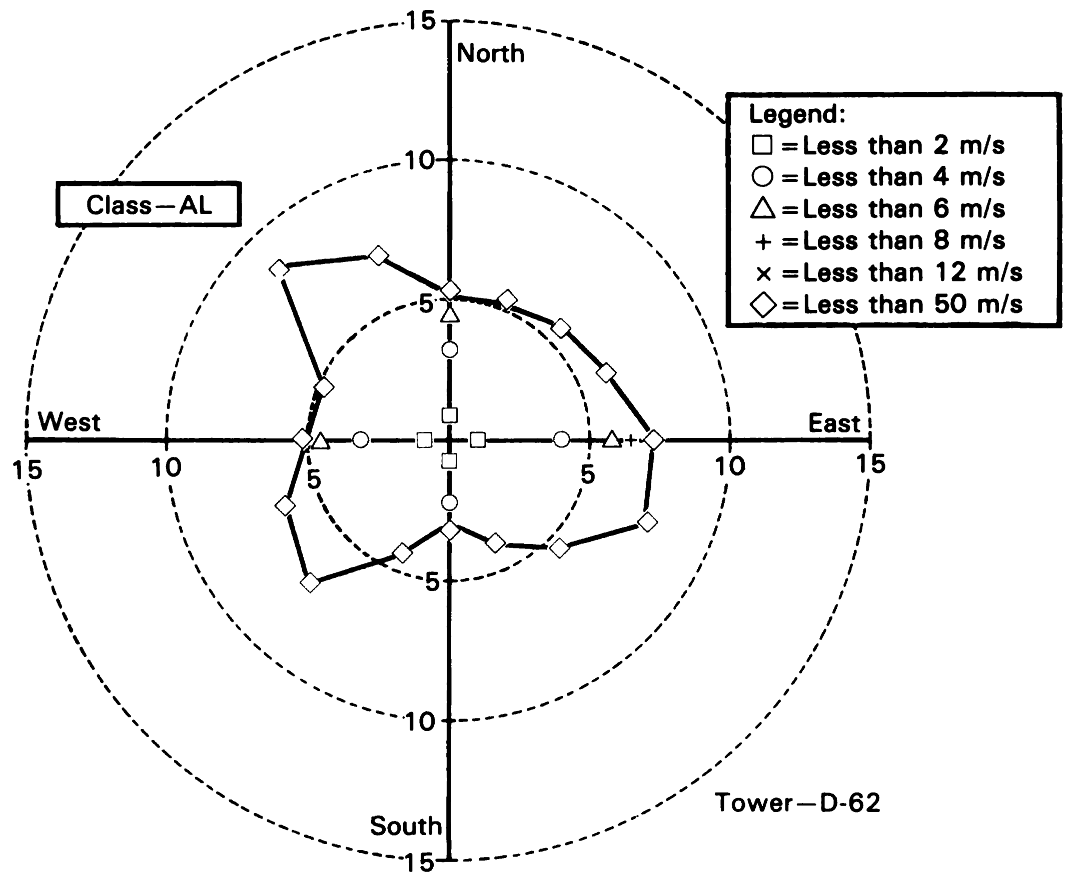
Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 114938

0 0 0 0 0 0 0 0 0 0 0

■■■■■Speed in Meters/Sec.■■■■■ ■■■■■ Percent Time Wind & Speed ■■■■■

Direction	0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total Tot	0-2	2-4	4-6	6-8	8-12	>12	Total
N	497	1016	665	115	2	0	2.42	2295	.43	.88	.58	.10	.00	.00	2.00
NNE	563	1457	971	330	53	0	2.77	3374	.49	1.27	.84	.29	.04	.00	2.94
NE	562	2257	2483	1288	245	10	3.55	6845	.49	1.96	2.16	1.12	.21	.00	5.96
ENE	713	2482	2934	1216	98	31	3.39	7474	.62	2.16	2.55	1.06	.08	.02	6.50
E	733	2980	2899	759	49	0	3.21	7420	.64	2.59	2.52	.66	.04	.00	6.46
ESE	641	2754	2425	636	43	0	3.21	6499	.56	2.40	2.11	.55	.03	.00	5.65
SE	681	2492	2831	1350	159	0	3.47	7513	.59	2.17	2.46	1.17	.14	.00	6.54
SSE	604	2070	3418	1576	159	5	3.71	7832	.53	1.80	2.97	1.37	.14	.00	6.81
S	636	2000	3162	1189	188	4	3.59	7179	.55	1.74	2.75	1.03	.16	.00	6.25
SSW	543	2290	2739	957	191	4	3.45	6724	.47	1.99	2.38	.83	.17	.00	5.85
SW	622	2563	2740	1190	231	12	3.54	7358	.54	2.23	2.38	1.04	.20	.01	6.40
WSW	666	2600	2827	1377	487	26	3.68	7983	.58	2.26	2.46	1.20	.42	.02	6.95
W	979	2940	3196	1310	733	59	3.36	9217	.85	2.56	2.78	1.14	.64	.05	8.02
WNW	1152	2846	3119	1834	928	91	3.30	9770	1.00	2.48	2.71	1.42	.81	.07	8.50
NW	877	2026	2102	880	382	19	3.03	6286	.76	1.76	1.83	.77	.33	.01	5.47
NNW	655	1268	972	216	41	0	2.57	3152	.57	1.10	.85	.19	.03	.00	2.74
No Direction	2800	3046	1413	580	141	37	2.06	8017	2.44	2.65	1.23	.50	.12	.03	2.00
Avg. Speed	1.21	2.96	4.87	6.70	9.09	14.11	3.19								
Tot. Entry	13924	39087	40896	16603	4130	298		114938							

Figure 3-11. C-Area Tower 1975-1979



Windrose Data

Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 105815

Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 105815

0 0 0 0 0 0 0 0 0 0 0

Direction	■■■■■Speed in Meters/Sec.■■■■■								■■■■■ Percent Time Wind & Speed ■■■■■						
	0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total Tot	0-2	2-4	4-6	6-8	8-12	>12	Total
N	886	1522	600	77	30	0	2.22	3115	.84	1.44	.57	.07	.02	.00	2.94
NNE	973	2269	1100	179	28	33	2.52	4582	.92	2.14	1.04	.17	.02	.03	4.33
NE	927	3253	2630	627	71	0	3.03	7508	.88	3.07	2.49	.59	.06	.00	7.10
ENE	825	2961	2332	422	71	0	2.99	6611	.78	2.80	2.20	.40	.06	.00	6.25
E	796	2672	1669	265	39	0	2.81	5441	.75	2.53	1.58	.25	.03	.00	5.14
ESE	905	2490	1414	334	38	3	2.68	5184	.86	2.35	1.34	.32	.03	.00	4.90
SE	1389	3733	2741	842	401	24	2.91	9130	1.31	3.53	2.59	.80	.38	.02	8.63
SSE	1039	2933	2639	596	191	14	2.98	7412	.98	2.77	2.49	.56	.18	.01	7.00
S	858	2531	1457	305	132	14	2.74	5297	.81	2.39	1.38	.29	.12	.01	5.01
SSW	902	2542	1460	410	120	4	2.73	5438	.85	2.40	1.38	.39	.11	.00	5.14
SW	1072	2620	1609	452	170	13	2.69	5936	1.01	2.48	1.52	.43	.16	.01	5.61
WSW	1149	2907	1696	466	229	21	2.71	6468	1.09	2.75	1.60	.44	.22	.02	6.11
W	1124	2960	2292	941	513	16	3.03	7846	1.06	2.80	2.17	.89	.48	.01	7.41
WNW	1015	2757	2552	1037	659	48	3.19	8068	.96	2.61	2.41	.98	.62	.04	7.62
NW	868	2127	1747	674	281	6	2.93	5703	.82	2.01	1.65	.64	.27	.00	5.39
NNW	842	1896	1119	250	54	0	2.54	4161	.80	1.79	1.06	.24	.05	.00	3.93
No Direction	3047	2791	1408	497	163	9	1.89	7915	2.88	2.64	1.33	.47	.15	.00	2.94
Avg. Speed	1.21	2.91	4.78	6.73	9.18	13.12	2.73								
Tot. Entry	18617	44964	30465	8374	3190	205		105815							

Figure 3-12. D-Area Tower 1975-1979

Table 3-7. Precipitation at Savannah River Plant, 1952-1982[a]

	Monthly precipitation (cm)		
Month	Maximum	Minimum	Average
Jan.	25.6	2.3	10.7
Feb.	20.3	2.4	10.9
Mar.	28.0	3.8	12.9
Apr.	21.0	1.5	8.9
May	27.9	3.4	10.8
June	27.9	3.9	11.1
July	29.4	2.3	12.5
Aug.	31.6	2.6	11.7
Sept.	22.3	1.4	10.2
Oct.	27.8	0.0	6.2
Nov.	16.5	0.5	5.9
Dec.	24.4	1.2	9.5
Annual			121.3

a. Adapted from Du Pont, 1983c.

Table 3-8. Extreme Wind Speeds for Area of Savannah River Plant[a] (meters per second)

	Return period	
Station	50-year	100-year
Greenville, S.C.	35	38
Macon, Ga.	30	31
Savannah, Ga.	35	39

a. Adapted from Simiu, Changery, and Filliben, 1979.

Thunderstorms

There is an average of 54 thunderstorm days per year at the Plant. The summer thunderstorms occur primarily during the late afternoon and evening; they can be accompanied by strong winds, heavy precipitation, or, less frequently, hail (NOAA, 1985). Summer thunderstorms are attributable primarily to convective activity resulting from solar heating of the ground and the presence of a moist unstable maritime tropical air mass. Thunderstorm activity in the winter months is attributable mainly to frontal activity.

Tornadoes

In the Southeastern United States, most tornadoes occur in early spring and late summer, with more than 50 percent occurring from March through June. In South Carolina, the greatest percentage of tornadoes occur in April and May, about 20 percent (Pepper and Schubert, 1978) in August and September. The latter are spawned mainly by hurricanes and waterspouts. One or two tornadoes can be expected in South Carolina during April and May, and one can be expected each in March, June, July, August, and September (Purvis, 1977).

Weather Bureau records show 278 tornadoes in Georgia over the period from 1916 to 1958, and 258 in South Carolina for the period from 1950 to 1980 (Table 3-9) (Hoel, 1983). The general direction of travel of confirmed tornado tracks in Georgia and South Carolina is southwest to northeast.

Table 3-9. Tornado Occurrence by Month

	Georgia (1916-1958)		South Carolina (1950-1980)	
Month	Number	Percent	Number	Percent
Jan.	24	8.6	6	2.3
Feb.	23	8.3	14	5.4
Mar.	49	17.6	26	10.1
Apr.	93	33.5	40	15.5
May	20	7.2	53	20.5
June	14	5.0	20	7.8
July	5	1.8	17	6.6
Aug.	10	3.6	25	9.7
Sept.	8	2.9	23	8.9
Oct.	2	0.7	8	3.1
Nov.	15	5.4	11	4.3
Dec.	15	5.4	15	5.8
Total	278		258	

Occasional tornadoes are to be expected in the SRP area. Investigations of tornado damage near the Plant in 1975 and 1976 indicated wind speeds varying from 45 to 78 meters per second (Du Pont, 1980a).

Hurricanes and High Winds

Thirty-eight damaging hurricanes occurred in South Carolina during the 272 years of record (1700 to 1972); the average frequency was one storm every 7 years. These storms occurred predominantly during August and September. At the SRP site, 160 kilometers inland, hurricane wind speeds are significantly lower than those observed along the coast. Winds of 34 meters per second were measured on the 61-meter towers only once during the history of the Plant, when Hurricane Gracie passed to the north on September 29, 1959 (Du Pont, 1982b).

Precipitation Extremes

Heavy precipitation can occur in the SRP area in association with either localized thunderstorms or hurricanes. The maximum 24-hour total was about 15.2 centimeters, which occurred during August 1964 in association with Hurricane Cleo.

Hail and Ice Storms

Hail in association with a severe thunderstorm can be expected to occur in the area about once every 2 years. Damage from such hail is rare. Ice storms caused by freezing rain can be expected about once every 4 years and are usually of short duration (Du Pont, 1982b).

3.1.7.4 Atmospheric Dispersion

Atmospheric Stability

The transport and dispersion of airborne material are direct functions of air movement. Transport direction and speed are governed by the general patterns of airflow (and by the nature of the terrain), whereas the diffusion of airborne material is governed by small-scale, random eddying of the atmosphere (i.e., turbulence). Turbulence is indicated by atmospheric stability classification. About 25 percent of the time, the atmosphere is unstable in the SRP regions; about 25 percent of the time it is neutral; and about 50 percent of the time it is stable.

Mixing Heights and Low-Level Inversions

The mixing height is the level of the atmosphere below which pollutants are easily mixed; it is often equal to the base of an elevated inversion. The depth of the mixed layer at the Plant has been measured by an acoustic sounder (Schubert, 1975). The acoustic data indicate that, as the day progresses, the mixing height rises beyond the 1000-meter range of the sounder.

An analysis of 5 years of upper-air meteorological data recorded at several stations in the SRP area (Holzworth, 1972) provides further mixing-height information. The average afternoon mixing height is about 1005 meters in the winter, 1700 meters in the spring, 1890 meters in the summer, and 1400 meters in the autumn. Mixing heights over the SRP site could be expected to be slightly lower.

Temperature inversions (air temperature increases with the height above the ground) inhibit atmospheric turbulence; hence, they are associated with small rates of atmospheric diffusion. Detailed temperature-inversion data are available from instruments on the WJBF-TV tower. The 1974 temperature measurements between 3 and 335 meters were analyzed to determine the frequency of occurrence of several categories of temperature structure (Pendergast, 1976). About 30 percent of the time, a temperature inversion extended to or beyond the 3-to-335-meter layer. About 12 percent of the time, there was an elevated inversion with an unstable layer below; this represents the early-morning breakup of a nighttime inversion. About 9 percent of the data showed an inversion at the lower levels with an unstable layer above; this represents the transition period between an unstable daytime regime and the onset of a nighttime inversion.

Restrictive-Dilution Conditions

The dilution capacity of the atmosphere depends on local wind speed, wind-direction variability, mixing depth, and the vertical temperature profile. From 1960 to 1970, the SRP area had about 50 forecast-days of high air-pollution potential, or an average of about 5 days per year (Holzworth, 1972). Air pollution episodes are most frequent in autumn, when large anti-cyclones, which are characterized by low wind speeds, clear weather, and large-scale temperature inversions, become nearly stationary off the Atlantic coast, affecting much of the Eastern United States.

Air Quality

The States of South Carolina and Georgia have established air-quality-sampling networks. The Savannah River Plant operates an onsite sampling network. These networks monitor suspended particulates, sulfur dioxide, and nitrogen dioxide. Ambient concentrations of these pollutants near the Plant in 1984, were below local air-quality standards (Du Pont, 1985a).

Correlation of Predicted to Measured Offsite Airborne Radionuclide Concentrations

A statistical air-pollution model, XOQDOQ, uses joint-frequency data on wind speed, wind direction, and atmospheric-stability class to estimate average relative effluent concentrations, X/Qs, and average relative deposition values, D/Qs, at specified locations and at standard radial distances downwind. It is based on a modified Gaussian-plume equation that assumes uniform horizontal dispersion over each of 16 sectors and calculates vertical dispersion using curves fitted with polynomials (Sagendorf and Goll, 1977). The mixing height is set to 1000 meters.

Predictions of the model were compared with measurements in air of the inert radioactive gas, krypton-85, which is routinely emitted in small quantities from the SRP chemical-separations facilities. The model predictions were slightly higher than the measured values (Telegadas et al., 1980).

3.1.8 RADIATION AND RADIONUCLIDES IN THE ENVIRONMENT

3.1.8.1 Sources of Environmental Radiation

Environmental radiation consists of natural background radiation from cosmic, terrestrial, and internal body sources; medical radiation; radiation from weapons test fallout; radiation from consumer and industrial products and air travel; and radiation from nuclear facilities.

Natural radiation contributes about 48 percent of the annual dose of 195 millirem received by an average member of the population within 80 kilometers of the Savannah River Plant. Medical exposure accounts for 47 percent of the annual dose, and the combined doses from offsite weapons test fallout, consumer and industrial products, and air travel account for about 5 percent of the dose. Releases of radioactivity to the environment from the Plant account for less than 0.1 percent of the total annual dose (DOE, 1984b).

External natural radiation comes from cosmic rays and the emissions from natural radioactive ores. It is highly variable with location and altitude. Internal natural radiation arises primarily from potassium-40, carbon-14, rubidium-87, and daughters of radium-226. The widespread distribution of fertilizers and food, as well as population mobility, has an averaging effect for these long-lived radionuclides that produce the internal dose. The estimated average internal radiation exposure in the United States from natural radioactivity is 28 millirem per year (BEIR III, 1980).

Medical radiation is the largest source of exposure to manmade radiation in the United States. The average dose to an individual from medical and dental X-rays, prorated over the total population, was 78.4 millirem per year (BEIR III, 1980). (Prorating the dose over the population, as used here and in following parts of this section, is a means of arriving at an average dose that, when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population receives radiation exposure from these sources.) In addition, radiopharmaceuticals administered to patients for diagnostic and therapeutic purposes account for an average annual dose of 13.6 millirem when prorated over the population. The occupational exposure of 0.45 millirem per year to medical and dental personnel must be added to these patient doses. Thus, the average medical radiation dose in the U.S. population is about 92.5 millirem per year.

Fallout from nuclear weapons tests is a small source of radioactivity in the environment. The large-scale atmospheric tests conducted by the United States and the Soviet Union in 1961 and 1962 introduced radioactive materials into the stratosphere that were later distributed worldwide. A small amount of radioactivity from these tests continues to be deposited. The more recent Chinese and French tests have maintained a relatively constant rate of fallout deposition. The past and present fallout contributes to human exposure through (1) external radiation from radioactive material on the earth's surface; (2) internal radiation from inhalation of airborne fallout; and (3) internal radiation from ingestion of food and water contaminated by fallout.

Cesium-137 deposited from past nuclear weapons tests is the major source of long-lived external gamma radiation from fallout. Short-lived radionuclides also contributed significantly to external radiation for a few years after major tests but now contribute little to the dose. The current dose rate from external gamma radiation is estimated at 0.9 millirem per year (EPA, 1972).

Most doses from inhalation of fallout are received in the years immediately after exposure. However, doses from strontium-90 and plutonium-239 will be received over a lifetime because of the long residence time of these radionuclides in the body. The annual dose from inhaled fallout radioactivity was estimated at only 0.04 millirem in 1969 (EPA, 1972) and is now even lower.

Ingestion of radioactivity in food and water is the largest source of radiation exposure from fallout. The estimated dose from this source of exposure in 1980 was 3.7 millirem per year: 0.6 millirem from carbon-14, 0.4 millirem from cesium-137, and 2.7 millirem from strontium-90.

The average annual total-body dose in 1980 from fallout from nuclear weapons tests was estimated at 4.6 millirem: 0.9 from external gamma and 3.7 from ingested radioactivity.

A variety of consumer and industrial products yield ionizing radiation or radioactive materials causing radiation exposure to the general population. Some of these sources are television sets, luminous-dial watches, airport X-ray inspection systems, smoke detectors, tobacco products, fossil fuels, and building materials. The estimated total-body dose for the U.S. population from these sources is 4 to 5 millirem per year (BEIR III, 1980). About three-fourths of this dose is from external exposure to naturally occurring radionuclides in building materials.

Persons who travel by aircraft receive additional exposure from cosmic radiation; at high altitudes the atmosphere provides less shielding from this source. The average annual dose to an airline passenger is 2.8 millirem, which when prorated over the entire U.S. population amounts to an average dose of 0.5 millirem per year (BEIR III, 1980).

3.1.8.2 Environmental Radiation Levels in the Southeastern United States

The contribution of cosmic radiation to natural background dose varies with both latitude and altitude and thus will be unique to a particular location. Sea-level doses range from 30 millirem per year in Florida to 45 millirem per year in Alaska; the exposure rate increases to 200 millirem per year at an altitude of about 2400 meters (EPA, 1977). The average unshielded cosmic radiation dose in Georgia and South Carolina is 40 millirem per year (EPA, 1972).

Terrestrial gamma radiation (external to the human body) is attributed primarily to gamma-emitting radionuclides in the natural radioactive series derived from uranium and thorium, with some additional contribution from potassium-40. Variation in the distribution of these natural radioactive materials with geologic formations and their inclusion in construction materials commonly used in urban areas lead to a wide variation with location. The average unshielded external dose from this source is 60 millirem per year in Georgia and 70 millirem in South Carolina. However, the variation in these states, including the SRP area, ranges from 6 to more than 350 millirem.

Nuclear facilities in an area will also contribute to the environmental radiation level. The growth of the nuclear industry and nuclear facilities in the southeastern United States - from West Virginia to Florida and from Arkansas to South Carolina - has been rapid, most of it occurring in the 1970s. In this region, 24 power reactors were either operating or licensed to operate in 1981. Another 34 power reactors were under construction and 4 reactors were being planned. When all of these are operating, there will be 62 power reactors in the southeastern United States. Typically, the average radiation dose to individuals within 80 kilometers of a nuclear facility is quite low.

Data on releases from 46 nuclear powerplants operating in 1979 indicate that the average radiation dose within 80 kilometers of a plant was 0.025 millirem (NRC, 1982).

An airborne radiological survey of the Savannah River coastal region was performed in 1975 to establish terrestrial dose equivalent rates (Hayes, 1977). TE These rates varied from about 0.001 millirem per hour over water to 0.009 millirem per hour at one location on Wassaw Island. In general, the higher rates occurred over beaches, where heavy minerals containing natural thorium and uranium occur. Excluding the water areas, the terrestrial rate averages about 0.003 millirem per hour in this area, which is comparable to other Coastal Plain rates of 0.002 to 0.003 millirem per hour and is about one-half that measured for the Plant. The average dose equivalent rate for the Savannah River marine area is about the same as that measured in Galveston, Texas, and Cape Canaveral, Florida, and somewhat less than that in the Los Angeles, California, area. One radiation anomaly defined in this survey was noted on Hutchinson Island, Florida, where dredge spoils have been deposited. The cesium-137 concentration of the post-1957 dredge soil sediment ranges from about 0.3 to 2.7 picocuries per gram. About half the cesium-137 in the post-1957 sediment can be attributed to fallout from weapons testing (Marter, 1974).

3.1.8.3 Environmental Radiation Levels in the Vicinity of the Savannah River Plant

A summary of the major sources of exposure for the population within 80 kilometers of the Plant and for the river-water-consuming population in Beaufort and Jasper Counties, South Carolina, and in Port Wentworth, Georgia, is presented in Table 3-10. Many of the factors such as the internal radionuclide dose and the medical dose are independent of the site. The factors that are site-dependent are discussed below.

The Savannah River Plant and the surrounding area lie between latitudes 33°N and 34°N, with an altitude variation between sea level and roughly 100 meters. The estimated total unshielded dose equivalent from cosmic radiation in the vicinity of the Plant within an 80-kilometer radius is 35 millirem per year, of which 29 millirem per year are from the ionizing component and 6 millirem per year are from neutrons (Langley and Marter, 1973). Shielding by buildings and the body reduces the cosmic radiation dose to about 32 millirem per year - a 10-percent reduction.

Within 80 kilometers of the Plant, measured external gamma dose rates range from 6 millirem to 385 millirem per year (Dukes, 1984). A value of 55 millirem per year represents the average unshielded external terrestrial background in the vicinity of the Plant. Shielding by buildings and the body reduces this terrestrial radiation dose to about 33 millirem per year - a 40-percent reduction.

Atmospheric testing caused 25,600,000 curies of cesium-137 to be deposited on the earth's surface (United Nations, 1977). About 104 millicuries of cesium-137 per square kilometer were deposited in the latitude band 30°N to 40°N, where South Carolina is located. The total deposition was 2850 curies in the 27,400 square kilometers of the Savannah River watershed and 80 curies of cesium-137 in the 780 square kilometers of the Plant. The deposited cesium-137 became attached to soil particles and has undergone only slow transport

Table 3-10. Major Sources of Radiation Exposure in the Vicinity of the Savannah River Plant

Source of exposure	Dose to average individual (mrem/yr)	Percent of exposure
Natural background radiation		
Cosmic radiation	32.0	
External terrestrial gamma	33.0	
Internal	28.0	
Total	93.0	47.6
Medical radiation		
Diagnostic X-rays	78.4	
Radiopharmaceuticals	13.6	
Medical and dental personnel	0.5	
Total	92.5	47.3
Weapons test fallout	4.6	2.4
Consumer and industrial products	4.5	2.3
Air travel	0.5	0.3
Nuclear facilities (other than SRP)	0.1	0.1
Savannah River Plant environmental radioactivity (1980)	0.2	0.1
TC Grand total	195.4	

from the watershed. Results from routine SRP Health Protection Department monitoring programs indicate that since 1963 about 1 percent of the 2850 curies of cesium-137 deposited on the total Savannah River watershed has been transported down the river (Hayes, 1983).

Onsite monitoring conducted by the SRP Health Protection Department from 1976 to 1982 shows that an average of 50 millicuries per square kilometer of cesium-137 were in the upper 5 centimeters of the soil column within an 80-kilometer radius (Du Pont, 1983a). This value is one-half the amount originally deposited from worldwide fallout and implies that some of the radiocesium has undergone hydrologic transport to the Savannah River.

SRP monitoring in the Savannah River shows that the concentration of radiocesium in river water has been very low in the past several years. From 1979 through 1982, the mean concentration of cesium-137 at the U.S. Highway 301 bridge was 0.08 picocurie per liter and was near the limit of detection at the control station upriver of the Plant (Du Pont, 1980b, 1981, 1982c, 1983a). For the second quarter of 1983, measurements of the radiocesium in the potable water at the North Augusta, Beaufort-Jasper, and Cherokee Hill water-treatment plants averaged 0.006, 0.028, and 0.033 picocurie per liter, respectively, or less than 0.017 percent of the EPA drinking water standard of 200 picocuries per liter (Kantelo and Milhom, 1983).

Turbulence in the Savannah River generally keeps fine soil particles in suspension. These particles are deposited where the river velocity and turbulence are low, such as inside river bends, downstream from obstructions, in oxbow lakes, and on the floodplain, and where flocculation occurs in the estuary below River Mile 40. Riverbed sediments upstream from the Plant normally have about 1 picocurie per gram or less of radiocesium (Du Pont, 1982b).

In 1974, riverbed sediments downstream of the Plant had concentrations of radiocesium of about 2 picocuries per gram near the U.S. Highway 301 bridge and 6.5 picocuries per gram at the South Carolina Highway 119 bridge near Clyo, Georgia (Du Pont, 1982b). Studies performed in 1978 showed that the radiocesium concentrations were about 0.6 picocurie per gram at the control station above the Plant and less than 0.8 picocurie per gram at sampling stations between Little Hell Landing and the Highway 301 bridge (Du Pont, 1982b).

In 1983 the tritium concentrations in the potable water produced by the Beaufort-Jasper and Cherokee Hill water-treatment plants averaged 2100 and 2800 picocuries per liter, respectively, or less than 14 percent of the EPA drinking water standard of 20 picocuries per milliliter; very low concentrations of cobalt-60, strontium-89 and -90, iodine-129, uranium, and plutonium-239 were also measured in the water produced by these plants (Du Pont, 1984).

Whole-body bioaccumulation factors - the ratio of cesium-137 concentrations in fish and cesium-137 concentrations in water - for fish taken from the Savannah River at the U.S. Highway 301 bridge from 1965 to 1970 average about 2300. The mean bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 whole-body and 3029 flesh (Smith et al., 1982; Ribble and Smith, 1983).

The radiation dose to a hypothetical individual on the Plant boundary from 1984 SRP atmospheric releases of radioactive materials was 2.4 millirem maximum and 0.87 millirem average. The average dose from SRP atmospheric releases to persons living within 80 kilometers of the Plant was 0.2 millirem per year. The maximum radiation doses to an individual downriver of the Plant who consumed Savannah River water were 0.2 millirem (adult) at the Cherokee Hill water treatment plant at Port Wentworth, Georgia, (near Savannah) and 0.18 millirem (child) at the Beaufort-Jasper County water treatment plant near Beaufort, South Carolina (Du Pont, 1985a).

The only other nuclear facility within 80 kilometers that has been operational during the operating history of the Savannah River Plant is a low-level-waste burial site operated by Chem-Nuclear Systems, Inc., near the eastern boundary of the Plant. This facility, which started operation in 1971, releases essentially no radioactivity to the environment (Chem-Nuclear Systems, Inc., 1980), and the population dose from normal operations is negligible. Plant Vogtle's unit 1 began commercial operations on June 1, 1987; therefore, background radiation levels will be evaluated as the data becomes available.

The Plant has monitored onsite streams since the early 1950s. Water quality monitoring in onsite streams shows that radioactive releases prior to entry into the Savannah River are well within DOE concentration guidelines established for releases to uncontrolled areas (Ashley and Zeigler, 1981; Ashley, Zeigler, and Culp, 1982; Ashley et al., 1982; Du Pont, 1985b).

Appendix D contains additional information on radiocesium and tritium in the SRP environment.

3.2 PEN BRANCH AND INDIAN GRAVE BRANCH (K-REACTOR)

3.2.1 GEOGRAPHY

Pen Branch follows a path roughly parallel to Four Mile Creek until it enters the Savannah River swamp (Figure 3-2). The only significant tributary to Pen Branch is Indian Grave Branch, which flows into Pen Branch about 8 kilometers upstream from the swamp. Pen Branch enters the swamp about 5 kilometers from the river, flows directly toward the river for about 2.4 kilometers, and then turns and runs parallel to the river for about 8 kilometers before joining with Steel Creek about 0.8 kilometer from its mouth at the river.

Pen Branch and Indian Grave Branch drain about 56 square kilometers of watershed upstream from the swamp. Indian Grave Branch receives the cooling water from K-Reactor. Upstream from K-Area discharges, the flow of Indian Grave Branch averages about 0.03 cubic meter per second and that of Pen Branch 0.1 to 0.3 cubic meter per second.

3.2.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Pen Branch watershed area, which includes Indian Grave Branch, was conducted from May through August 1984. Forty sites were located in the watershed during this survey (see Figure E-1 in Appendix E). Of the sites found in the Pen Branch area, none is in an area that could be affected by the proposed cooling-tower alternatives for K-Reactor.

3.2.3 HYDROLOGY

Since November 1976, a USGS flow recorder has been maintained at SRP Road A-13.2 on Pen Branch. From 1976 to 1982, the flow at this station ranged from a minimum of 0.6 cubic meter per second when K-Reactor was not operating to a maximum of 26.9 cubic meters per second during simultaneous K-Reactor operation and heavy precipitation. During water year 1982, the mean flow rate at this station was 10.8 cubic meters per second.

Before 1951, Pen Branch was a small, single-channel meandering creek flowing through a broad, heavily vegetated floodplain. K-Reactor effluent changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss around the creek. Deltas accreted at the stream mouth where a substantial volume of the eroded material was deposited. Deposition was initially rapid, and then gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Data collected under the recent intensive water quality study initiated in July 1983 suggest that input of large flows (11 cubic meters per second) of Savannah River water at high temperatures (40°-70°C) has the most pronounced effect on the water quality of Pen Branch. Concentrations of nutrients, cations, and metals in the thermal portion of Pen Branch reflect those of its source water, the Savannah River (Du Pont, 1985b). Table 3-11 provides a comparison of selected water-quality parameters from sampling points upstream and downstream of K-Reactor discharges.

3.2.4 ECOLOGY

3.2.4.1 Terrestrial Ecology

Indian Grave Branch/Pen Branch have about 1730 acres of wetlands upstream of the swamp. Emergent marsh (115 acres) and open water (145 acres) are common below the K-Reactor discharge point. Some hardwoods exist on the outer perimeter of the thermally affected areas (326 acres), but most occur in nonthermal tributaries (338 acres) or upstream of the K-Reactor discharge (724 acres). K-Reactor cooling water releases have altered more than 38 percent (670 acres) of the Indian Grave Branch/Pen Branch forested wetlands (Du Pont, 1985b). The star-nosed mole, marsh rabbit, beaver, muskrat, rice rat, river otter, and mink are mammals commonly associated with wetland/floodplain habitats. Studies indicate that none of these mammals inhabit reactor effluent streams on the Savannah River Plant during periods of elevated water temperatures. Beaver and otter, however, have been found to reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985b). TE

The Savannah River Swamp System is used extensively by waterfowl, particularly during the fall and winter months when these areas provide foraging habitat for migratory species. Based on roost counts, 1200 wood ducks and mallards wintered (1983-1984) in the Steel Creek delta and associated areas. Waterfowl use of the swamp normally is associated with open areas with sparse vegetation caused by increased flows and heated effluent. Of the 12 waterfowl species, researchers have performed the most thorough studies of the foraging ecology of the wood duck, followed by that of the mallard. Most of the swamp (thermal, post-thermal, and nonthermal) was used by migrating wood ducks from October through March. TE

Approximately 22 species of amphibians and reptiles reside in the natural (i.e., nonthermal) streams and swamps of the Savannah River Plant. All of these species have also been reported in the post-thermal areas of Steel Creek (Du Pont, 1985b). TE

No amphibians or reptiles are known to persist on a routine basis in areas of severe thermal alteration, although some species of frogs live in aquatic TE

Table 3-11. Pen Branch and Indian Grave Branch Water Quality: November 1983 to May 1984[a]

Parameter, mean concentration (mg/l[b])	Pen Branch upstream of K-Reactor at Road B	Indian Grave Branch downstream of K-Reactor	Pen Branch downstream of K-Reactor at Road A-13
Temperature (°C)	12.4	57.6[c]	49.8[c]
Dissolved oxygen	8.4	5.7	5.9
pH (units) (range)	5.3-8.5	5.9-8.7	5.6-8.1
Total suspended solids	10.5	11.7	25.1
Chloride	2.3	5.2	5.1
Phosphorus, total	0.029	0.078	0.083
Nitrate-nitrogen	0.035	0.289	0.266
Calcium, total	3.7	3.0	2.8
Aluminum, total	0.57	1.35	1.58
Sodium, total	1.7	5.3	5.5
Iron, total	0.54	1.06	1.22

a. Adapted from Du Pont, 1985b.
b. Except as noted.
c. During reactor operations; other tabulated values represent measurements made during reactor operations and during periods of reactor shutdown.

habitats that experience elevated temperatures, and some have deposited eggs in aquatic sites where extreme temperatures occurred. Frogs and toads exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at smaller sizes than larvae developing under normal temperature conditions (Du Pont, 1985b).

TE The slider is the most prevalent turtle on the Plant. This species apparently thrives in areas of moderately elevated water temperatures; here they have faster growth rates and attain larger body sizes than turtles from local natural habitats. These changes can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985b).

A few other reptile species, primarily water snakes and turtles, might also occur in thermally affected areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985b).

3.2.4.2 Aquatic Ecology

Aquatic Flora

The substrate from the upper reaches of Pen Branch is primarily sand and silt, with interspersions of leaf packs, woody debris, macrophytes and algae, and isolated gravel beds (Du Pont, 1985b). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush, while duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area in a shallow sheet flow. Dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Closed canopy areas at the delta support fewer emergent plants. TE

Aquatic Fauna

Between November 1983 and May 1984, studies for the Comprehensive Cooling-Water Study sampled macroinvertebrates from one station in the main Pen Branch channel and two stations in the Pen Branch delta (Du Pont, 1985b; Appendix C). The main channel of Pen Branch is dominated by (in decreasing abundance) segmented worms (Oligochaeta), midges (Diptera), roundworms (Nematoda), and snails (Gastropoda). Also present were mayflies (Ephemeroptera), caddisflies (Tricoptera), beetles (Coleoptera), scuds (Amphipoda), and mites (Hydracarina).

Nearly twice as many taxa occurred in the delta area than in the main channel. In the delta, sites with a closed canopy exhibited a higher average density (Du Pont, 1985b; Appendix C). Species composition was very similar to that of the main Pen Branch channel (i.e., midges, segmented worms, roundworms, and mayflies dominate).

The dominant adult fish in the nonthermal upper reaches of Pen Branch are sunfish, bullheads, and chubsuckers. Most of these species are benthic in habitat or are found near instream woody structures. Fish species generally associated with fast-flowing waters (i.e., darters) are absent. The thermal reaches of Pen Branch are dominated by shiners, sunfish, madtoms, and darters.

Ichthyoplankton abundance in Pen Branch is very low, ranging from zero to greater than 50 per 1000 cubic meters (Du Pont, 1985b; Appendix C). Among the ichthyoplankton, the dominant species was the mosquitofish, which is more tolerant of high temperatures. The few ichthyoplankters present probably drifted into the main channel from adjacent cooler refuge areas. The area above the reactor discharge is populated by minnows and darters in very low abundance.

3.2.5 RADIOACTIVITY RELEASES AND RADIOLOGICAL TRANSPORT

Approximately 16.2 curies of cesium-137 (decay corrected to 1980) have been released to Pen Branch from the K-Reactor area (Lower and Hayes, 1984), where the creek (Indian Grave Branch) receives a cooling water discharge of about 11.3 cubic meters per second. Sediment samples 8 centimeters in depth obtained from the Pen Branch delta-swamp system below Road A-13.2 typically exhibit cesium-137 concentration less than 1.5 picocuries per gram (Du Pont, 1985b). Table 3-12 lists radionuclide concentrations in water and aerial radiological survey results for Pen Branch and Indian Grave Branch. After receipt of cesium-137 from both Pen Branch and Steel Creek (DOE, 1984b), the sediments at the mouth of Steel Creek exhibit average concentrations of 16.7 picocuries per gram.

Approximately 357,600 curies of tritium were released to Pen Branch from the K-Reactor area through 1980. Approximately 41 percent of this tritium was

Table 3-12. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Pen Branch and Indian Grave Branch (K-Reactor)

	Water (pCi/l)[a]		Sediment (pCi/gm)[b]	Aerial Survey (R/hr)[c]	
Location	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Road A	1.63	34,700	(d)	-	1.2
Road A[e]	1.52	32,000	(d)	NA[f]	NA
Delta	(d)	(d)	4.7	-	1.2
Steel Creek-Pen Branch Mouth	(d)	(d)	16.7	(d)	(d)

a. Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.
b. Five-year-mean concentration (1977-1981). Source: Lower, 1984.
c. 1979 survey. Source: Boyns and Smith, 1982.
d. No data available.
e. 1984 data only. Source: Du Pont, 1985b.
f. NA = Not available.

from the K-Area containment basin migration (Du Pont, 1985b). Released tritium, which remains soluble in Pen Branch and Indian Grave Branch, is released to the Savannah River via Steel Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301.

3.3 FOUR MILE CREEK (C-REACTOR)

3.3.1 GEOGRAPHY

Four Mile Creek follows a generally southwesterly path to the Savannah River for a distance of about 24 kilometers (Figure 3-2). In the Savannah River swamp along the river, part of the creek flow empties into Beaver Dam Creek. The remainder discharges through an opening in the levee between the swamp and the river, seeps through the levee into the river, or moves through the swamp and mixes with the flows from Steel Creek and Pen Branch (Du Pont, 1985b).

Four Mile Creek and Beaver Dam Creek together drain about 90 square kilometers. Reactor cooling water from C-Area is discharged to Four Mile Creek. After the junction with the C-Reactor cooling water, the creek flows about 11 kilometers before entering the Savannah River swamp (Du Pont, 1985b).

3.3.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Four Mile Creek watershed area was conducted from May through August 1984. A total of 25 sites was located in the watershed during this survey (see Figure E-1 in Appendix E). Only one site (38BR548) in the Four Mile Creek survey area could be affected by the proposed cooling-tower alternatives for C-Reactor. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No further work has been recommended for this site, because the potential yield of additional research information is negligible.

3.3.3 HYDROLOGY

The average flow upstream of any SRP discharge to Four Mile Creek is about 0.015 cubic meter per second, which is increased by SRP discharges and drainage to about 0.6 cubic meter per second just upstream from the confluence with the C-Reactor discharges. After the junction with the C-Reactor cooling water discharge, the creek flows about 11 kilometers before entering the river swamp at flow rates exceeding 11 cubic meters per second during periods of C-Reactor operation (Lower, 1985).

Prior to 1951, Four Mile Creek was a small, single-channel, meandering creek flowing through broad, heavily vegetated floodplains. C-Reactor discharges changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss in a zone around the creek. Deltas accreted at the stream mouth, where much of the substantial volume of eroded material was deposited. The initial rapid progression of deposition gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Table 3-13 provides a comparison of temperature and dissolved oxygen data from sampling stations above and below C-Reactor discharges (Du Pont, 1985b).

Table 3-13. Temperature and Dissolved Oxygen in Four Mile Creek[a]

Location	Mean temperature (°C)	Mean dissolved oxygen (mg/l)
Four Mile Creek upstream of C-Reactor	16.0	7.6
Four Mile Creek downstream of C-Reactor at Road A	38.5	6.6

a. Source: Adapted from Jacobsen et al., 1972; Du Pont, 1985b.

In relation to upstream concentrations from the Four Mile Creek Road A-7 site, concentrations of sulfates, aluminum, calcium, and sodium were slightly to significantly reduced at the mouth of Four Mile Creek (Table 3-14). Some buffering might have occurred in the onsite swamp for the Four Mile Creek flow prior to the river confluence; however, concentrations of chlorides and total iron were unchanged or were increased (Du Pont, 1985b).

3.3.4 ECOLOGY

3.3.4.1 Terrestrial Ecology

The Four Mile Creek floodplain has approximately 1900 acres of wetlands, which are principally (72 percent) bottomland hardwoods. Downstream of the C-Reactor outfall, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, hardwoods occupy 445 acres. Overall, approximately 60 percent (1147 acres) of the Four Mile Creek wetlands have been impacted by C-Reactor discharges (Du Pont, 1985b).

Waterfowl use of Four Mile Creek is associated primarily with the delta area where Four Mile Creek empties into the Savannah River swamp. A census of this system and the stream deltas was taken by aerial surveys weekly from November 1 to April 1, from 1981 to 1983. In addition, ground counts were conducted between October and March, 1981 to 1984 (Du Pont, 1985b).

Table 3-14. Four Mile Creek Water Quality[a]

Parameter, mean concentration (mg/l)[b]	Four Mile Creek upstream of C-Reactor at Road A-7	Four Mile Creek downstream of C-Reactor at the mouth
pH (units) (range)	5.0-7.6	5.7-7.9
Chlorides	3.3	4.84
Sulfates	5.94	5.45
Aluminum	0.53	0.43
Calcium	3.40	2.00
Sodium	10.8	6.32
Iron, total	0.29	0.33
Mercury, total	0.001	0.002

a. Source: Adapted from Du Pont, 1985b.
b. Except as noted.

No self-sustaining reproducing populations of the American alligator have been observed in Four Mile Creek or its delta (Du Pont, 1985b). Wood storks were observed feeding in the Four Mile Creek swamp area in 1984 but not in 1983 (Coulter, 1986).

3.3.4.2 Aquatic Ecology

Aquatic Flora

Four Mile Creek is a relatively deep (0.3- to 1.5-meter), fast-flowing (about 140 centimeters per second) stream above its confluence with the Savannah River swamp. In this area the flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of bluegreen algae cover the bottom. Tag alder and wax myrtle dominate the riparian vegetation. Further downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation, but there are thick growths of sedges on the banks. Thick mats of blue-green algae cover the shallower areas. Deeper substrates (mainly sand) are void of vegetation (Du Pont, 1985b).

Aquatic Fauna

Studies conducted for the Comprehensive Cooling-Water Study sampled macroinvertebrates from the lower and middle reaches of Four Mile Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Four Mile Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

Four Mile Creek had the fewest taxa (16 to 29) and nearly the lowest density considering all sampling methods (natural and artificial substrates) of all

SRP streams sampled, including the thermally disturbed sites (Du Pont, 1985b; Appendix C). The macroinvertebrates were dominated by nematode roundworms (Nematoda), segmented worms (Oligochaeta), and midges (Diptera). Also collected - in decreasing order of abundance - were caddisflies (Trichoptera), mayflies (Ephemeroptera), snails (Gastropoda), springtails (Collembola), and scuds (Amphipoda).

Many aquatic studies have been conducted during the past 34 years on the Savannah River Plant; however, the most intensive study (the Comprehensive Cooling-Water Study) of the fish community of the SRP streams and the Savannah River began in 1983 (Du Pont, 1985b). Appendix C summarizes the results of this investigation and presents additional pertinent data.

Creek flows and reactor effluent discharge temperatures influence the relative abundance, species composition, and seasonal occurrence of adult fish in Four Mile Creek. Adult fish are most abundant in the mouth of the creek during the winter (December through February), when C-Reactor is operating. Fish avoid this region during periods of excessively high water temperatures (greater than 40°C), which usually occur from May to October.

Upper Four Mile Creek was sampled between Road A and the swamp during a 50-day reactor shutdown in early 1984. Mosquitofish accounted for more than 97 percent of the fish collected at the three sites; other species collected included bowfin, sunfish, mudminnows, shiner, and pickerel. A more diverse assemblage of fish was collected from the lower Four Mile Creek station between the delta and the Savannah River. Gizzard shad (42 percent) and largemouth bass (14 percent) dominated the catch; mosquitofish comprised only 2 percent. The low abundance and low species diversity at both stations is related to the extremely low habitat diversity in Four Mile Creek.

The Comprehensive Cooling Water Study (Du Pont, 1985b) included a sampling program to characterize the adult fish community of SRP streams for fish spawning. Researchers collected ichthyoplankton samples weekly at six locations in Four Mile Creek; they collected 203 ichthyoplankters between March 14 and June 3, 1984. The dominant taxa were sunfish or bass (32 percent) and the brook silverside (14 percent). Other taxa present were shad, crappie, yellow perch, darters, minnows, and carp (Appendix C). Because C-Reactor was not operating during most of March 1984, mean temperatures were only 5° to 10°C above Savannah River temperatures. During this time, ichthyoplankton were absent from the middle and upper reaches of the creek, but were found in low densities in the creek mouth and swamp. During C-Reactor operation, creek temperatures ranged from 30° to 50°C; as expected, few ichthyoplankters were present. Brook silversides and other unidentifiable eggs and larvae collected during C-Reactor operations from the middle and upper reaches might have drifted into the channel from adjacent refuge areas (Appendix C).

Ichthyoplankton abundance in Four Mile Creek and the associated swamp appear to be strongly influenced by water levels in the Savannah River (Du Pont, 1985b; Appendix C). High river flows probably transport ichthyoplankton into thermally impacted portions of the swamp from adjacent unimpacted areas. In addition, some fish might use thermally impacted areas for spawning during high river flows because flow patterns for the heated water are altered dramatically during such periods.

3.3.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 53.4 curies of cesium-137 (decay corrected to 1980) have been released to Four Mile Creek. Of this total, about 31.5 curies were released to the creek from the F- and H-Areas, where the stream flow averages less than 0.5 cubic meter per second (Lower, 1984; Lower and Hayes, 1984). The remainder (21.9 curies) was released from the C-Reactor area, where the cooling water discharge to the creek is about 11 cubic meters per second. Creek sediments at SRP Road A-7 (above the confluence of Four Mile Creek and the C-Reactor cooling water discharge) exhibit average cesium-137 concentrations of 37.5 picocuries per gram, some four times the average concentration in the delta area. Table 3-15 lists radionuclide concentrations in water, sediments, and aerial survey results for Four Mile Creek.

Released tritium remains soluble in Four Mile Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301. Comparisons of the amount of tritium released from SRP facilities with the amount of tritium measured in transport in the Savannah River have continued to show excellent agreement (about 97 percent in 1983) (Lower and Hayes, 1984).

Approximately 388,600 curies of tritium were released to Four Mile Creek through 1980. Of this total, about 139,200 curies were released to the creek from the F- and H-Areas. The remainder (249,400 curies) were released from the C-Reactor area (Du Pont, 1985b). Approximately 99 percent of the F- and H-Area tritium was from seepage-basin migration.

3.4 BEAVER DAM CREEK (D-AREA COAL-FIRED POWERHOUSE)

3.4.1 GEOGRAPHY

Beaver Dam Creek is located 1.6 to 3.2 kilometers west of Four Mile Creek; it flows in a southwesterly direction from the 400-D Area through the Savannah River swamp to the Savannah River (Figure 3-2). Beaver Dam Creek is the receiving stream for the cooling water effluent from the coal-fired powerhouse in the D-Area.

Since June 1974, a flow recorder located 1.6 kilometers downstream from D-Area in Beaver Dam Creek has recorded an average discharge of about 2.4 cubic meters per second during D-Area operation.

3.4.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the watershed during these surveys (see Figure E-1 in Appendix E). Site 38BR450 is considered a significant archaeological resource and has been recommended for eligibility for nomination to the National Register of Historic Places.

AT-1
AT-2
AZ-1

Table 3-15. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Four Mile Creek (C-Reactor)

	Water (pCi/l)[a]		Sediment (pCi/gm)[b]	Aerial Survey (R/hr)[c]	
Location	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Opposite F- and H-Areas	[e]	[e]	[e]	1.2	38.1
Road A-7[f]	[e]	800,000	18.0	NA	NA
Below F-Area to Road 3	[e]	[e]	[e]	1.2	19.0
Road A	2.08	70,500[d]	37.5	-	1.2
Road A[f]	2.05	61,000	[e]	NA[g]	NA
Delta	[e]	[e]	8.6	1.2	4.8

a. Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.
b. Five-year-mean concentration (1977-1981). Source: Lower, 1984.
c. 1979 Survey. Source: Boyns and Smith, 1982.
d. 1980 and 1981 data only.
e. No data available.
f. 1984 data only. Source: Du Pont, 1985b.
g. NA = Not available.

3.4.3 HYDROLOGY

Since placement of the heavy-water plant on standby status in 1982, the only direct thermal input to Beaver Dam Creek has been that resulting from the powerhouse operations. Thermal effluent also enters the lower portion of Beaver Dam Creek via Four Mile Creek, which receives C-Reactor discharges. The water from Beaver Dam Creek mixes with part of the flow from Four Mile Creek in the onsite swamp before it is discharged to the Savannah River through the mouth of Beaver Dam Creek (Jacobsen et al., 1972). Data from the water quality station at the mouth of Beaver Dam Creek thus reflects inputs from both streams (Du Pont, 1985b). At this station, the flow inputs from Beaver Dam Creek and Four Mile Creek are approximately equal (Du Pont, 1982b).

The water quality station located in Beaver Dam Creek upstream from the onsite swamp is the only station monitored routinely in a thermally impacted zone. From 1973 to 1982, Beaver Dam Creek received heated effluents from both the powerhouse and the heavy-water production facilities. Since June 1974, flows in the creek have ranged from about 1.2 to 5.6 cubic meters per second (Du Pont, 1985b). With the exception of temperature criteria, all other water classification requirements for Class B streams (see Section 3.1.5.1.2) were met at this station. Water quality data for selected parameters are provided in Table 3-16.

3.4.4 ECOLOGY

3.4.4.1 Terrestrial Ecology

Before the Savannah River Plant began operations, Beaver Dam Creek was probably an intermittent stream. During the construction of facilities in D-Area, a canal was built to carry cooling water to the creek, which discharges after 1700 meters to the Savannah River swamp. A narrow band of bottomland hardwood and scrub-shrub forest borders the stream from the D-Area process-water outfall to the swamp (Du Pont, 1985b).

Current D-Area powerhouse thermal discharges, combined with the slow-flowing backwaters along the creek, have provided habitat for a dense population of alligators. A minimum of 28 alligators representing multiple size classes (equivalent to age classes) longer than 1 meter inhabit this stream (based on aerial surveys from December 1983 to March 1984). Subsequent ground surveys in April and May 1984 resulted in the capture of 11 alligators representing age classes of 1-, 2-, and 3-year-olds. With the exception of one 3-year-old, the other 10 alligators were probably not large enough to have been observed during the aerial surveys. The backwater areas along the creek provide excellent breeding and nesting habitat; they probably support a self-sustaining alligator population, because both adult and juvenile sizes have been observed (Du Pont, 1985b).

In 1983 between 306 and 363 wood storks were observed onsite from June 21 to September 29 (Smith et al., 1983; Coulter, 1986). There were a total of 15 group sightings during 35 observation days, with 80 percent of the sightings occurring on Beaver Dam Creek (7 sitings) and Steel Creek (5 sitings) (Coulter, 1986). The 12 sightings that were made on the two creeks accounted for more than 90 percent of the total members of wood storks observed on the site (Coulter, 1986).

Table 3-16. Beaver Dam Creek Water Quality Downstream of All 400-D Area Effluents (November 1983-May 1984)[a]

Parameters	Mean concentration (mg/l[b])
Temperature (°C)	21.9
Dissolved oxygen	7.5
pH (units) (range)	6.4-7.6
Chlorides	5.8
Nitrate + nitrite (as N)	0.24
Iron, total	1.16
Total alkalinity (as $CaCO_3$)	13.2
Phosphorus, total	0.078
Calcium, total	3.0
Aluminum, total	1.51
Sodium, total	5.6
Suspended solids	46.4

a. Adapted from Du Pont, 1985b.
b. Except as noted.

In 1984, more than 370 wood storks were observed on the Plant from May 20 to November 16. There were a total of 59 group sightings during 89 observation days, with more than 54 percent of the sightings occurring on Beaver Dam Creek and Steel Creek (Coulter, 1986). Use of Four Mile Creek was documented in 1984 for the first time and accounted for 22 percent of the group sightings (Coulter, 1986). The 32 sightings that were made on Beaver Dam Creek (19 sitings) and Steel Creek (13 sitings) accounted for 54 percent of the total number of wood storks observed on the Plant (Coulter, 1986).

Apparently wood storks were more widely dispersed over the site in 1984 than 1983. However, some of the variability may be explained by an increased effectiveness of observers in locating birds, a more intensive survey, and a survey of longer duration.

Estimates of prey density and biomass from the 1984 and 1983 Steel Creek sites were highly variable. Generally, however, there was a higher density and biomass of prey in 1984. No prey density or biomass data were collected on Beaver Dam Creek (Coulter, 1986).

3.4.4.2 Aquatic Ecology

Aquatic Flora

Immediately below the discharge structure, Beaver Dam Creek is characterized by a deep channel (1 to 2.5 meters) and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985b). Riparian vegetation is dominated by wax myrtle and tag alder. The aquatic flora are sparse, reflecting the influence of high flow and elevated water temperatures.

Aquatic Fauna

Studies conducted for the Comprehensive Cooling Water Study sampled macroinvertebrates from the middle reaches of Beaver Dam Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Beaver Dam Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

More species were collected in Beaver Dam Creek than in the other thermally influenced streams (i.e., Four Mile Creek and Pen Branch). Dominant macroinvertebrate species were segmented worms (Oligochaeta), roundworms (Nematoda), midges (Diptera), stoneflies (Plecoptera), and snails (Gastropoda). Also found in lesser abundance were mites (Hydracarina), scuds (Amphipoda), dragonflies (Odonata), and caddisflies (Tricoptera).

The dominant species of adult fish in Beaver Dam Creek are mosquitofish, sunfish, and gizzard shad (Bennett and McFarlane, 1983; Du Pont, 1985b). Relative abundance and species composition increase toward the creek mouth and swamp where greater habitat diversity occurs and temperatures are somewhat moderated (Du Pont, 1985b).

Ichthyoplankton in Beaver Dam Creek reflected the adult composition, with sunfish or bass being dominant. Although thermally influenced, Beaver Dam Creek exhibited greater density and species diversity than the other thermal streams (i.e., Four Mile Creek and Pen Branch), but it did not produce the density expected considering the lower level of thermal loading (Du Pont, 1985b; Appendix C).

3.4.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 0.004 curie of cesium-137 (decay corrected to 1980) has been released to Beaver Dam Creek from D-Area (Lower and Hayes, 1984). Data on cesium-137 concentrations are not available for Beaver Dam Creek. However, based on the release data, such concentrations are considered to be negligible.

Released tritium remains soluble in Beaver Dam Creek. Approximately 124,100 curies of tritium were released to Beaver Dam Creek from D-Area through 1980 (Du Pont, 1985b).

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CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

This chapter discusses the potential environmental consequences of the construction and operation of the cooling water alternatives for K- and C-Reactors [once-through cooling towers (preferred), recirculating cooling towers, and no action] and the D-Area powerhouse [increased flow with mixing (preferred), direct discharge to the Savannah River, and no action]. TE

This chapter also discusses the cumulative impacts of the construction and operation of these cooling water alternatives in relation to other Savannah River Plant (SRP) facilities and to major facilities near the Plant, and unavoidable and irreversible impacts of these alternatives.

Sections of this chapter have been expanded to include new data and analyses resulting from the Comprehensive Cooling Water Study (Du Pont, 1985b, 1987) and additional studies conducted in response to public and agency comments on the draft environmental impact statement (EIS). A major change to this chapter is the inclusion of predictive Section 316(a)-type biological data; these data enable a detailed evaluation of the potential impacts of the proposed cooling water alternative systems on the major biological components of the stream ecosystems in relation to the South Carolina water classification standards. BB-3

4.1 ALTERNATIVES FOR K-REACTOR

4.1.1 ONCE-THROUGH COOLING TOWER

As discussed in Section 2.2.1.1, the U.S. Department of Energy (DOE) performed design evaluations and studies to optimize system performance and achieve cost savings in the construction and operation of once-through cooling towers without introducing major changes in the nature or magnitude of environmental impacts. The following description of the potential environmental consequences of constructing and operating a once-through cooling tower for K-Reactor includes a discussion of the major system features that were studied and evaluated. TE TC

4.1.1.1 Construction Impacts

The following sections describe the environmental impacts expected to occur with the construction of a once-through, gravity-feed, natural-draft cooling tower for K-Reactor. TE

Socioeconomics

The construction of a once-through cooling tower for K-Reactor would be accomplished in approximately 36 months, after a 9-month lead design period. Construction could involve a combined workforce for the towers in both K- and C-Areas. Two groups of workers would be involved in constructing both towers. The first group, which would include the architect and building crew, would initially number about 60; this would increase to about 100 when work on TC the second cooling tower began because construction of the first tower would be continuing. The second group of workers, which would perform related construction activities such as installing electrical facilities and piping, would involve an estimated peak workforce of 330 workers. These two groups would peak at different times during the construction of the towers. The maximum total construction workforce during these combined activities would not exceed 400; therefore, the estimated peak construction workforce for K-Reactor alone is 200 persons.

For planning purposes, average annual construction workforce estimates have been prepared for the next several years for the SRP and for Georgia Power Company's Vogtle Electric Generating Plant (Plant Vogtle), which is in nearby
TC Burke County, Georgia. Table 4-1 lists the projected total levels at both plants from 1987 through 1989. The SRP estimates include the number of workers required to build the cooling towers.

Table 4-1. Projected Total Construction Workforces at Savannah River Plant and Plant Vogtle[a]

	Workforce		
Location	FY 1987	FY 1988	FY 1989
Savannah River Plant[b]	5700	6600	4500
Vogtle Nuclear Power Plant	3575	30	0

TC

a. Sources: Du Pont, 1985a; Castrichini, 1985.
b. The size of the SRP construction workforce is subject to change, contingent on changes in DOE authorized programs.

Historic and Archaeological Resources

The most recent archaeological and historic resources survey of the Pen Branch watershed area, including Indian Grave Branch, was conducted from May through August 1984, as described in Appendix E. The survey study area encompassed
TC the areas that would be disturbed by facilities associated with a once-through cooling tower for K-Reactor. The survey located 40 sites in the watershed (see Figure E-2 in Appendix E). None of the sites is in an area that would be affected by the construction of once-through cooling-tower system.

Water Quality

The principal impact to water quality in Pen Branch during construction of the once-through cooling-tower system would be temporary increases in suspended solids due to runoff and erosion. Temporary measures such as berms, drainage ditches, drains, sedimentation basins, grassing, and mulching would control runoff until permanent drainage and erosion control facilities could be completed. Turbidity screens would prevent downstream movement of suspended material where construction activities occur near Four Mile Creek.

Ecology

For a once-through cooling tower with gravity feed, approximately 25 acres of uplands and bottomland hardwoods would be disturbed by the construction, including 19 acres for the gravity flow canals, 2 acres for the cooling tower, and the remaining acreage for the relocation of various other facilities and construction of service roads and parking areas. The effluent canal from the cooling tower to Indian Grave Branch would require the removal of about 0.5 acre of bottomland hardwoods consisting mainly of sweet gum-nuttall oak-willow community. BB-3

Construction activities could temporarily affect certain wildlife species, such as birds and turtles at the construction site. Most of the wildlife would leave the immediate area of construction when activities increase; however, some should return when construction is complete. The clearing of areas for construction would result in the loss of some small mammals, such as shrews and mice; however, significant adverse impacts to the populations are unlikely. When construction has been completed, areas that are no longer needed would be replanted with appropriate grasses, shrubs, or trees and thus made available for use by wildlife.

The expected impacts from sediment loading on fish and macroinvertebrates caused by construction would be minimal because the upper reaches of Pen Branch near the proposed construction are sparsely inhabited at present due to high temperature conditions (Appendix C).

Radiological Releases

During the construction of the once-through cooling tower, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Indian Grave Branch and Pen Branch would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the creek bed and, consequently, radiation doses to the offsite population would not change.

Because the proposed location for the cooling tower is on the SRP, TC construction personnel for the tower would experience levels of radiation slightly elevated above background, resulting from the operation of Plant facilities. From measurements made at the construction site of the Defense TE Waste Processing Facility (DWPF; DOE, 1982), augmented by estimates made for that site, the annual dose increment to a construction worker who spends 2000 hours (40 hours per week for 50 weeks per year) in the cooling-tower construction area is approximately 20 millirem. This dose is below the standards of 25 millirem per year from airborne releases and 100 millirem per year from all pathways established by DOE for uncontrolled areas.

Other Construction Impacts

The construction of the once-through cooling tower for K-Reactor would result in the emission of small quantities of carbon monoxide and hydrocarbons from engine exhausts of construction equipment and truck traffic, and suspended particulates and dust from ground-surface disturbances. All applicable emissions standards would be met during construction.

Construction of the once-through cooling tower would also cause temporary increases in noise levels in the immediate area from construction equipment such as earth-moving equipment and cranes; however, no noise from these activities is expected to be detectable offsite.

Solid waste generated during construction (excluding clearing debris) would be placed in containers for disposal in an approved manner. Fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.1.1.2 Operational Impacts

The following sections present the expected environmental impacts associated with the operation of a once-through cooling tower for K-Reactor. The discussion includes the environmental impacts attributable to the potential operation of a gravity-feed, natural-draft, cooling-tower system. TE

Socioeconomics

TE The number of workers associated with the operation of a once-through cooling tower at K-Reactor would not result in any socioeconomic impacts, because only four additional mechanics would be required.

Historic and Archaeological Resources

Operation of the once-through cooling tower with gravity feed would cause no impacts to historic and archaeological resources. During the operation of the cooling tower, effluent would be discharged to Indian Grave Branch, which is a tributary of Pen Branch. Expected flows in Indian Grave Branch and Pen Branch would be nearly the same as those at present, with little change in stream morphology. An archaeological and historic resources survey in the Pen Branch watershed area located no significant sites requiring impact mitigation.

Water Quality and Hydrology

The once-through cooling-tower alternative for K-Reactor would lower the temperature in Pen Branch and the Savannah River swamp. Temperatures, even under extreme 5-day average conditions, would comply with the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C. However, during certain times of the year, the discharge would raise the stream temperature more than the 2.8°C maximum above ambient specified in the State of South Carolina's Class B water classification standards. BB-3

The cooling tower would be designed and operated in a manner that would meet the maximum weekly average temperature (MWAT) criteria (EPA, 1977) to minimize thermal shock of fish that could occur with a reactor outage (Muhlbaier, 1986). Because instream temperatures during winter and spring average conditions probably would be raised by more than 2.8°C above ambient due to BB-3 the operation of the cooling-tower system, a Section 316(a) Demonstration study would be performed after operation begins; the results would be submitted to the South Carolina Department of Health and Environmental Control (SCDHEC) in accordance with amended Consent Order 84-4-W. The Section 316(a) BB-3 study would determine whether effluent temperature conditions would ensure the protection and propagation of a balanced indigenous population of fish, shellfish, and wildlife in and on the waters affected by the discharge.

The reduction of the temperature in Indian Grave Branch and Pen Branch would cause a corresponding increase in dissolved oxygen concentrations. Studies show that water temperature controls oxygen content in the thermal portions of SRP streams (Du Pont, 1985b, 1987). Under current operating conditions, dis- TC solved oxygen concentrations in Pen Branch are sometimes below South Carolina Class B stream standards during the summer months. Lower water temperatures would produce higher dissolved oxygen concentrations during the summer months, which would result in compliance with water classification standards. The operation of a once-through cooling-tower system would also reduce both the BC-10 suspended solids discharged to Pen Branch and sedimentation rates in the delta. There are two causes of these effects: First, the reduction of water temperatures would allow some vegetation to develop along the banks of the stream in areas where plants cannot now grow because of the heated discharge water, thereby stabilizing the stream banks and reducing erosion; and second, some of the suspended solids concentrations in the cooling water from the BC-10 Savannah River would be reduced by settlement in the cooling-tower basin.

Effluents discharged to Indian Grave Branch as the result of the implementation of this alternative would be chemically similar to those associated with the present once-through system. Chlorine biocide would be added to reactor cooling water to prevent biofouling of the cooling-tower system and to control the growth of pathogenic organisms that could develop in the heated waters. Chlorine would be neutralized with a sodium sulfite addition prior to discharge to Indian Grave Branch. In bioassay testing conducted at the SRP using K-Reactor effluent (Appendix C; Wilde, 1987), residual chlorine concentrations expected to occur with chlorination of the BB-1 cooling towers were found to be toxic to representative local fishes BB-2 (largemouth bass and bluegill). However, after neutralization of residual chlorine with sodium sulfite, the effluent was no longer toxic to these species. The proposed neutralization scheme also was found to cause no significant reductions in dissolved oxygen concentrations or changes in pH (Appendix C; Wilde, 1987). There would be a small increase in the concentration of nonvolatile constituents due to evaporative losses of water from the cooling tower. However, discharges would meet all NPDES permit limits. When K-Reactor is not operating, the concentrations of chemical pollutants in Pen Branch would not change appreciably because of the absence of the cooling water discharge; the stream would meet State Class B water classification standards (see Section 3.2.3 and Du Pont, 1985b, 1987). TC

The operation of a once-through cooling tower would result in only small changes to the water flows in Pen Branch and the swamp, compared to present conditions. The evaporation of cooling water from the once-through tower BC-10 would reduce the discharge flow into the creek from its current level of about 11.3 to about 10.5 cubic meters per second; this would produce no significant

change in the water flows in the waterways below the outfall. When K-Reactor
BC-10 is not operating, the flow in Indian Grave Branch and Pen Branch would be reduced significantly.

The operation of the once-through cooling-tower system would produce no
TE significant impacts on the subsurface hydrology in the area of K-Reactor. Present groundwater discharges from the Barnwell and McBean Formations would
TC continue to discharge to Indian Grave Branch and Pen Branch.

Air Quality

TE The operation of a once-through, natural-draft cooling tower at K-Reactor could result in the formation of ground-level fog, ice, elevated visible plumes, and total-solids (drift) deposition on the ground. As discussed in Appendix B, a computer model (Fisher, 1974) was used to predict the atmospheric effects of cooling-tower operation. Hourly meteorological data for the period January 1975 to October 1979 were used in the analyses; they were derived from the Savannah River Plant and from the National Weather Service (NWS) station at Bush Field in Augusta, Georgia. Wind and atmospheric stability data collected at 61 meters elevation from the K-Reactor tower and temperature data obtained from the NWS station at Bush Field were the primary sources of meteorological input. For those periods when wind data from the K-Reactor tower were unavailable, data from the other SRP meteorological monitoring stations (described in Section 3.2) were used. If SRP data were not available, wind and atmospheric stability data based on the Pasquill-Turner approach were used, based on data from the Bush Field NWS station.

The effects of an evaporative-heat-dissipation system on the formation of fog and ice were determined by the quantity and location of added moisture and by the existing ambient air conditions. The significant factors in determining the increase of fogging and icing are the characteristics and quantity of the effluent air, the height of the effluent plume, and the downwind dispersion of the plume. The fogging calculations were based on the international definition of fog (i.e., the reduction of visibility to less than or equal to 1 kilometer) (Pettersen, 1956).

For the once-through natural-draft cooling tower with gravity feed, the calculated maximum annual mean frequency of reduced ground-level visibility to less than 1000 meters would be less than 2 hours per year for all directions
TC from the K-Reactor cooling tower.

The calculated maximum ice accumulation on horizontal surfaces due to the operation of a once-through natural-draft tower would be no more than 1 millimeter.

The maximum occurrence of visible plumes aloft would be 180 hours per year in
TC the immediate vicinity (0.4 kilometer) of the cooling tower. The plumes would be visible from SRP roads within 2 kilometers of the tower, for approximately 50 hours per year.

Figure 4-1 shows the isopleths of annual total solids deposition due to the
TC operation of the once-through natural-draft cooling tower with gravity feed for K-Reactor.

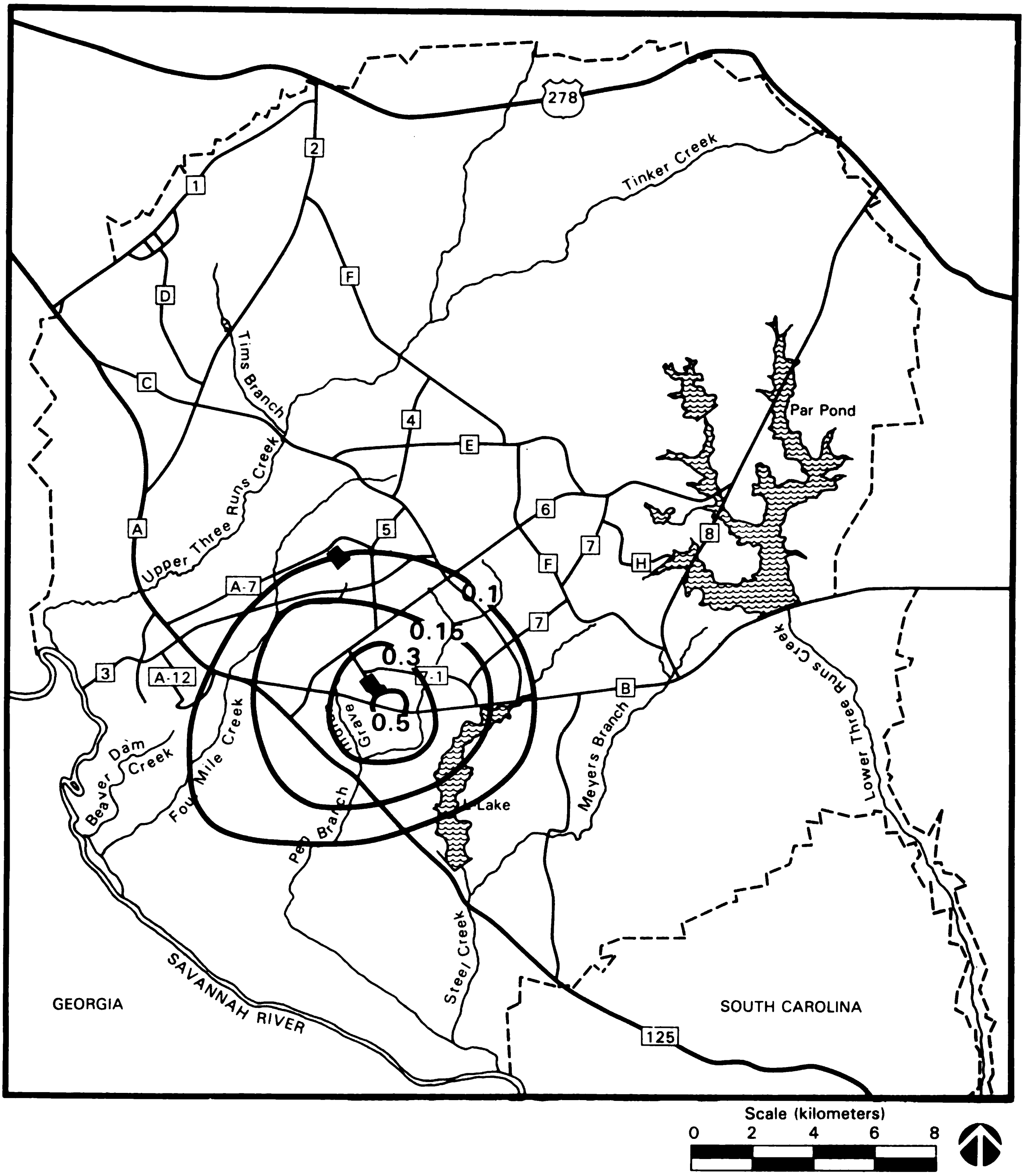

Figure 4-1. K-Reactor Once-Through Tower, Total Solids Deposition, Kilograms/Acre-Year

BB-3

TC The calculated maximum annual total-solids deposition (defined as the total amount of solid material deposited as dry particles and in droplet form) would be about 0.5 kilogram per acre per year within 2 kilometers of the tower in all directions.

Noise

TE The operation of a once-through natural-draft cooling tower with gravity feed at K-Reactor would cause increases in noise levels. Cooling-tower noise would come from falling water. Beyond approximately 152 meters from the cooling tower, average sound levels would be below 70 decibels. [Continuous exposure to 70 decibels or less has been determined to cause no loss of hearing (EPA, 1974).] At the nearest offsite area, noise from K-Area activities would not be detectable.

Ecology

Vegetation and Wetlands

Vegetation near the cooling tower would be subject to salt deposition attributable to drift from the tower. Cooling-tower drift can cause vegetation stress either directly by deposition of salts on the foliage or indirectly from excess accumulations of salts in the soil. Salt stress in plants, which can occur via various mechanisms, includes (1) increased osmotic potential of the soil solution affecting the availability of soil moisture to the plant; (2) alteration of the mineral nutrition balance in the salt tissues; and (3) toxic effects due to specific ion concentrations in the plants (Bernstein, 1975; Hanes, Zelazny, and Blaser, 1970; Allison, 1964; Levitt, 1980).

Tolerances and susceptibility to salt deposition are highly variable, depending on the plant species and on other conditions in the environment. Vegetative studies indicated that thresholds for development of visible salt stress symptoms on the most sensitive species were approximately 83 kilograms per acre per year of sodium chloride salt (INTERA, 1980). Studies indicate that at sodium chloride deposition rates of about 41 kilograms per acre per year, agricultural productivity can be reduced (Mulchi and Armbruster, 1981). Because private agriculture is not permitted on the SRP, vegetative stress, if any, from cooling-tower drift would be limited to the natural plant communities in the vicinity of the towers.

The composition of the drift is equivalent to that of the circulating water. Table 3-3 indicates the concentration of substances in the circulating water for the once-through cooling tower. The substance of particular interest with regard to its potential for damage is the chloride ion. The other constituents listed in Table 3-3 either are at concentrations low enough to be negligible or are potentially beneficial.

TC The operation of a once-through natural-draft cooling tower with gravity feed would result in an estimated total solids deposition of about 0.5 kilogram per acre per year within 2 kilometers. The sodium chloride deposition rates from the cooling tower would be much less than the critical values (reported by

Mulchi and Armbruster, 1981 and INTERA, 1980) that can cause reduced productivity of plant species. Therefore, no significant impacts on vegetation are expected. TC

The most significant impact on the vegetation resulting from operation of a once-through cooling-tower system would be a reduction in the loss of wetland habitat due to thermal discharges. Because the stream would still be subject to variable flows, there would be incomplete reestablishment of upstream wetland communities along Indian Grave Branch and Pen Branch. From 1955 through 1984, about 670 acres of wetlands were affected in the Pen Branch floodplain and swamp due to thermal discharges and flooding (Du Pont, 1985b, 1987; Appendix F), with an average loss of about 26 acres per year in the swamp. TC The operation of a once-through cooling-tower system would eliminate additional losses in the stream corridor. Thermal effects are one of the three major factors (the others are flooding from reactor operation and river flooding) responsible for continuing swamp canopy loss (Du Pont, 1985b, 1987). TC The reduction in effluent temperatures would, therefore, have a positive effect on wetland communities by significantly reducing wetland loss rates.

To assist in ongoing consultations with the U.S. Fish and Wildlife Service (FWS), a Habitat Evaluation Procedure (HEP) analysis (Mackey et al., 1987) was conducted; this procedure identified the value of habitat to be gained or lost BC-3 with the once-through cooling-tower alternative (see Section 4.6 and Appendix C for more details on HEP analysis).

Aquatic Habitat and Biota

Balanced communities containing indigenous species in all biotic categories should develop and remain in all natural portions of the Pen Branch ecosystem following the implementation of a once-through cooling-tower system for K-Reactor. Predicted maximum water temperatures in the immediate discharge area would be below the maximum of 32.2°C required for Class B waters of the State of South Carolina. However, the other temperature criterion for Class B waters (maximum temperature change of 2.8°C) would sometimes be exceeded in the stream. Accordingly, a Section 316(a) Demonstration study would be conducted to determine if a balanced biological community would be maintained.

To compare and assess environmental impacts to the Pen Branch watershed before and after operation of the once-through cooling system, the stream system has BB-3 been divided into three reaches based on the presence of distinct stream gradients: Reach 1 extends from the K-Reactor outlet down to SRP Road A, Reach 2 extends from SRP Road A to the mouth of the Pen Branch delta, and Reach 3 extends from the Pen Branch delta to the Savannah River.

Conditions for all biotic categories would be greatly enhanced following mitigation in comparison to present conditions. Based on extensive data from Steel Creek, which had been impacted previously, recolonization of areas within the Pen Branch system that are presently uninhabitable because of excessive temperatures would occur rapidly. Furthermore, an analysis of the temperature requirements of the representative and important species indigenous to the creek system has revealed that these species would not be affected adversely by the higher-than-ambient temperatures resulting from K-Reactor operation following mitigation with the once-through cooling-tower system (Du Pont, 1987).

The Pen Branch system, which includes Pen Branch and Indian Grave Branch, is a low potential impact area for phytoplankton. The food base throughout this system consists of detrital material rather than phytoplankton, as is typical in lotic systems. Primary producers in the Pen Branch system consist mainly of periphyton and macrophytes (Du Pont, 1985b, 1987).

Following the implementation of a once-through cooling tower, zooplankton would become established in the primary study area. This newly established zooplankton community would provide food for the establishment of balanced indigenous macroinvertebrate and fish communities. The maximum predicted summer temperatures in the Pen Branch system would be within the range tolerated by most, if not all, indigenous species; accordingly, the heated discharge should cause no appreciable harm to the zooplankton community. The standing crop of zooplankton could be enhanced by the relatively slight temperature elevations above ambient, and species composition and community structure should be similar to those of the Pen Branch system before K-Reactor operation and to those of other natural streams in the region. The heated discharge is not likely to alter the standing crop, community structure, or seasonal periodicity of zooplankton in the farfield study area from those values typical of the receiving water body segment before reactor operation. Furthermore, cooling-tower discharge flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

BB-3

The habitat-formers community would improve with the addition of a once-through cooling tower for K-Reactor. However, the pattern of recovery is difficult to predict. Unlike the Steel Creek delta, which in early 1968 stopped receiving both high flow and temperature from L-Reactor, temperatures will become reduced, but high flow will remain from the K-Reactor tower.

At present, much of the Pen Branch system (especially Reaches 1 and 2) have temperatures that exceed the thermal tolerances of many aquatic plants. The reduction of temperatures to below lethal limits would allow the establishment of macrophytes and other aquatic plants, especially into Reaches 2 and 3. Reach 1 (Indian Grave Branch) is in a steeper, higher gradient stream valley than the rest of Pen Branch; macrophytes and other vascular flora are not as likely to develop there. Reaches 2 and 3 have lower gradients, are more open, and are more conducive to the establishment of mature plant communities. However, the high flows from the cooling tower probably would impede the types of vegetative communities that could develop. A reduction of macrophyte growth in the main channel caused by an increase in flow has been observed in Lower Three Runs Creek. A reduction in the size of macrophyte beds (Polygonum) has been observed in Steel Creek along the main channels after increased flows in Steel Creek since the restart of L-Reactor in October 1985. Macrophyte development in Pen Branch probably would be restricted to the edges of the islands throughout Reaches 2 and 3. Typha, Ludwigia, Cyperus, Sagittaria, Leersia, Hydrolea, and Polygonum should become established along the channel margins and in backwater areas of reduced flow. Due to high flows and changing water levels, macrophytes would be uncommon in the main portions of the stream channels. In deeper water areas of slow flow, Ceratophyllum and Myriophyllum could be abundant. Buttonbush and willow should continue to develop in areas of reduced temperatures, provided flooding and erosion of islands through channel modification is not extensive. Algae, including blue-green species, should continue to be common in the warmer months due to nutrient loading from the cooling tower (Du Pont, 1987).

The reduced temperature regime resulting from the cooling tower would permit the invasion of some species of aquatic macrophytes and periphyton in parts of the system that are presently too hot to support plant life. However, rapid water velocities and a scoured stream substrate would make root penetration difficult; these conditions are expected to retard the development of macrophyte communities in the center of the stream channel. In contrast, good development of aquatic macrophyte and riparian communities is expected along the stream margins, as well as in the delta area, where the stream channel is braided and water velocities are reduced.

The combination of above-ambient temperatures and the nutrient-rich river water that is used for reactor cooling should result in higher levels of primary production than would occur without reactor discharge. In addition, much more aquatic habitat would exist with a once-through cooling tower than would exist without the reactor discharge, because of the higher water levels.

However, flow fluctuations during reactor cycling would result in the dewatering and subsequent dessication of large areas of stream bottom during reactor outages. The flow fluctuations probably would result in a macrophyte community dominated primarily by emergent species that could withstand dewatering, although some submerged macrophyte species probably would become established in pools and backwater areas. The dewatering also would impact periphyton communities, causing major die-offs during reactor outages. Thus, although conditions with the cooling tower would be improved over existing conditions due to reductions in stream temperatures, flow fluctuations would perturb the ecosystems of the stream corridor and delta areas to some extent and would influence the types of communities that would develop in these areas.

BB-3

A once-through cooling tower would reduce stream water temperatures (see Chapter 2 and Appendix B) in comparison to present conditions, and would provide a thermal regime in the Pen Branch system conducive to the establishment of a reasonably diverse macroinvertebrate community. Following implementation of this alternative, the maximum predicted temperatures in the three reaches of the stream would be within the range tolerated by most, if not all, indigenous macroinvertebrate species.

Macroinvertebrates that utilize detritus (i.e., dead algae and other organic material; collector-gatherers and collector-filterers) probably would be favored in Pen Branch. In time, as riparian vegetation develops and begins to shed leaves into the stream, the relative abundance of shredders should increase. Organisms with short generation times (less than 1 month) should have a competitive advantage over longer-lived species, because they probably would be able to complete one or more life cycles during a single reactor cycle. Mobility would also be a factor in determining the macroinvertebrate species composition of Pen Branch, because species that can move quickly into deeper water or that can enter the drift rapidly would be favored over more sessile species. Species that can resist dessication in one or more life stage would have a competitive advantage.

Numerically, the chironomids should continue to dominate the macroinvertebrate community of the Pen Branch corridor, as they do in most southeastern streams (Smock et al., 1985). The dominant chironomid taxa, however, would shift, with the more thermally tolerant species being replaced by other species that are not thermally tolerant. Organisms (e.g., mayflies and beetles) that can migrate quickly would be favored in Pen Branch, while sessile organisms, as well as taxa that pupate in the water (e.g., caddisflies) could experience high rates of mortality during reactor outages. Species that inhabit the stream substrate might not be greatly impacted, except during extended reactor outages, when discharges could be reduced long enough to dry out portions of the stream substrate completely. Although Pen Branch should support a reasonably diverse macroinvertebrate community, fluctuations in water level and an elevated temperature regime could preclude the establishment of some of the more sensitive macroinvertebrate taxa in the stream.

Although above-ambient temperatures should produce earlier emergence of many species of aquatic insects, no major adverse impacts should occur. The slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate community.

The fluctuating water levels during reactor cycling would affect the macroinvertebrate community of Pen Branch to some extent. Increased drift would occur during rising and receding water levels, which could result in increased predation and possibly temporary reductions in standing crop. BB-3 Dewatering of macroinvertebrate habitat (logs, leaf packs, stream substrate, etc.) during reactor outages could result in substantial mortality for some species of macroinvertebrates. If large periphyton die-offs are caused by dewatering, secondary production could be reduced temporarily due to the reduced availability of food. However, the standing crop of macroinvertebrates in Pen Branch should be sufficient to ensure a good supply of food for higher trophic levels (i.e., fish).

The cooling-tower discharge flow would not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperature of the plume would be less than the upper thermal limits of most macroinvertebrate species indigenous to the southeast. No significant farfield impacts should occur, because the water would be near ambient temperature by the time it reaches the Savannah River (see Appendix B, Table B-4).

A once-through cooling tower would improve conditions for the fish communities in the Pen Branch system. The community in upper Pen Branch above K-Reactor is not expected to change substantially from present conditions, because the fish communities in the upper reaches of SRP tributary streams appear to be stable and not affected significantly by reactor operations. One major difference caused by cooling-tower operation could enhance the fish community in this portion of the stream system. Water temperatures at the confluence of Indian Grave Branch and Pen Branch would never exceed 32°C or have an average monthly ΔT greater than 10°C (winter; see Appendix B, Table B-4). Accordingly, water temperature should not inhibit the movement of fish between the Savannah River and the headwaters of Pen Branch. This could result in additional spawning in the upper reaches and could provide a pathway for immature fishes spawned in these reaches to contribute to the populations in Reaches 1, 2, and 3 below K-Reactor and in the Savannah River.

Following implementation of this alternative, a temperature-restricted zone of passage in Reach 1 should not exist; this would allow fish to reinvade this section and could provide spawning and nursery areas for some species. Maximum temperatures in Reach 2 would not exceed 32°C and average monthly ΔT values would not exceed 10°C (see Appendix B, Table B-4); this should allow indigenous fish species to inhabit Reach 2. Some areas of Reach 2 should be suitable for spawning, thereby increasing fish populations. Furthermore, the addition of slightly heated and relatively nutrient-rich Savannah River water to Pen Branch via the cooling-tower discharge should increase primary and secondary production in this area. The result would be an enhancement of fish growth in this portion of the creek in comparison to expected fish growth under ambient conditions. All of Reach 3 should be suitable habitat for all indigenous fishes of the Pen Branch system. Water temperatures should not exceed 31°C and average monthly ΔT values would not exceed 8°C in this region during the winter (see Appendix B, Table B-4). Reactor operation should have no adverse impact on reproduction. Growth should be enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the system.

The maximum predicted water temperature at the cooling-tower discharge point would be 32°C (see Appendix B, Table B-4) and the maximum predicted average BB-3
monthly temperature would be 29°C. In contrast, the upper incipient lethal temperatures for representative and important species (largemouth bass, bluegill, and catfish) are in the mid- to upper 30s°C. The cooling-tower system would comply with the temperature shock limits proposed by the U.S. Environmental Protection Agency (EPA) for the protection of all warm-water fishes (EPA, 1977). Laboratory studies have shown these limits to be protective of the temperature tolerance limits of largemouth bass, bluegill, and channel catfish (Wilde, 1987; Storms, 1985). Reproductive success and growth of all indigenous fish species should be improved over present conditions by implementation of this alternative; growth could be enhanced even above potential ambient temperature levels because the slight warming from the cooling-tower discharge would result in optimal growth temperatures for more of the year than with ambient conditions. Maximal absolute temperatures and ΔTs should not block fish migration. Thus, the entire Pen Branch system should be available for fish habitation; the free movement of fishes between the headwaters of Pen Branch and the Savannah River should not be inhibited by K-Reactor operations at any time during the year. The thermal discharge flow should not block fish migration or exclude fish from any part of the ecosystem.

Entrainment and Impingement

The operation of a once-through cooling tower would not require any changes to the intake cooling water flow rates. Accordingly, expected entrainment and impingement impacts would be similar to current impacts for K-Reactor.

The entrainment rates at the 1G and 3G intakes, as determined by onsite studies conducted annually from 1983 to 1985 (DOE, 1987), result in the average loss of approximately 17.6 x 10^6 fish larvae (range: 10.2 x 10^6 to 26.1 x 10^6 fish larvae; Appendix C) during the February-to-July spawning season at the Plant. Estimated losses of fish eggs average 9.3 x 10^6 (range: 5.3 x 10^6 to 14.0 x 10^6 eggs; Appendix C) each spawning season. Because about 50 percent of the water drawn into the two intakes is used for cooling K-Reactor, about half the total loss of larvae (8.8 x 10^6) and eggs (4.6 x 10^6) can be attributed to the operation of this facility. The taxonomic groups whose larvae are most impacted by entrainment through the 1G and 3G intakes are the Clupeidae (shad, herring, etc.) the Centrarchidae (crappie, sunfish, etc.), and the Cyprinidae (carp, etc.). The eggs of the American shad and striped bass were entrained most often, accounting for an average 73 percent of all eggs entrained.

Overall entrainment losses for K-Reactor operation averaged approximately 5.4 percent (range: 4.4 to 7.5 percent) of the ichthyoplankton passing the SRP intakes (DOE, 1987). Egg losses were concentrated among two anadromous species, American shad and striped bass, but only populations spawning in the 30 miles of the river between the New Savannah Bluff Lock and Dam and the SRP are affected. American shad and striped bass spawn throughout the Savannah River, but the primary region for striped bass spawning is in the tidally influenced portions of the river near Savannah. Entrainment of ichthyo-
BB-3 plankton of fresh water species primarily affects the eggs and larvae of individuals that spawn in the vicinity of the intake canals, either in the river or in the 1G and 3G canals. Consequently, the effect of entrainment of fish eggs and larvae should be small and restricted to local fish populations.

The current rates of impingement at the 1G and 3G intake screens would not be expected to change with a once-through cooling-tower system. During investigations conducted annually from 1983 to 1985 (DOE, 1987), projected annual impingement for the two intakes combined averaged approximately 5885 fish (range: 2986 to 9534 fish per year; Appendix C), about half (2942 fish per year) of which can be attributed to K-Reactor. The principal species affected were bluespotted sunfish and threadfin shad; gizzard shad, redbreast sunfish, and warmouth were also impinged frequently.

Threatened and Endangered Species

Several inactive red-cockaded woodpecker colonies are located in the Pen Branch area. However, because the preferred habitat of this species is mature pine forests rather than wetland or bottomland hardwoods near the creek, the operation of the once-through cooling tower would not impact the habitat of this endangered woodpecker.

The American alligator occurs on the SRP site in both flowing-water and lake environments. Temperatures in the thermal region of Pen Branch under present operating conditions are higher than 50°C in the summer, which exceeds the critical thermal maximum of 38°C for the alligator. Thus, alligators cannot inhabit major portions of the stream during reactor operation. This alter-
BB-3 native would improve habitat quality over existing conditions; however, fluctuating water levels and elevated water temperatures could affect this

species adversely by flooding nests, eggs, and hibernation sites. Elevated temperatures during the winter and spring months could influence reproduction, nesting, and survival by hastening sexual maturation and nesting in the spring. BB-3

The federally endangered bald eagle is a fairly common permanent breeding resident in South Carolina and is most abundant in the coastal region; it migrates from the southeast to the northern states and Canada in mid-summer and returns south in the fall and early winter to nest and rear its young (Sprunt and Chamberlain, 1970). The presence of this species on Par Pond was first recorded in May 1959 (Norris, 1963); eagles have been sighted frequently on the SRP since 1978 (Mayer et al., 1986).

TC

The first sighting of an active bald eagle nest on the SRP occurred on June 5, 1986. The nest contained two eaglets. In 1987, the mating pair returned to their nest and fledged two eaglets. The nest is located below Par Pond dam in the Lower Three Runs Creek drainage area. Because this nest is outside the preferred alternative cooling impact zones and due to the implementation of management practices in accordance with the guidelines of the 1984 bald eagle recovery plan, the U.S. Fish and Wildlife Service (FWS) issued a finding of no effect to this species in 1986 (Henry, 1986).

Although shortnose sturgeon larvae and adults have been collected from the Savannah River and the intake canals, no shortnose sturgeon have been collected from any SRP creeks, nor do these areas provide spawning habitat. Current SRP operations have been determined to have no adverse impact on the endangered shortnose sturgeon population in the Savannah River (Oravetz, 1983).

A total of 59 endangered wood storks were observed foraging in the Pen Branch delta from 1983 through 1986 (Du Pont, 1987). The high flow rate, water depth, and lengthy reactor cycles associated with the operation of K-Reactor and a once-through cooling tower could minimize the availability of quality foraging habitat for the wood stork. BB-3

Formal consultation was held between DOE and FWS on the bald eagle, American alligator, red-cockaded woodpecker, and wood stork. Based on this consultation, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986). In addition, the National Marine Fisheries Service (NMFS) has previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah River would not be affected adversely by SRP operations (Oravetz, 1983). TC

Radiological Releases

The radiological releases associated with the discharge of cooling water from K-Reactor are those resulting from either the remobilization of radionuclides contained in the Indian Grave Branch and Pen Branch streambeds and floodplain, or those resulting from small process-water leaks into the cooling water.

The operation of the once-through cooling tower would not result in any significant changes in the remobilization of radionuclides contained in the streambed and floodplain, because the flow rate of cooling water discharged to the creek would remain essentially unchanged. The operation of the cooling tower, however, would decrease the amount of tritium discharged to the stream and, correspondingly, would increase the amount of tritium released to the atmosphere because of evaporation from the tower. The following sections discuss changes in the doses to the maximally exposed individual at the SRP boundary and to offsite population groups (based on Year 2000 projections) attributable to the change in atmospheric and liquid releases of tritium resulting from operation of the cooling tower.

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age group.

Atmospheric Releases

TE The amount of tritium released to the atmosphere is expected to increase by 50 curies per year (about 0.012 percent of total SRP releases of tritium to the atmosphere) as a result of cooling water evaporation. This release would increase the atmospheric dose commitments of the regional population and the maximally exposed individual. Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below.

Maximum Individual Dose - The hypothetical individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is assumed to reside continuously at the SRP boundary TC about 8.8 kilometers west of K-Reactor. This location has the minimum atmospheric dilution, based on distance to the Plant boundary and meteorological dispersion characteristics. This individual is assumed to receive doses by inhalation and by the ingestion of meat, vegetation, and cow's milk.

The annual increase in soft-tissue and effective whole-body doses to the maximally exposed individual due to the atmospheric release of tritium is summarized in Table 4-2.

Population Dose - Collective doses resulting from atmospheric releases associated with this cooling alternative have been calculated for the population within 80 kilometers of the Plant. The annual effective whole-body TE dose to this population would increase by 4.97×10^{-3} person-rem as a result of the increase in tritium released to the atmosphere.

Liquid Releases

TC

The operation of the once-through cooling tower would reduce the amount of tritium released to Pen Branch. The release of tritium would decrease by 50 curies per year (about 0.12 percent of total releases of tritium to streams) as a result of the evaporation of cooling water in the tower. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

TE

Maximum Individual Dose - The hypothetical individual who would experience the greatest change in dose from liquid effluents is assumed to live near the Savannah River downstream from the Savannah River Plant. The individual is assumed to use river water regularly for drinking, to consume fish from the

Table 4-2. Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Once-Through Cooling Tower

Age group	Incremental dose increase (mrem/yr) Effective whole body	All soft tissue[a]
Adult	1.05×10^{-4}	1.23×10^{-4}
Teen	1.14×10^{-4}	1.34×10^{-4}
Child	7.86×10^{-5}	9.24×10^{-5}
Infant	2.33×10^{-5}	2.74×10^{-5}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.

river, and to experience external exposures from shoreline activities. The individual is also assumed to drink more water and eat more fish than an average person.

TE

Table 4-3 summarizes the annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual due to a decrease in the liquid release of tritium.

Population Dose - Savannah River water is not used for drinking within 80 kilometers downstream of the Savannah River Plant; therefore, the dose to the population in this area would come from fish and shellfish consumption, and shoreline activities.

The decrease in the collective dose to the Year-2000 population of 852,000 within 80 kilometers of the Savannah River Plant from liquid releases of tritium associated with this cooling alternative would be 2.46×10^{-5} person-rem per year (Table 4-4).

TE

The Beaufort-Jasper and Port Wentworth population groups use the Savannah River as a source of potable water. While these groups are more than 80 kilometers from the Savannah River Plant (about 100 river miles downstream), their drinking-water doses have been calculated. The decrease in the collective dose delivered to these populations (an estimated 317,000 people will consume water from the Beaufort-Jasper and Port Wentworth water-treatment plants by the Year 2000) from tritium in drinking water is 3.26×10^{-2} person rem per year, as presented in Table 4-4.

Table 4-3. Decrease in Annual Doses to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from K-Reactor Once-Through Cooling Tower

Age group	Incremental dose reduction (mrem/yr) Effective whole body	All soft tissue[a]
Adult	2.19×10^{-4}	2.58×10^{-4}
Teen	1.54×10^{-4}	1.81×10^{-4}
Child	1.50×10^{-4}	1.76×10^{-4}
Infant	9.52×10^{-5}	1.12×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.

Table 4-4. Decrease in Collective Effective Whole-Body Dose Resulting from Liquid Releases of Tritium from K-Reactor Once-Through Cooling Tower

Population group	Incremental collective dose reduction (person-rem/yr)
80-kilometer radius	2.46×10^{-5}
Beaufort-Jasper	1.13×10^{-2}
Port Wentworth	2.13×10^{-2}
Total	3.26×10^{-2}

Overall Changes in Offsite Doses

Table 4-5 summarizes changes in the effective whole-body dose received by the maximally exposed individual resulting from the operation of this cooling alternative. Table 4-6 indicates changes in the collective dose.

Table 4-5. Changes in Effective Whole-Body Dose Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Once-Through Cooling Tower (millirem per year)[a]

Source of exposure	Adult	Teen	Child	Infant
Atmospheric tritium releases	1.05×10^{-4}	1.14×10^{-4}	7.86×10^{-5}	2.33×10^{-5}
Liquid tritium releases	-2.19×10^{-4}[b]	-1.54×10^{-4}	-1.50×10^{-4}	-9.52×10^{-5}
Net dose change	-1.14×10^{-4}	-4.00×10^{-5}	-7.14×10^{-5}	-7.19×10^{-5}

a. Tritium imparts an equal dose to all soft tissues that is about 18 percent higher than the effective whole-body dose.
b. Negative sign denotes a decrease in dose.

The average background total-body dose to an individual living in the vicinity of the Savannah River Plant is 93 millirem per year. By extrapolation, the annual collective dose to the 80-kilometer population is 79,200 person-rem; to the Port Wentworth water users, it is 18,600 person-rem; and to the Beaufort-Jasper water users, 10,900 person-rem. TE

This cooling alternative would reduce the annual dose to the effective whole body of the maximally exposed adult and the annual collective effective whole-body dose to Port Wentworth and Beaufort-Jasper water users by 1.14×10^{-4} millirem, 2.13×10^{-2} person-rem, and 1.13×10^{-2} person-rem, respectively; it also would increase the collective effective whole-body dose to the 80-kilometer population by 4.95×10^{-3} person-rem per year. These dose changes are very small compared to the normal year-to-year variations in natural background radiation. BC-22

Present tritium releases to the Savannah River from Indian Grave Branch and Pen Branch result in an effective whole-body dose of 5.18×10^{-2} millirem per year to the maximally exposed adult. This alternative would reduce the liquid tritium dose by 2.19×10^{-4} millirem per year and increase the atmospheric dose by 1.05×10^{-4} millirem per year, resulting in an overall reduction of 1.14×10^{-4} millirem per year. BC-22

Health Effects

Risk estimators used to project health effects are 120 fatal cancers and 257 genetic effects per 1 million person-rem of collective dose; Appendix G presents the risk estimators by organ. According to these estimators and the organ doses, the population within 80 kilometers of the SRP could experience an annual increase of 5.82×10^{-7} excess cancer fatality and 1.50×10^{-6} additional genetic disorder from the operation of this alternative cooling water system. The populations at Beaufort-Jasper and Port Wentworth downstream from the Plant could experience decreases of 3.84×10^{-6} fatal

Table 4-6. Changes in Collective Effective Whole-Body Dose Resulting from Operation of K-Reactor Once-Through Cooling Tower (person-rem per year)

Source of exposure	80-kilometer population	Beaufort-Jasper	Port Wentworth	Total
Atmospheric tritium releases	4.97×10^{-3}	--	--	4.97×10^{-3}
Liquid tritium releases[a]	-2.46×10^{-5}	-1.13×10^{-2}	-2.13×10^{-2}	-3.26×10^{-2}
Net dose change	4.95×10^{-3}	-1.13×10^{-2}	-2.13×10^{-2}	-2.77×10^{-2}

a. Negative sign denotes a decrease in dose.

BC-22

cancer and 9.87×10^{-6} genetic disorder per year. Table 4-7 summarizes this information.

Table 4-7. Changes in Annual Health Effects

Population group	Genetic disorders	Fatal cancers
80-kilometer radius	1.50×10^{-6}	5.82×10^{-7}
Beaufort-Jasper[a]	-3.42×10^{-6}	-1.33×10^{-6}
Port Wentworth	-6.45×10^{-6}	-2.51×10^{-6}
Total	-8.37×10^{-6}	-3.26×10^{-6}

a. Negative sign denotes a decrease in health effects.

4.1.2 RECIRCULATING COOLING TOWERS

4.1.2.1 Construction Impacts

Socioeconomics

Construction of the recirculating cooling towers for K-Reactor would be accomplished in approximately 42 months after a 9-month lead design period. This construction could involve a combined workforce for the towers in K- and C-Areas. Two groups of workers would be involved in constructing these cooling towers. The first group, which would include the architect and building crew, would initially number about 90. This group would increase to about 150 when work on the cooling towers for C-Reactor began because construction of the towers for K-Reactor would be continuing. The second group of workers would perform related construction activities, such as installing electrical facilities and piping; this group would involve a peak workforce of 490 personnel. The two workforce groups would peak at different times during construction. The maximum total construction workforce during these combined activities would not exceed 600; therefore, the estimated peak construction workforce for K-Reactor alone is 300 persons. TC

As described in Section 4.1.1.1, construction workers from other local projects would be available for employment on the Plant. Because these workers already reside in the SRP area, no impacts to local communities and services due to immigrating workers would occur.

Historic and Archaeological Resources

No sites within the Pen Branch and Indian Grave Branch watershed area would be affected by the construction of recirculating cooling towers (see Appendix E for more details). TE

Water Quality

The impacts on water quality in Indian Grave Branch and Pen Branch from the construction of recirculating cooling towers would be similar to those associated with the construction of a once-through cooling tower (see Section 4.1.1.1). The principal impact would be some temporary localized increases in the concentration of suspended material in the stream water due to runoff and erosion from construction activities. The application of standard erosion control practices, described in Section 4.1.1.1, would minimize these temporary effects.

Ecology

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BC-9
BC-13

The construction of recirculating cooling towers would disturb about 50 acres of upland forest (21 acres for the cooling towers, 27 acres for the canal and pipeline right-of-ways, and the remainder for relocation of various facilities and for the construction of service roads and parking areas). No adverse effects on vegetation should occur outside the immediate construction areas.

The impacts to fish and wildlife from the construction of the recirculating cooling towers would be similar to those described for the construction of a once-through cooling tower (see Section 4.1.1.1).

Radiological Releases

During the construction of recirculating cooling towers for K-Reactor, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Indian Grave Branch and Pen Branch would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the creek bed and, consequently, radiation doses to the offsite population would not change.

The only change would be in doses delivered to onsite construction personnel, as discussed in Section 4.1.1.1. This dose, estimated to be approximately 20 millirem per year, is below the standards established by DOE for uncontrolled areas of 25 millirem per year from airborne releases and 100 millirem per year from all pathways.

Other Construction Impacts

The construction of recirculating cooling towers for K-Reactor would also result in air quality and noise impacts similar to those described for the once-through cooling tower (Section 4.1.1.1). All applicable atmospheric emission standards would be met during construction, and solid waste generated during construction would be disposed of in an approved manner. Fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.1.2.2 Operational Impacts

Socioeconomics

The number of workers associated with the operation of recirculating cooling towers at K-Reactor would not result in any socioeconomic impacts, because only six additional mechanics would be required.

Historic and Archaeological Resources

The operation of recirculating cooling towers for K-Reactor would not cause any impacts to any historic and archaeological resources. During the operation of the towers, cooling water effluent would be conveyed to Indian Grave Branch and Pen Branch; flows in the creek would be significantly reduced. An archaeological and historic resources survey in the Four Mile Creek watershed area located no significant sites requiring impact mitigation (Appendix E).

Water Quality and Hydrology

The operation of recirculating cooling towers would lower discharge temperatures such that the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C) would be met throughout the year. The discharge from the recirculating cooling tower would raise the stream temperature in Pen Branch more than the 2.8°C maximum above ambient specified in the State's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate if a balanced biological community would be maintained.

The operation of the recirculating cooling towers would result in discharges to Indian Grave Branch and Pen Branch, with concentrations of most chemical BC-9
constituents about three times higher than corresponding values for Savannah BC-10
River water drawn into the intakes, due to evaporative concentrations in the recirculating tower. An important difference between the compositions of river water and ambient creek water is the higher concentration of phosphorus and nitrogen compounds (i.e., orthophosphate, total phosphorus, nitrates, and ammonia) in the river. Although the concentrations of chemical constituents (e.g., nutrients) would increase by about three times due to cycling in the recirculating tower, the total quantity of nutrients and other chemicals transported to the swamp river system would decrease because the intake flow of Savannah River water for this alternative would be much less than either the present cooling water system or the once-through cooling-tower alternative. Chlorine biocide added to reactor cooling water to prevent biofouling of the cooling towers would be neutralized with sodium sulfite addition prior to discharge to Indian Grave Branch. As discussed for the once-through cooling-tower alternative, no adverse effects should occur to aquatic biota or water quality from these additions. All discharges would comply with NPDES permit requirements and State Class B water classification standards.

With the operation of recirculating cooling towers, dissolved oxygen levels in Indian Grave Branch and Pen Branch should comply with Class B water classification standards throughout the year as a result of lower discharge water temperatures and the aeration resulting from water passing through the cooling towers. Under present conditions, dissolved oxygen concentrations sometimes fall below Class B water classification standards (5 milligrams per liter average; 4 milligrams per liter minimum) during warmer summer periods. The lower flow in the stream would reduce erosion, and the lower water temperatures would allow vegetation to grow along the waterway, thereby stabilizing the shoreline areas. Thus, the levels of total suspended solids would be lower in Indian Grave Branch and Pen Branch and the Savannah River swamp.

The operation of recirculating cooling towers would have a significant effect on the hydrology of Indian Grave Branch and Pen Branch due to a reduction in discharge flow from the present level of about 11.3 cubic meters to about 1 cubic meter per second. The flow in the creek from areas upstream of K-Reactor is about 0.03 cubic meter per second. Under these conditions, the
BC-9 morphology of the stream channel would be altered significantly; generally,
BC-10 its depth and width would be reduced. Existing patterns and rates of erosion and deposition would change; one of the most important results would be a significant reduction in the rate of delta growth. The overall impact of the reduction in flow on the hydrology of the swamp would be small because the Savannah River is the principal factor influencing hydrological conditions in the swamp.

Impacts to subsurface hydrology would be similar to those discussed in Section 4.1.1.2 for the once-through cooling tower.

Air Quality

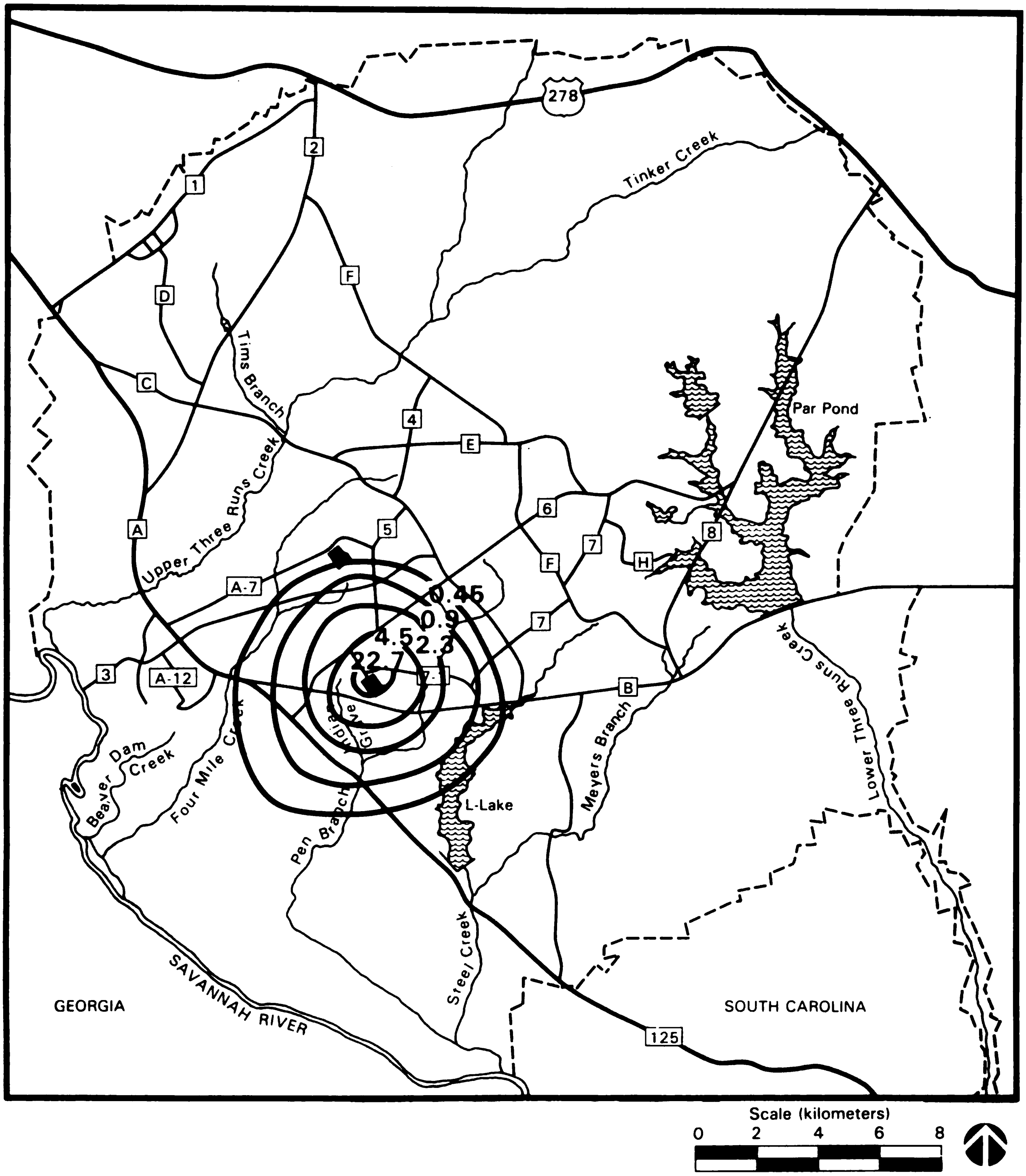
Air quality impacts from the operation of recirculating cooling towers at K-Reactor would be similar to those for a once-through cooling tower (Section 4.1.1.2).

The calculated maximum annual-mean frequency of reduced ground-level visibility to less than 1000 meters would be approximately 2 hours per year, occurring about 8 kilometers south-southwest and about 10 kilometers northwest of the recirculating cooling towers. The maximum ice accumulation on horizontal surfaces would be no more than 1 millimeter beyond 0.8 kilometer in all directions from the towers. The maximum predicted ice thickness would be about 7 millimeters, occurring within 0.4 kilometer from the towers with a total frequency of 88 hours per winter season.

BC-9

The maximum occurrence of visible plumes would be about 180 hours per year within 2 kilometers of the cooling towers in all directions.

Figure 4-2 shows isopleths of annual total solids deposition due to the operation of the K-Reactor recirculating towers. The maximum annual total-solids deposition would be about 22.7 kilograms per acre per year within 0.5 kilometer of the cooling towers and approximately 4.5 kilograms per acre per year within 1 kilometer from the cooling tower. At 2 kilometers, the predicted solids deposition is calculated to be about 2.2 kilograms per acre per year.



BB-3
BC-9

Figure 4-2. K-Reactor Recirculating Tower, Total Solids Deposition, Kilograms/Acre-Year

Noise

The operation of K-Reactor with recirculating cooling towers would cause
increases in noise levels. Cooling-tower noise would consist of fan noise and
3C-9 falling water. Beyond approximately 152 meters from the cooling tower,
average sound levels would be below 70 decibels. [Continuous exposure to 70
decibels or less has been determined to cause no loss of hearing (EPA, 1974).]

Ecology

Vegetation and Wetlands

Vegetation near the recirculating cooling towers would not receive adverse
impacts by cooling-tower drift. Operation of the towers would result in an
3C-9 estimated total solids deposition of about 2.2 kilograms per acre per year at
:-19 2 kilometers and about 22.7 kilograms per acre per year within 0.5 kilometer
3D-3 of the cooling towers. Because these rates would be much less than the
critical values reported (see Section 4.1.1.2), no significant impacts on
vegetation should occur with this alternative.

K-Reactor operations have affected about 670 acres of wetlands in the floodplain and swamp (Du Pont, 1985b; Appendix F). Operation of recirculating cooling towers would reduce the rate of growth of the delta. Reestablishment of vegetation through the process of natural succession would occur for approximately 500 acres of wetland habitat along the creek corridor and swamp.

To assist in ongoing consultations with FWS, a HEP analysis (Mackey et al.,
:-3 1987) was conducted; it identified the value of habitat to be gained or lost
with the recirculating cooling-tower alternative (see Section 4.6 and
Appendix C for more details on HEP analysis).

Aquatic Habitat and Biota

Balanced communities containing all indigenous species in all biotic
categories should develop and remain in all natural portions of the Pen Branch
ecosystem following implementation of a recirculating cooling-tower system for
K-Reactor. Predicted maximum water temperatures in the immediate discharge
area would not exceed 30°C and, therefore, would be below the maximum of
32.2°C required for Class B waters of the State. However, the other
temperature criterion for Class B waters (maximum ΔT of 2.8°C) would be
exceeded at times in the immediate discharge area and to a decreasing extent
as far downstream as the Pen Branch delta (the beginning of the swamp; see
3-3 Appendix B, Table B-5). Accordingly, a Section 316(a) Demonstration would be
:-4 conducted for NPDES compliance after the cooling-tower system becomes
operational. In addition to temperature mitigation, flow in the creek system
would be reduced to levels typical of small streams in the SRP region; these
levels would be conducive to recolonization by habitat formers,
macroinvertebrates, and fish (Du Pont, 1987).

To compare and assess environmental impacts to the Pen Branch watershed before and after operation of the recirculating cooling-tower system, the stream system has been divided into three reaches based on the presence of three distinct stream gradients: Reach 1 extends from the K-Reactor outlet down to SRP Road A, Reach 2 extends from SRP Road A to the mouth of the Pen Branch delta, and Reach 3 extends from the delta to the Savannah River.

Conditions for all biotic categories would be enhanced greatly following the implementation of this alternative in comparison to present conditions. Based on extensive data from Steel Creek, which had been impacted previously, recolonization of areas within the Pen Branch system that are presently uninhabitable because of excessive temperatures and flows would occur rapidly. Furthermore, an analysis of the temperature and flow requirements of the representative and important species indigenous to the creek system has revealed that these species should not be affected adversely by the slightly higher-than-ambient temperatures and lower flows resulting from K-Reactor operation following implementation of the recirculating cooling-tower system (Du Pont, 1987).

The Pen Branch system, which includes Pen Branch and Indian Grave Branch, is a low potential impact area for phytoplankton. The food base throughout this system consists of detrital material rather than phytoplankton, which is typical in lotic systems. Primary producers in the Pen Branch system consist primarily of periphyton and macrophytes (Du Pont, 1987).

Following implementation of a recirculating cooling-tower system, a zooplankton community would become established in the study area; this community would not be affected adversely by the operation of K-Reactor. This newly established community would provide food for the establishment of balanced indigenous macroinvertebrate and fish communities. The maximum BB-3
predicted temperatures in the Pen Branch system would be within the range BC-9
tolerated by most, if not all, indigenous species; accordingly, the heated discharge should cause no appreciable harm to the zooplankton community. The standing crop of zooplankton should be enhanced by the relatively slight temperature elevation and species composition and community structure should be similar to those of the Pen Branch system before SRP operation and to those of other natural streams in the region. The heated discharge is not likely to alter the standing crop, community structure, or seasonal periodicity of zooplankton in the farfield study area from those values typical of the receiving water body segment before reactor operation. Furthermore, cooling-tower blowdown flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

The habitat-formers community should improve significantly with the addition of a recirculating cooling-tower system to K-Reactor. Following the cessation of L-Reactor thermal discharges in 1968 and the resultant reduction in both temperature and flow to Steel Creek, habitat formers along the stream corridor and on its delta began to improve immediately. Similarly, when temperature and flow to Beaver Dam Creek were reduced in the late 1970s, wetlands in the creek's delta in the Savannah River swamp began to improve. Both of these areas now have a mosaic of herbaceous persistent and nonpersistent marsh and scrub-shrub wetlands that directly and indirectly support diverse biological communities (Du Pont, 1987).

The heated discharge from recirculating cooling towers at K-Reactor would not result in any deterioration of the habitat-formers community, or in any appreciable harm to the balanced indigenous population in Pen Branch or the

Pen Branch delta region of the Savannah River swamp. Reach 1 (Indian Grave Branch) of the Pen Branch system is in a steeper, higher gradient stream valley; accordingly, macrophyte and other habitat formers would not be as likely to develop. Reaches 2 and 3 are at a lower gradient and are more open; thus, habitat-former communities would be more evident (Du Pont, 1987).

Following implementation of a recirculating cooling-tower system, reactor discharges would be reduced from approximately 11.3 cubic meters per second to about 1.1 cubic meters per second. This discharge, combined with the natural stream discharge, would result in a total discharge of 1.13 cubic meters per second. The reduced discharge would result in substantial reductions in stream width, depth, and water velocity in comparison to present conditions. Reduced water velocities would decrease the erosion rate of the stream channel in Reaches 1 and 2 and would be more conducive to the retention of logs and other organic debris in the stream channel, which provide structure for aquatic macroinvertebrates. Lower stream temperatures, coupled with reduced stream velocities, would permit the invasion of aquatic macrophytes into the stream channel, and would also permit the establishment of riparian vegetation in what is presently the high water channel of Pen Branch. Aquatic habitat in the delta (Reach 3) should differ somewhat from that in Reaches 1 and 2. At present, water flows through the delta in a series of shallow braided channels. With reduced discharge, most of the flow should follow the path of the original stream channel, but some water could flow through one or two of the deeper side channels that have been cut through the delta. This, coupled with the more gradual stream gradient of the delta, would probably result in lower velocities than would exist in Reaches 1 and 2. The delta area should
BB-3 provide prime habitat for many species of aquatic and semiaquatic macrophytes,
BC-9 which in turn would provide habitat for species of macroinvertebrates that prefer slow-moving streams and dense stands of macrophytes.

At present, the macroinvertebrate community of the thermally impacted portion of Pen Branch is dominated by thermally tolerant chironomids and nematodes (Du Pont, 1987). Following implementation of the recirculating alternative, a diverse and productive community should develop. This newly established community would provide food necessary for the establishment of a balanced indigenous fish community.

The species composition of the Pen Branch corridor (Reaches 1 and 2) should be somewhat similar to that of the unimpacted headwaters portion of Pen Branch, although differences would exist due to a more open canopy and to greater stream discharge volumes from K-Reactor operations. Increased light availability would result in a system that is more autochthonous. Thus, macroinvertebrate species that utilize periphyton or macrophytes as food would be more abundant. Scrapers (such as snails and beetles), as well as collector-gatherers and collector-filterers (such as mayflies) that feed on particulate organic matter, should be more abundant downstream from the reactor outfall. As macrophyte beds become established, macroinvertebrate species that are commonly associated with macrophyte beds, such as scuds, water mites, beetles, and aquatic bugs (Hemiptera) would increase in abundance. Numerically, however, the chironomids should continue to dominate the macroinvertebrate community of the Pen Branch corridor, as they do in most southeastern streams. The dominant chironomid taxa, however, would shift, with the more thermally tolerant species being replaced by other species that are less thermally tolerant (Du Pont, 1987).

The macroinvertebrate community of Reach 3 would differ from that of Reaches 1 and 2 due to habitat differences (i.e., current velocity and stream sediment) that occur where the stream enters the delta. The macroinvertebrate community of Reach 3, through succession, eventually should resemble that of the recovering Steel Creek delta. Species expected to be most abundant in the delta would include snails, scuds, water mites, many species of odonates, coleopterans, hemipterans, and several chironomid genera. The chironomids should dominate numerically, although other groups, such as snails and amphipods, could be more important with respect to biomass.

A recirculating cooling-tower system would improve the thermal regime of Pen Branch over existing conditions. With this system, the maximum predicted summer temperatures in the three reaches of the stream would be 30°C, 29°C, and 29°C, respectively (see Appendix B, Table B-5). These temperatures are within the range tolerated by most, if not all, indigenous species, because ambient summer water temperatures in many southeastern streams equal or exceed these values. Maximum average monthly ΔT for the three reaches would be 6°C, 4°C, and 5°C, respectively. Although the increases in temperatures could result in the earlier emergence of some species, no significant adverse impacts should occur, and the potential for cold shock would not exist during reactor outages in the winter. Thus, the cooling-tower blowdown should cause no appreciable harm to the macroinvertebrate community of Pen Branch.

However, the standing crop of macroinvertebrates in Pen Branch should be enhanced by the relatively slight elevation in temperature, due in part to an expected increase in the standing crop of periphyton and heterotrophs, which BB-3
would provide more food for many species of macroinvertebrates. In addition, BC-9
the slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate community.

The cooling-tower blowdown flow should not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperature of the flow is less than the upper thermal limits of most macroinvertebrate species indigenous to the area. No farfield impacts should occur, because the water is essentially at ambient temperature by the time it enters Steel Creek.

The fish community in upper Pen Branch above K-Reactor should not change substantially from present conditions because the fish communities in the upper reaches of SRP tributary streams appear to be stable and not affected significantly by reactor operations (Du Pont, 1987). One major difference caused by cooling-tower operation could enhance the fish community in this portion of the stream system. Water temperatures at the confluence of Indian Grave Branch and Pen Branch would never exceed 30°C and the average monthly ΔT would not exceed 6°C. Thus, water temperature should no longer inhibit the movement of fish between the Savannah River and the headwaters of Pen Branch. This could result in additional spawning in the upper reaches and would provide a pathway for immature fishes spawned in the upper reaches to contribute to the populations in Reaches 1, 2, and 3 of Pen Branch below K-Reactor and in the Savannah River.

Following implementation of the recirculating cooling-tower alternative, a temperature-restricted zone of passage in Reach 1 should no longer exist. Flow would be reduced during reactor operation because cooling water discharge would decline from about 11.3 cubic meters per second to about 1 cubic meter per second. These changes would allow fish to reinvade this section of the stream system, and would provide spawning and nursery areas for some species.

Maximum absolute temperatures in Reach 2 would not exceed 29°C and average monthly ΔT values would not exceed 4°C throughout the year. Together with reduced flow, this factor would allow indigenous fish species to inhabit Reach 2. Some areas of Reach 2 should be suitable for spawning, thereby increasing fish populations. Furthermore, the addition of slightly heated and relatively nutrient-rich Savannah River water to Pen Branch via the cooling-tower blowdown could increase primary and secondary production in this area. The result would be an enhancement of fish growth in this portion of the creek in comparison to expected fish growth under ambient conditions.

All of Reach 3 should be suitable habitat for all indigenous fishes of the Pen Branch system. Maximum temperatures would not exceed 29°C and average monthly ΔT would not exceed 5°C. Reactor operation should have no adverse impact on reproduction. Growth should be enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the system. The areal extent of
BB-3 aquatic habitat should be reduced from the present situation because of the
BC-9 reduced flows (present discharge of 11.3 cubic meters per second versus cooling-tower blowdown plus auxiliary system flows of 1 cubic meter per second). However, the system would more closely resemble ambient conditions.

The absolute maximum predicted water temperature at the cooling-tower discharge point would be 30°C (see Appendix B, Table B-5) and the maximum predicted average monthly temperature would be 27°C. In contrast, the upper incipient lethal temperatures for representative and important species (largemouth bass, bluegill, and catfish) are in the mid- to upper 30s°C. The cooling-tower system would comply with the temperature shock limits proposed by EPA for the protection of all warm-water fishes (EPA, 1977). Laboratory studies have shown these limits to be protective of the temperature tolerance limits of largemouth bass, bluegill, and channel catfish (Wilde, 1987; Storms, 1985). Reproductive success and growth of all indigenous fish species would be improved over present conditions by this mitigation plan; growth should be enhanced even above potential ambient temperature levels because the slight warming from the tower blowdown would result in optimal growth temperatures for more of the year than with ambient conditions. Maximal absolute temperatures (30°C) and maximum average monthly ΔT values (6°C) should not block fish migration. Thus, the entire Pen Branch system would be available for fish habitation; the free movement of fishes between the headwaters of Pen Branch and the Savannah River should not be inhibited by K-Reactor operations at any time during the year. The thermal discharge flow would not block fish migration or exclude fish from any part of the ecosystem.

Entrainment and Impingement

BD-5 The operation of recirculating cooling towers for K-Reactor would reduce the requirements for cooling water withdrawal from about 11.3 to about 1.6 cubic meters per second. The rates of entrainment of fish eggs and larvae into a cooling water system are directly proportional to the flow rate through that system. Because the flow requirements of recirculating towers would be about 14.5 percent of current levels, entrainment losses would be reduced proportionally. The estimated annual entrainment losses of fish larvae from operating recirculating cooling towers for K-Reactor would decline from an average of about 8.8×10^6 with current operations to about 1.3×10^6 individuals; annual losses of fish eggs would decline from an average of about 4.6×10^6 to about 6.7×10^5 individuals (DOE, 1987). The taxonomic groups benefiting from these reductions would be the clupeids (principally the American shad), the centrarchids, and the cyprinids.

The rate at which fish are impinged on the SRP intake screens is related not only to intake flow rates, but also to such factors as river water level, water temperature, and the density of fish species in the intake canal (Du Pont, 1985b). Assuming that the rates of impingement are proportional to intake flow rates, the impingement loss with a recirculating cooling-tower system would be about 14.5 percent of current levels. The 1983-1985 investigations conducted at the 1G and 3G intakes projected the impingement of 2942 annually on the screens as a result of K-Reactor operation (DOE, 1987). The operation of recirculating cooling towers would reduce this number to about 427 individuals annually. This reduction would most benefit the bluespotted sunfish, threadfin shad, gizzard shad, redbreast sunfish, and warmouth, which are the species now impinged in greatest numbers at the intakes. BD-5

Threatened and Endangered Species

Implementation of this alternative would result in a reduction of the effluent discharge from 11.3 to about 1 cubic meter per second; this would allow the stream channel to revert approximately to its original width, and would allow fish and invertebrates to inhabit the stream channel. It would also create foraging habitat for the endangered wood stork and provide potential habitat for the American alligator. Because of the reduced flow rate, nests, eggs, and hibernation sites of the American alligator should not be impacted. BB-3

Formal consultations were held between DOE and the FWS to comply with the Endangered Species Act of 1973. Based on these consultations, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986). TC

Radiological Releases

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age-group.

Remobilization of Radionuclides

The operation of the recirculating cooling towers would reduce the flow rate of cooling water in Indian Grave Branch and Pen Branch and, therefore, would decrease the amount of radionuclides being remobilized from the creek bed and BC-22

BC-22 transported to the Savannah River. The primary radionuclide contained in Pen Branch sediments is cesium-137 (Appendix D). The reduced flow in Pen Branch would result in a decrease of about 0.12 curie of cesium-137 released annually to the Savannah River.

Maximum Individual Dose - The individual who would experience the greatest change in dose from cesium remobilization is assumed to live near the Savannah River downstream from the SRP. This individual is assumed to use river water regularly for drinking, to consume fish from the river, and to experience external exposures from shoreline activities. This individual is also assumed to drink more water and eat more fish than an average person.

Table 4-8 lists the changes in effective-whole-body and most-affected-organ (gonads) doses to the maximally exposed individual resulting from the decrease in cesium-137 released to the Savannah River.

BC-22

Table 4-8. Decrease in Doses to Maximally Exposed Individual Resulting from Cesium Redistribution Associated with K-Reactor Recirculating Cooling Towers

	Incremental dose reduction (mrem/yr)	
Age group	Effective whole body	Gonads[a]
Adult	6.88×10^{-2}	6.88×10^{-2}
Teen	5.27×10^{-2}	5.27×10^{-2}
Child	2.29×10^{-2}	2.29×10^{-2}
Infant	2.21×10^{-4}	2.21×10^{-4}

a. Dose to gonads is directly comparable to soft-tissue doses resulting from tritium, because tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

Population Dose - Table 4-9 lists the decreases in the collective doses delivered to the affected population groups.

Tritium Releases

The following sections discuss changes in the doses to the maximally exposed individual at the SRP boundary and to offsite population groups (based on year 2000 projections) that are attributable to changes in atmospheric and liquid releases to Indian Grave Branch and Pen Branch of tritium resulting from the operation of recirculating cooling towers.

Atmospheric Releases - The amount of tritium released annually to the atmosphere is expected to increase by 425 curies (about 0.1 percent of total SRP releases of tritium to the atmosphere) as a result of evaporation of

Table 4-9. Decrease in Collective Effective Whole-Body Dose Resulting from Cesium Redistribution Associated with K-Reactor Recirculating Cooling Towers

Population group	Incremental collective dose reduction (person-rem/yr)
80-km population	1.91×10^{-1}
Beaufort-Jasper	1.05×10^{-2}
Port Wentworth	3.81×10^{-2}
Total	2.40×10^{-1}

BC-22

cooling water. This would increase the atmospheric dose commitments of the regional population and the maximally exposed individual. Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below. TE

Maximum Individual Dose - The individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is at the same location described in Section 4.1.1.2. BC-22

Table 4-10 summarizes the annual increases in soft-tissue and effective whole-body doses received by the maximally exposed individual due to the atmospheric release of tritium.

Table 4-10. Increase in Annual Dose to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Recirculating Cooling Towers

	Incremental dose increase (mrem/yr)	
Age group	Effective whole body	All soft tissues[a]
Adult	8.92×10^{-4}	1.05×10^{-3}
Teen	9.65×10^{-4}	1.13×10^{-3}
Child	6.69×10^{-4}	7.87×10^{-4}
Infant	1.98×10^{-4}	2.32×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

BC-22

Population Dose - Collective doses resulting from atmospheric releases associated with this cooling alternative are calculated for the population within 80 kilometers of the SRP. The annual collective effective whole-body dose to this population would increase by 4.22×10^{-2} person-rem as a result of the increase in tritium released to the atmosphere.

Liquid Releases - The operation of this cooling alternative would reduce the amount of tritium released to the stream by 425 curies per year (about 1 percent of the total SRP releases of tritium to streams) as a result of evaporation of cooling water. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

BC-22

Maximum Individual Dose - The hypothetical individual who would experience the greatest change in dose from liquid effluents is the same as that described earlier in Section 4.1.1.2.

Table 4-11 summarizes the annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual due to a decrease in the liquid release of tritium.

Table 4-11. Decrease in Annual Dose to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from K-Reactor Recirculating Cooling Towers

	Incremental dose reduction (mrem/yr)	
Age group	Effective whole-body	All soft tissues[a]
Adult	1.85×10^{-3}	2.18×10^{-3}
Teen	1.31×10^{-3}	1.53×10^{-3}
Child	1.27×10^{-3}	1.50×10^{-3}
Infant	8.06×10^{-4}	9.48×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

Population Dose - The decrease in the collective effective whole-body dose within 80 kilometers of the Savannah River Plant from reduced liquid releases of tritium associated with this cooling alternative would be 2.09×10^{-4} person-rem per year (Table 4-12).

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The decrease in the collective effective whole-body dose delivered to the Beaufort-Jasper and Port Wentworth population groups who use the Savannah River as a source of potable water (about 317,000) from tritium in drinking water would be 2.78×10^{-1} person-rem per year, as presented in Table 4-12.

Table 4-12. Decrease in Collective Effective Whole-Body Dose Resulting from Liquid Releases of Tritium from K-Reactor Recirculating Cooling Towers

Population group	Incremental collective dose reduction (person-rem/ea. yr)
80-km radius	2.09×10^{-4}
Beaufort-Jasper	9.58×10^{-2}
Port Wentworth	1.82×10^{-1}
Total	2.78×10^{-1}

Overall Changes in Offsite Doses

Table 4-13 summarizes changes in the effective whole-body and the most-affected-organ doses received by the maximally exposed individual resulting from the operation of this cooling alternative. Table 4-14 lists changes in the annual collective effective whole-body dose. BC-22

The average background total-body dose to an individual living in the vicinity of the Savannah River Plant is 93 millirem per year. By extrapolation, the annual collective total-body dose to the 80-kilometer population is 79,200 person-rem; to the Port Wentworth water users, it is 18,600 person-rem; and to the Beaufort-Jasper water users, 10,900 person-rem. This cooling alternative would reduce the annual effective whole-body dose to the maximally exposed adult by 6.98×10^{-2} millirem, and the collective effective whole-body dose to the 80-kilometer population and the Port Wentworth and Beaufort-Jasper water users by 1.49×10^{-1}, 2.20×10^{-1}, and 1.06×10^{-1} person-rem per year, respectively. These changes are very small in comparison to year-to-year variations in natural background radiation. BC-22

Present SRP operations result in an effective whole-body dose of 5.18×10^{-2} millirem per year to the maximally exposed adult from tritium releases to the Savannah River from Indian Grave Branch and Pen Branch. This alternative would reduce the liquid tritium dose by 1.85×10^{-3} millirem per year and increase the atmospheric tritium dose by 8.92×10^{-4} millirem per year, resulting in an overall reduction of 9.58×10^{-4} millirem per year. Similarly, the current effective whole-body dose to the maximally exposed adult from cesium releases is 8.03×10^{-2} millirem per year. This alternative would reduce this dose by 6.88×10^{-2} millirem per year.

Health Effects

BC-22

Using the cancer and genetic damage risk estimators discussed above and the organ doses presented in Appendix G, the population within 80 kilometers of the Savannah River Plant could experience a decrease of 1.11×10^{-5} cancer

Table 4-13. Changes in Effective Whole-Body and Gonadal Doses Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Recirculating Cooling Towers (millirem per year)

Source of exposure	Adult	Teen	Child	Infant
		EFFECTIVE WHOLE-BODY DOSE INCREMENT		
Atmospheric tritium releases[a]	8.92×10^{-4}	9.65×10^{-4}	6.69×10^{-4}	1.98×10^{-4}
Liquid tritium releases[a]	-1.85×10^{-3}[b]	-1.31×10^{-3}	-1.27×10^{-3}	-8.06×10^{-4}
Cesium transport	-6.88×10^{-2}	-5.27×10^{-2}	-2.29×10^{-2}	-2.21×10^{-4}
Net dose change	-6.98×10^{-2}	-5.30×10^{-2}	-2.35×10^{-2}	-8.29×10^{-4}
		GONADAL DOSE INCREMENT[c]		
Atmospheric tritium releases[a]	1.05×10^{-3}	1.13×10^{-3}	7.87×10^{-4}	2.32×10^{-4}
Liquid tritium releases[a]	-2.18×10^{-3}	-1.53×10^{-3}	-1.50×10^{-3}	-9.48×10^{-4}
Cesium transport	-6.88×10^{-2}	-5.27×10^{-2}	-2.29×10^{-2}	-2.21×10^{-4}
Net dose change	-6.99×10^{-2}	-5.31×10^{-2}	-2.36×10^{-2}	-9.37×10^{-4}

a. Tritium imparts a dose to soft tissues about 18 percent higher than to the effective whole body.
b. Negative sign preceding number denotes a decrease in dose.
c. Gonadal dose is directly comparable to soft-tissue doses resulting from tritium, because tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

BC-22 fatality and 3.66×10^{-5} genetic disorder per year from the operation of this system. The populations at Beaufort-Jasper and Port Wentworth downstream from the SRP could experience decreases of 3.67×10^{-5} fatal cancer and 9.65×10^{-5} genetic disorder per year. Table 4-15 summarizes this information.

4.1.3 NO ACTION - EXISTING SYSTEM

The no-action alternative for K-Reactor would maintain the existing once-through cooling water system that withdraws water from the Savannah River and discharges it into Pen Branch via Indian Grave Branch. Chapter 3 and Appendix C describe the environmental baseline conditions that are associated with this system. This section summarizes the major environmental impacts of the existing system.

Table 4-14. Changes in Collective Effective Whole-Body Dose Resulting from Operation of K-Reactor Recirculating Cooling Towers (person-rem per year)

Source of exposure	80-kilometer population	Beaufort Jasper	Port Wentworth	Total
Atmospheric tritium releases	4.22×10^{-2}	-	-	4.22×10^{-2}
Liquid tritium releases	-2.09×10^{-4}[a]	-9.58×10^{-2}	-1.82×10^{-1}	-2.78×10^{-1}
Cesium transport	-1.91×10^{-1}	-1.05×10^{-2}	-3.81×10^{-2}	-2.40×10^{-1}
Net dose change	-1.49×10^{-1}	-1.06×10^{-1}	-2.20×10^{-1}	-4.76×10^{-1}

a. Negative sign denotes a decrease in dose.

BC-22

Table 4-15. Changes in Annual Health Effects

Population group	Genetic disorders	Fatal cancers
80-kilometer radius	-3.66×10^{-5}	-1.11×10^{-5}
Beaufort-Jasper	-3.17×10^{-5}	-1.21×10^{-5}
Port Wentworth	-6.48×10^{-5}	-2.46×10^{-5}
Total	-1.33×10^{-4}	-4.78×10^{-5}

4.1.3.1 Water Quality and Hydrology

The average flow in Pen Branch when K-Reactor is operating would continue to be about 11.3 cubic meters per second in excess of the natural stream flow of 0.03 cubic meter per second. BC-22

Maximum water temperatures of the discharge would reach 73°C during extreme summer conditions with water temperatures at the delta about 52°C; ambient stream temperatures would be 33°C. Under average winter conditions, temperatures along Pen Branch would range from 66°C at the discharge point to 43°C in the delta. These conditions would be present only when K-Reactor was in operation. The continuation of the existing cooling water discharge from K-Reactor would not comply with South Carolina Class B water classification standards.

Dissolved oxygen concentrations would continue to be depressed in Indian Grave Branch and Pen Branch during reactor operations because of the elevated water temperatures. Concentrations in Indian Grave Branch just below the reactor discharge point would average about 5.4 milligrams per liter. The mean concentration in Pen Branch would be about 5.7 milligrams per liter, with a range of 3.3 to 11.1 milligrams per liter. Values occasionally would fall below minimum state Class B water classification standards (5 milligrams per liter) in both streams.

Generally, nutrient concentrations in the thermal reaches of the two streams would continue to be higher than in nonthermal reaches of the streams, due to inputs of nutrient-rich Savannah River water because of the addition of higher nutrient content Savannah River water.

4.1.3.2 Ecology and Wetlands

The aquatic and terrestrial communities in and along Indian Grave Branch and Pen Branch would continue to be influenced largely by the heated discharges from K-Reactor. Blue-green algal mats would continue to cover much of the sand and silt substrate in Pen Branch. Riparian vegetation would include sedges, grasses, wax myrtle, and buttonbush, while duckweed would be abundant in the many side pools and channels. The delta region of the stream would be
BB-3 characterized by an open and closed canopy of living and dead bald cypress and
BC-19 tupelo. A total of about 670 acres of wetlands would continue to be affected in the Pen Branch floodplain and delta; canopy losses would continue at the rate of about 26 acres per year.

Most aquatic invertebrate species would be absent from Indian Grave Branch and Pen Branch during reactor operations (DOE, 1984). Benthic invertebrate species would be more abundant in the delta area than in the main channel of Pen Branch (Du Pont, 1985b; Appendix C). Resident populations of fish (sunfish, shiners, bullheads, etc.) would be present in the upper reaches of Pen Branch above the confluence with Indian Grave Branch; some spawning could continue (DOE, 1984). No fish would be present in the reaches of the creeks below K-Reactor during discharges of heated effluents; in addition, population numbers would be smaller in the swamp/delta area during reactor operation. Fish would be found in cooler refuge areas along the shoreline of the main thermal channels. The heated discharge water would cause no impact to fish populations in the Savannah River. Ichthyoplankton would continue to be absent or at greatly reduced densities in Pen Branch. In the delta, the dominant ichthyoplankton would be mosquitofish, which are found principally in the cooler refuge areas (DOE, 1984).

TE

Waterfowl use of Pen Branch would continue to be associated primarily with the delta and slough areas where the creek empties into the swamp. These areas, as well as much of the Savannah River swamp near the Plant, would continue to provide foraging habitat for migratory species during fall and winter.

4.1.3.3 Entrainment and Impingement

BB-3

No action would result in the continued loss of an average 8.8×10^6 fish larvae and 4.6×10^6 fish eggs each year (DOE, 1987). The principal taxa entrained as larvae would be expected to be the clupeids (shad, herring, etc.), the centrarchs (crappie, sunfish, etc.), and the cyprinids (carp, etc.). The eggs of the American shad and the striped bass would be entrained most often.

The estimated average impingement on the intake screens of the 1G and 3G pumphouses (which provide cooling water to K- and C-Reactors) would be about 5885 fish per year, half (2942 fish) of which would be attributed to K-Reactor, based on 1983-1985 investigations (DOE, 1987). The principal species would be bluespotted sunfish and threadfin shad; gizzard shad, redbreast sunfish, and warmouth would also be impinged frequently. BB-3 BD-5

4.1.3.4 Threatened and Endangered Species

Although temperatures in the thermal affected areas of Indian Grave Branch and Pen Branch would exceed the critical thermal maximum for the American alligator, a few individuals could occupy cooler refuges along the margins of the creeks and delta (DOE, 1984). The wood stork should not inhabit Pen Branch during reactor operations because the habitat would not be suitable for foraging; however, wood stork have been observed during periods of extended reactor shutdowns. BB-3

4.2 ALTERNATIVES FOR C-REACTOR

The cooling water alternatives for C-Reactor are identical to those for K-Reactor (i.e., a once-through cooling tower, recirculating cooling towers, and no action). In many instances, the expected environmental consequences resulting from construction and operation of the alternatives are identical or similar. The following sections describe expected environmental consequences of the alternatives for C-Reactor that differ from those expected for K-Reactor. TE

4.2.1 ONCE-THROUGH COOLING TOWER

As discussed for K-Reactor, design evaluations and studies were performed to optimize the performance and achieve cost savings in the construction and operation of once-through cooling towers without introducing major changes in the nature or magnitude of environmental impacts. The following discussion emphasizes differences between the construction and operational impacts of cooling-water alternatives for K- and C-Reactors. TC TE

4.2.1.1 Construction Impacts

Socioeconomics

The construction of a once-through cooling tower for C-Reactor would be accomplished in approximately 36 months, after a 9-month lead design period. Construction could involve a combined workforce for the towers in both K- and C-Areas. The estimated peak construction work for C-Reactor alone is 200 persons. TC TE

Historic and Archaeological Resources

The most recent archaeological and historic resources survey of the Four Mile Creek watershed area was conducted from May through August 1984, as described in Appendix E; this survey located 25 sites in the watershed. The implementation of the once-through cooling-tower alternative would disturb only one site (38BR548) in the Four Mile Creek area. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No impact mitigation has been recommended for this site, because the potential yield of additional research information is negligible.

Water Quality

The water quality impacts from construction of a once-through cooling tower for C-Reactor would be the same as those described for K-Reactor (Section 4.1.1.1).

Ecology

TC For a once-through cooling tower with gravity feed, approximately 35 acres of existing habitat would be disturbed by construction. Most of the affected habitat lies north of SRP Road 3 and is characterized by dense shrub, intermixed with pine 4 meters tall. The area south of SRP Road 3 contains mixed pine and hardwood forest with a sparse understory. No effects are expected on vegetation outside the immediate construction area. The effluent canal from the cooling tower to Castor Creek would require the removal of about 0.5 acre of bottomland hardwoods consisting mainly of sweet gum and yellow poplar.

The potential effects on fish and wildlife from the construction of a once-through cooling-tower system would be similar to those associated with K-Reactor (see "Ecology" in Section 4.1.1.1).

Radiological Releases

During the construction of the once-through cooling tower, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Four Mile Creek would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the stream bed and, consequently, radiation doses to the offsite population would not change.

TC As discussed in Section 4.1.1.1, construction personnel for the tower would experience levels of radiation slightly elevated above background from the operation of Plant facilities, which is estimated to be approximately 20 millirem per year.

Other Construction Impacts

Other construction impacts would be similar to those described for K-Reactor (i.e., air quality, noise, solid waste, and onsite construction personnel exposure to radioactive releases). All applicable atmospheric emission standards would be met during construction, solid waste generated from construction would be disposed of in an approved manner, and fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.