3 AFFECTED ENVIRONMENT

This chapter describes the environment affected by the resumption of L-Reactor operations. Major emphasis is placed on those areas that past operations have shown to have the greatest potential for being affected (e.g., Steel Creek, the swamp, and the Savannah River).

3.1 SITE LOCATION, SITE DESCRIPTION AND LAND USE, AND HISTORIC AND ARCHEOLOGICAL RESOURCES

3.1.1 Site location

The site of the L-Reactor is on the Savannah River Plant (SRP) in southwestern South Carolina. The Savannah River Plant occupies an approximately circular area of about 800 square kilometers. Augusta, Georgia, is about 37 kilometers northwest; Aiken, South Carolina, is about 27 kilometers north; Barnwell, South Carolina, is about 10 kilometers east; and Columbia, South Carolina, is about 93 kilometers northeast (Figure 3-1).

The L-Reactor site is located in the south-central portion of the Savannah River Plant (Figure 3-2). Three small South Carolina towns, Snelling (population 111), Jackson (1771), and New Ellenton (2628), and the City of Barnwell (5572) lie within 25 kilometers of L-Reactor. Chem-Nuclear Services, Inc., and the Barnwell Nuclear Fuel Plant, which is owned by Allied-General Nuclear Services, are about 25 kilometers east of L-Reactor, and the Vogtle Nuclear Power Plant is approximately 15 kilometers to the west-southwest.

3.1.2 Site description and land use

The U.S. Department of Energy, formerly the Atomic Energy Commission, selected the location of the Savannah River Plant in November 1950 after studying more than 100 potential sites. Factors in the selection of the site included the low population density, the accessibility of a large cooling-water supply, and the freedom from floods and major storms. The Savannah River Plant was the largest construction job undertaken by the Atomic Energy Commission. Construction began in February 1951, and it eventually involved more than $1 billion in expenditures and a peak construction force of 39,000 workers.

Uranium fuel fabrication began in M-Area and extraction of heavy water (D_2O) began in D-Area in 1952. The first production reactor (R) began operation in December 1953. Other production reactors began operation in February 1954 (P), July 1954 (L), November 1954 (K), and March 1955 (C). Reactors were placed in standby in June 1964 (R), and February 1968 (L).

Another site, at the confluence of Steel Creek and Meyers Branch, could be eligible for nomination to the National Register. It could yield important data on relatively uninterrupted prehistoric occupation that began in the Early Archaic (9500-7500 B.C.) and continued through the Mississippian Period (1000-1700 A.D.). A 1961 aerial photographic study of high-water levels in the Steel Creek floodplain and physical inspection of the terrace edge did not reveal any erosion due to flooding of the Steel Creek-Meyers Branch system when the Steel Creek-Meyers Branch system was previously receiving cooling water discharges from P- and L-Reactors.

3.2 SOCIOECONOMIC AND COMMUNITY CHARACTERISTICS

In June 1980, approximately 97 percent of the 9100 SRP employees resided in a 13-county area surrounding the Savannah River Plant (Figure 3-4). The greatest concentrations resided in the six-county area of Aiken, Allendale, Bamberg, and Barnwell Counties in South Carolina, and Columbia and Richmond Counties in Georgia.

Table 3-1 lists the 1980 populations for counties and major communities in this area. Over the last three decades, the rate of population growth has varied significantly from county to county. From 1950 to 1980, the presently urbanized counties--Aiken, Columbia, and Richmond--experienced a positive growth rate; the combined annual average rate was about 3 percent. The most significant population increases occurred in Columbia County, where the average growth rate between 1960 and 1980 was about 10 percent per year. The rural counties--Allendale, Bamberg, and Barnwell--had net population declines between 1950 and 1970; they experienced significant reversals of this trend between 1970 and 1980, when their population increases ranged from 9 to 16 percent.

Since 1970, the greatest rates of increase in the number of housing units have occurred in Columbia, Aiken, and Richmond Counties. Columbia County has grown the fastest, nearly doubling its number of housing units. Between 1970 and 1980, Aiken and Richmond Counties each experienced an approximate 36-percent increase in the number of housing units. In Aiken County, half of this increase resulted from the high growth rate in the number of mobile homes.

In the six-county area, public services and facilities can be described as adequate for the existing populations. All school districts, except Allendale, reported available classroom space. All public water systems except the Pine Hill System in Richmond County, Georgia, have the capacity to accommodate new users; this system does not draw from the Savannah River. Most municipal and county wastewater-treatment systems have the capacity to treat additional sewage. Selected rural municipalities in Allendale, Bamberg, and Barnwell Counties and the City of Augusta in Richmond County are experiencing problems in treatment-plant capacities. Programs to upgrade facilities are under way or planned in most of these areas.

All the counties except Allendale have active civil defense departments and State-approved emergency preparedness plans. In addition, the Savannah River Plant has service agreements for mutual assistance or special support with Fort Gordon and with Talmadge Hospital in Augusta. The Savannah River Plant also shares fire-fighting support with Allied-General Nuclear Services, the City of Aiken, and the South Carolina Forestry Commission. Memoranda of understanding between the SRP and the States of South Carolina and Georgia cover notifications and emergency responsibilities in the event of an actual or potential radiological emergency at the SRP.

Table 3-1. 1980 populations for counties and communities

Jurisdiction	Population
South Carolina	
Aiken County	105,625
City of Aiken	14,978
City of North Augusta	13,593
Allendale County	10,700
Town of Allendale	4,400
Bamberg County	18,118
City of Bamberg	3,672
City of Denmark	4,434
Barnwell County	19,868
City of Barnwell	5,572
Georgia	
Columbia County	40,118
City of Grovetown	3,491
Richmond County	181,629
City of Augusta	47,532
Total (Georgia & South Carolina)	376,058

Source: Bureau of the Census (1981a,b).

3.3 GEOLOGY AND SEISMOLOGY

Located in the Aiken Plateau physiographic division of the Atlantic Coastal Plain, the L-Reactor site is about 40 kilometers southeast of the fall line that separates the Atlantic Coastal Plain and the Piedmont tectonic province of the Appalachian system. Relief in the region of the L-Reactor site, about 20 meters, is related primarily to stream incision.

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 site. Evidence for the last movement on the Belair Fault is not conclusive (Prowell et al., 1976; Prowell and O'Connor, 1978). The time of the latest movement on the Millet Fault, which is nearly coincident with the southeastern SRP boundary, is not precisely known (Faye and Prowell, 1982). Macroseismicity is not correlated with either the Belair or the Millet Faults. There is no evidence of any recent displacement along any of the other faults within 300 kilometers of the site (DOE, 1982). In addition, no apparent association exists between local seismicity and specific faults, except for the Ashley River and Woodstock Faults and perhaps the Cooke Fault in the meizoseismal area of the 1886 Charleston earthquake, which occurred approximately 145 kilometers from the Savannah River Plant (Talwani, 1982; Behrendt et al., 1981).

Seismological studies indicate that the Savannah River Plant is in an area that could incur moderate damage from earthquakes (Langley and Marter, 1973). Historic records indicate an estimated maximum horizontal ground acceleration in sound bedrock of 11 percent of gravity [a ground-shaking intensity on the Modified Mercalli scale (Langley and Marter, 1973) of MMI = 7.2] could be experienced in the area with a 90-percent probability of not being exceeded within 50 years (Algermissen and Perkins, 1976; O'Brien et al., 1977).

3.4 HYDROLOGY

3.4.1 Surface water

3.4.1.1 Savannah River

The Savannah River Plant is drained almost entirely by the Savannah River, one of the major drainage networks in the southeastern United States (Langley and Marter, 1973). The peak historic flood between 1796 and the present--10,190 cubic meters per second--corresponds to a stage of about 36 meters, which is about 40 meters below the elevation of L-Reactor. Two large reservoirs, Clarks Hill (completed in March 1953, with about 3.1×10^9 cubic meters of storage) and Hartwell (completed in June 1962, with about 3.1×10^9 cubic meters of storage), which are upstream from the Savannah River Plant, provide power, flood control, and recreational areas. These reservoirs and the Savannah Bluff Dam and Lock at Augusta have stabilized the river flow near the Savannah River Plant to a yearly average of about 295 cubic meters per second (Bloxham, 1979). Russell Reservoir, which will begin filling in June 1983, will furnish about 1.2×10^9 cubic meters of storage to further stabilize Savannah River flows. Since 1963, it has been the operating practice of the U.S. Army Corps of Engineers to attempt to maintain a minimum flow of about 173 cubic meters per second below the Savannah Bluff Dam and Lock at Butler Creek to accommodate commercial river traffic.

An extreme value analysis, which followed the procedures outlined by Gringorten (1963), was used to assess low-flow conditions on the river for the 17-year period of record (water years 1963 to 1979). Results of this analysis suggest that a 7-day low flow of approximately 157 cubic meters per second would have a return period of 10 years. Because another 9 to 10 cubic meters per second can be expected to be acquired during low-flow conditions between Augusta and Ellenton Landing (the USGS gauging station at the Savannah River Plant is listed as Jackson at River Mile 156.8), the 7-day, 10-year low flow at the Savannah River Plant is about 166 cubic meters per second.

Figure 3-5 shows the mean monthly flow rates for the Savannah River measured at Augusta for water years 1970 to 1979. Highest flows occur in the winter and spring, and the lowest occur in the summer and fall.

The temperature of the Savannah River below the Clarks Hill Dam, which increases as flow continues downstream, is as much as 8°C below the natural equilibrium temperature in the summer because of the cold-water storage in Clarks Hill Reservoir, about 120 kilometers upstream from the Savannah River Plant (Neill and Babcock, 1971).

In 1980, the average temperature of the Savannah River 3 kilometers above the Savannah River Plant was 18°C with a range of 1.5 to 25°C (du Pont, 1982). Figure 3-6 shows average daily maximum temperatures above and below the Savannah River Plant. June, July, August, and September are the warmest months on the river. Table 3-2 lists the distribution of river temperatures greater than 25.6°C measured at Ellenton Landing (Figure 3-2) from June through September between 1955 and 1978.

Table 3-2. Number of days in 23-year period (June 1, 1955, to September 30, 1978) when maximum temperature of Savannah River near Ellenton Landing, South Carolina, equaled or exceeded upper water-temperature limits

Water temperatures[a]		Month				23-year period
°C	°F	June	July	August	September	Number
25.6	78.0	3	41	80	69	193
25.8	78.5	2	28	73	42	145
26.1	79.0	2	20	57	30	109
26.4	79.5	1	11	42	12	66
26.7	80.0	1	8	39	11	59
26.9	80.5		3	18	4	25
27.2	81.0		1	13	1	15
27.5	81.5			7		7
27.8	82.0			4		4
28.0	82.5			2		2
28.3	83.0			1		1

a. Upper class limits.

3.4.1.2 SRP streams and swamp

Five main stream systems drain the Savannah River Plant. Upper Three Runs Creek is the largest of these and the only one that has not received thermal discharges. Lower Three Runs Creek has the second largest watershed of the SRP streams; in 1958, its headwaters were impounded to form Par Pond for the recirculation of cooling water from P- and R-Reactors. Cooling water from P-Reactor was discharged to Steel Creek until 1963, when it was diverted to Par Pond.

Four Mile Creek receives nonthermal discharges from F- and H-separations areas and thermal discharges from C-Reactor. Pen Branch, which receives thermal discharges from K-Reactor, and Four Mile Creek each currently receives 11 cubic meters per second of discharged cooling water.

The L-Reactor site is drained by both Steel Creek and Pen Branch. The headwaters of Steel Creek rise near P-Area and flow southwesterly for about 7 kilometers, turn south for about 9 kilometers, and enter the Savannah River swamp about 3 to 5 kilometers from the river. A delta of about 150 acres surrounded by a tree-kill zone of another 100 acres (see Figure 3-13--deltaic fan) has developed where the creek enters the swamp (Smith et al., 1981). Beyond the delta, it is joined by flows from Pen Branch and Four Mile Creek before Steel Creek discharges into the Savannah River near Steel Creek Landing.

The expected average natural flow of Steel Creek is about 1.0 cubic meter per second. In addition, the creek receives about 0.4 cubic meter per second of nonheated process water from P-Area. As listed in Table 3-3, Steel Creek has had a varied history with respect to the release of reactor effluents. The release of thermal effluents into Steel Creek from L- and P-Reactors reached a peak of about 23 cubic meters per second in 1961. In 1963, P-Reactor effluents were diverted to Par Pond, and thermal discharges to the creek were reduced to about 11 cubic meters per second. Since 1968, Steel Creek has received only infrequent and short-term inputs of effluents (Smith et al., 1981; du Pont, 1982).

Table 3-4 compares stream characteristics before and after Steel Creek received heated discharges from L- and P-Reactors. Table 3-5 summarizes temperature measurements made on Steel Creek before, during, and after cooling-water discharges. Between 1951 and 1972, the Steel Creek channel width increased by more than five times and the average depth increased by more than 20 percent. The temperature measured in Steel Creek in 1972 was 50 percent higher than in 1951. The loss of vegetative canopy, which increases solar effects, could account for the increase in temperature. The discharge of thermal effluents from reactor operations affected the Steel Creek System and enlarged the streambed.

The three streams that have received the greatest input of thermal effluent (Four Mile Creek, Pen Branch, and Steel Creek) flow into a contiguous swamp of about 7800 acres that is separated from the main flow of the Savannah River by a 3-meter-high natural levee along the river bank. These streams generally flow as shallow sheets, with well-defined channels only where they enter the swamp and near breaches in the levee (Smith et al., 1981). The combined natural flow and reactor effluent discharges have a strong influence on water levels in the swamp during nonflood conditions.

Table 3-3. Reactor discharges to Steel Creek[a]

Years	Discharge (m^3/second)		
	P-Reactor	L-Reactor	Total
1954-1958	5.6	5.7	11.3
1958-early 1961	9.3	9.3	18.6
Mid-1961	11.3	11.3	22.6
Late 1961-late 1963	9.3	11.3	20.6
Late 1963-February 1968	0.4[b]	11.3	11.7
February 1968 to present	0.4[b]	0	0.4[b]

a. Source: du Pont, 1982.
b. Flow from miscellaneous P-Area sources at about ambient temperature.

Table 3-4. Steel Creek stream characteristics[a,b]

Date	Width (m)	Average depth (m)	Mean velocity (m/s)	Flow rate (m^3/s)	Temp (°C)
May 1951	5.1	0.30	0.21	0.59[c]	16.1
June 1972	16.5	0.37	0.12	0.79	24.6

a. Source: du Pont, 1982.
b. Based on measurements taken at Road A.
c. July 1951 determination.

Table 3-5. Typical Steel Creek temperatures (°C)[a]

Location	5/51	6/9/54, P[b]	6/7/55, P,L[b]	8/66, L[b]	10/26/71, None[b]
Steel Creek at L-Reactor	--[c]	38.3	48.4	69.5 (outfall)	--
Steel Creek at Road A	16.1	31.4	37.0	52.5	19.7
Steel Creek at discharge to swamp	--	28.6	33.9	--	19.9

a. Source: du Pont, 1982.
b. Reactors discharging heated water to Steel Creek.
c. Data not available

The flow of water in the swamp is altered when the Savannah River is in flood stage (28 meters) with a flow rate of about 440 cubic meters per second. Under flooding conditions, Four Mile Creek, Pen Branch, and Steel Creek discharge to the Savannah River at Little Hell Landing after crossing an offsite swamp (Figure 3-2). Flooding of the swamp occurs approximately 23 percent of the time, predominantly from January through April (Langley and Marter, 1973).

3.4.1.3 Surface water use

Downstream from Augusta, Georgia, the Savannah River is a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and--after treatment--domestic use. The river upstream from the Savannah River Plant supplies municipal water for Augusta, Georgia, and North Augusta, South Carolina. Downstream, the Beaufort-Jasper Water Authority (River Mile 39.2) in South Carolina withdraws about 19,700 cubic meters per day (0.23 cubic meter per second) to supply domestic water for a population of about 51,000. The Cherokee Hill Water Treatment Plant (River Mile 29.0) at Port Wentworth, Georgia, withdraws about 116,600 cubic meters per day (1.35 cubic meters per second) to supply a business-industrial complex near Savannah that has an estimated consumer population of about 20,000 (du Pont, 1982).

The Savannah River Plant currently withdraws a maximum of 26 cubic meters per second from the river, primarily for use as once-through cooling water in nuclear reactors and coal-fired power plants (du Pont, 1982). Most of this water returns to the river via the SRP streams. The river receives sewage treatment effluents from Augusta, Georgia, and North Augusta, Aiken, and Horse Creek Valley, South Carolina, and heated water and other waste discharges from the Savannah River Plant via its tributaries. The river is used for recreation, primarily boating and sport fishing. Upstream, recreational uses of the impoundments on the river, including water-contact activities, are more extensive than they are near the Savannah River Plant and downstream. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (du Pont, 1982).

The Savannah River Plant is a major user of river water; it can remove 3.6 million cubic meters of water a day (41.6 cubic meters per second) when all 24 pumps are in use. Currently, a portion of this water is used primarily to cool C- and K-Reactors and to provide makeup cooling water for Par Pond and P-Reactor. Under the worst conditions, the withdrawal of the full 41.6 cubic meters per second would consume about 25 percent of the 7-day, 10-year low flow of 166 cubic meters per second. The withdrawal of the full 41.6 cubic meters per second would be about 14 percent of the average flow of 295 cubic meters per second (McFarlane et al., 1978).

3.4.2 Subsurface hydrology

3.4.2.1 Occurrence of ground water

Three distinct geologic systems underlie the Savannah River Plant: (1) the Coastal Plain sediments, where water occurs in porous sands and clays; (2) the buried crystalline metamorphic beneath the sediments where water occurs in small fractures in schist, gneiss, and quartzite; and (3) the Dunbarton basin (Triassic age) within the crystalline metamorphic complex, where water occurs in intergranular spaces in mudstones and sandstones. The Coastal Plain sediments, which contain several prolific and important aquifers, consist of a wedge of stratified sediments that thickens to the southeast. Near L-Reactor, the sediments are about 300 meters thick and consist of sandy clays and clayey sands. The sandier beds form aquifers and the clayier beds form confining beds. The Coastal Plain sediments consist of the Barnwell (combined with the Hawthorn as one mapping unit) Formation, which is underlain successively by the McBean, Congaree, Ellenton, and Tuscaloosa Formations (Figure 3-7).

In the L-Reactor area, the water table is generally 3 to 12 meters below the ground surface (Figure 3-8). Shallow ground water beneath the L-Reactor area generally moves to the south-southeast in the direction of Steel Creek and to the west-southwest in the direction of Pen Branch.

The Barnwell and McBean water-bearing units are separated by the "tan clay" (Figure 3-7), a unit with relatively low hydraulic conductivity that generally consists of two thin clay beds separated by a sandy bed. The "tan clay" diverts most of the water in the Barnwell Formation laterally to the creeks. The "green clay" unit, which separates the McBean and Congaree Formations, diverts most of the water in the McBean Formation laterally to the creeks. The Ellenton and Tuscaloosa Formations are hydraulically separated from the Congaree Formation by a clay unit and are not recharged near L-Reactor area.

The Tuscaloosa Formation is, stratigraphically, the lowest of the Coastal Plain sediments at the Savannah River Plant. This prolific water-producing unit consists of approximately 180 meters of interbedded sands, gravels, and clays. Based on studies around F- and H-Areas, the hydraulic pressures in the Tuscaloosa and Ellenton Formations are higher than those in the overlying Congaree Formation, indicating that these two formations are not recharged from the formations above.

3.4.2.2 Ground-water movement

The direction and rate of ground-water flow are determined by the hydraulic conductivity, the hydraulic gradient, and the effective porosity of the aquifer. Laboratory and pump tests were used to determine the hydraulic conductivities.

In the Barnwell Formation, the median hydraulic conductivity of the clayey sand unit is 0.04 meter per day. No pumping tests were made on the silty sand unit, but pumping tests in a sand lens in this unit determined the median hydraulic conductivity to be 0.3 meter per day.

In the McBean Formation, the median hydraulic conductivity of the upper sand unit is 0.13 meter per day, and that of the lower unit of calcareous clayey sand is 0.07 meter per day (Marine and Root, 1976). Fluid losses experienced in the calcareous unit during the drilling operations give the impression that this unit is very permeable. Apparently the zones of high permeability are not continuous over large distances and the hydraulic conductivity of the calcareous unit is lower than it appears from the drilling experience. The median hydraulic conductivity in the Congaree Formation is 1.5 meters per day (Root, 1976).

The presence of mica and kaolinitic clays in the subsurface materials will make ion exchange a significant factor in controlling the transport of contaminants in ground water. Ion-exchange capacities of the various unconsolidated sediments--except the clays of the McBean Formation--are low. Figure 3-9 shows typical ion-exchange capacities for these sediments. Ion-exchange capacities of the clays in the streambed sediments from Steel Creek average about 3 milliequivalents per 100 grams (Hawkins, 1971).

3.4.2.3 Ground-water quality

The water in the Coastal Plain sediments is generally of good quality, suitable for industrial and municipal use with minimal treatment. It is generally soft, slightly acidic, and low in dissolved and suspended solids. The Tuscaloosa and Congaree Formations are prolific aquifers and are major sources of municipal and industrial water. The McBean and Barnwell Formations yield sufficient water for domestic use (du Pont, 1982).

3.4.2.4 Ground-water use

Total pumpage for municipal users in the vicinity of the Savannah River Plant is about 39,000 cubic meters per day. Of this amount, 21,000 cubic meters per day come from the Tuscaloosa Formation, 15,000 cubic meters per day come from the Congaree Formation, and the remaining 3000 cubic meters per day come from the McBean Formation (du Pont, 1982).

The communities of Talatha and Jackson are the closest municipal users; they consume about 150 and 660 cubic meters per day from the Tuscaloosa Formation, respectively. The largest user (about 15,000 cubic meters per day) is the City of Barnwell, about 26 kilometers away, which obtains its water from the Congaree Formation.

The total industrial pumpage of ground water near the Savannah River Plant is about 50,000 cubic meters per day, all from the Tuscaloosa Formation (DOE, 1982). The closest user to L-Reactor is E. T. Barwick, Inc., in Barnwell County, about 26 kilometers away, which uses 950 cubic meters per day. The largest user (about 11,000 cubic meters per day) is the Sandoz Company in Allendale County, about 29 kilometers from the L-Reactor.

Currently identified future ground-water uses include the pumpage of 4000 cubic meters per day at the Defense Waste Processing Facility on the Savannah River Plant, 15,000 cubic meters per day at the Barnwell Nuclear Fuel Plant, and 11,000 cubic meters per day at the Alvin W. Vogtle Nuclear Power Station (DOE, 1982).

The total current ground-water use at the Savannah River Plant is about 24,500 cubic meters per day (DOE, 1982). The projected ground-water use at the L-Reactor area is about 2000 cubic meters per day, which will be supplied from two wells during operations, drawing from the Tuscaloosa Formation (du Pont, 1982).

Ground water has been withdrawn from the Tuscaloosa aquifer at an average rate of about 23,000 cubic meters per day for the past 27 years. Long-term hydrographs of producing wells show that ground water has been withdrawn without a progressive decline in water levels (du Pont, 1980).

3.5 METEOROLOGY AND CLIMATOLOGY

The descriptions of the meteorology of the Savannah River Plant and of the L-Reactor area are based on data collected at the Savannah River Plant and at Bush Field, Augusta, Georgia (du Pont, 1980; NOAA, 1980). Meteorological data tapes for 1976 and 1977 (15-minute sampling intervals) provided additional data about the Savannah River Plant.

3.5.1 Climatology

The Savannah River Plant has a temperate climate, with mild winters (9°C average temperature) and long summers. The summers are humid and have about 50 days with temperatures of 32°C or more. Cold weather usually lasts from late November to late March.

3.5.2 Wind speed and direction

The average wind speed measured in Augusta from 1951 to 1980 was 3.0 meters per second. The average wind speed recorded at a height of 10 meters on the WJBF-TV tower, near Beech Island about 25 kilometers northwest of the Savannah River Plant, was 2.5 meters per second from 1976 to 1977. Table 3-6 lists the monthly average wind speeds for three levels of the TV tower.

Figures 3-10 and 3-11 depict seasonal and annual wind roses (percent frequency and average speed by direction) based on WJBF-TV tower measurements for 1976 and 1977. Prevailing winds are from the west and southwest quadrants; minimum frequencies occur for northeast winds. The highest average wind speeds occur from the northwest quadrant.

3.5.3 Precipitation

The average annual rainfall at the Savannah River Plant from 1952 through 1978 was about 120 centimeters (du Pont, 1980a). The average annual rainfall at Augusta from 1941 to 1970 was about 108 centimeters (NOAA, 1980). The maximum monthly precipitation in Augusta was about 29 centimeters, recorded in March 1980; the minimum was a trace recorded in October 1953. Table 3-7 summarizes the average rainfall at the Savannah River Plant by month.

Table 3-6. Monthly and annual average wind speeds from WJBF-TV tower, 1976-1977 (meters per second)

Month	Tower elevation		
	10 meters	36 meters	91 meters
January	3.0	4.5	6.1
February	2.9	4.6	5.8
March	3.3	4.5	5.9
April	2.8	4.2	5.4
May	2.5	3.7	5.0
June	2.4	4.0	4.8
July	2.0	3.1	4.4
August	2.1	3.2	4.3
September	2.1	3.3	4.7
October	2.4	4.1	5.6
November	2.4	4.1	5.6
December	2.7	4.4	6.3
Annual	2.5	3.9	5.3

Table 3-7. Precipitation at Savannah River Plant, 1952-1978

Month	Monthly rainfall (cm)		
	Maximum	Minimum	Average
January	25.5	3.2	11.0
February	20.2	2.4	10.6
March	22.0	3.8	12.8
April	20.8	3.2	8.7
May	27.7	3.4	10.3
June	27.7	6.3	11.5
July	26.7	5.0	12.1
August	31.3	2.6	12.0
September	22.1	2.5	10.1
October	15.6	0	6.2
November	16.4	0.5	5.9
December	19.1	1.2	9.1
Average annual rainfall			120.3

Source: du Pont, 1980.

3.5.4 Severe weather

3.5.4.1 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 Savannah River Plant, only Hurricane Gracie, in September 1959, had winds in excess of 34 meters per second. Occasional winter storms with winds as high as 32 meters per second have been recorded (du Pont, 1980). Thunderstorms can generate winds as high as 18 meters per second with stronger gusts. The fastest wind speed recorded at Augusta between 1951 and 1980 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 Savannah River Plant (Simiu et al., 1979).

Table 3-8. Extreme wind speeds (meters per second) for SRP area

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

Source: Simiu et al., 1979.

3.5.4.2 Tornadoes

Occasional tornadoes are to be expected in the SRP area. Records show that South Carolina is struck by an average of 10 tornadoes per year (Purvis, 1977). No SRP production facility has ever suffered significant damage from a tornado. Several tornado funnels have been sighted in unpopulated areas on the SRP site, but they did not touch the ground or cause damage. Investigations of tornado damage near the Savannah River Plant in 1975 and 1976 indicated wind speeds varying from 45 to 78 meters per second (du Pont, 1980).

Several tornado studies covering the period from 1916 through 1975 were used to assess the risk of tornado damage to an SRP facility (DOE, 1982). The annual probability of a tornado striking any large building is about 1×10^{-3} compared to 1×10^{-4} for striking a specific point (du Pont, 1980).

3.5.5 Atmospheric dispersion

3.5.5.1 Atmospheric stability

Table 3-9 lists monthly and annual frequencies of atmospheric stability classes A to G. These statistics were derived from 15-minute average data for

1976 and 1977 from the WJBF-TV tower. The stability class was determined from vertical temperature gradients between 10 and 91 meters based on methodology presented in the U.S. Nuclear Regulatory Commission's Regulatory Guide 1.23 (NRC, 1980).

Table 3-9. Monthly and annual atmospheric stability class distributions based on ΔT (91-10 meters) for 1976-1977 (%)

	Stability class						
	Unstable			Neutral	Stable		
Month	A	B	C	D	E	F	G
January	16.63	3.72	3.98	26.14	38.27	9.37	1.90
February	19.92	3.89	3.58	14.86	31.60	17.39	8.75
March	11.74	4.24	4.42	21.88	34.80	17.81	5.12
April	18.66	3.41	3.10	12.76	30.14	25.31	6.61
May	15.32	4.04	3.88	20.24	29.72	21.24	5.56
June	15.23	4.93	5.15	19.44	29.27	20.73	5.26
July	12.17	3.23	4.07	22.93	32.10	21.74	3.76
August	10.19	4.00	4.18	20.38	34.87	22.80	3.59
September	14.00	4.17	5.14	22.87	29.76	16.95	7.11
October	14.08	4.23	3.63	20.09	25.16	23.52	9.30
November	12.78	4.41	5.21	12.16	26.82	20.54	9.08
December	6.96	3.24	3.83	21.55	42.79	16.56	5.07
Annual	14.24	3.99	4.17	20.03	31.91	19.62	6.04

3.5.5.2 Mixing height and low-level inversions

The mixing height is the level of the atmosphere below which pollutants can be mixed; it is often equal to the base of an elevated inversion. The depth of the nocturnal mixed layer at the Savannah River Plant is measured by an acoustic sounder that has been operated since 1974 (Schubert, 1975). The average morning mixing height is about 400 meters in the winter, spring, and summer, and decreases to about 300 meters in the fall. The acoustic data indicate that, as the day progresses, the mixing height rises beyond the 1000-meter range of the sounder.

Temperature inversions (air temperature increases with the height above the ground) inhibit atmospheric turbulence and, hence, 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 an elevated inversion was observed with an unstable layer below; this represents the early morning breakup of the nighttime inversion. About 9 percent of the data showed an inversion developing at the lower levels with an unstable layer above; this represents the transition period between the unstable daytime regime and the onset of the nighttime inversion.

The dilution capacity of the atmosphere depends on local wind speed, wind direction variability, mixing depth, and vertical temperature profile. From 1960 to 1970 the SRP area had about 50 forecast-days of high meteorological potential for air pollution (episodes), or an average of about 5 days per year. Forecast episodes are most frequent in autumn, when large anticyclones, 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.

3.5.6 Air quality

South Carolina and Georgia both have established air sampling networks; Table 3-10 summarizes the air quality measurements of both networks near the Savannah River Plant for suspended particulates, sulfur dioxide, and nitrogen dioxide. Ambient concentrations of these pollutants near the Savannah River Plant are below the air quality standards.

3.6 ECOLOGY

In 1972, the Savannah River Plant was designated a National Environmental Research Park. It contains perhaps one of the most intensively studied environments in this country; Smith et al. (1981) lists more than 700 scientific publications resulting from ecological research efforts. This section is based on several of these research efforts as well as on recent terrestrial and aquatic ecological studies performed by the Savannah River Ecology Laboratory (SREL) (Smith et al., 1981, 1982); the emphasis is on the ecology of Steel Creek and the Savannah River swamp because these areas are the most likely to be impacted by L-Reactor operations. Those species observed in Steel Creek, the Steel Creek delta, and the associated Savannah River swamp systems, except for a population of the striped mud turtle of Florida, have also been observed elsewhere on the Savannah River Plant.

3.6.1 Vegetation

The Savannah River Plant is near the line that divides the oak-hickory-pine forest and the southern mixed forest (Kuchler, 1964). Consequently, it has species representative of each forest association. In addition, SRP vegetation has been influenced strongly by farming, fire, edaphic features, and topography; no virgin forest remains in the region (Braun, 1950). Except for the production areas and their support facilities, many previously disturbed areas have been reclaimed by natural plant succession or planted with pine by the U.S. Forest Service.

Table 3-10. 1979 South Carolina and 1980 Georgia ambient air quality standards and measures

Locations[a]	Suspended particulates				Sulfur dioxide				Nitrogen dioxide			
	Maximum 24-hour average		Annual average		Maximum 24-hour average		Annual average[b]		Maximum 24-hour average		Annual average[b]	
	Standard (μg/m^3)	Measured (μg/m^3)	Standard (μg/m^3)	Measured[c] (μg/m^3)	Standard (μg/m^3)	Measured (μg/m^3)	Standard (μg/m^3)	Measured (μg/m^3)	Standard (μg/m^3)	Measured (μg/m^3)	Standard (μg/m^3)	Measured (μg/m^3)
South Carolina												
1	250	147	60	47.5	365	62	80	17.8	No std.	72	100	30.2
2	250	134	60	48.0	365	34	80	4	No std.	—	100	—
3	250	106	60	40.5	365	—[d]	80	—	No std.	—	100	—
Georgia												
1	150	119	75	55.3	365	—	80	—	No std.	122	100	48.1
2	150	120	75	56.0	365	—	80	—	No std.	—	100	—
3	150	115	75	47.7	365	—	80	—	No std.	—	100	—
4	150	161[e]	75	54.5	365	—	80	—	No std.	—	100	—
5	150	172[e]	75	63.6	365	—	80	—	No std.	—	100	—
6	150	—	75	—	365	66	80	17	No std.	—	100	—

a. South Carolina locations: (1) Fire Station, Beech Island; (2) Police Department, North Augusta; (3) County Health Department, Orangeburg. Georgia locations: (1) Sandbar Ferry Junior High School, Augusta; (2) Student Center, Medical College, Augusta; (3) Water Treatment Plant, Augusta; (4) Bungalow Road School, Augusta; (5) Clara Jenkins School, Augusta; (6) Regional Youth Development Center, Augusta.

b. Arithmetic mean.

c. Geometric mean.

d. No analysis.

e. Exceeded only once in 1980 at indicated location; this standard may be violated once per year at each monitoring station.

The vegetation that is most likely to be affected by the proposed action consists of two plant communities: (1) those associated with the Steel Creek corridor from the reactor outfall to the delta, and (2) those associated with the Steel Creek delta and that portion of the swamp near Steel Creek's confluence with the Savannah River. The structure and species composition of these communities reflect not only the heterogeneity of the physical environment, but also the impacts of earlier reactor operations.

During earlier L-Reactor operations, the thermal effluent eliminated vegetation in the Steel Creek channel, floodplain, and swamp. A delta developed rapidly at the entrance of the creek to the swamp from the sediments transported down the creek. A large tree-kill zone, covering about 250 acres, developed in the swamp. Large stands of deciduous forest, composed primarily of cypress and gum tupelo, died as a result of these discharges to Steel Creek.

These impacts were caused by the elevation of stream temperatures above ambient levels and marked increases in the stream flow. The discharge of thermal reactor effluents into Steel Creek before 1968 essentially eradicated the emergent and semiemergent flora, as well as portions of the swamp forest, leaving stumps and standing dead cypress and tupelo. Since that time, the Steel Creek corridor and portions of the swamp have been overgrown by successional woody and herbaceous vegetation (Smith et al., 1981).

3.6.1.1 Steel Creek corridor

The vegetation and physical features of the Steel Creek corridor vary markedly above the delta. More than 85 species of plants representing 50 families were listed from this area in the summer of 1981. The vegetation in the corridor is included in the palustrine wetland system (Cowardin et al., 1979). Figure 3-12 shows the distribution of the principal plant communities of the corridor. This 420-acre parcel consists of aquatic beds, emergents, scrub-shrub wetland, and forested wetland; the dominant flora of these cover types are described briefly in the following sections (Smith et al., 1981).

Aquatic bed

The Steel Creek corridor contains open water bordered by persistent herbaceous species and occasional shrubs.

Emergent wetland

Emergent wetland communities consist of both persistent and nonpersistent vegetation. Persistent vegetation was dominated by dense grasses and forbs with scattered low shrubs. A single nonpersistent community, just north of the Steel Creek delta, was dominated by an erect, deeply rooted, emergent annual that dies back in winter, bordered by persistent herbs including cattail, burreed, Canada rush, and sugarcane beard grass.

Scrub-shrub wetland

Two scrub-shrub wetland communities exist in the corridor. One is dominated by a dense canopy of buttonbush and willow. The second covers approximately 24 percent of the floodplain and is dominated by alder, which is the dominant species on Steel Creek. Beneath these shrubs, blackberry is abundant over a diverse herbaceous flora of false nettle, goldenrod, wapato, jewel-weed, cut grass, knot grass, and water purslane. The alder community generally borders the stream channels and, for most of the length of Steel Creek, extends nearly across the width of the floodplain.

Forested wetland

Approximately 73 percent of the wetland vegetation from the outfall to the delta consists of communities containing broad-leaved deciduous and coniferous/deciduous communities. Nearly half (46 percent) of these wetlands are dominated by wax myrtle and alder. These codominants sometimes reach heights of more than 7 meters and grow in dense stands. Willow-dominated communities rank second (13 percent) in vegetative coverage; they are more common near the mouth of Steel Creek. The herbaceous stratum is sparse. A mixed deciduous/coniferous community codominated by cypress and tupelo occurs just above Road A and also above the Seaboard Coast Line Railroad. This type of community is much more common in the swamp. Many small communities containing a mixture of sweet gum, red maple, and willow occur intermittently below the outfall. Upland arboreal species adjacent to Steel Creek have become established on the more stable sandbars, and near bridges and dikes. Also common are tulip tree, sycamore, various shrubs, and a diversified herbaceous flora.

3.6.1.2 Steel Creek delta

The Steel Creek delta contains five vegetative associations, four of which are differentiated by the degree of prior reactor discharges of thermal effluent (Figure 3-13). Impacted zones that have experienced structural reductions of the vegetative canopy include deepwater habitats and the deltaic fan. Bottomland hardwoods and deepwater and upland habitats comprise the nonimpacted zones. Since the inactivation of L-Reactor in 1968, vegetative recovery has varied according to the hydrologic regime (Figure 3-14).

The deltaic fan zone, which was formed by the deposition of sediments at the mouth of Steel Creek, consists of a raised substrate composed primarily of organic and alluvial deposits over sand. Measuring approximately 1200 meters by 500 meters, it is stabilized by vegetation. The more successionally advanced vegetation stages include (1) broad-leaved deciduous forest (willow), (2) scrub-shrub wetland (buttonbush and willow), and (3) persistent emergent wetland.

The impacted deepwater zone (Figure 3-13) extends as an arc on the periphery of the deltaic fan. Most of the trees in this zone were eliminated during earlier L-Reactor thermal discharges. The zone is characterized by scattered cypress, an abundance of stumps bearing shrubs, and submergent and nonpersistent aquatic herbs. The main channel of Steel Creek flows through this zone. The rooted vascular aquatic bed, nonpersistent emergent wetland, mixed forest/scrub-shrub wetland, and mixed scrub-shrub/rooted vascular wetland associations have their best developments here.

The nonimpacted deepwater zone contains mixed deciduous forest that was typical of the swamp before the beginning of thermal discharges from L-Reactor. The underlying substrate near the impacted zone is composed of fine particulate material less than 0.5 meter deep.

The bottomland hardwood zone generally is flooded in the spring, but not during the growing season. Two types of broad-leaved deciduous forest are found exclusively in this zone: areas dominated by laurel oak are inundated only during the flood stage; the area intermixed with overcup oak, water hickory, and water tupelo might retain standing water until early in the growing season.

Figure 3-14 shows the distribution of the principal plant communities of the Steel Creek delta, as determined from 1978 aerial photography and field studies conducted in the summer of 1981; the classification and mapping terminology follow Cowardin et al. (1979), with minor modifications. All categories are termed palustrine, which includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, or emergent mosses or lichens.

Approximately one-fourth of the delta area is covered by shrub communities that are dominated by buttonbush and willow. Five habitat types are similar in coverage, and three minor habitat types also occur. Forested areas dominated by cypress and water tupelo border the delta. More than 123 species of plants representing 66 families were listed during the 1981 field studies (Smith et al., 1981).

3.6.2 Wildlife

The abundance and diversity of wildlife that inhabit the Savannah River Plant reflect the interspersion and heterogeneity of the habitats occurring there. Emphasis has been given to those fauna that inhabit Steel Creek and the Savannah River swamp.

Amphibians and reptiles

Because of its temperate climate and many aquatic habitats, the Savannah River Plant contains a diversified and abundant herpetofauna. Seventeen species of salamanders, 26 frogs and toads, 10 turtles, one crocodilian, 9 lizards, and 31 snakes have zoogeographic ranges that include the Savannah River Plant (Conant, 1975). The ranges of many other species are peripheral to the Savannah River Plant, and they could also occur on SRP lands. Gibbons and Patterson (1978) provide an overview of the herpetofauna, including the relative abundance and peripheral species.

During field studies conducted in the summer of 1981, over 1050 individuals representing 60 species were collected or observed in the Steel Creek area. In the order of decreasing relative abundance, turtles, frogs and toads, and salamanders comprised more than 82 percent of the species. Six habitat types were examined during the surveys: (1) the stream channel below and (2) above the delta, (3) the delta, (4) islands, (5) the floodplain, and (6) the swamp forest. Twice as many species were collected on the floodplain as in the other habitats, because of its greater interspersion (Smith et al., 1981).

Earlier studies (Freeman, 1955; Jenkins and Provost, 1964) indicate that the alligator has always been a resident of the area. Its abundance probably increased after the Savannah River Plant was closed to the public in the early 1950s.

Murphy (1981) reported sightings and encounters with alligators in the Savannah River swamp and in the major SRP streams. Juveniles have been reported occasionally in the Steel Creek delta, indicating that breeding occurs there. Observations of alligators and their signs confirm their presence and use of Steel Creek from the L-Reactor outfall to the forests adjacent to the delta, including such areas as Carolina bays, backwater lagoons, and beaver ponds (Figure 3-15). At least 25 alligators have been observed in the Steel Creek area; of these, at least 21 represent different individuals. However, sample sizes are inadequate to provide accurate estimates of the population. Sex ratios and size data suggest a higher reproductive potential than that for Par Pond, where nearly 80 percent of the adults are males (Murphy, 1977).

A single nest containing 51 eggs was located in the swamp, but no hatching occurred (Smith et al., 1982). Several alligators, including at least 15 juveniles and one adult, inhabit the lagoon where Road A crosses Steel Creek. These observations suggest active nesting during the past 2 or 3 years. An abandoned nest was also located in Steel Creek Bay, about 0.3 to 0.5 kilometer west of the Steel Creek floodplain (Smith et al., 1981).

The alligator is indigenous to most aquatic habitats on the SRP (total around 120 alligators), except those in which the water temperatures exceed the thermal tolerance level. The Steel Creek ecosystem is not a critical habitat as defined by the U.S. Fish and Wildlife Service.

Birds

Birds of the Steel Creek ecosystem were studied in the summer of 1981 at eight locations, using a combination of strip censuses, mist nets, and aerial surveys. A total of 1062 birds representing 59 species was tabulated during the summer survey.

The avifauna listed along Steel Creek in the summer of 1981 can be assumed to breed there. Active nests of the bachman's sparrow, parula warbler, and red-headed woodpecker were observed, as were juveniles of 22 other species. The white-eyed vireo was the most abundant species based on all census techniques, followed closely by the Carolina wren (Smith et al., 1981). The frequency of observation or capture of the other species was relatively similar, and no single species dominated the census results. The Steel Creek delta and swamp provide excellent habitat for wintering waterfowl.

Mammals

The Savannah River Plant includes zoogeographic ranges of 41 species of mammals (Conant, 1975); 25 of these are known to occur near Steel Creek. Two additional species, the muskrat and the black bear, were confirmed near Steel Creek.

Based on the use of drift fences, pitfall traps, and board transects during the summer of 1981, the short-tailed shrew, the least shrew, and the southeastern shrew were the most frequently captured small mammals. The Steel Creek delta provides habitat for the rice rat, and probably for the eastern woodrat and the hispid cotton rat. The gray squirrel, the fox squirrel, and the southern flying squirrel were common in the upland and lowland forests along Steel Creek. Large mammals such as the feral pig and the white-tailed deer were common on the Steel Creek floodplain and delta. Other inhabitants of the floodplain and delta included the raccoon, the opossum, and the gray fox. Beaver signs were common along the length of Steel Creek.

3.6.3 Aquatic flora

Approximately 400 algae species have been identified from the Savannah River near the Savannah River Plant (Patrick et al., 1967). Diatoms dominate the assemblage although blue-greens are, at times, an important component, particularly upstream from the site where organic loading from municipal sources occurs. Since 1951, when algae studies began, diversity has lessened, which is thought to be the result of an increase in organic loading to the river from the area above the Savannah River Plant (ANSP, 1961; 1974).

Aquatic macrophytes in the river, most of which are rooted, are limited to shallow areas of reduced current and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the river adjacent to the Savannah River Plant, the most abundant being water milfoil, hornwort, alligator weed, water weed, and duck potato.

In the SRP streams that receive thermal effluents, the flora is greatly reduced, reflecting the overriding influence of large flows and high (greater than 50°C) water temperatures. In these areas, thermophilic bacteria and blue-green algae thrive where no other aquatic life occurs (Gibbons and Sharitz, 1974). The macrophytic communities of Steel Creek are described in section 3.6.1.1.

3.6.4 Aquatic invertebrates

Shallow areas and quiet backwaters and marshes of the Savannah River near the SRP site support diverse aquatic invertebrate assemblages; however, the bottom substrate of most open portions of the river consists of shifting sand that does not provide the best habitat for bottom-dwelling organisms. A sharp decrease in the total number of invertebrate species occurring in the river during the 1950s 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 early 1960s, but complete recovery has not taken place. The groups most affected are those sensitive to the effects of siltation and substrate instability. Results of insect faunal studies conducted during 1972 (ANSP, 1974) indicated substantial organic loading to the river upstream from the Savannah River Plant.

To evaluate the effects of thermal loading to SRP streams, Howell and Gentry (1974) compared the aquatic insect populations of Upper Three Runs Creek (natural stream), Pen Branch (thermal stream), and Steel Creek (post-thermal stream). In the thermal stream, the associations were characterized by low diversity and low evenness. The absence of trichopterans, plecopterans, and ephemeropterans in this stream indicates that a significant portion of the natural aquatic insect community had been eliminated by thermal effects. The few remaining insect populations were large, which is indicative of thermal influence. The assemblage sampled in Steel Creek was intermediate in both diversity and evenness, which suggests that the stream is in a successional stage. Five years after the termination of thermal input, most major insect groups that occur in Upper Three Runs Creek were also present in Steel Creek. The Steel Creek assemblage, however, appeared to be still developing into a more complex community organization.

3.6.5 Fish

Like other typical southeastern coastal plain rivers and streams, the Savannah River and its associated swamp and tributaries have a diverse fish fauna. Dahlberg and Scott (1971) listed 102 freshwater species from the Savannah River drainage. Seventy-six of these plus 15 additional species have been reported from water bodies on and near the Savannah River Plant (Smith et al., 1981; Bennett and McFarlane, 1981).

SRP streams have not been sampled with equal intensity, but 66 species were reported in one or more of them (Bennett and McFarlane, 1981).

Fish population studies conducted in the Steel Creek swamp system during the summer of 1981 recorded more than 500 fish representing 37 species (Smith et al., 1981). Largemouth bass, spotted sunfish, spottail shiner, brook silverside, and mosquitofish were the most common species. The larger predatory fish were most common in the main channel areas, while forage species, such as brook silverside and pirate perch occurred most frequently in side channels and in the cypress-tupelo swamp.

The diversity and abundance of fish in the thermally affected streams are high only during periods of reactor shutdown (McFarlane, 1976). In addition, the fauna upstream of the thermal effluents are depauperate in both numbers and diversity. With the exception of the mosquitofish, few fish live in the streams when thermal effluent is present. Mosquitofish are abundant in shallow peripheral areas at temperatures as high as 41°C. A few centrarchids might be present at lower temperatures, but the high numbers and the behavior of mosquitofish in the thermal habitat, contrasted with that in a nonthermal habitat, suggest that predation has been greatly reduced. During reactor shutdown, the streams return to ambient temperature and are invaded immediately by many fish from adjacent nonthermal areas. These fish range broadly until thermal effluent flows once more. Then they retreat downstream or into contiguous nonthermal areas. The diversity and abundance of species in the headwater tributaries of Four Mile Creek and Pen Branch upstream from reactor thermal effluents are reduced greatly in contrast to comparable areas in Upper Three Runs Creek or Steel Creek (McFarlane, 1976). Collection efforts have revealed that the first- and second-order tributaries of these streams are essentially devoid of fish.

To evaluate the potential for the entrainment of young stages of fish in the cooling-water systems, an ichthyoplankton sampling program was conducted in the river from March to August 1977 (McFarlane et al., 1978). Fish eggs occurred in the collections during each month of the study; the greatest densities occurred in May. American shad comprised 96 percent of all fish eggs. More than 1700 fish larvae representing at least 22 species were identified from the plankton collections. Clupeids, primarily blueback herring, accounted for more than half of the larvae collected. Other abundant species were spotted sucker, black crappie, cyprinids, and channel catfish. The greatest larval densities occurred in April, preceding the peak abundance of fish eggs. The greatest number of fish larvae were collected in Upper Three Runs Creek and in the 1G and 3G intake canals, which reflects the high densities of larval blueback herring that were occasionally swept from the forest floodplain into the river at the mouth of Upper Three Runs Creek and then transported into the canals.

3.6.6 Endangered and threatened species

This section describes species that are protected by the U.S. Fish and Wildlife Service as endangered or threatened and by the State of South Carolina as species of "special concern"; these species have been seen in the area of potential impacts from the operation of L-Reactor.

Two species listed as endangered or threatened by the U.S. Fish and Wildlife Service--the red-cockaded woodpecker and the American alligator--have been identified as being potentially in the area. Only the alligator has been found in any of the areas to be affected by the operation of L-Reactor. No plant species with protective status have been found. No habitat defined as "critical" to the survival of the species by the U.S. Fish and Wildlife Service exists on the Savannah River Plant.

The State of South Carolina has a Nongame and Endangered Species Act (Section 50-15, 1976, South Carolina Code of Laws). The rules established to implement this Act protect Federally protected endangered and threatened wildlife that occurs in the State (R123-150), sea turtles (R123-150.1), and predatory birds of the orders Falconiformes and Strigiformes (R123-160). No plant species receives State-level protection.

The State has also developed a listing of species of "special concern" (i.e., the species is either of undetermined status or is vulnerable to loss if not now endangered or threatened) (Forsythe and Ezell, 1979). These species do not have legal protection, but they warrant consideration because their status is unknown.

The following paragraphs list those species seen on the Savannah River Plant that have been identified as endangered or threatened by the Federal or State government:

Brother spike mussel - Listed as endangered by the State, this mussel has been identified only in the Chattahoochee and Savannah Rivers from sandbars beneath 0.3 to 0.6 meter of water (Britton and Fuller, 1980). The 1972 discovery of this bivalve near the Savannah River Plant was the first documented collection in 130 years.

American alligator - Listed Federally as endangered (USDOI, 1980), the alligator is common locally and breeds in Par Pond, in the Savannah River swamp (Gibbons and Patterson, 1978), and along Steel Creek. The population ecology of this species has been examined intensively on the Savannah River Plant.

Cooper's hawk - This hawk is listed by the State as threatened, and has been documented on the Savannah River Plant during Christmas bird counts (Angerman, 1979, 1980; DOE, 1982).

Bald eagle - The bald eagle is an endangered species and has been observed over Par Pond (du Pont, 1982), but its presence near L-Reactor and Steel Creek is unknown.

Wood stork - The wood stork is designated by South Carolina as threatened. The U.S. Fish and Wildlife Service has published a "Notice of Status Review" (47 FR 6675) to solicit information about this species to determine if it should be proposed as endangered or threatened. As many as 25 individuals have been observed in the Steel Creek area during the summers of 1979 and 1980 (Smith, et al., 1982).

Osprey - The osprey, which is listed by the State as threatened, has been observed on the Savannah River Plant (du Pont, 1982) but is considered an occasional migrant. It typically does not breed or winter in South Carolina (Robbins et al., 1966), but might utilize the swamp and riverine habitats on the Savannah River Plant briefly during migration.

Red-cockaded woodpecker - The Federally endangered, nonmigratory red-cockaded woodpecker was first listed in 1970, and is estimated to number fewer than 10,000 individuals (Finnley, 1979). This habitat-specific woodpecker nests in cavities in living upland pine trees that average 75 years of age. The colony nearest to Steel Creek is approximately 0.8 kilometer from Road A-19 (du Pont, 1982).

3.6.7 Commercially and recreationally valuable biota

Although the ecosystems on the Savannah River Plant support many populations of game and fish, commercial exploitation is prohibited and recreational use is restricted to controlled hunts of the white-tailed deer and feral hog. Commercially valuable plant biota include approximately 175,000 acres of timber managed by the U.S. Forest Service.

The Savannah River supports both commercial and sport fisheries. Many fisheries are confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia. The only commercial fishes of significance near the Savannah River Plant are the American shad and the channel catfish. These species are exploited to a limited degree by local fishermen. Sportfishermen 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., nd).

3.7 RADIATION ENVIRONMENT

3.7.1 L-Reactor area

In 1980, radiation-level survey measurements were made outside the L-Reactor area perimeter fence, yielding an average dose rate of about 66 millirem per year, approximately equal to background. In 1981, radiation survey measurements were made inside the L-Reactor area perimeter fence, but outside the reactor building. These measurements also indicated an exposure rate of about 66 millirem per year. This indicates that only very small amounts of radionuclides, if any, were deposited in the L-Reactor area during its years of operation. Additionally, a radiation survey is made annually along major SRP roads. A 1978 survey indicated no significant contamination along any major SRP road, including Road B, which runs next to L-Reactor.

One facility--the L-Reactor area low-level liquid seepage basin--has been sampled regularly. The basin is now empty, but it is contaminated from releases made during earlier L-Reactor operations. The following table lists maximum concentration values in the soil of the seepage basin for three radionuclides detected in 1978:

Radionuclide	Concentration (pCi/g dry weight)
Co-60	12,800
Sr-90	112
Cs-137	400

3.7.2 Cesium-137 inventory in the Steel Creek-Savannah River system

Since 1955, approximately 520 curies of radiocesium have been discharged to onsite streams. Of this total, about 284 curies were released to Steel Creek. The primary source of this radiocesium was leaking failed fuel elements stored in disassembly basins in the P- and L-Areas. Water was released routinely from these basins to maintain the clarity needed for underwater manipulation of irradiated fuel elements, hence the release of radiocesium (with a cesium-134-to-cesium-137 ratio of about 1:20).[1] A sharp decrease in the release of cesium-137 occurred in the late 1960s and early 1970s when (1) the P-Reactor area basin was fitted with sand filters; (2) water was demineralized before its release; and (3) the leaking fuel elements were removed to an area where discharge to surface waters could not occur.

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[1]For convenience, the radiocesium will usually be described as cesium-137, but the presence of both cesium-134 and -137 is implied.

After the radiocesium was discharged from the P- and L-Areas to Steel Creek, it became associated primarily with the silts and clays in the Steel Creek system. Here the sediments and associated cesium-137 were subjected to continued resuspension, transport, and deposition by the flow regime in the creek.

3.7.2.1 Cesium in sediments

Radiocesium, primarily cesium-137, is strongly associated with the sediments in Steel Creek. 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. A distribution coefficient (K_d = 3960) measured for sediments from Four Mile and Steel Creeks (Kiser, 1979) demonstrates the strong affinity of cesium-137 for the sediments in the Steel Creek system.

Soil cores collected in 1974 at two transects in Steel Creek between Road A and the swamp showed that about 70 percent of the radiocesium was located within the upper 20 centimeters of sediment and nearly all was confined to the upper 100 centimeters. Soil cores collected in 1981 at 12 transects between the Steel Creek delta and P-Reactor showed that the radiocesium has moved down in the soil column, with about 77 percent in the upper 40 centimeters. Sediment samples taken in 1981 from the center of the creek had markedly lower radiocesium concentrations than the sediments from either bank. The radiocesium is associated with smaller soil particles (Tables 3-11 and 3-12).

Table 3-11. Range of cesium-137 concentrations (pCi/g dry weight) of soil types in Steel Creek (1981)

Soil type[a]	Number of samples	% total	Concentrations Mean	Concentrations Standard error
1 (clay)	101	19	137	20
2	108	21	80	16
3	127	24	39	7
4	83	16	55	12
5 (sand)	106	20	17	3

a. Soil samples were graded visually from 1 to 5, according to their "average" particle size; samples with the highest clay content are type 1 and those with the least clay and silt (i.e., predominantly sand) are type 5 (Smith et al., 1981).

Table 3-12. Mean radiocesium concentration (pCi/g) in soil column by soil particle size[a]

Location[c]	Soil type[b]				
	1 (fine)	2	3	4	5 (coarse)
Above L-Reactor	166	104	62	117	43
L-Reactor - Road A	171	112	38	36	8
Road A - delta	78	46	18	21	9
Delta	219	59	13	24	17

a. Source: Smith et al., 1982.

b. Soil samples were graded visually from 1 to 5, according to their "average" particle size; samples with the highest clay content are type 1 and those with the least clay and silt (i.e., predominantly sand) are type 5 (Smith et al., 1982).

c. Figure 3-2 shows the locations of these areas.

Soil samples and thermoluminescent dosimeter surveys from 10 transects in the Savannah River swamp (from the SRP boundary to Little Hell Landing) were made between 1974 and 1980. Soil cores collected in 1974 showed that about 70 percent of the radiocesium was confined to the upper 6 to 7 centimeters but the radionuclide was detectable at depths of 25 centimeters (du Pont, 1982).

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 and downstream from obstructions. Riverbed sediments from such locations upstream from the Savannah River Plant normally have about 1 picocurie per gram or less of radiocesium (du Pont, 1982).

Because of its strong association with sediment (K_d = 3960; Kiser, 1979), the cesium-137 in a water sample can be assumed to associate with the suspended solids. Cesium-137 concentrations of 1200 ±716 picocuries per gram were measured in suspended solids in Steel Creek water during a P-Area cold water diversion (du Pont, 1982). In 1980, solids suspended in Steel Creek water entering the swamp had an average cesium-137 concentration of about 5 picocuries per gram.

3.7.2.2 Radiocesium inventory

An estimate of radiocesium currently in Steel Creek was made using core samples to a depth of 1 meter (Smith et al., 1982). The results are listed below:

Location	Inventory (Ci)
Above L-Reactor	9.2
L-Reactor to Road A	24.4
Total above Road A	33.6
Road A to delta	10.4
Delta area	23.1
Total below Road A	33.5
Total inventory	67.1

Figure 3-16 is a summary diagram based on radiocesium concentrations measured in Steel Creek, the swamp, and the Savannah River passing the Highway 301 bridge (Marter, 1974); it shows the distribution of radiocesium in the Steel Creek-Savannah River system; about 64 curies remain unaccounted for. These curies possibly could be attributed to one or more of the following causes:

- Less radiocesium released than originally indicated
- The cesium-134-to-cesium-137 ratio greater than 1:20
- Cesium-137 deposited in the river between the mouth of Steel Creek and the Highway 301 bridge
- More cesium-137 from Steel Creek transported past the Highway 301 bridge than indicated by the measurements
- More cesium-137 below depths of 1 meter

3.7.2.3 Cesium-137 in biota

Vegetation samples were collected from 1970 to 1981 at 10 transects in Steel Creek between the delta and L-Reactor. Samples were also collected at 10 transects in the Savannah River swamp. The average radiocesium concentrations in swamp vegetation are generally less than those in vegetation from the creek. The total radiocesium inventory in Steel Creek vegetation is about 0.4 curie (du Pont, 1982).

The concentration of radiocesium in wildlife is generally not high in Steel Creek, the Savannah River swamp, and Creek Plantation Swamp. Concentrations in Savannah River fish are lower than those measured in fish from Steel Creek. Bioaccumulation factors (cesium-137 concentrations in fish/cesium-137 concentrations in water) for fish taken from the river from 1965 to 1970 average about 2300. The mean whole-body bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 (Smith et al., 1982). In contrast, fish from Par Pond exhibit bioaccumulation factors that average about 1000 (Harvey, 1964). However, a bioaccumulation factor of 3000 was chosen for analysis to accommodate the higher factors found in bass and larger fish typically caught by fishermen.

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