D B Moore, Section Mgr.
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REACTOR OPERATION ENVIRONMENTAL INFORMATION DOCUMENT

VOLUME II

ECOLOGY (U)

L. D. Wike
W. L. Specht
H. E. Mackey
M. H Paller
E. W. Wilde
A. S. Dicks

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Environmental Sciences Section
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DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

Reviewing Official: C. J. Banick
C. J. Banick, ~~ADD~~ Class Officer
Date 11/30/89

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U. S. Department of Energy under Contract No. DE-AC09-88SR18035

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VOLUME SUMMARY

The Savannah River Site (SRS) is a large United States Department of Energy (DOE) installation on the upper Atlantic Coastal Plain of South Carolina, centered approximately 40 kilometers (25 miles) southeast of Augusta, Georgia. The SRS contains diverse habitats, flora, and fauna. Habitats include upland terrestrial areas, varied wetlands including Carolina Bays, the Savannah River swamp system, and impoundment related and riparian wetlands, and the aquatic habitats of several stream systems, two large cooling reservoirs, and the Savannah River. These diverse habitats support a large variety of plants and animals including many commercially or recreationally valuable species and several rare, threatened or endangered species. This volume describes the major habitats and their biota found on the SRS, and discuss the impacts of continued operation of the K, L, and P production reactors.

Soils, an influential determinant in the development of terrestrial biotic communities, are predominantly well drained loamy sands on the SRS. Terrestrial land cover types found on the SRS include: industrial land cover around administrative and production facilities; grassland/forbland, found in power line right-of-ways, forest openings and wildlife food plots; scrub-shrub which is typical of recently clear cut or block-planted areas; young evergreen/deciduous regeneration stands; upland forests, either evergreen or deciduous forests of trees at least 6 m tall; and bottomland hardwood forests found along streams and on higher ground within the Savannah River swamp. The commercial timber crop on the SRS, contained within the upland forests, is actively managed and had an estimated value of over $118 million in 1987.

The SRS supports a diverse and abundant fauna due to its temperate climate and numerous diverse habitats. The herpetofauna of the SRS includes 17 salamanders, 26 frogs and toads, one crocodilian, 11 turtles, nine lizards, and 31 snakes. The SRS supports a diverse and mobile avifauna that may be migrant, seasonal, or permanent residents. Various surveys have identified a total of 213 different species of birds on the SRS. Waterfowl utilize most of the suitable habitat available on the SRS and have been studied to a much greater extent than the upland birds. Over 30 species of waterfowl or water related birds utilize suitable areas of the SRS. Forty nine of the 57 species of mammals found in South Carolina may occur on the SRS. The eight species that could potentially occur on the SRS whose presence has not been confirmed include the cougar, white-footed mouse, swamp rabbit, big brown bat, hoary bat, Brazilian free-tailed bat, little brown bat, and the southeastern myotis bat. Introduced mammal species on the SRS include the feral dog, feral cat, feral pig, house mouse, Norway rat, and black rat. Potentially valuable commercial and recreational wildlife resources on the SRS that are not available for exploitation due to restricted access to the site. Animals that could be commercially trapped or recreationally hunted include bobcat, beaver, fox, mink, muskrat, opossum, otter, rabbit, raccoon, skunk, squirrel, migratory waterfowl, bobwhite, dove, turkey, snipe, and woodcock. The wild turkey has been

actively managed to provide stock animals for other areas of the state. Public hunts of deer and feral hogs are the only available public recreational use of SRS wildlife. From 1965 to 1987 a total of 25,097 deer and 1293 hogs were killed during organized public hunts; the average kill per year was 1091 deer and 56 hogs.

Aquatic habitats on the SRS include six major streams, two large cooling reservoirs (Par Pond and L Lake), the Savannah River, and the Savannah River swamp system. The tributaries that originate or pass through the SRS before flowing into the Savannah River are: Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs creeks. The sixth stream, Pen Branch, does not flow directly into the Savannah River but joins Steel Creek in the floodplain swamp. The upper reaches of Lower Three Runs Creek are impounded to form Par Pond. L Lake was formed by damming Steel Creek. Par Pond has developed extensive macrophyte beds along its shoreline during its 30-year history, and initial macrophyte beds have been established in L Lake.

The SRS contains 17,427 ha of wetlands of which 13,587 ha are bottomland hardwood and cypress-tupelo forest. Portions of the 3800-ha Savannah River floodplain on the SRS are dominated by bald cypress (*Taxodium distichium*) and water tupelo (*Nyssa aquatica*). Portions of this floodplain have been differentially exposed to thermal and sedimentation stresses associated with cooling water discharges from several nuclear production reactors and a coal-fired powerhouse on the SRS since the mid 1950s.

The most obvious effect of SRS cooling water releases on wetland plant communities is canopy loss by wetland tree species. About 1020 ha of wetland tree canopy exhibits some degree of alteration as a result of SRS cooling water releases. These closed canopy forests have been replaced by a mixture of wetland communities including submerged algal mats, thermally tolerant herbaceous plants, and scrub-shrub communities in the thermal streams and deltas.

Following cessation of thermal cooling water discharges, stream and delta areas are revegetated by a variety of herbaceous and scrub-shrub hardwood species. Successional processes in the post-thermal areas result in a shift from herbaceous dominated to shrub dominated wetland communities. Results from the Steel Creek Delta and the Beaver Dam Delta indicate that reductions in effluent water temperatures and flows may also reverse the pattern of canopy loss and result in re-establishment of vegetation cover. However, the replacement wetland communities do not resemble the original cypress-tupelo forests. Little regeneration of cypress and tupelo has occurred.

Quality of SRS surface waters has been, and continues to be, monitored by routine, nonroutine, and special study programs. Intake and discharge of cooling water are the main SRS activities affecting site surface water quality. With the exception of thermal parameters, SRS surface waters generally meet applicable water quality standards. Nonthermal, post-thermal, and Savannah River waters routinely comply with Class B Water Classification Standards of the State of South Carolina. Thermally

altered streams show 100% compliance with many standards, but have lower compliance rates for others, including temperature, dissolved oxygen, and alkalinity. The high discharge flows associated with reactor operations also affect physical factors such as erosion, sediment load, and channel morphology. Water quality in Par Pond has changed little in the last decade and is comparable to that expected for a lake of its type and size. The water quality of L Lake is primarily influenced by thermal and nutrient load of Savannah River water used for reactor cooling.

Phytoplankton (unattached algae) and zooplankton are of little significance in lotic habitats such as Steel Creek and Pen Branch where detrital material, macrophytes, and periphyton (attached algae) provide the base of most aquatic food chains. In lentic habitats such as Par Pond and L Lake, phytoplankton and zooplankton are an integral part of many food webs. Historical discharges of reactor cooling water withdrawn from the Savannah River to Par Pond, L Lake, Steel Creek, and Pen Branch have influenced the phytoplankton, periphyton, and zooplankton communities in each of these systems because the discharges caused increases in flow, temperature, and nutrients relative to ambient conditions. Par Pond is part of a recirculating cooling system for P Reactor. The discharged cooling water reaches Par Pond via a series of precooler ponds connected by a canal system. Therefore, the increase in flow, temperature, and nutrient levels are much less severe in Par Pond than in the other aquatic systems impacted by SRS reactor operations with once-through cooling systems. Studies have demonstrated that the principal effects from P-Reactor operation on the lower food chain organisms of Par Pond are increases in primary and secondary production. Although there is some entrainment of phytoplankton and zooplankton at the Par Pond pumphouse, no significant adverse impacts to these communities have been observed in Par Pond during previous operations of P Reactor.

In contrast to the P-Reactor cooling system, L Reactor discharges cooling water directly to L Lake in a once-through mode. The thermal input and nutrient enrichment resulted in algal communities dominated by blue-green algae during the first two years after the lake was constructed. The blue-green algal dominance has subsequently subsided; however, the extent to which this is a result of the termination of L-Reactor operations relative to reservoir aging and other factors cannot be accurately determined. Zooplankton community structure and abundance in the lower half of L Lake (the only section sampled) did not appear to be adversely influenced by reactor operations. Temperatures of the water released to Steel Creek from the L-Lake dam were only slightly above ambient. Thus, effects in Steel Creek from L-Reactor operations resulted from a slight temperature elevation, substantially increased flow and nutrient enrichment, and an export of organisms from L Lake. Measurable effects were primarily restricted to the upper corridor portion of Steel Creek from L Lake and included increased algal abundance, increased relative abundance of blue-green algae, and atypically high populations of limnetic zooplankton and algal species. K-Reactor operation has impacted the flow, temperature and nutrient levels of the upper corridor of Pen Branch Creek and its principal tributary Indian Grave Branch. Adverse impacts to phytoplankton, zooplankton, and periphyton in response to K-Reactor operations have

not been well documented but are believed to occur from the reactor cooling water discharge to the Savannah River swamp. Studies of periphyton and zooplankton in the Pen Branch Delta and swamp have shown no significant adverse impacts attributable to operation of the reactor.

Macroinvertebrate studies were conducted in Par Pond, L Lake, Steel Creek, Pen Branch, and the Savannah River in order to assess the potential impacts of SRS thermal discharges on these ecosystems. Par Pond supports a diverse macroinvertebrate community, with no evidence of thermal impacts, except for elevated densities of macroinvertebrates in the Hot Arm of the reservoir. The higher densities probably result from higher levels of primary production, which result in increased food availability in the Hot Arm. The lower 50% of L Lake (Regions 5-8) maintains a diverse macroinvertebrate community, with no evidence of thermal perturbation. In accordance with special condition 16 of the SRS NPDES permit SC0000175, biological sampling is not required in the upper regions of L Lake adjacent to the reactor outfall (Regions 2 and 3). However, these areas are thermally perturbed during reactor operation and probably contain greatly reduced numbers of macroinvertebrates adjacent to the reactor outfall, and thermally tolerant species throughout most of Regions 2 and 3. The macroinvertebrate community of Steel Creek just downstream from L Lake has been altered from that which existed prior to the restart of L Reactor, however, the changes are not thermally induced, but rather are due to seston (primarily algae) inputs from L Lake. Such species shifts in macroinvertebrate fauna commonly occur downstream from impoundments. The changes in Steel Creek are localized and are not viewed as a negative impact. The macroinvertebrate community of Pen Branch has undergone substantial, but not complete, recovery since the cessation of thermal discharges in April 1988. It is anticipated that most of the existing macroinvertebrate community will be lost when K Reactor is restarted. The Savannah River showed no evidence of thermal perturbation, with the possible exception of slightly elevated densities of macroinvertebrates just downstream from Four Mile Creek when C Reactor was operating. C Reactor has not operated since 1985, and it is not expected to be restarted.

The SRS supports a diverse fish fauna (at least 79 species) in a variety of aquatic habitats. Several of these habitats are affected by the operation of the nuclear reactors on the SRS. Apart from the congregation of some species in thermal areas and lower than average condition among adult largemouth bass, the Par Pond fish community is typical of southeastern reservoirs. The fish community in the lower half of L Lake has developed normally and resembles those in other southeastern reservoirs. Warmer temperatures in the upper half of L Lake, however, have precluded normal community development, and fish kills have occurred following reactor restarts. After cooling to near ambient temperatures, water from L Lake discharges to Steel Creek. Except for the reach directly below L Lake (where increased discharge and emigration of L-Lake fish have altered community structure), the Steel Creek fish assemblage has not been significantly influenced by L-Reactor operations. Pen Branch has received direct discharge from K Reactor via its tributary, Indian Grave Branch. Discharges have scoured Indian Grave Branch and the mid-reaches of Pen Branch. Due to the high flows and temperatures, these areas are largely

devoid of fish during reactor operations but are recolonized during outages. The reach of Pen Branch above K Reactor supports a typical headwater fish assemblage. The swamp in the lower reaches of Pen Branch supports a typical swamp assemblage in areas where temperatures have cooled to near ambient levels. Water used to cool the SRS nuclear reactors is withdrawn from three water intakes on the Savannah River. Impingement of adult and juvenile fish at these intakes is minor relative to impingement at other nuclear plants. Approximately 10% of the ichthyoplankton passing the SRS water intakes are entrained; egg entrainment is greatest for American shad and striped bass. There is no evidence that fish populations in the Savannah River have declined as a result of entrainment at the SRS intakes.

The diverse biota of the SRS includes many species of special concern. The wood stork, bald eagle, red-cockaded woodpecker, shortnose sturgeon, and brother spike mussel are listed by the federal government as endangered and have been found on or in the vicinity of the SRS. The American alligator, listed as threatened by similarity of appearance is a relatively common inhabitant of the SRS. In addition there are many plants and animals found on the SRS that are considered as threatened or species of concern by government agencies. Although the state of South Carolina does not afford official protection of flora other than federally listed species, the Nongame and Heritage Trust Section of the South Carolina Wildlife and Marine Resources Department lists 178 plant species of national, regional, or state-wide concern; of the 178 listed species, 31 are known to exist on the SRS, and an additional 28 species are likely to be found there.

The wood stork, bald eagle, red-cockaded woodpecker, shortnose sturgeon, and alligator are the most studied of the species of concern found on the SRS. The breeding population of wood storks in North America has declined from an estimated 20,000 to between 4000 and 5000 pairs in the last 50 years. In 1983 studies of potential effects of SRS operations of the wood stork were begun. Extensive breeding and foraging studies on the Birdsville Wood Stork Colony about 45 km southwest of SRS indicate that during the pre-fledging period and adults forage in shallow, open-water aquatic habitats within about 20 km of the colony. Fledging dispersal from the colony normally occurs by mid-summer at which time the juvenile storks may visit the SRS Savannah River swamp. Data from foraging surveys at SRS from 1983 through 1988 indicate that flows to the swamp may influence wood stork foraging areas in the swamp. However, a series of foraging ponds, referred to as "Kathwood Lake," were built on the Silver Bluff Plantation Sanctuary. Construction of this area was completed and the ponds were stocked in late 1985. Wood storks have used the Kathwood Lake facilities extensively during the summers of 1986, 1987, and 1988. This level of use more than compensates for any potential limitation in available foraging area due to SRS operation.

The bald eagle is a permanent breeding resident of South Carolina and has been observed in the SRS area since 1904. A study of bald eagle usage by the SRS was conducted from September 1984 through Augusta 1985. During the survey, 36 eagles were sighted on 31 occasions, most of them in the Par Pond area. Since the study, 22 more eagles have been sighted. The presence of a bald eagle nest on the SRS was confirmed in May of 1986.

Since that time, the mated pair have hatched and fledged chicks every year except 1989 when the nest and two chicks were lost during a severe storm in April. The Savannah River Forest Station (SRFS) has developed and implemented an active management plan to encourage use of the SRS by bald eagles and has taken actions to encourage the pair of eagles to re-establish their nest for the next breeding season.

The red-cockaded woodpecker is a resident of the SRS. Since 1979 the SRFS's wildlife management program has been actively working to improve red-cockaded woodpecker habitat. The SRFS monitors 35 colony sites, of which four currently house productive clans. These clans have been hatching and fledging chicks consistently in recent years.

Although the shortnose sturgeon is found in the Savannah River and appears to spawn both upstream and downstream of the SRS, important life history habitats such as spawning grounds and foraging areas are not known or have not been specifically identified in the vicinity of the SRS. Even though the shortnose sturgeon can be impacted by loss of habitat, entrainment impingement, and thermal effects, there is no evidence that the population of shortnose sturgeon in the Savannah River is negatively impacted by SRS operations.

The American alligator, due to its previous endangered status, has been extensively studied at the SRS. Recent research indicates that the alligator population on the SRS is growing. The Par Pond population has apparently doubled in the last 14 years. The SRS provides extensive areas of suitable habitat, minimal human disturbance, and ample forage for alligators. Impacts of reactor operation are minimal, since alligators can actively avoid high-temperature water. Impacts are generally limited to some loss of habitat due to high temperatures and flows along thermal streams.

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1.0 INTRODUCTION

1.1 GENERAL OVERVIEW

The purpose of Volume II of this Environmental Information Document (EID) is to provide ecological information to assist in the assessment of environmental impacts of the operation of reactors K, L, and P at the Savannah River Site (SRS). The SRS is a major United States Department of Energy (DOE) installation for the production of nuclear materials.

In addition to the preceding summary and this introductory chapter, Volume II contains four additional chapters dealing with the following areas.

Chapter 2, Terrestrial Resources, contains descriptions of the soils, vegetation cover, and wildlife found on the SRS and evaluates the potential impacts of reactor operations.

Chapter 3, Wetland Resources, describes general site-wide wetlands and deals specifically with wetland areas in the vicinity of K, L, and P reactors and their associated cooling water system areas. Chapter 3 also presents information on the Savannah River Swamp and long-term effects of cooling water releases on the wetland resources of the area.

Chapter 4, Aquatic Resources, contains descriptions of the major stream drainages and bodies of water on the SRS. It also discusses water quality, phytoplankton, periphyton, zooplankton, macroinvertebrate and fish populations for Pen Branch, L Lake, Steel Creek, and the Par Pond/Lower Three Runs system. The water quality, macroinvertebrates, and fish communities of the Savannah River are also considered.

Chapter 5, Threatened and Endangered Species, discusses the status of organisms on the SRS listed by the state or federal government as threatened, endangered, or of special concern, and considers potential impacts of continued reactor operation. Species of prime interest are those found on the SRS that are listed as threatened or endangered by the federal government. These species include the red-cockaded woodpecker, bald eagle, wood stork, American alligator, shortnose sturgeon, and the brother spike mussel.

1.1.1 Location and Description

The SRS occupies an area in South Carolina of about 780 square kilometers (192,741 acres) in portions of Aiken, Allendale, and Barnwell counties, and is bounded on the southwest by the Savannah River. The SRS is centered approximately 40 kilometers (25 miles) southeast of Augusta, Georgia (Figure 1-1), and its facilities include five nuclear production reactors, two chemical separations areas, a fuel and target fabrication facility, and various support facilities (Figure 1-2).

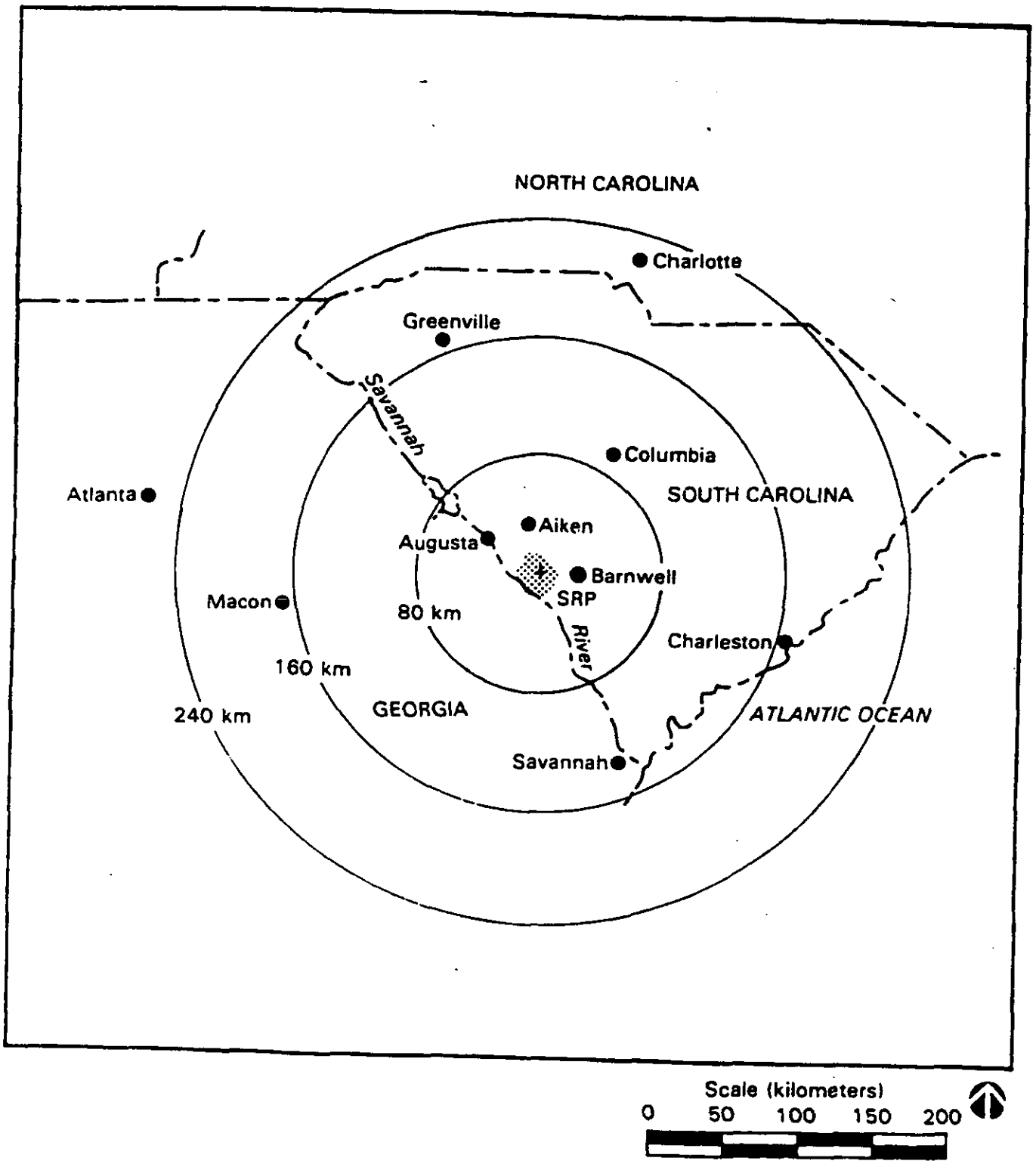

FIGURE 1-1. SRS Location in Relation to Surrounding Population Centers

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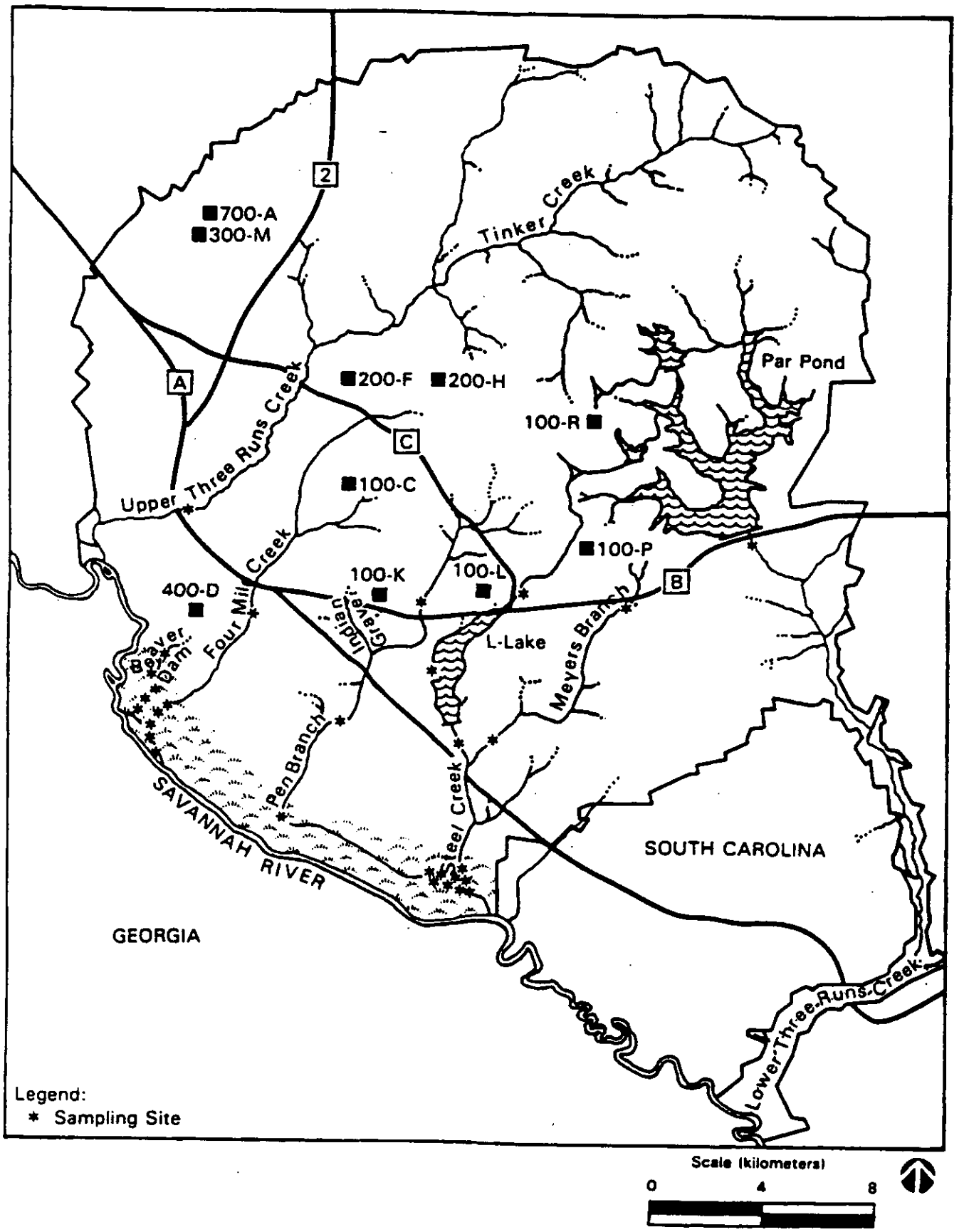

FIGURE 1-2. Savannah River Site Map

W8906070

The SRS contains a wide range of habitats including upland terrestrial areas and various types of wetlands such as Carolina Bays, bottomland hardwood forests, lake and stream associated wetlands, and the Savannah River swamp system. The SRS also contains varied aquatic habitats ranging from small undisturbed headwater streams to large thermally affected drainages and large impoundments. The majority of the SRS is drained by six drainages feeding tributaries of the Savannah River. There is one small stream in the northeastern sector that drains into the Salkahatchie River instead of the Savannah.

2.0 TERRESTRIAL RESOURCES

2.1 SOILS

Soils are an important component of the environment because they influence the occurrence and distribution of the vegetation, wildlife, and potential land use. Figures 2-1, 2-2, and 2-3 show the distribution of soils in the vicinity of K, L, and P Reactors. Figures 2-4, 2-5, 2-6, and 2-7 show the distribution of soils in the vicinity of the Pen Branch and Steel Creek corridors from the reactor areas to the Savannah River (Virgil Rodgers, personal communication, US SCS and Al Guber, EG&G, Las Vegas, NV). Figure 2-8 contains the legend for Figures 2-1 through 2-7 and Table 2-1 lists the areas of coverage for each soil type in Figures 2-1 through 2-7 (Al Guber, personal communication, EG&G, Las Vegas, NV). Figures 2-9 through 2-12 show the soil types around the Par Pond area. Table 2-2 summarizes the statistsics for Figures 2-9 through 2-12. The most common soil type near the reactor areas are udorthents, arents, and urban are the most prevalent. These soils consist of material that has been previously deposited or material that remains after some of the soil has been removed; the material contains fragments of discontinuous layers of diagnostic horizons or layers.

The dominant texture of the surficial horizons is loamy sand; slopes typically range less than 12%, and most soils are well drained. Streambed soils of lower Pen Branch Creek and Indian Grave Branch and lower Steel Creek consist primarily of loamy sands; reactor operations have scoured and eroded these soils.

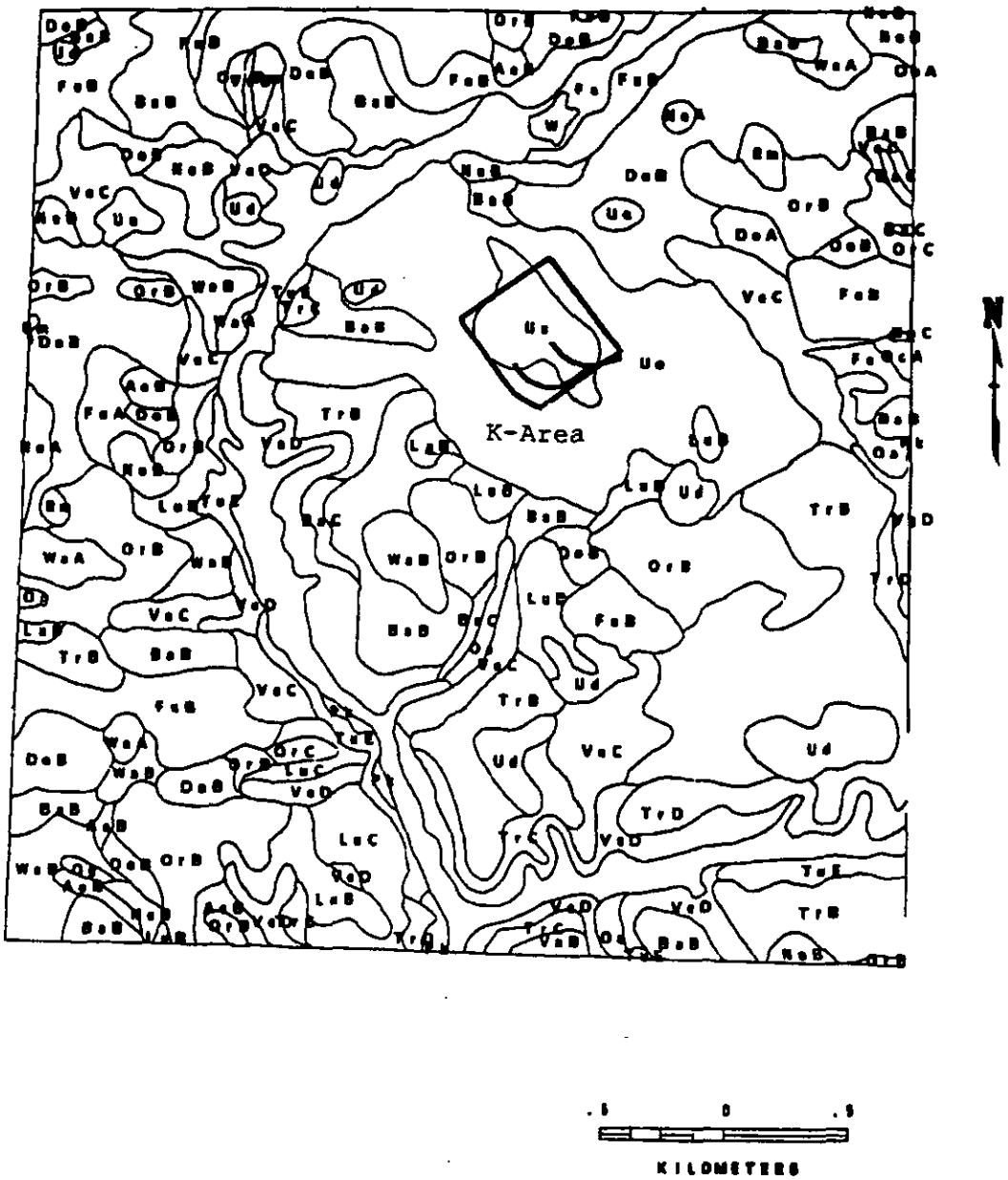

FIGURE 2-1. Soils, K Reactor and Immediate Vicinity

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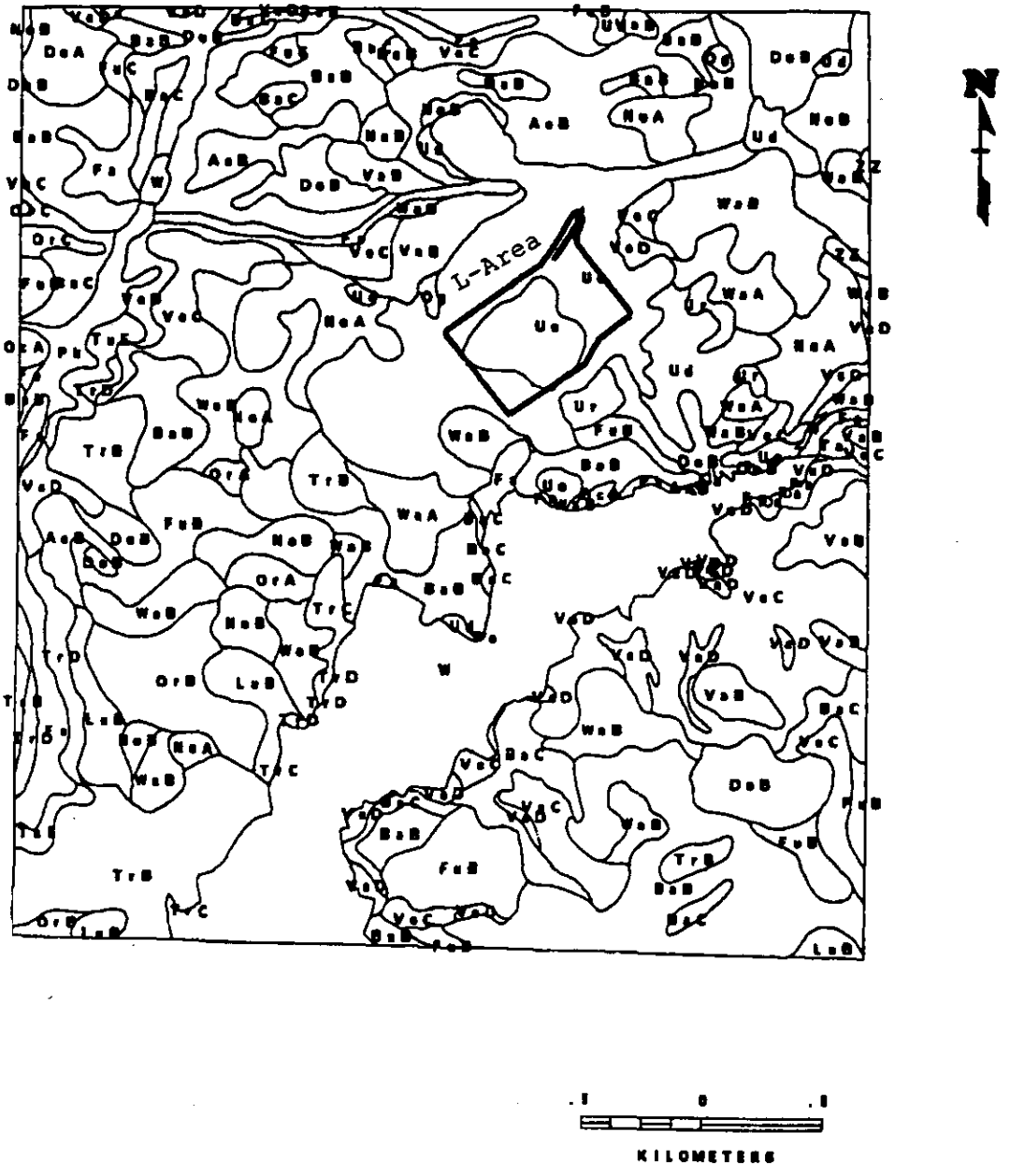

FIGURE 2-2. Soils, L Reactor and Immediate Vicinity

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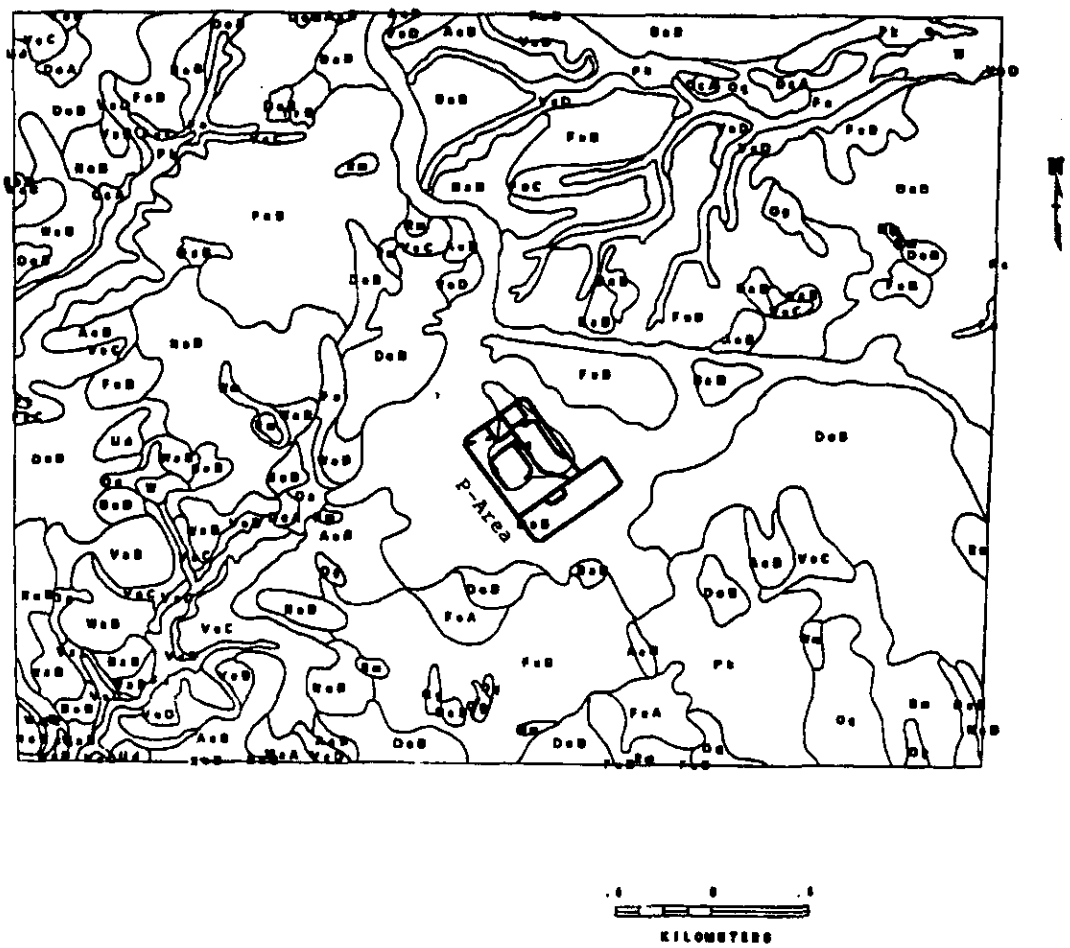

FIGURE 2-3. Soils, P Reactor and Immediate Vicinity

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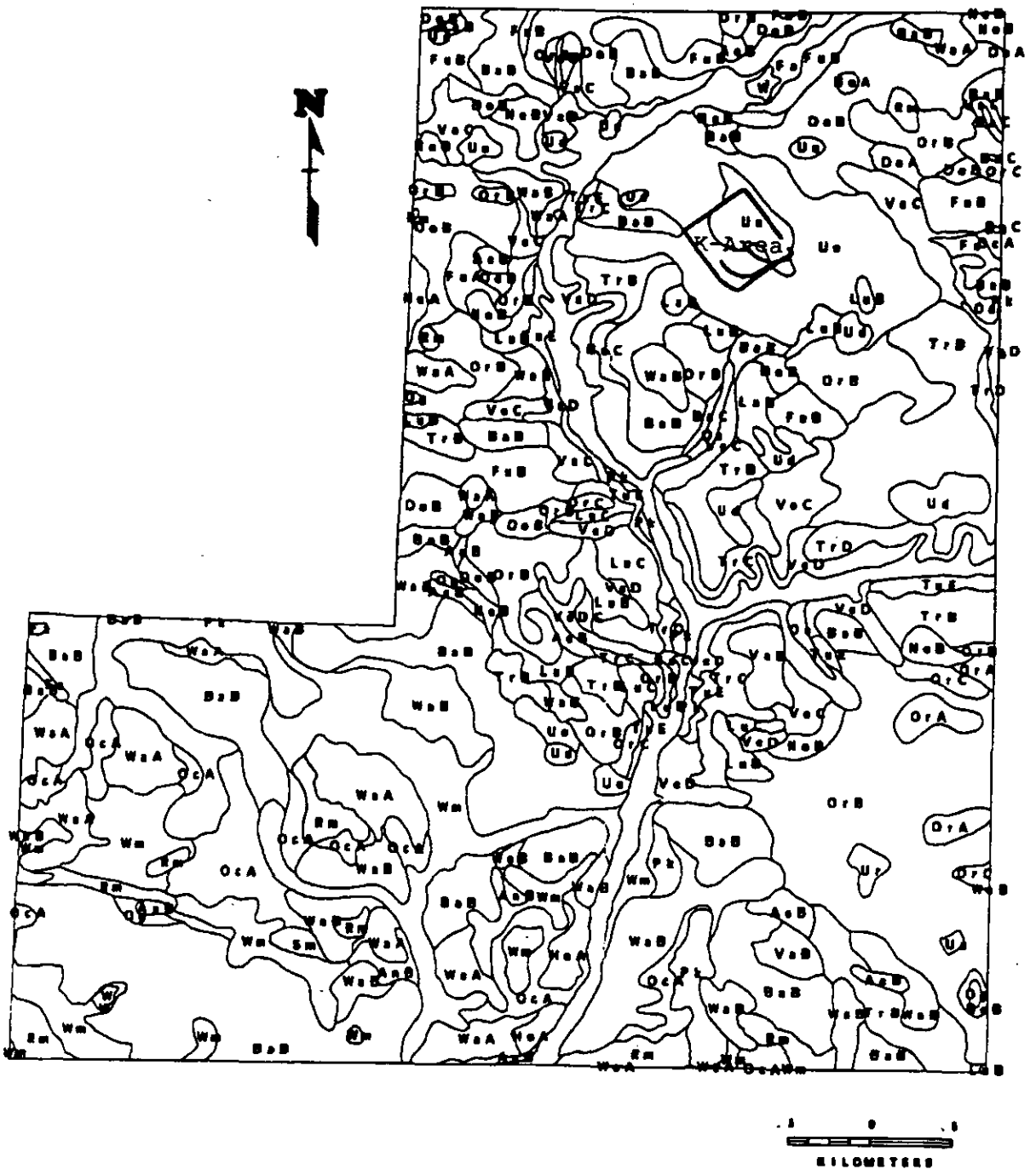

FIGURE 2-4. Soils, North Pen Branch Corridor

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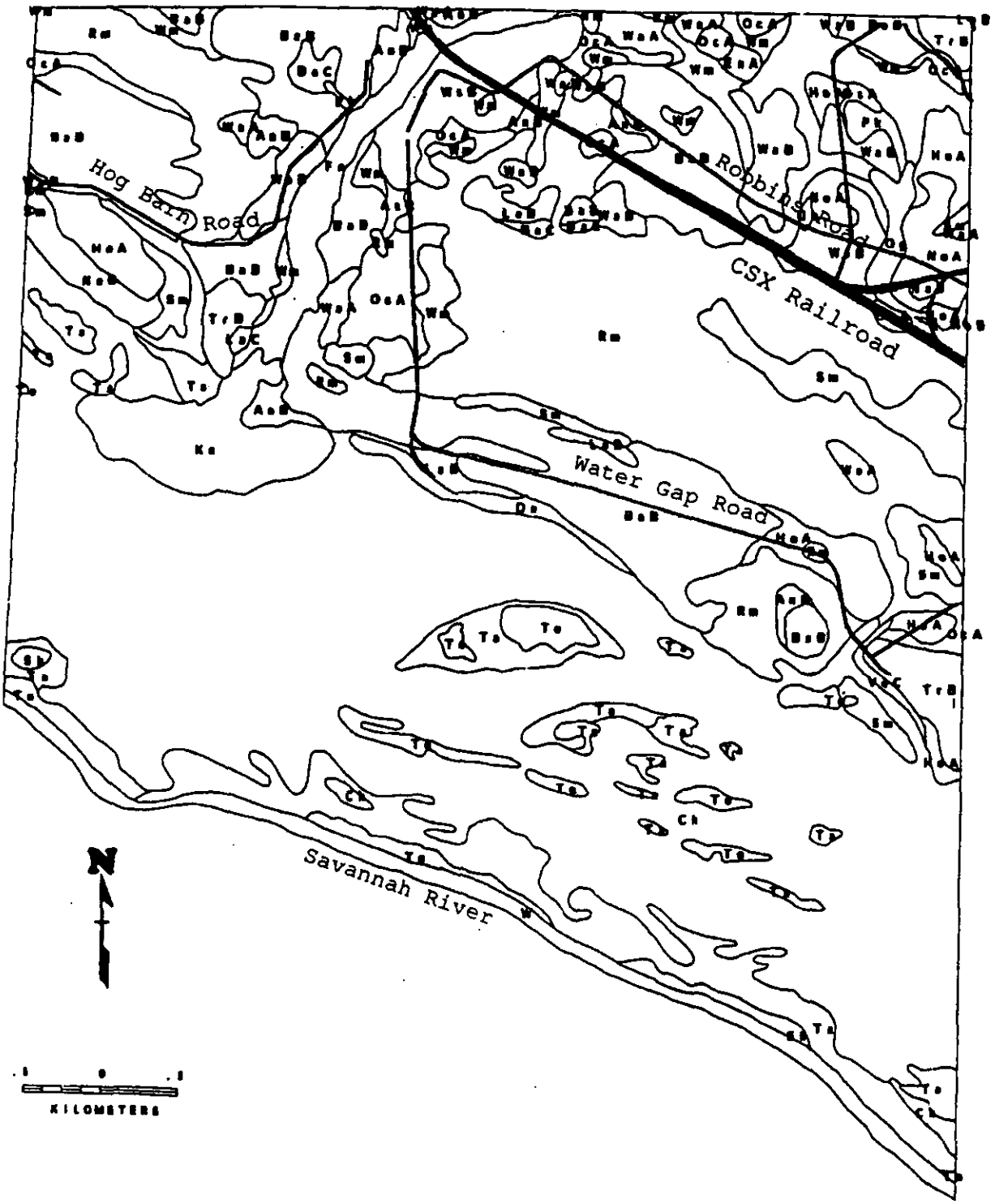

FIGURE 2-5. Soils, South Pen Branch Corridor

W8906070

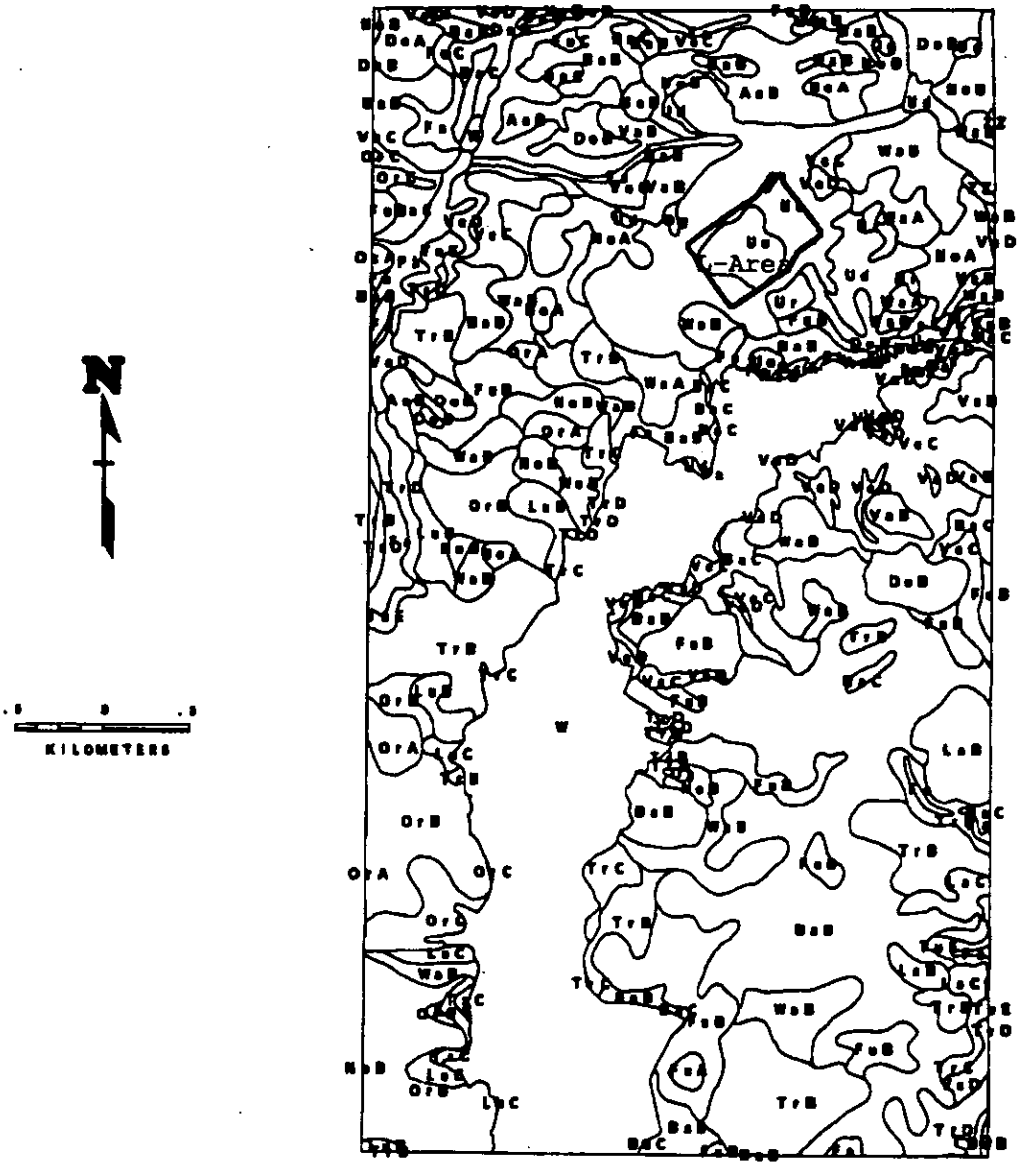

FIGURE 2-6. Soils, North L Lake/Steel Creek Corridor

W8906070

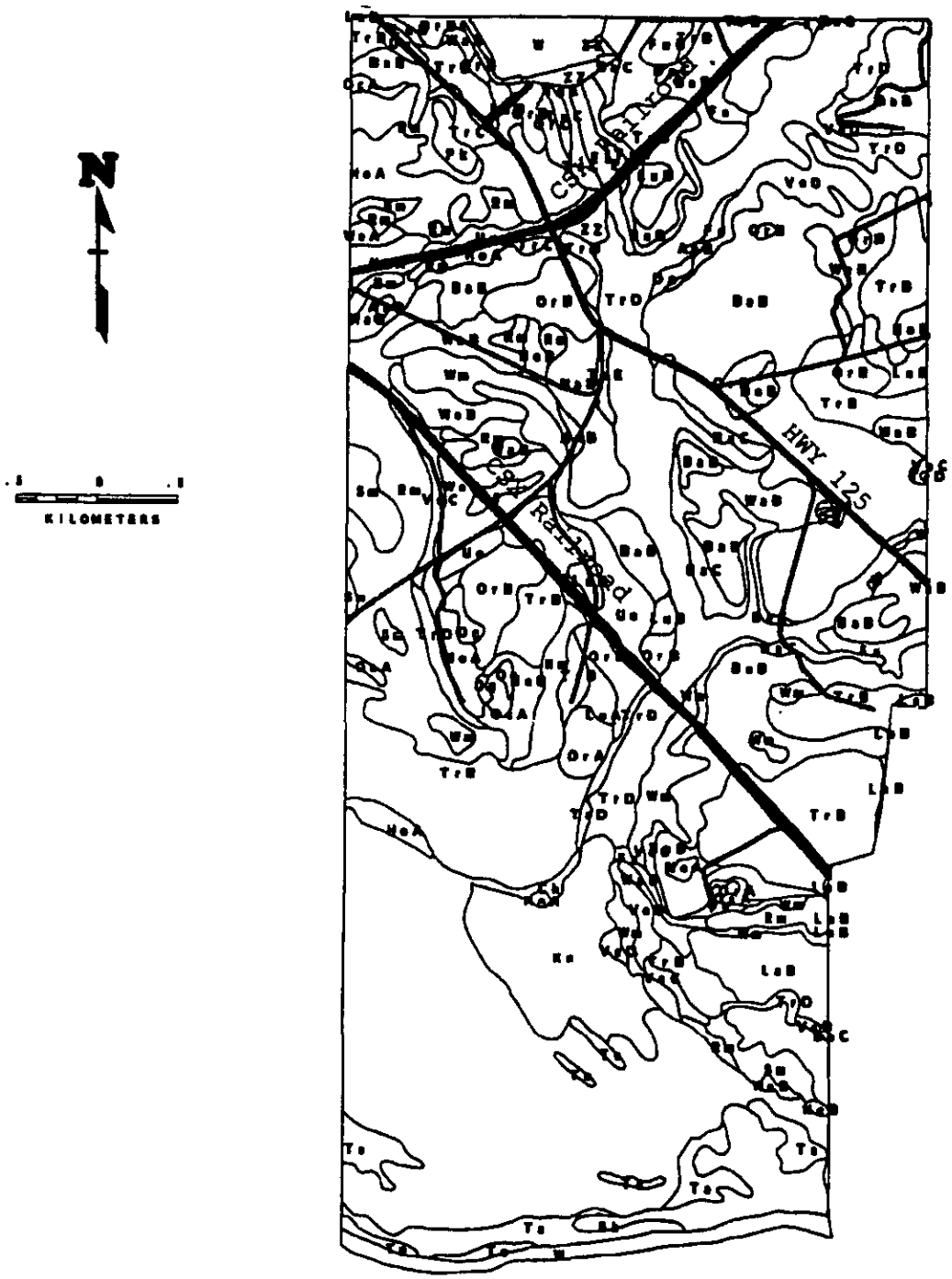

FIGURE 2-7. Soils, South L Lake/Steel Creek Corridor

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AeB	Ailey sand, 2 to 6% slopes, Wet Substratum
AnB	Albany sand, 0 to 6% slopes
BaB	Blanton sand, 0 to 6% slopes
BaC	Blanton sand, 6 to 10% slopes
Ch	Chastain clay, frequently flooded
Da	Dorovan muck, frequently flooded
DoA	Dothan sand, 0 to 2% slopes
DoB	Dothan sand, 2 to 6% slopes
EnA	Eunola fine sandy loam, 0 to 2% slopes
Fa	Flavaquents, frequently flooded
FuA	Fuquay sand, 0 to 2% slopes
FuB	Fuquay sand, 2 to 6% slopes
FuC	Fuquay sand, 6 to 10% slopes
HoA	Hornsville fine sandy loam, 0 to 2% slopes
Kn	Kinston loam, frequently flooded
LaB	Lakeland sand, 0 to 6% slopes
LaC	Lakeland sand, 6 to 10% slopes
LuA	Lucy sand, 0 to 2% slopes
LuB	Lucy sand, 2 to 6% slopes
LuC	Lucy sand, 6 to 10% slopes
NeB	Neeses loamy sand, 2 to 6% slopes
NoA	Norfolk loamy sand, 0 to 2% slopes
NoB	Norfolk loamy sand, 2 to 6% slopes
Oa	Ochlockonee loamy sand, occasionally flooded
OcA	Ocilla loamy sand, 0 to 2% slopes
Og	Ogeechee sandy loam, ponded
OrA	Orangeburg loamy sand, 0 to 2% slopes
OrB	Orangeburg loamy sand, 2 to 6% slopes
OrC	Orangeburg loamy sand, 6 to 10% slopes
Pk	Pickney sand, frequently flooded
Rm	Rembert sandy loam
Sh	Shellbluff loam, frequently flooded
Sm	Smithboro loam
Ta	Tawcaw silty clay, frequently flooded
To	Toccoa loam, frequently flooded
TrB	Troup sand, 0 to 6% slopes
TrC	Troup sand, 6 to 10% slopes
TrD	Troup sand, 10 to 15% slopes
TuE	Troup and Lucy sands, 15 to 25% slopes
TuF	Troup and Lucy sands, 25 to 40% slopes
Ud	Udorthents, firm substratum
Uo	Udorthents, friable substratum
Ur	Udorthents-Urban land complex, gently sloping
Uu	Urban land

FIGURE 2-8. Legend, Savannah River Site Soils

VaB	Vaucluse sandy loam, 2 to 6% slopes
VeC	Vaucluse-Ailey complex, 6 to 10% slopes
VeD	Vaucluse-Ailey complex, 10 to 15% slopes
WaA	Wagram sand, 0 to 2% slopes
WaB	Wagram sand, 2 to 6% slopes
Wm	William sand
W	Water
ZZ	Other

FIGURE 2-8. Legend, Savannah River Site Soils, Contd

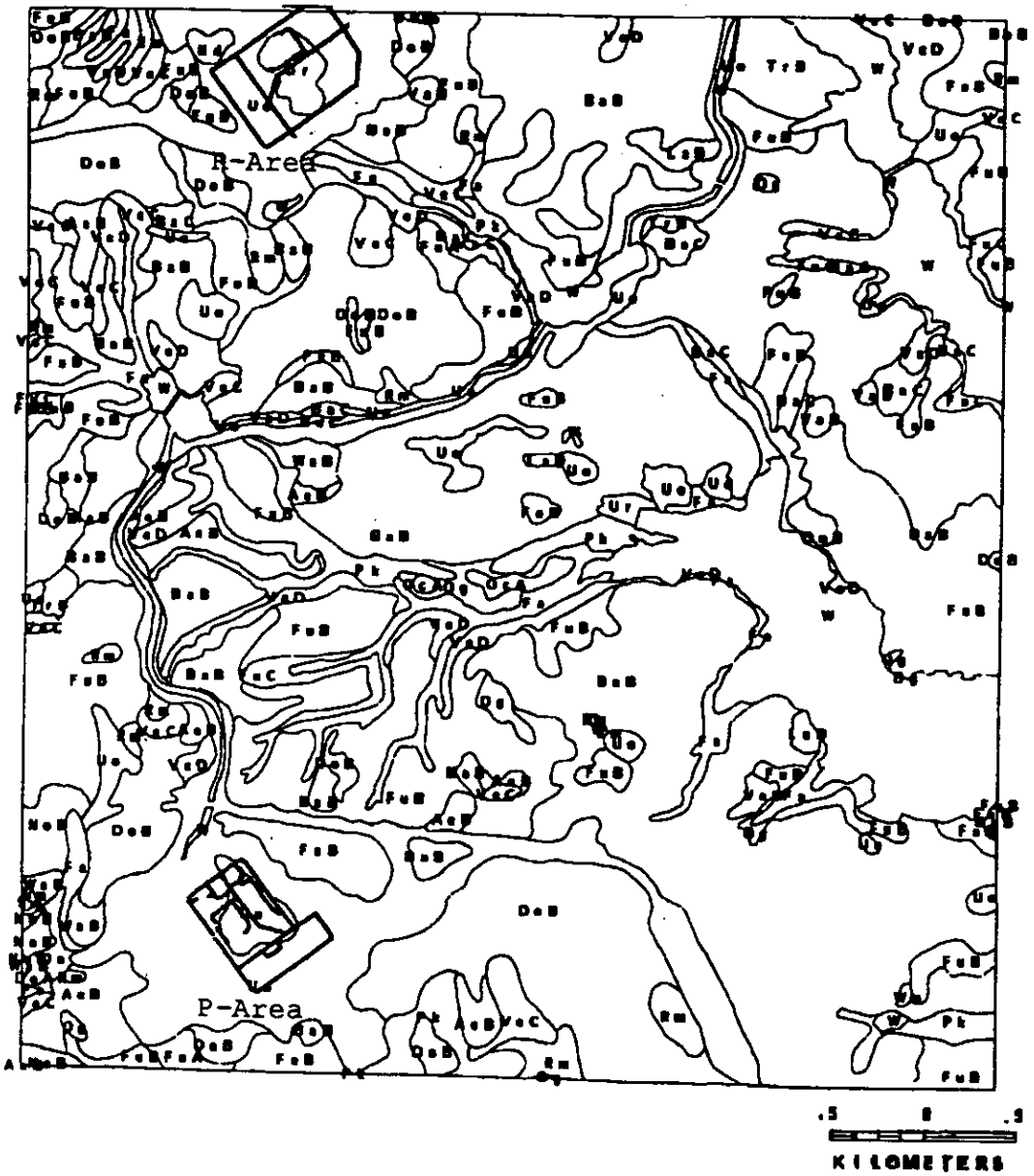

FIGURE 2-9. Soils, Southwest Par Pond Vicinity

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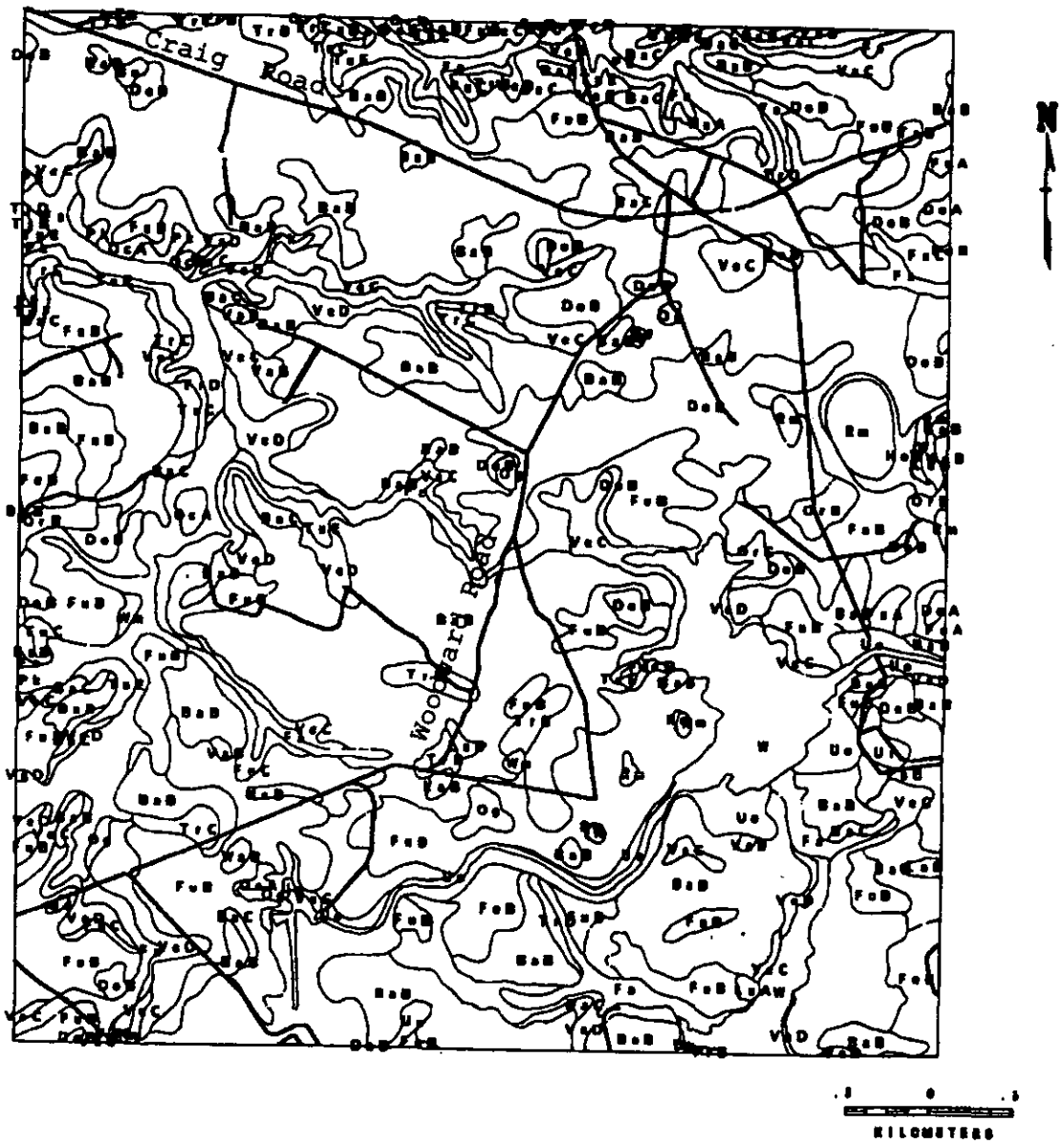

FIGURE 2-10. Soils, Northwest Par Pond Vicinity

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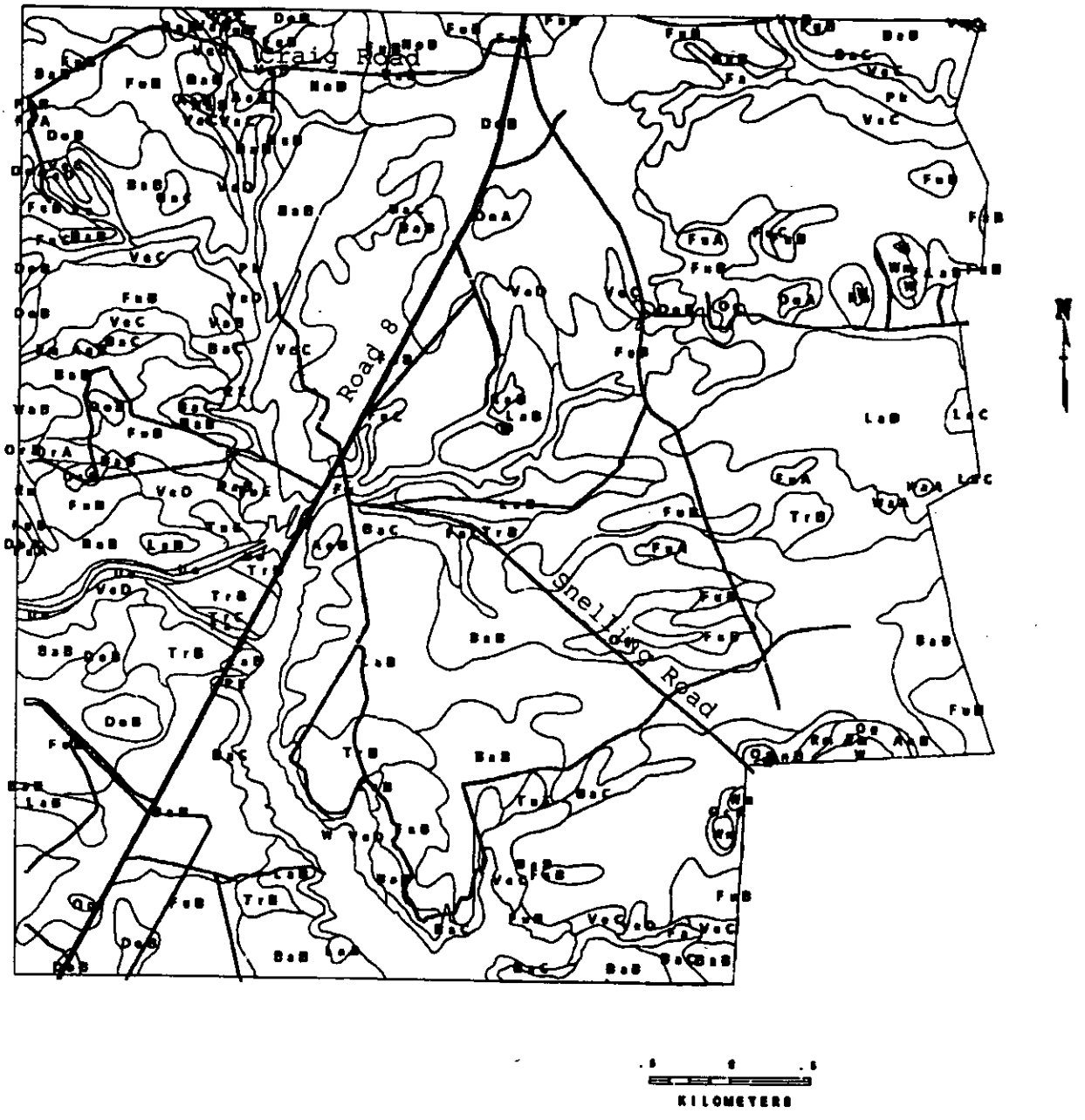

FIGURE 2-11. Soils, Northeast Par Pond Vicinity

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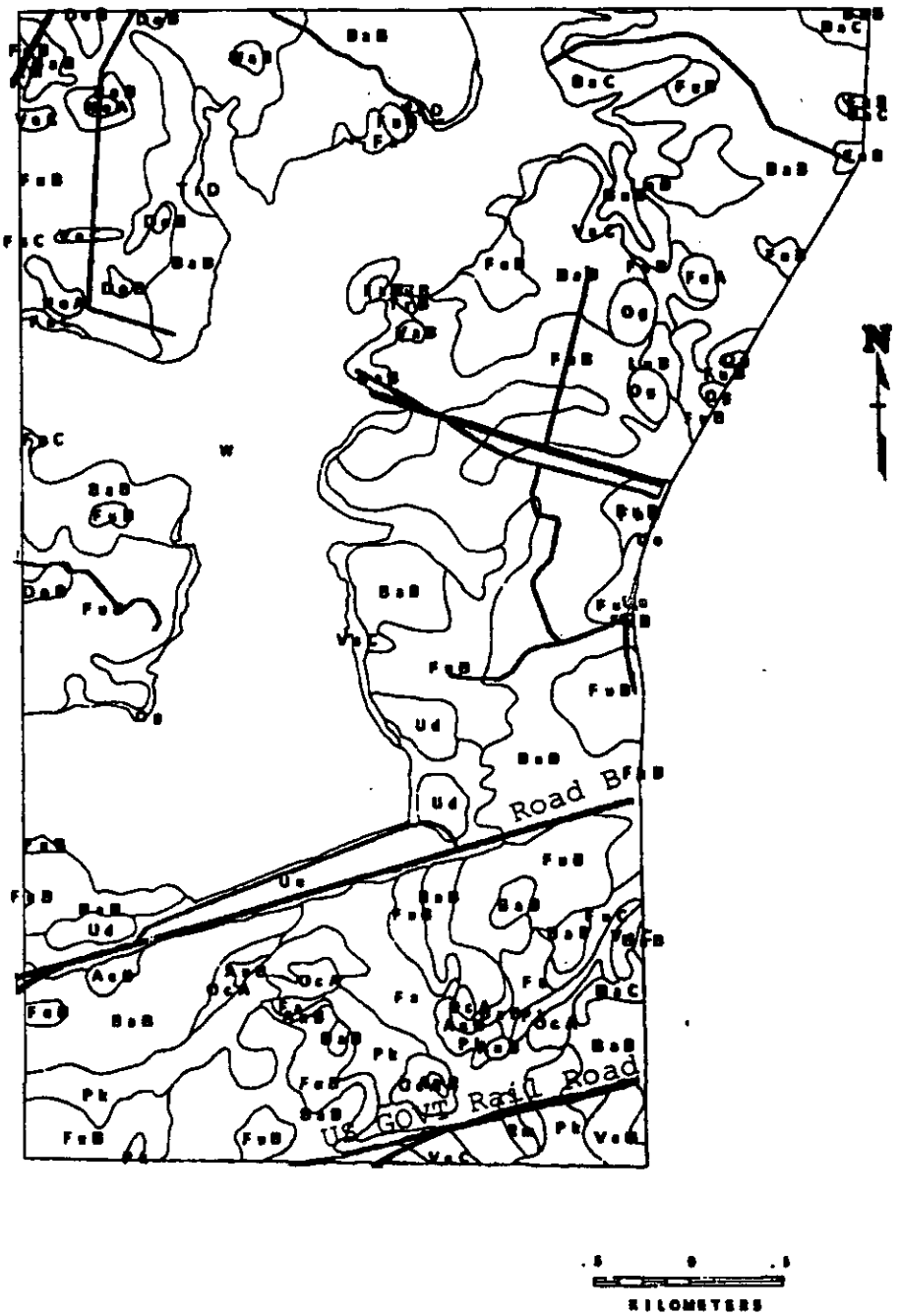

FIGURE 2-12. Soils, Southeast Par Pond Vicinity

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TABLE 2-1

Soils Statistics for Selected Areas of the Savannah River Site (area in hectares)

Soil Class or Type	Figure Symbol	L Reactor Vicinity	K Reactor Vicinity	P Reactor Corridor	North Steel Creek Corridor	South Steel Creek Corridor	North Pen Branch Corridor	South Pen Branch Corridor
Ailey sand, 2 to 6% slopes	AeB	57.98	12.50	85.32	57.98	1.16	24.70	
Albany sand, 0 to 6% slopes	AnB	0.2			0.20	2.60	13.35	37.49
Blanton sand, 0 to 6% slopes	BaB	168.46	112.20	232.81	404.35	459.30	497.72	442.99
Blanton sand, 6 to 10% slopes	BaC	49.85	7.39		52.10	39.91	9.00	11.38
Chastain clay, frequently flooded	Ch							1214.08
Dorovan muck, frequently flooded	Da					2.67		16.57
Dothan sand, 0 to 2% slopes	DoA	12.34	5.26	5.99	12.34		5.26	
Dothan sand, 2 to 6% slopes	DoB	68.48	169.83	512.23	68.48		169.83	
Fluvaquents, frequently flooded	Fa	39.24	104.05	65.81	44.41	29.80	140.83	57.71
Fuquay sand, 0 to 2% slopes	FuA		8.95	23.05	3.30		8.95	
Fuquay sand, 2 to 6% slopes	FuB	54.64	99.73	429.63	126.56	6.24	99.73	
Fuquay sand, 6 to 10% slopes	FuC	3.50		13.78	3.50			
Hornsville sandy loam, 0 to 2% slopes	HoA					63.60	15.38	93.53
Kinston loam, frequently flooded	Kn				82.83		80.32	

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TABLE 2-1, Contd

Soil Class or Type	Figure Symbol	L Reactor Vicinity	K Reactor Vicinity	P Reactor Corridor	North Steel Creek Corridor	South Steel Creek Corridor	North Pen Branch Corridor	South Pen Branch Corridor
Lakeland sand, 0 to 6% slopes	LaB	2.78	2.63		28.78	34.72	2.63	20.44
Lakeland sand, 6 to 10% slopes	LaC			14.42				1.71
Lucy sand, 0 to 2% slopes	LuA					5.42		
Lucy sand, 2 to 6% slopes	LuB	22.01	43.15		28.28	24.94	59.17	10.64
Lucy sand, 6 to 10% slopes	LuC		22.63		13.01	2.97	33.04	
Neeses loamy sand, 2 to 6% slopes	NeB	3.59	17.91	12.25	3.59	0.93	18.00	24.79
Norfolk loamy sand, 0 to 2% slopes	NoA	49.60	5.99		49.60	25.75	5.99	39.20
Norfolk loamy sand, 2 to 6% slopes	NoB	48.34	11.31	102.85	51.67	34.52	25.29	
Ochlockonee loamy sand, ocassionally flooded	Oa			12.02	5.38			13.34
Osilla loamy sand, 0 to 2% slopes	Oca	2.87	1.61	11.60	2.87	10.01	103.95	80.36
Ogeechee sandy loam no slope	Og	2.13	1.97	54.48	3.03	380.39	6.23	13.55
Orangeburg loamy sand, 0 to 2% slopes	OrA	7.17	1.64		17.07	11.40	21.11	
Orangeburg loamy sand, 2 to 6% slopes	OrB	29.07	122.95		135.90	88.26	330.71	
Orangeburg loamy sand, 6 to 10% slopes	OrC	3.32	8.05		23.16	4.63	20.47	

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TABLE 2.1, Contd

Soil Class or Type	Figure Symbol	L Reactor Vicinity	K Reactor Vicinity	P Reactor Corridor	North Steel Creek Corridor	South Steel Creek Corridor	North Pen Branch Corridor	South Pen Branch Corridor
Pickney sand, frequently flooded	Pk	14.98	4.02	123.41	14.98	8.61	94.71	8.76
Rembert Sandy loam, no slope	Rm		8.17	55.88		191.81	60.40	705.19
Shellbluff loam, frequently flooded	Sh					40.92		12.37
Smithboro loam, no slope	Sm					35.33	4.29	101.45
Tawcaw Silty loam frequently flooded	Ta	1.92			1.92	56.51		217.06
Toccoa loam frequently flooded	To					10.42		82.06
Troup sand, 0 to 6% slopes	TrB	73.86	147.20	4.09	166.28	326.04	190.74	50.04
Troup sand, 6 to 10% slopes	TrC	5.83	17.58		22.82	13.04	36.77	
Troup sand, 10 to 15% slopes	TrD	14.54	22.85		38.75	251.09	23.35	
Troup and Lucy sand 15 to 25% slopes	TuE	9.82	22.19		14.14	4.42	28.86	
Troup and Lucy sand 25 to 40% slopes	TuF							
Udorthents, no slope	Ud	29.98	36.99	6.32	29.98		39.23	
Udorthents, no slope	Uo	116.13	153.91		116.13	47.35	163.30	1.29
Udorthents-Urban land, gently sloping	Ur		8.66			8.66		4.55
Urban Land, no slope	Uu	14.85	18.22	14.66	14.85		19.59	

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TABLE 2-1, Contd

Soil Class or Type	Figure Symbol	L Reactor Vicinity	K Reactor Vicinity	P Reactor Corridor	North Steel Creek Corridor	South Steel Creek Corridor	North Pen Branch Corridor	South Pen Branch Corridor
Vaucluse sandy loam, 2 to 6% slopes	VaB	37.75	3.76	21.78	37.75		24.01	
Vaucluse-Alley complex 6 to 10% slopes	VeC	159.90	91.95	95.85	159.90	19.89	100.91	4.96
Vaucluse-Alley complex 10 to 15% slopes	VeD	38.97	76.91	62.41	43.51	39.16	108.16	
Wagram sand, 0 to 2% slopes	WaA	25.90	20.20	4.99	25.90	3.75	133.66	31.33
Wagram sand, 2 to 6% slopes	WaB	108.32	41.82	65.93	153.90	133.82	199.95	158.53
Williman sand, no slope	Wm			6.99		62.12	220.55	80.15
Water, no slope	W	156.44	2.42	18.53	395.42	55.61	3.97	68.14
Other soils	ZZ	1.99		4.39	1.99	14.42		4.38
Total Area		1445.39	1439.97	2040.40	2391.49	2626.53	3081.66	3670.47

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TABLE 2-2

Soil Statistics (hectares) for Par Pond Area

Soil Class or Type	Figure Symbol	NW Par Pond Site	NE Par Pond Site	SW Par Pond Site	SE Par Pond Site
Ailey Sand, 2 to 6% slopes	AeB		7.40	83.85	4.09
Albany Sand, 0 to 6% slopes	Anb		6.31		6.23
Blanton Sand, 0 to 6% slopes	BaB	835.30	1015.59	968.97	714.47
Blanton Sand, 6 to 10% slopes	BaC	78.47	145.63	33.44	38.37
Chastain Clay, frequently flooded	Ch				
Dorovan Muck, frequently flooded	Da				
Dothan Sand, 0 to 2% slopes	DoA	4.25	11.42	1.70	
Dothan Sand, 2 to 6% slopes	DoB	220.97	287.62	338.71	10.07
Fluvaquents, frequently flooded	Fa	148.08	78.18	108.42	73.28
Fuquay Sand, 0 to 2% slopes	FuA	9.96	24.40	11.36	10.67
Fuquay Sand, 2 to 6% slopes	FuB	1161.09	652.91	616.45	461.35
Fuquay Sand, 6 to 10% slopes	FuC	22.65	18.44	28.12	9.08
Hornsville Sandy Loam, 0 to 2% slopes	HoA	9.80			
Kinston Loam, frequently flooded	Kn				
Lakeland Sand, 0 to 6% slopes	LaB	6.88	529.84	8.26	13.91
Lucy Sand, 0 to 2% slopes	LuA	1.69			
Lucy Sand, 2 to 6% slopes	LuB	4.99	2.17	3.04	4.88
Lucy Sand, 6 to 10% slopes	LuC				
Neeses Loamy Sand, 2 to 6% slopes	NeB	3.01	3.35	6.38	
Norfolk Loamy Sand, 0 to 2% slopes	NoA				5.96
Norfolk Loamy Sand, 2 to 6% slopes	NoB		44.29	14.16	5.72

TABLE 2-2, Contd

Soil Class or Type	Figure Symbol	NW Par Pond Site	NE Par Pond Site	SW Par Pond Site	SE Par Pond Site
Ochlockonee Loamy Sand, occasionally flooded	Oa			5.38	
Ocilla Loamy Sand, 0 to 2% slopes	OcA	9.61	3.43	7.22	25.43
Ogeechee Sandy Loam, no slope	Og	17.67	17.23	22.08	23.76
Orangeburg Loamy Sand, 0 to 2% slopes	OrA		5.38		
Orangeburg Loamy Sand, 2 to 6% slopes	OrB	18.92	6.22		
Orangeburg Loamy Sand, 6 to 10% slopes	OrC	4.74			
Pickney Sand, frequently flooded	Pk	96.41	49.61	83.80	81.53
Rembert Sandy Loam, no slope	Rm	29.69	18.38	47,83	4.02
Shellbluff Loam, frequently flooded	Sh				
Smithboro Loam, no slope	Sm				
Tawcaw Silty Loam, frequently flooded	Ta				
Toccoa Loam, frequently flooded	To				
Troup Sand, 0 to 6% slopes	TrB	50.36	95.59	34.14	0.85
Troup Sand, 6 to 10% slopes	TrC	32.00	2.18		
Troup Sand, 10 to 15% slopes	TrD	10.40	5.03		5.16
Troup and Lucy Sand, 15 to 25% slopes	TuE	60.12	12.76		
Troup and Lucy Sand, 25 to 40% slopes	TuF	0.59			
Udorthents, no slope	Ud	0.81		6.46	24.83
Udorthents, no slope	Uo	116.20	10.60	425.25	58.25
Udorthents-Urban Land, gently sloping	Ur	6.14		16.03	
Urban Land, no slope	Uu			14.66	

TABLE 2-2, Contd

Soil Class or Type	Figure Symbol	NW Par Pond Site	NE Par Pond Site	SW Par Pond Site	SE Par Pond Site
Vaucluse Sandy Loam, 2 to 6% slopes	VaB	6.30	20.71	11.62	1.45
Vaucluse-Alley Complex, 6 to 10% slopes	VeC	227.83	179.91	70.48	54.87
Vaucluse-Alley Complex, 10 to 15% slopes	VeD	122.42	80.43	94.96	13.43
Wagram Sand, 0 to 2% slopes	WaA	2.46	2.56		
Wagram Sand, 2 to 6% slopes	WaB	3.89	9.38	15.87	2.23
Williman Sand, no slope	Wm	3.57	9.41	2.64	
Water, no slope	W	132.50	119.11	314.37	597.02
Other Soils	22		3.45		
Total Area		3459.58	3492.65	3396.65	2250.93

2.2 VEGETATION COVER

2.2.1 Terrestrial Land Cover Types

The following is a brief description of the major terrestrial land cover types found on the SRS. More detailed descriptions of the land cover types and vegetation within these cover types can be found in Ezra et al. (1986); Gladden et al. (1985); Jones et al. (1981); and Whipple et al. (1981).

Figures 2-13 through 2-15 show the land cover types in the vicinity of K, L, and P reactors. Figures 2-16 through 2-19 show the land cover types near the corridors along Pen Branch and Steel Creek. Figure 2-20 is the legend of cover types for Figures 2-13 through 2-19 and Table 2-3 summarizes the areas of coverage in each of these figures (Figures 2-13 through 2-19). Wetland land cover maps are shown in Figures 2-21 through 2-23 for the vicinities of K, L, and P reactors and in Figures 2-24 through 2-27 for the vicinities of the Pen Branch an Steel Creek corridors. Figures 2-28 through 2-31 show the land cover types in and around Par Pond. Figures 2-32 through 2-35 show the wetland cover types in and around Par Pond. Table 2-4 summarizes the statistics for Figures 2-28 through 2-35. Descriptions of the wetland land cover of Pen Branch and Steel Creek are given in more detail in Chapter 3 and will not be covered here.

2.2.1.1 Industrial Related Land Cover Types

This land cover type includes administrative or production facilities and immediately contiguous surrounding areas (e.g., fly ash basins, borrow pits, and cleared areas). Roads and right-of-ways, as well as railroad facilities, are included in the transportation class. Utility corridors and electric substations are included in the utility land cover type; however, cleared utility corridors are included in the land cover present (e.g., grassland/forbland and scrub-shrub) and substations were mapped as utilities. Borrow pits are considered as active, reclaimed covered with grasses/forbs, or reclaimed covered with scrub-shrub vegetation (Ezra et al. 1986).

2.2.1.2 Grassland/Forbland

This land cover type is dominated by nonwoody plants with grasses and forbs composing more than 50% of the vegetation cover. This land cover type occurred primarily on power line right-of-ways and in a few forest openings. The SRS wildlife food plots are included in the grassland/forbland cover type.

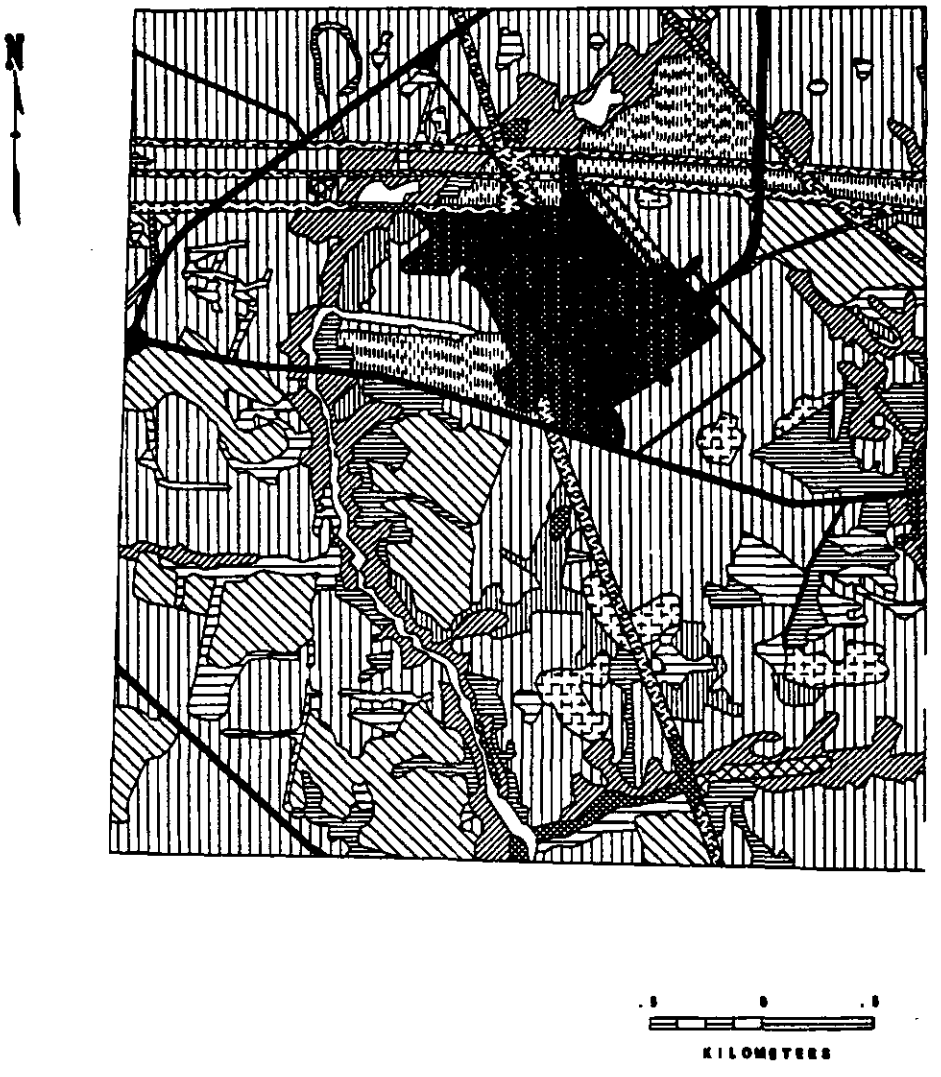

FIGURE 2-13. Land Cover, K Reactor and Immediate Vicinity

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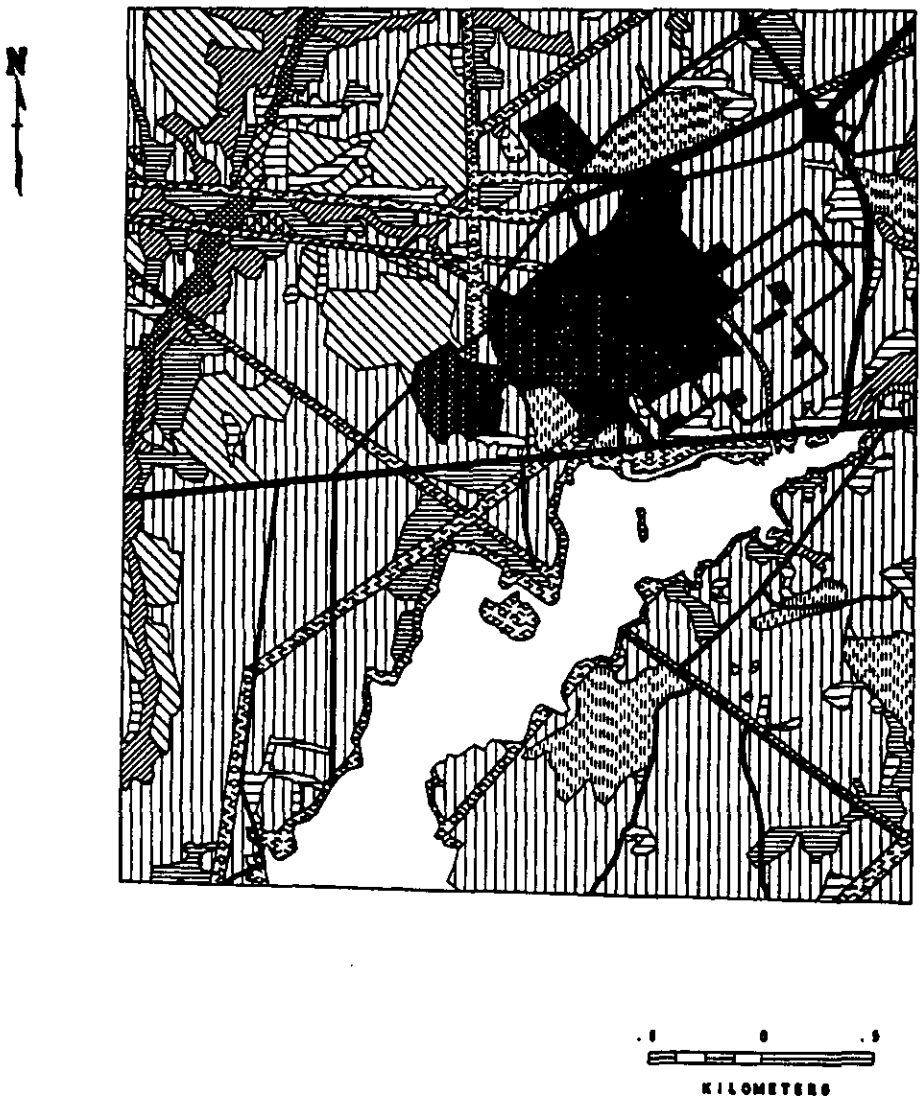

FIGURE 2-14. Land Cover, L Reactor and Immediate Vicinity

W8906070

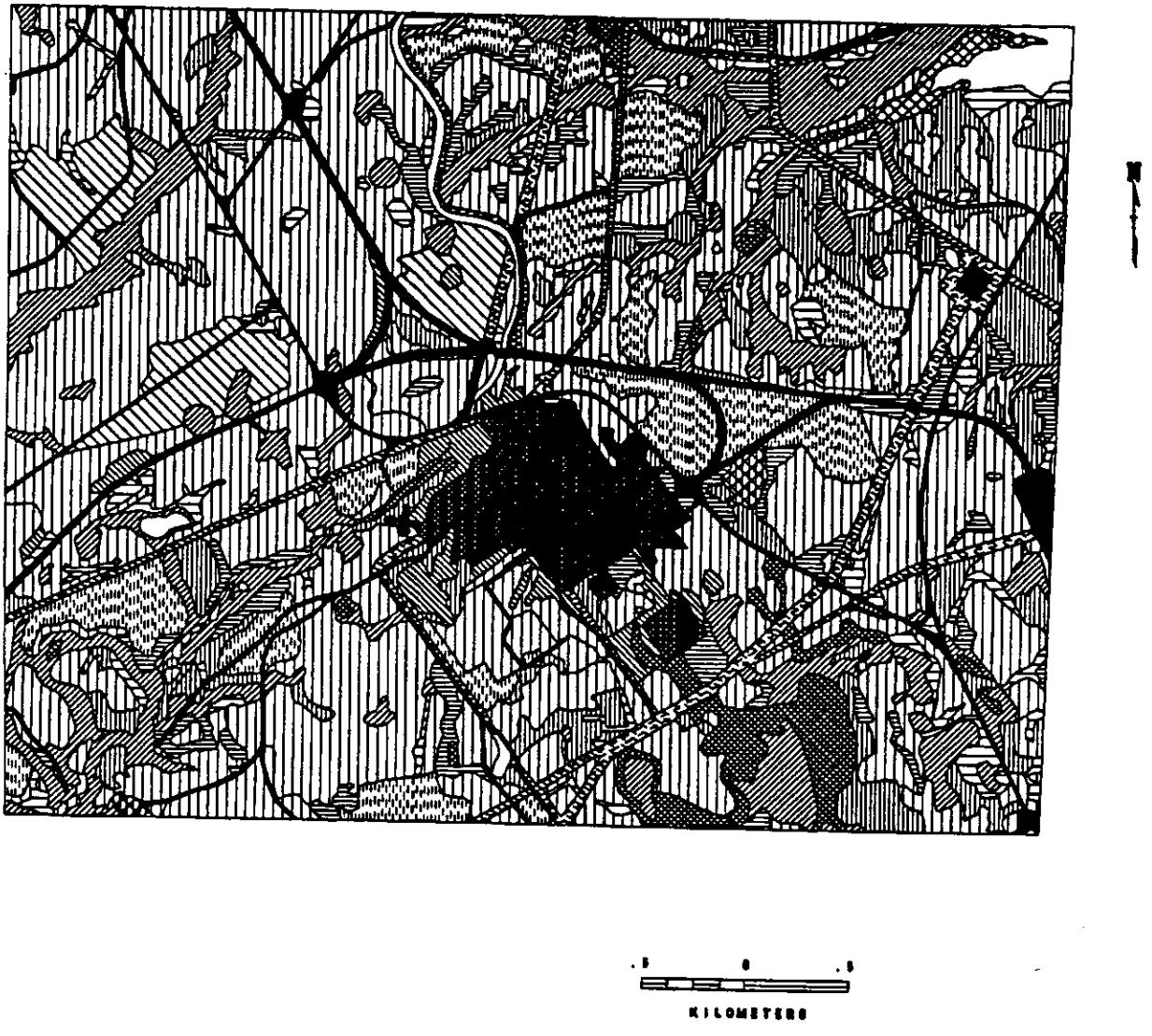

FIGURE 2-15. Land Cover, P Reactor and Immediate Vicinity

W8906070

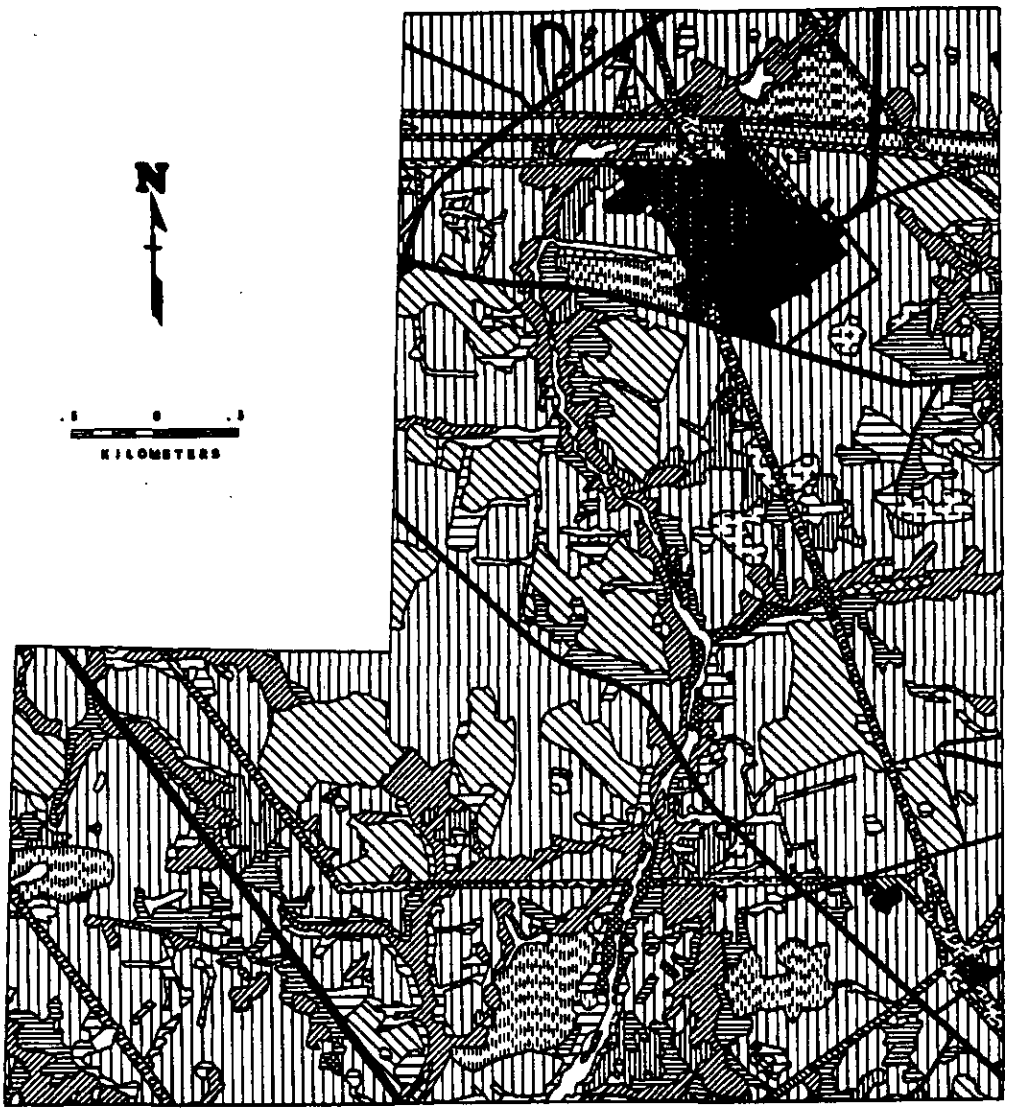

FIGURE 2-16. Land Cover, North Pen Branch Corridor

W8906070

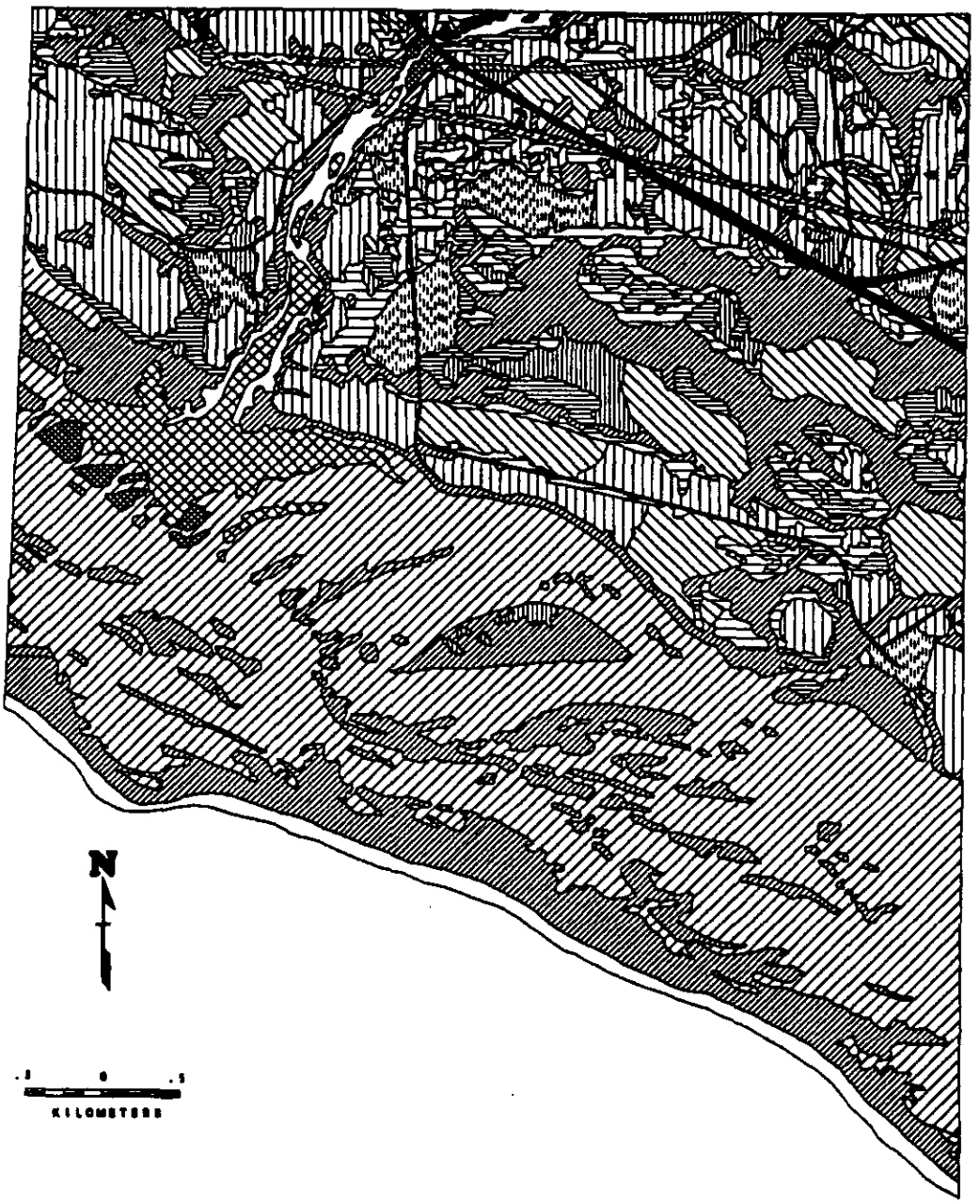

FIGURE 2-17. Land Cover, South Pen Branch Corridor

W8906070

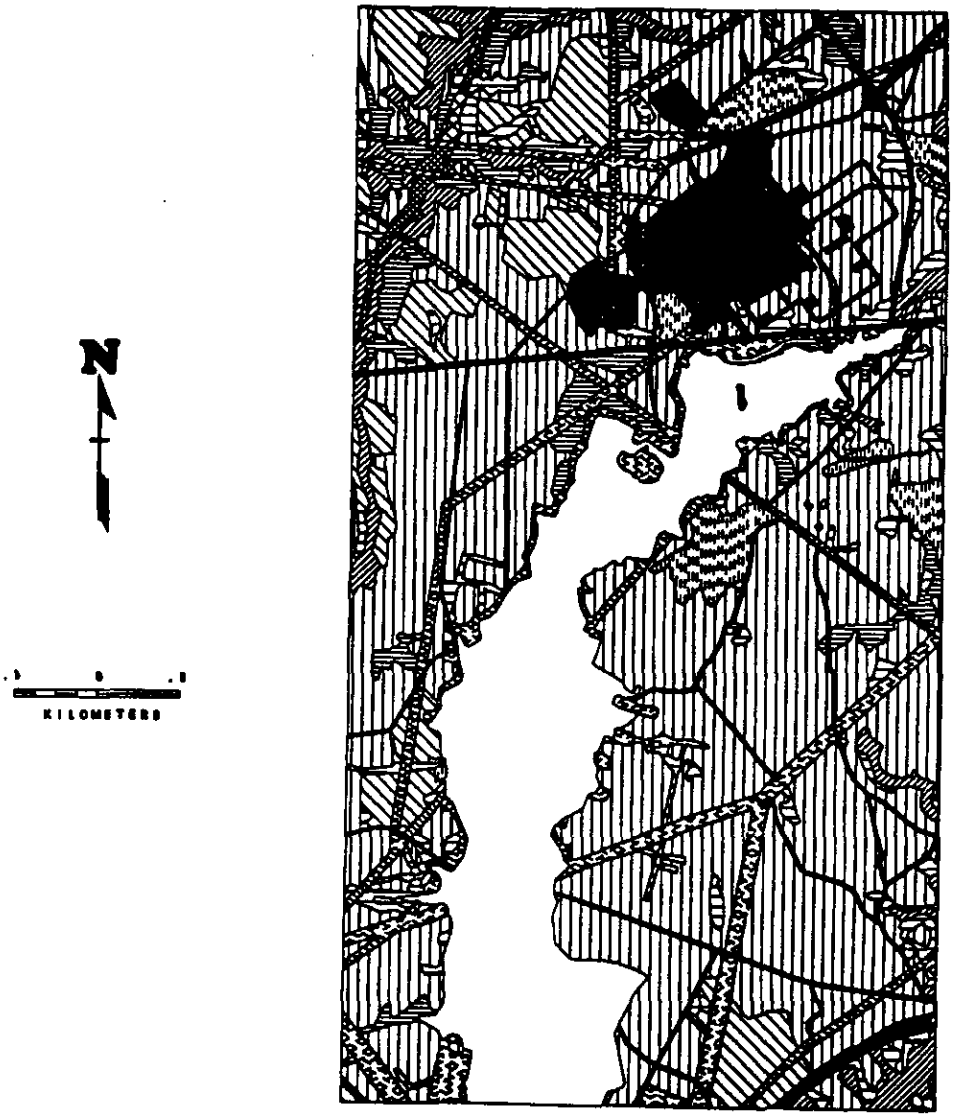

FIGURE 2-18. Land Cover, North L Lake/Steel Creek Corridor

W8906070

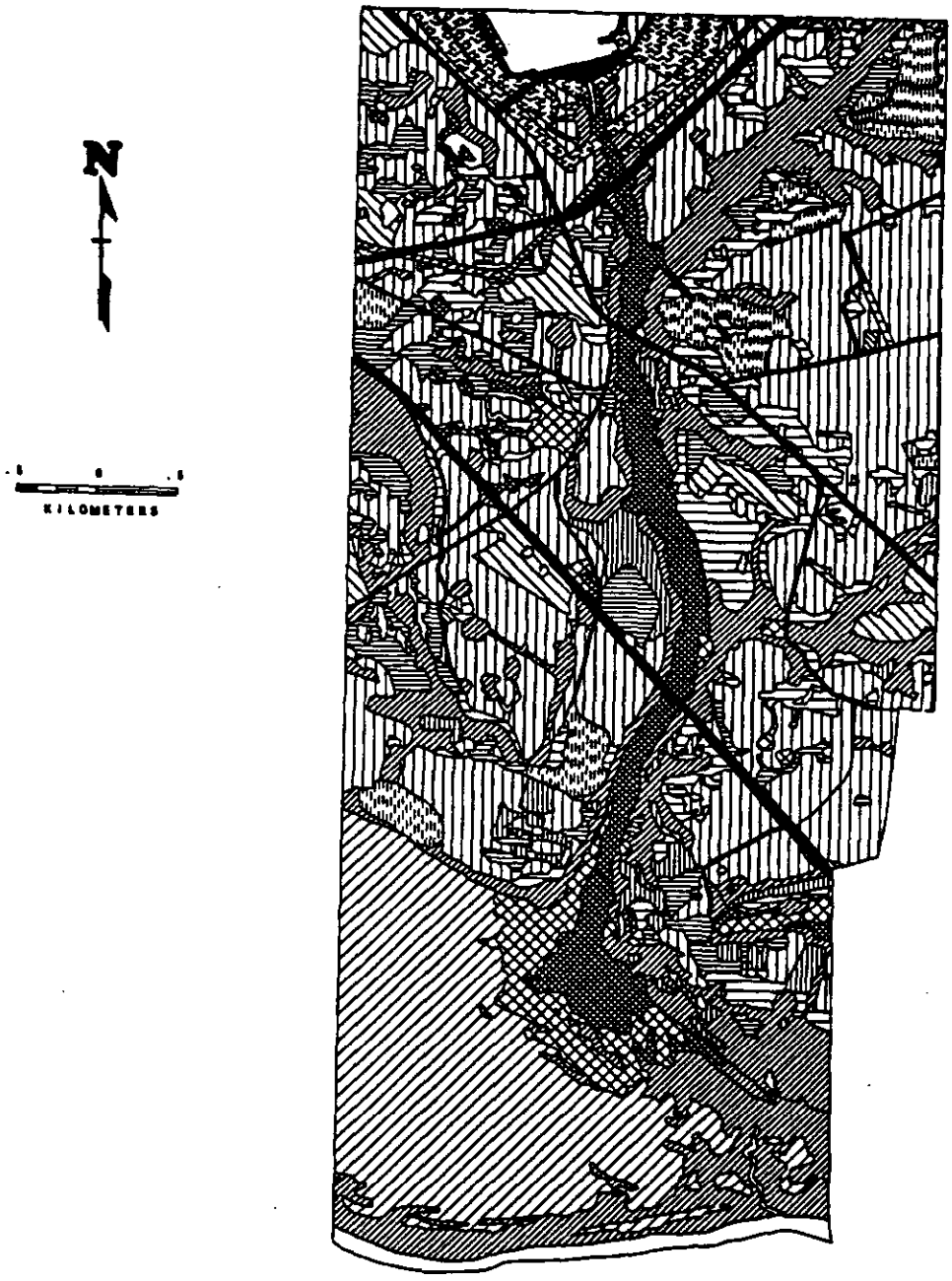

FIGURE 2-19. Land Cover, South L Lake/Steel Creek Corridor

W8906070

LEGEND

SAVANNAH RIVER SITE LAND COVER

- FACILITY
- TRANSPORTATION
- OPEN WATER
- EVERGREEN FOREST
- MIXED EVERGREEN FOREST
- DECIDUOUS FOREST
- MIXED DECIDUOUS FOREST
- REGENERATION SCRUB/SHRUB
- BOTTOMLAND HARDWOOD
- WETLAND SCRUB/SHRUB
- SWAMP FOREST
- EMERGENT WETLAND
- OTHER SCRUB/SHRUB
- BARE SOIL
- ACTIVE BORROW
- BORROW GRASS/SHRUB
- GRASSLAND
- CLEAR CUT

FIGURE 2-20. Legend, Savannah River Site Land Cover

M890607O

TABLE 2-3

Land Cover Statistics for Selected Areas of the Savannah River Site (area in hectares)

Land Cover Class	L Reactor Area	K Reactor Area	P Reactor Area	North Steel Creek Corridor	South Steel Creek Corridor	North Pen Branch Corridor	South Pen Branch Corridor
Emergent Wetlands	2.62	4.76	8.10	2.62	75.99	7.34	103.27
Scrub-Shrub Wetlands	11.99	13.95	55.67	11.99	137.30	31.06	28.17
Bottomland Hardwood	65.20	120.36	242.62	87.33	505.11	299.03	922.76
Swamp Forest					338.09		1061.38
Open Water	152.76	18.48	25.68	391.74	63.25	42.36	112.50
Deciduous Forest	55.74	72.98	61.31	92.46	190.99	181.12	217.98
Mixed Deciduous Forest	77.38	75.71	88.17	82.66	143.97	184.84	152.45
Evergreen Forest	659.79	671.52	892.73	1141.42	791.41	1489.41	565.55
Mixed Evergreen Forest	2.64	38.26	164.38	3.30	67.02	81.64	80.48
Regeneration Scrub-Shrub	96.80	152.72	70.82	141.43	67.75	321.12	242.87
Other Scrub-Shrub	1.07		32.64	3.37	1.93	4.85	6.87
Clear Cuts	62.93	65.33	152.43	63.54	93.25	140.56	95.67
Grassland/Forbland	100.23	54.96	73.92	184.59	68.79	110.37	31.42
Bare Soil	0.93	0.63	2.11	2.96		0.63	
Active Borrow	2.22	0.98	6.16	2.22		0.98	
Borrow Grass/Shrub	1.19	29.38	1.03	1.19		31.87	2.44
Transportation	57.80	37.45	90.39	84.58	74.97	67.20	46.64
Facilities	94.07	82.50	72.23	94.07	6.72	87.28	
Total Area	1445.39	1439.97	2040.40	2391.49	2626.53	3081.66	3670.47

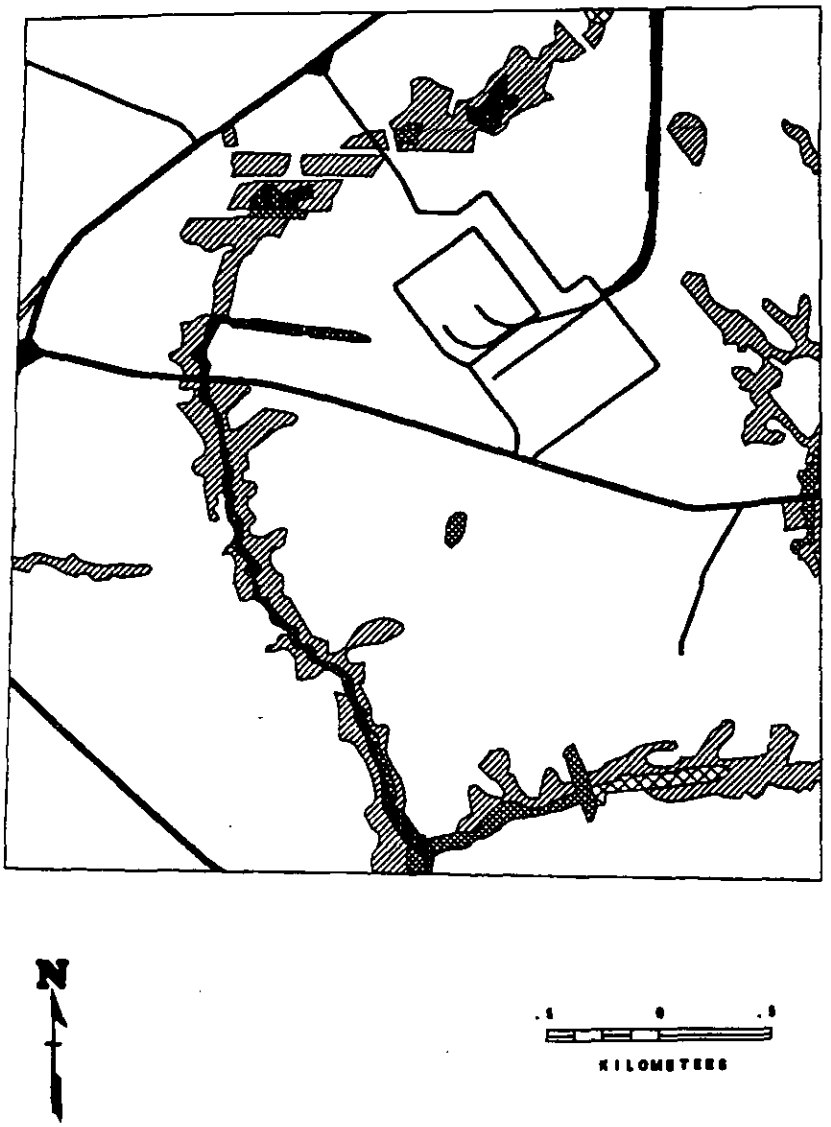

FIGURE 2-21. Wetland Land Cover, K Reactor and Immediate Vicinity

W8906070

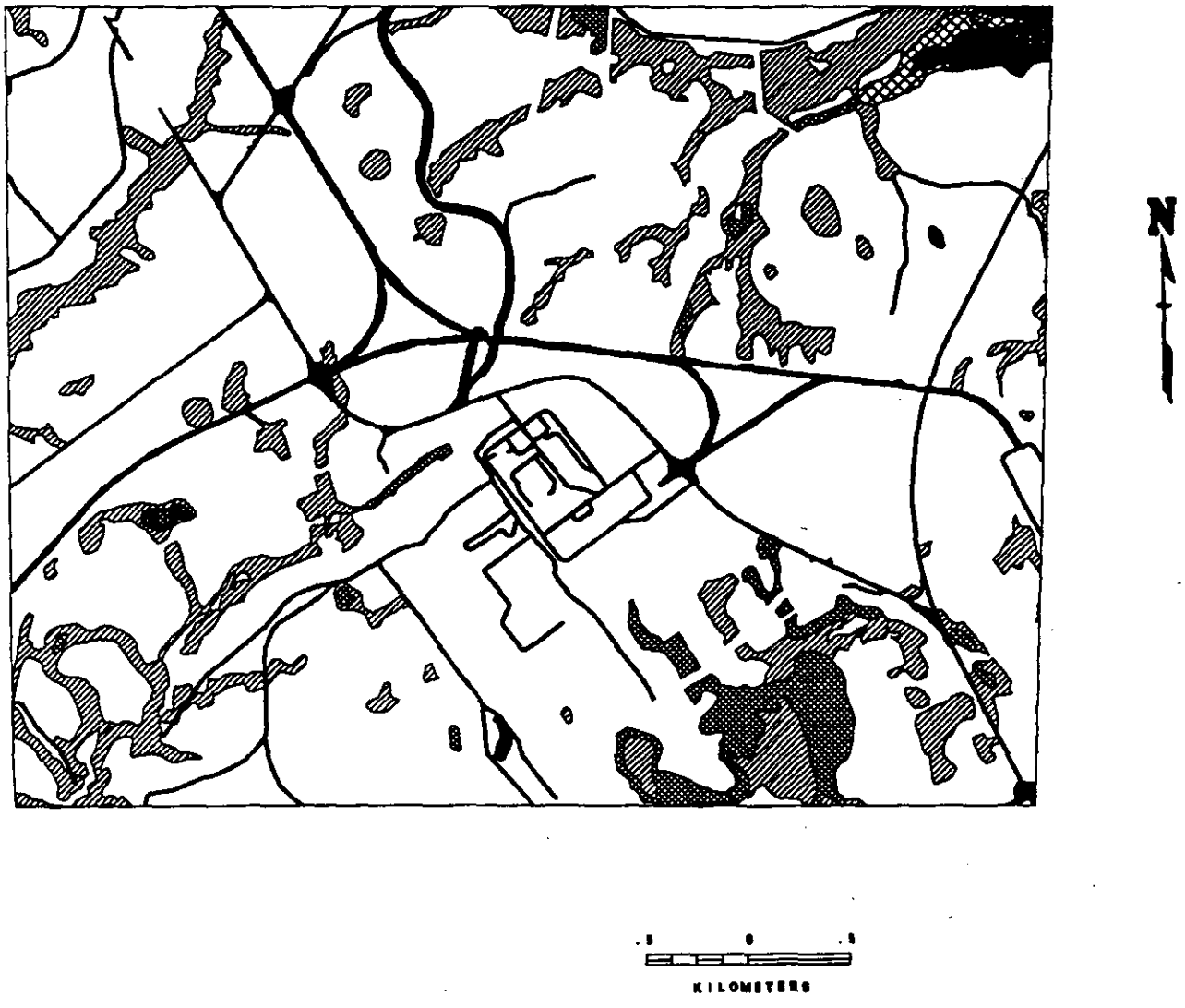

FIGURE 2-22. Wetland Land Cover, P Reactor and Immediate Vicinity

W8906070

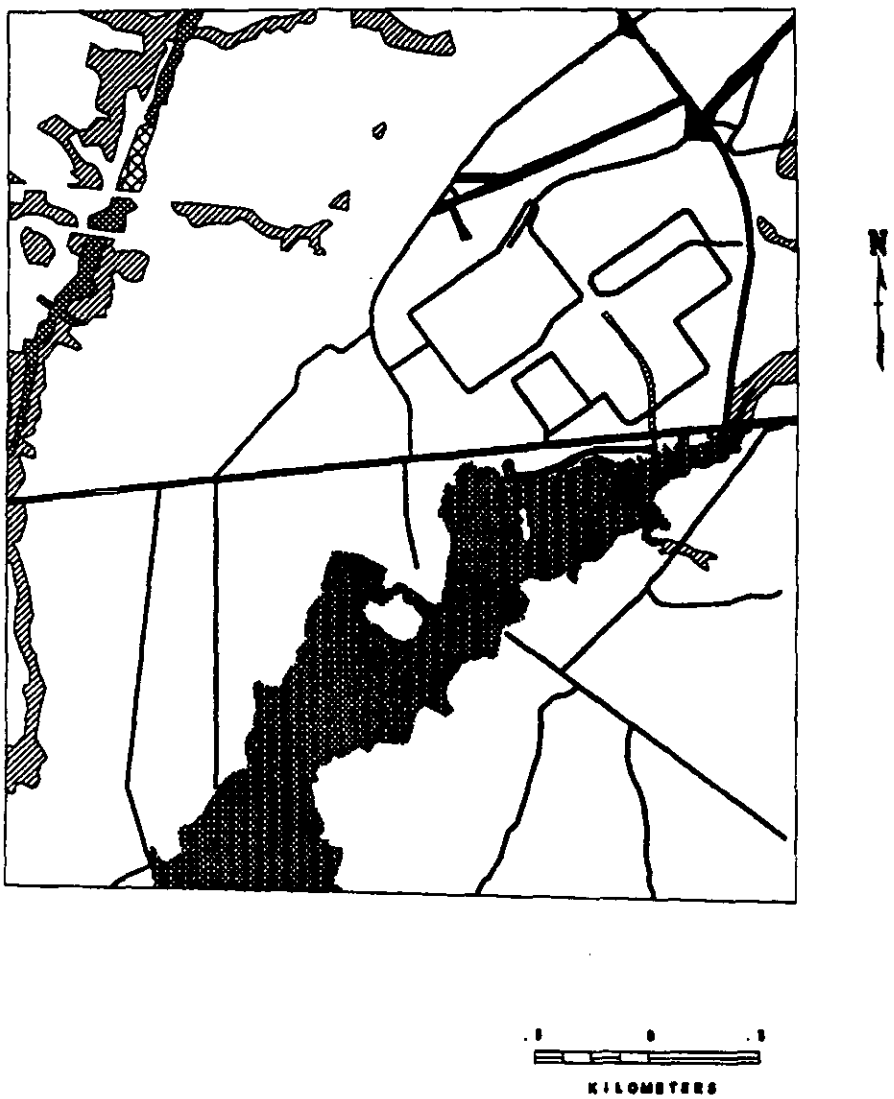

FIGURE 2-23. Wetland Land Cover, L Reactor and Immediate Vicinity

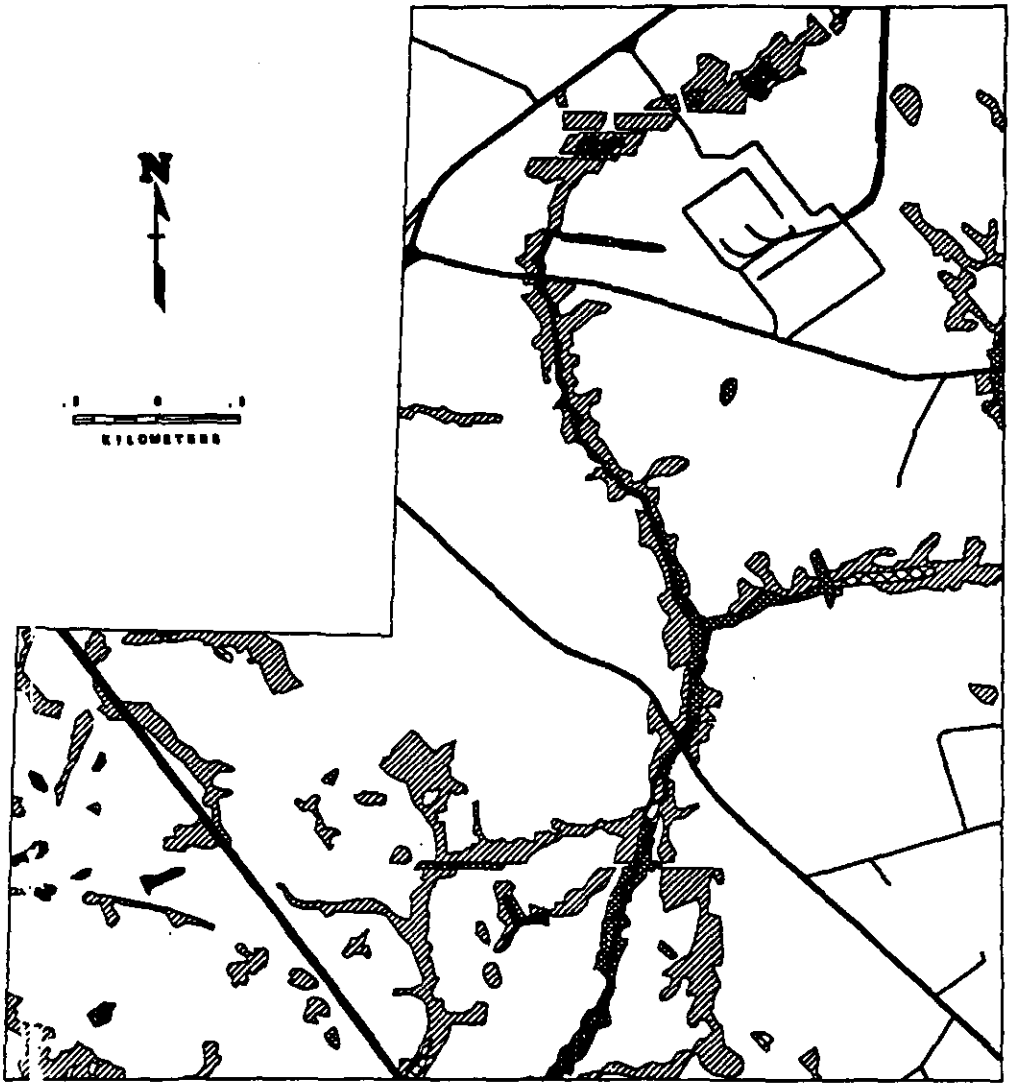

FIGURE 2-24. Wetland Land Cover, North Pen Branch Corridor

W8906070

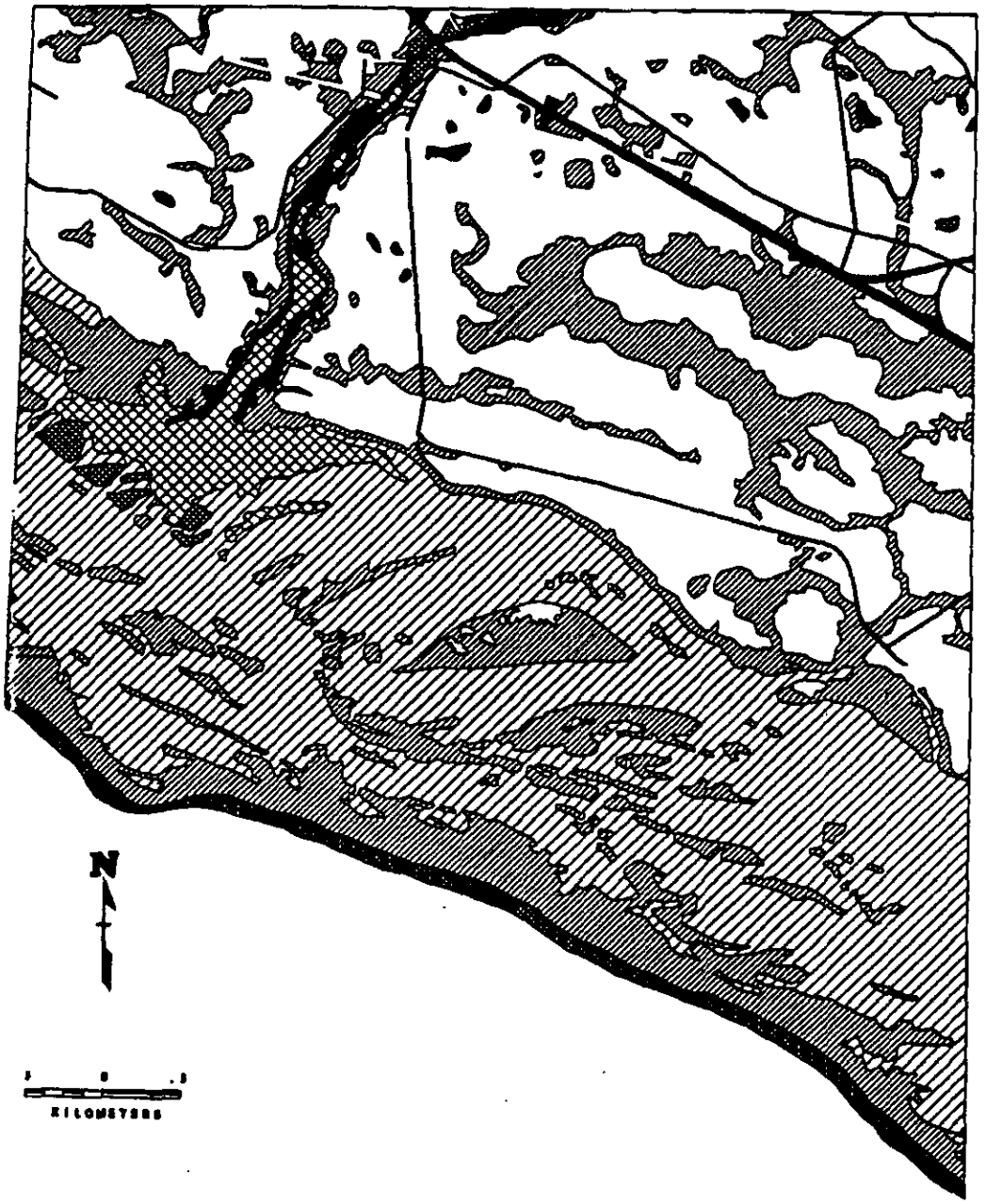

FIGURE 2-25. Wetland Land Cover, South Pen Branch Corridor

W8906070

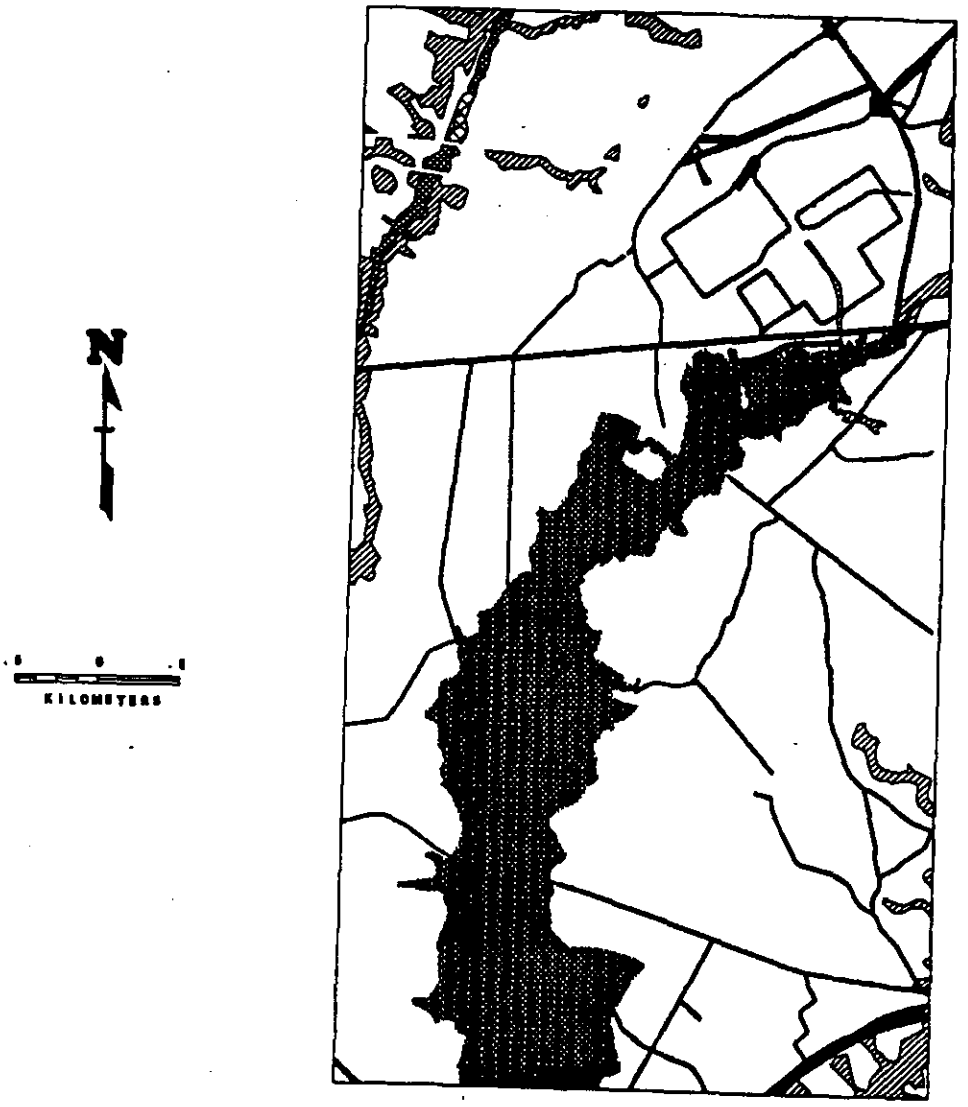

FIGURE 2-26. Wetland Land Cover, North L-Lake/Steel Creek Corridor

W8906070

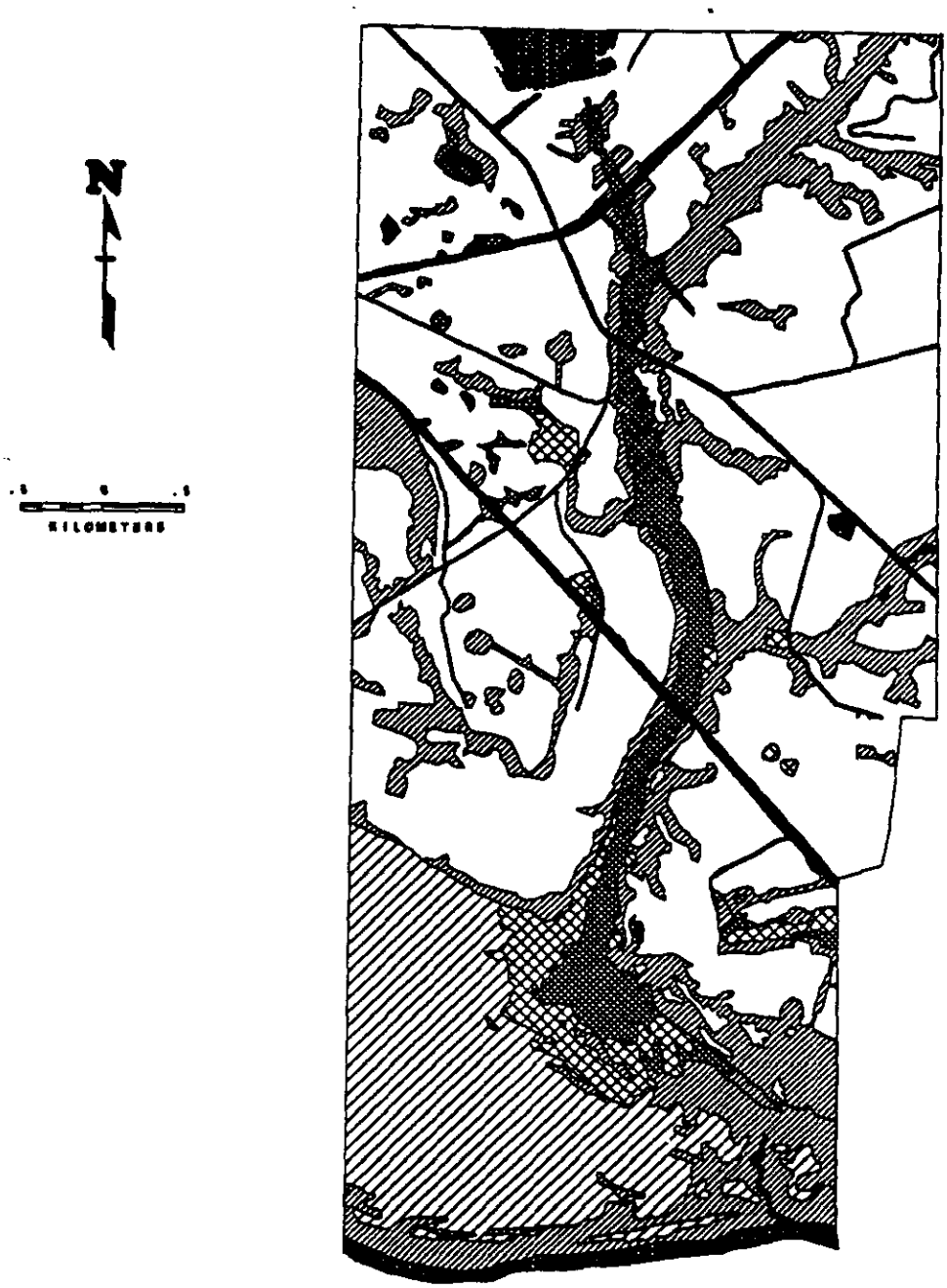

FIGURE 2-27. Wetland Land Cover, South L-Lake/Steel Creek Corridor

W8906070

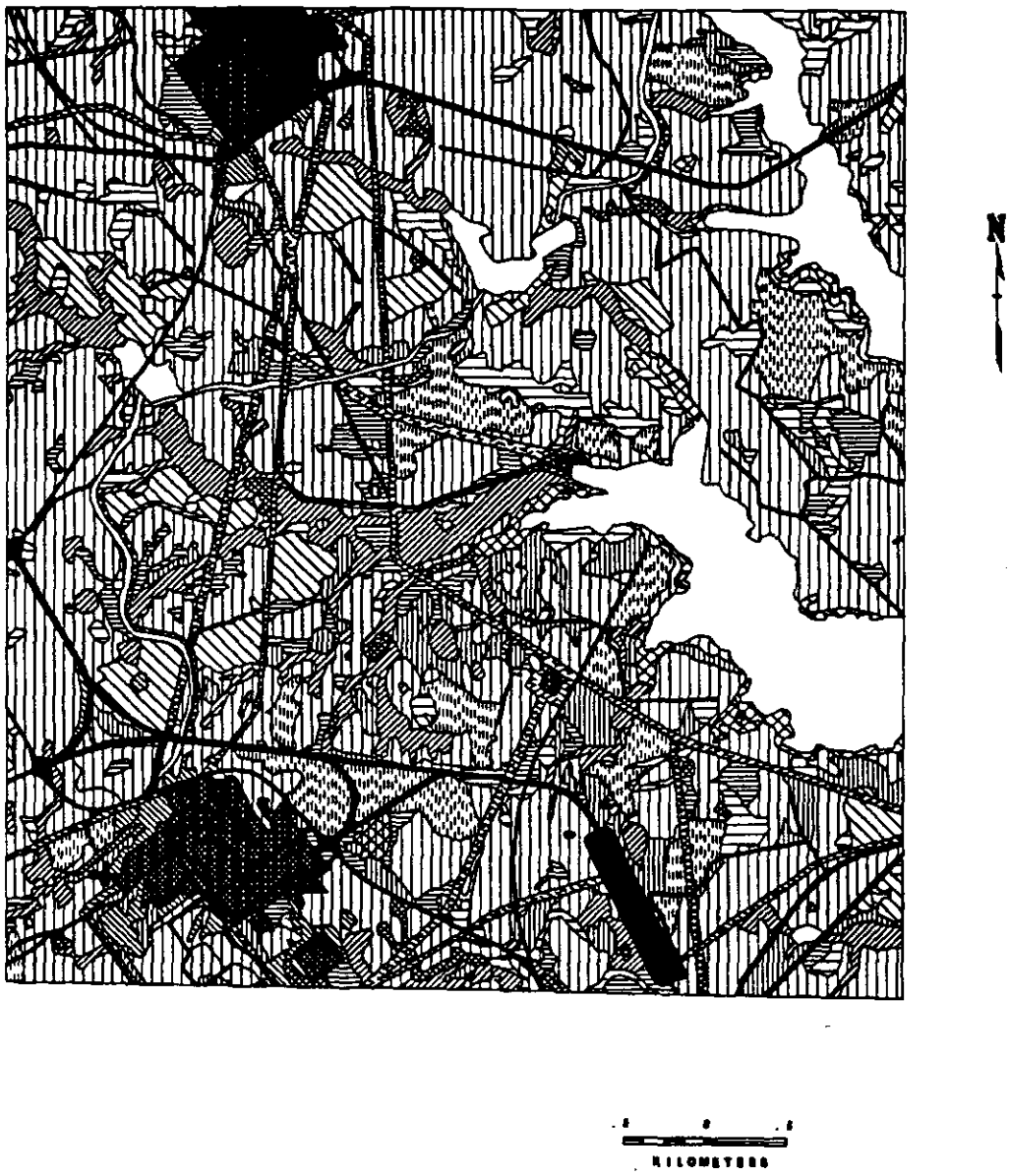

FIGURE 2-28. Land Cover, Southwest Par Pond Vicinity

W8906070

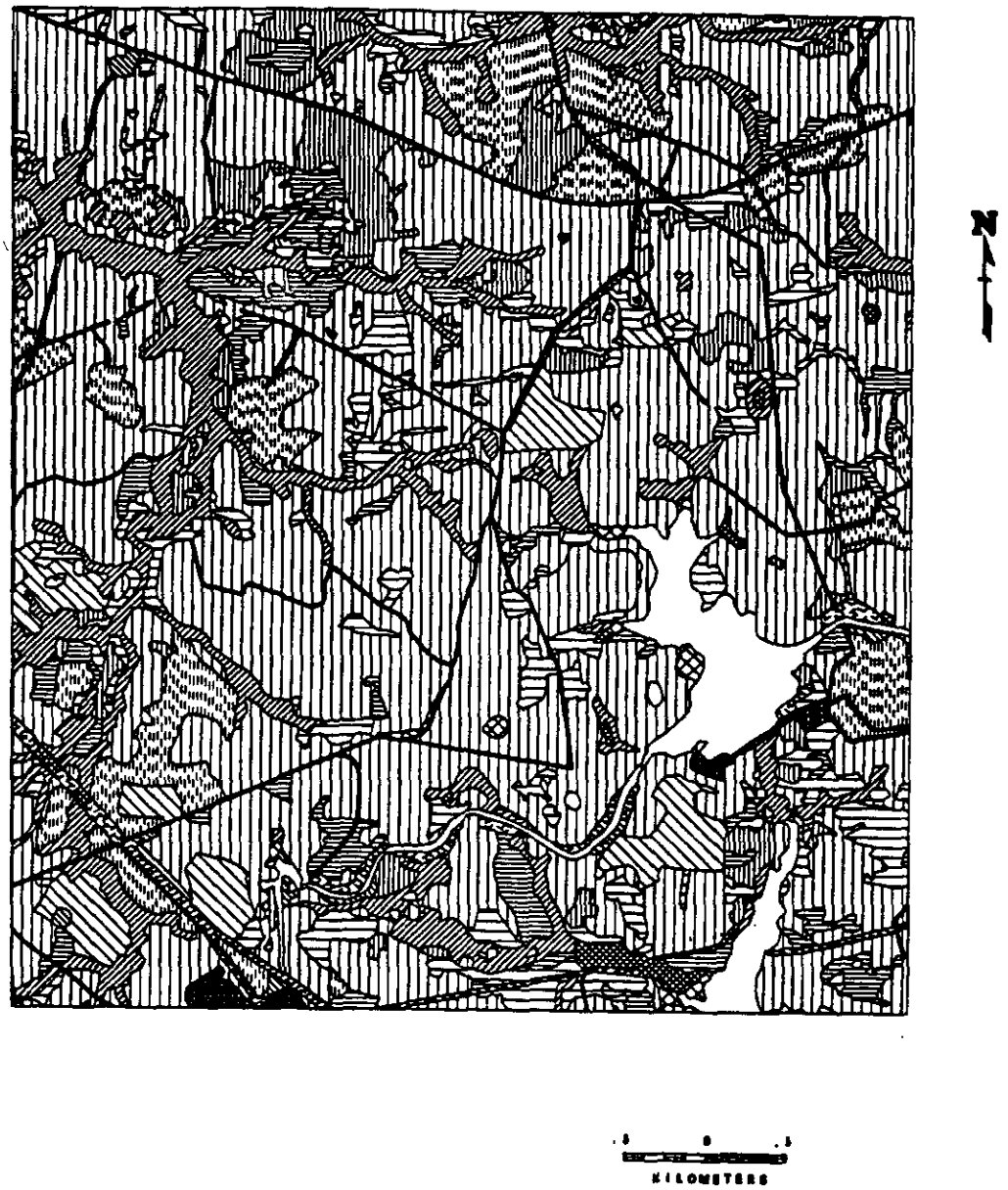

FIGURE 2-29. Land Cover, Northwest Par Pond Vicinity

W8906070

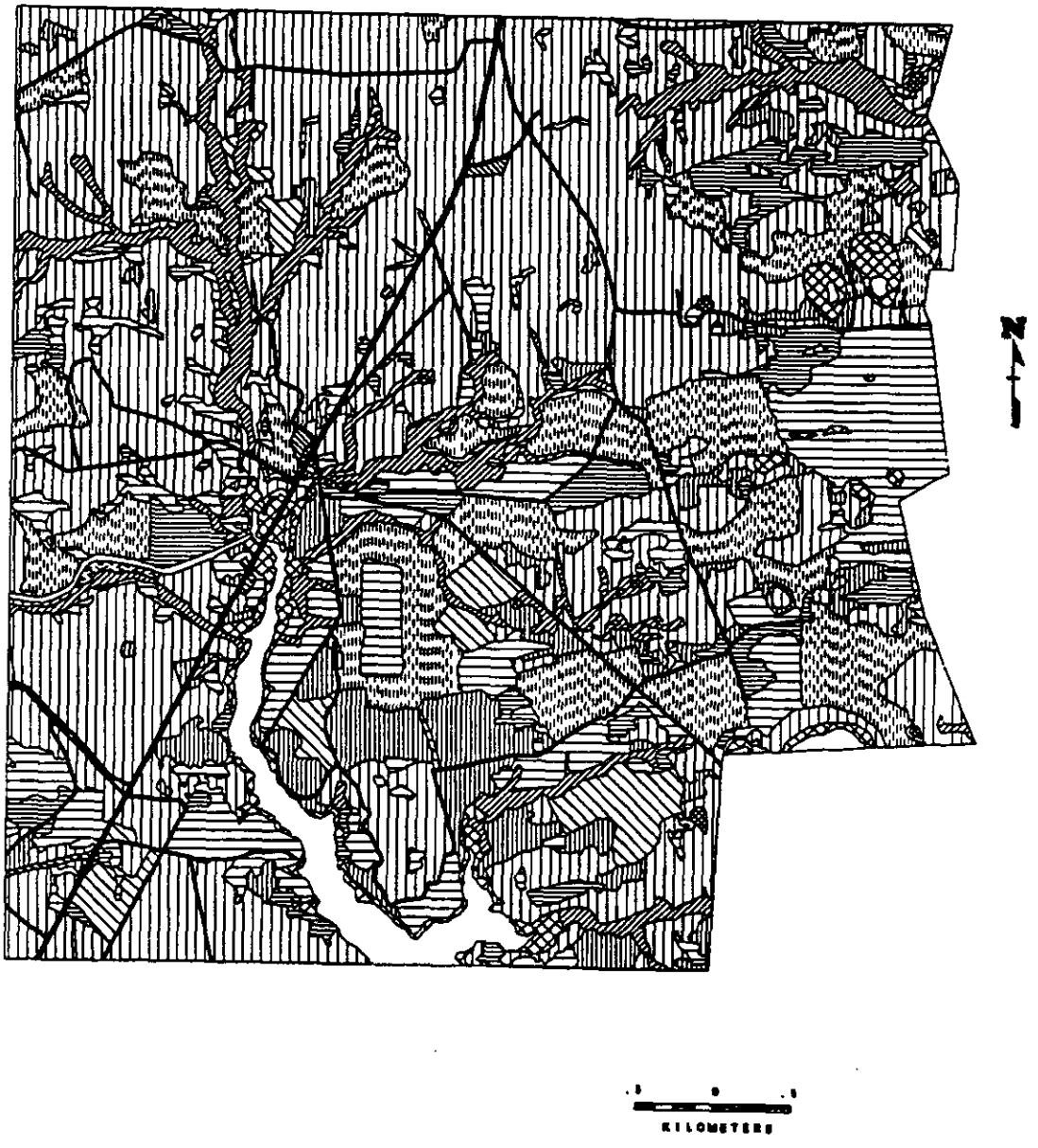

FIGURE 2-30. Land Cover, Northeast Par Pond Vicinity

W8906070

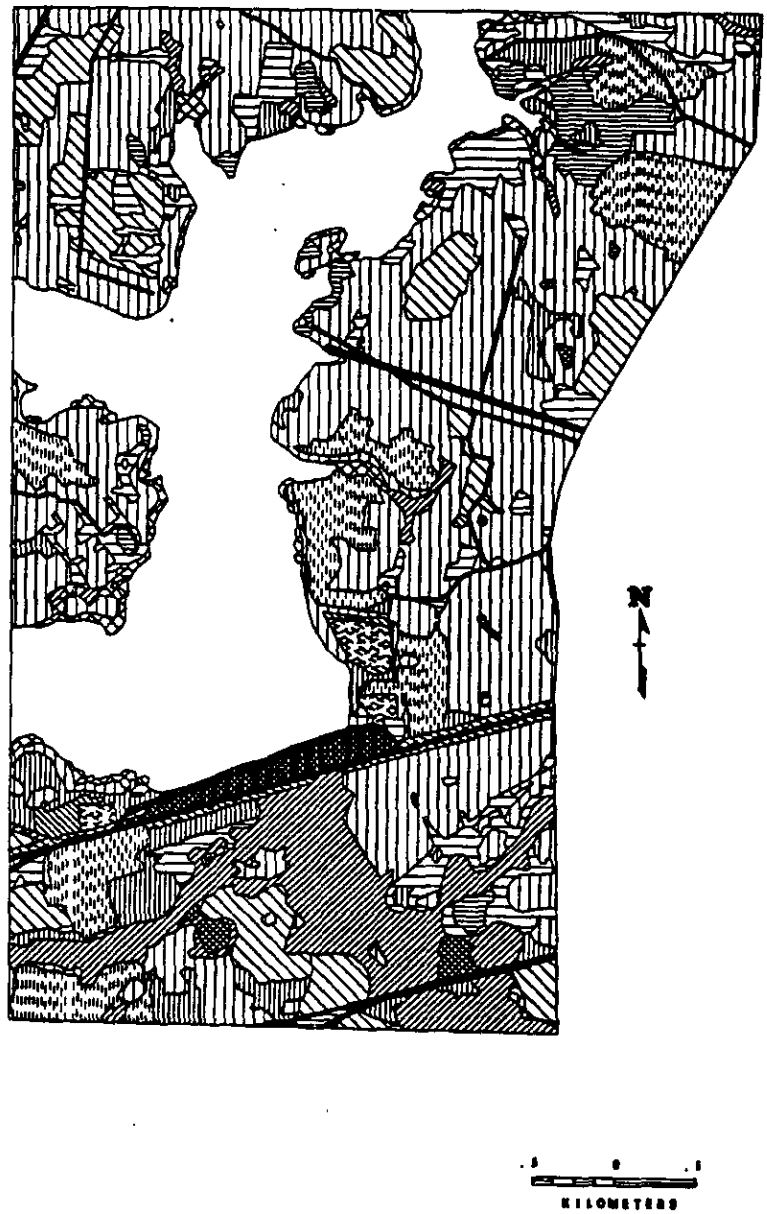

FIGURE 2-31. Land Cover, Southeast Par Pond Vicinity

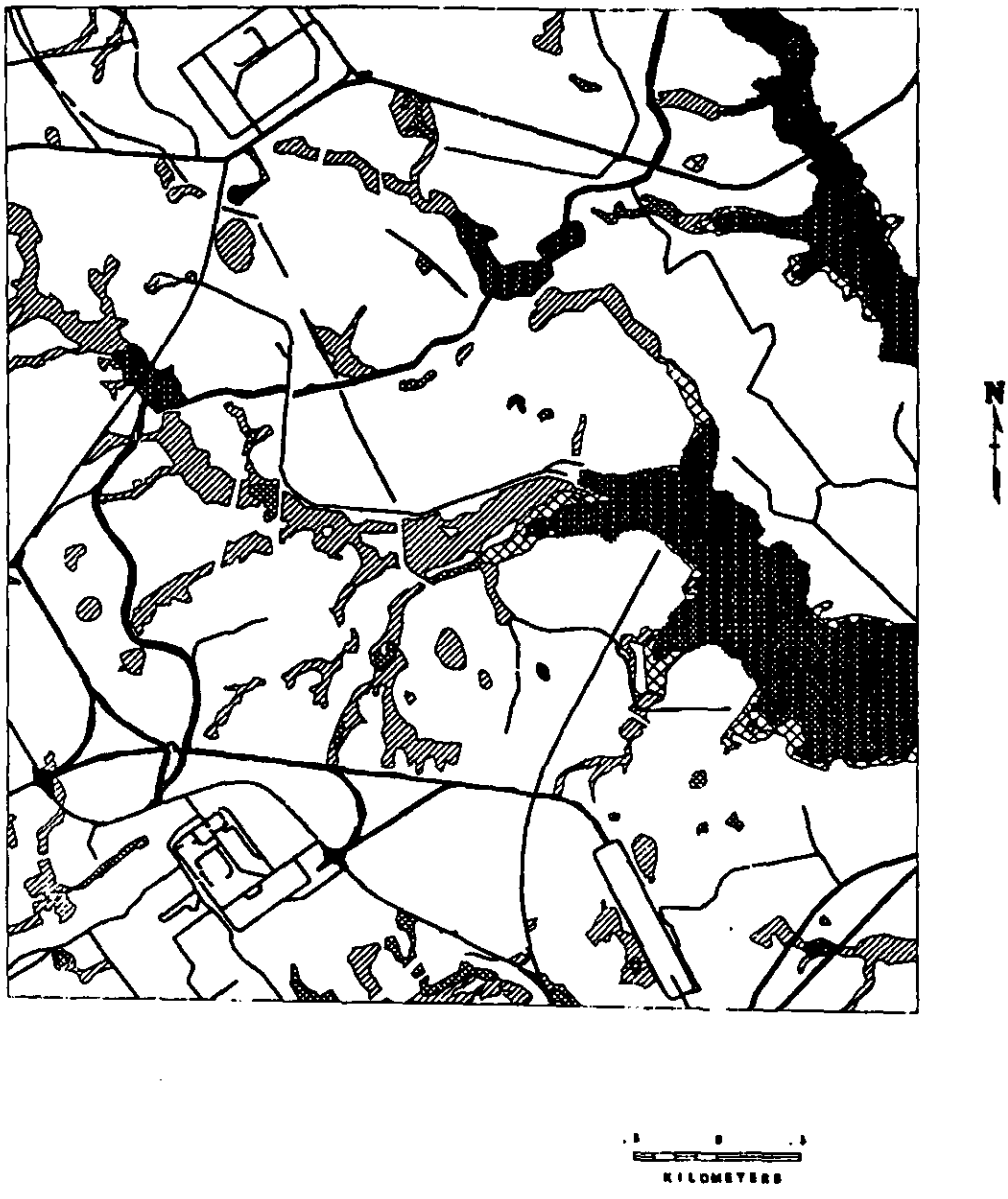

FIGURE 2-32. Wetland Land Cover, Southwest Par Pond Vicinity

W8906070

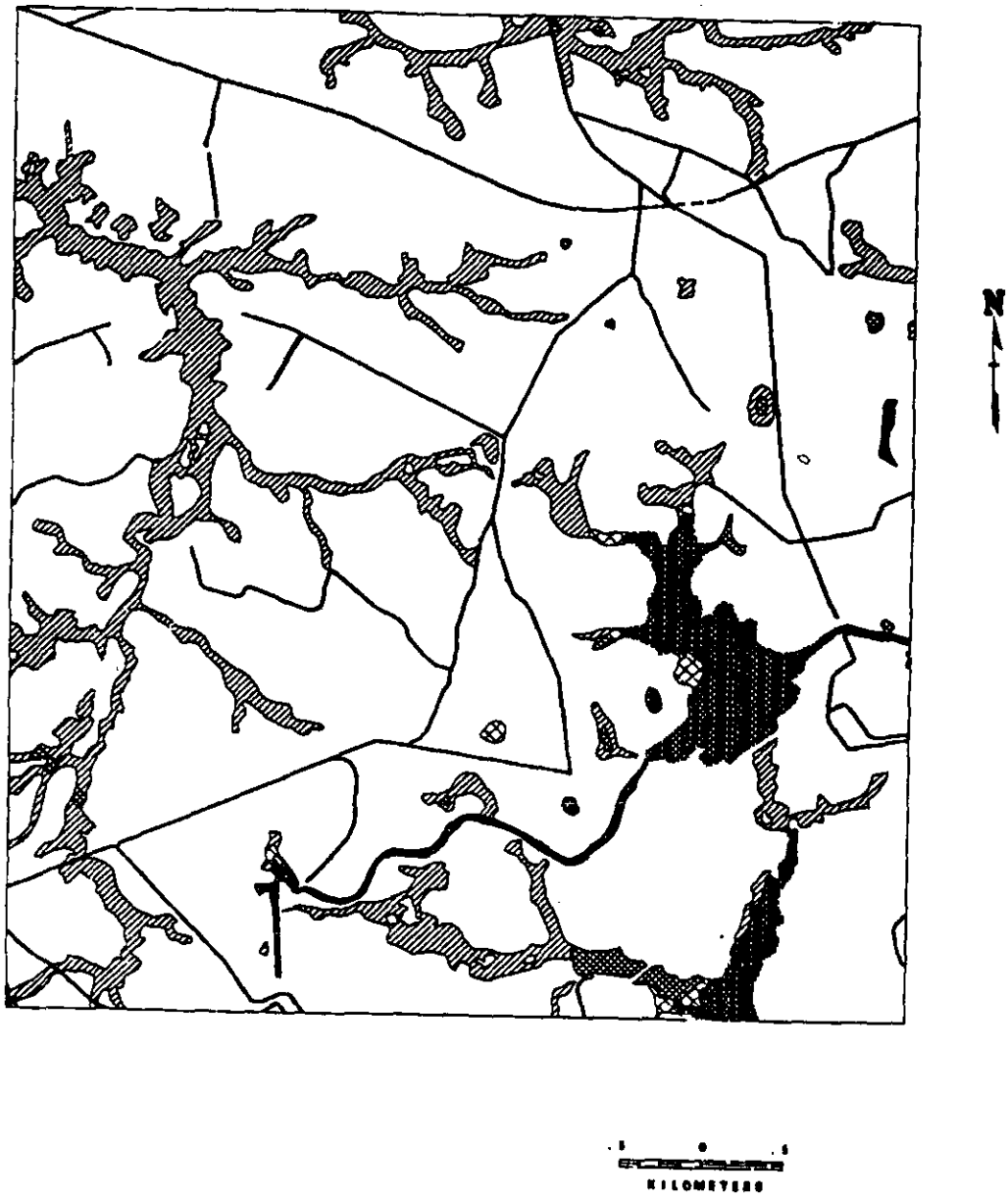

FIGURE 2-33. Wetland Land Cover, Northwest Par Pond Vicinity

W8906070

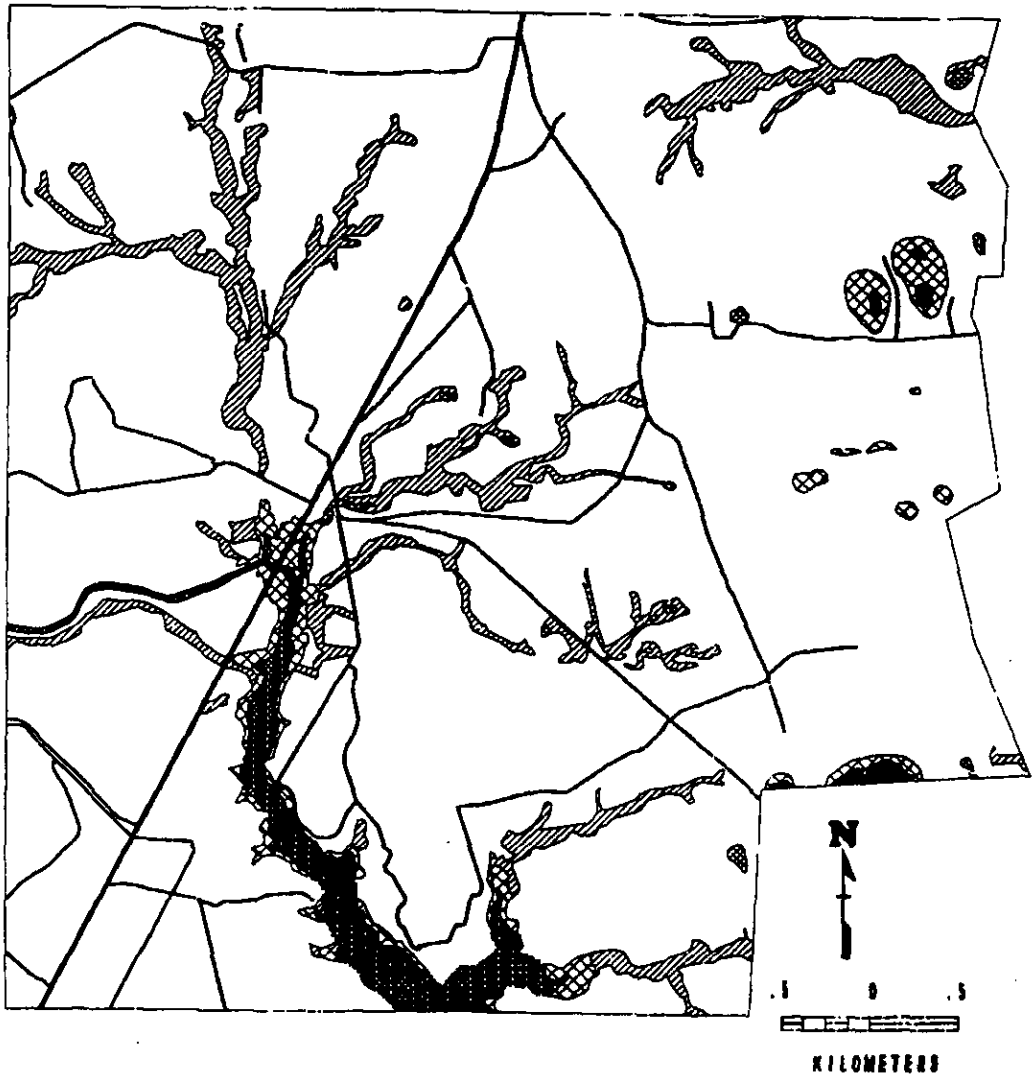

FIGURE 2-34. Wetland Land Cover, Northeast Par Pond Vicinity

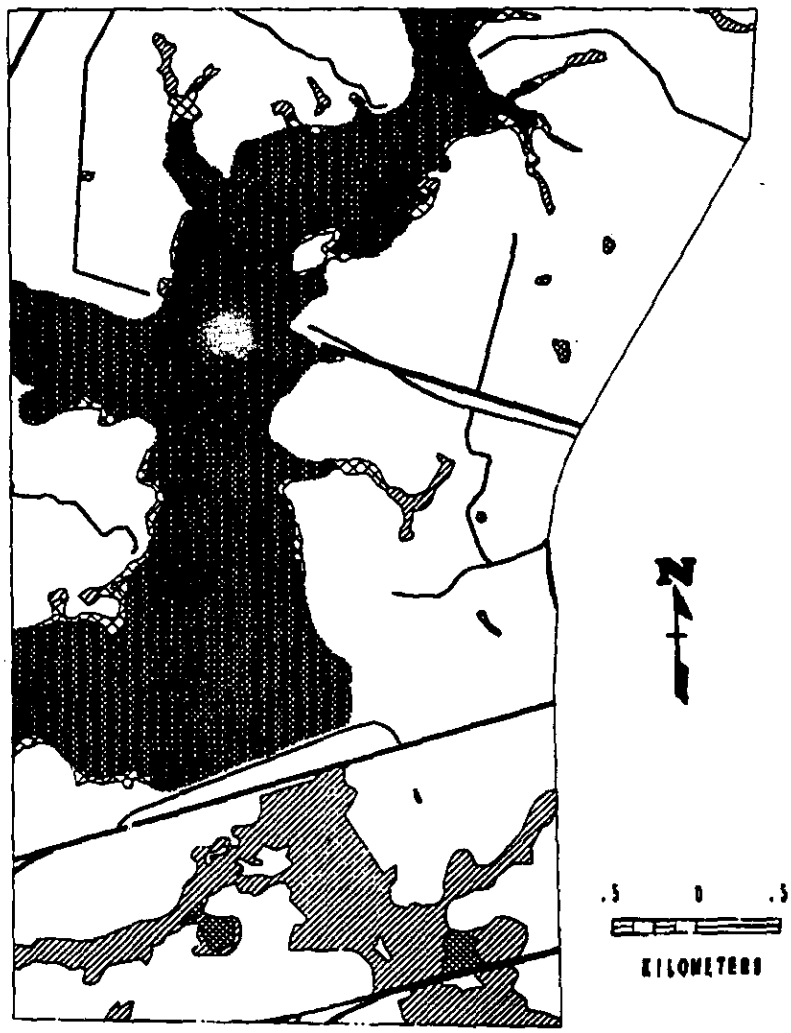

FIGURE 2-35. Wetland Land Cover, Southeast Par Pond Vicinity

TABLE 2-4

Land Cover Statistics (hectares) for Areas Near the Par Pond Area

Land Cover Class	NE Par Pond Site	NW Par Pond Site	SW Par Pond Site	SE Par Pond Site
Emergent Wetlands	64.19	5.45	40.22	31.99
Scrub-Shrub Wetlands	7.07	17.99	31.18	12.26
Bottomland Hardwood	227.53	355.67	244.60	180.40
Swamp Forest	-	-	-	-
Open Water	97.18	127.42	307.17	580.44
Deciduous Forest	588.87	259.41	151.79	148.31
Mixed Deciduous Forest	329.30	188.31	138.02	83.10
Evergreen Forest	1634.73	19.16	1540.00	765.41
Mixed Evergreen Forest	278.23	194.76	174.51	134.83
Regeneration Scrub-Shrub	46.80	57.25	47.85	89.64
Other Scrub-Shrub	2.37	9.79	38.23	7.67
Clear Cuts	60.76	212.95	266.37	122.52
Grassland/Forbland	8.31	41.02	235.98	34.83
Bare Soil	0.22	2.03	14.92	5.34
Active Borrow	-	-	4.59	-
Borrow Grass/Shrub	-	-	1.03	-
Transportation	77.08	55.55	143.31	41.75
Facilities		15.80	126.88	24.16
Total Area	3492.65	3459.58	3396.65	2262.65

2.2.1.3 Scrub-Shrub Land

This cover type include timber land from which trees have recently been cleared with less than 10% canopy or crown closure. These areas are primarily areas where there has been recent clear cutting (or regeneration cutting) and block-planting of pines, primarily loblolly pine. Scrub-shrub land includes predominantly bare soil, scrub-shrub canopy of less than 25% closure, and young pine seedlings and saplings less than five years old and less than 6 m tall. Other scrub-shrub land is found primarily along right-of-ways.

2.2.1.4 Young Evergreen/Deciduous Regeneration Forest Stands

This scrub-shrub land cover type included areas of evergreen and deciduous shrubs and small trees 6 m or less in height with a canopy cover of at least 25%. These areas are present primarily in clear-cut areas managed for timber production.

2.1.2.1.5 Upland Forests

The upland forest land cover type included trees that were at least 6 m tall and included evergreen and deciduous forest land. The evergreen forested areas are dominated by pines, primarily longleaf or loblolly pine. (Pinus palustris and P. taeda, respectively). Other broad-leaved species, such as some of the oaks, which are tardily deciduous and maintain some of their leaves throughout the season, are not included. This cover type is generally located on dry upland sites and includes former agricultural fields. Understory species include black cherry (Prunus serotina), oaks (Quercus spp.), persimmon (Diospyros virginiana), broom sedge (Andropogon spp.), and other species.

An area was classified as deciduous forest when deciduous trees comprised at least 70% of the canopy layer. The deciduous forest class include the upland hardwood forest and the mesic hardwood forest types described by Whipple et al. (1981). On drier sites and sandy ridges, turkey, blue-jack, and black-jack oaks dominated the canopy with longleaf pine present in various densities. In less xeric areas, oaks and hickories (Carya spp.) are also present. Understory species in the drier sites include vacciniums, hollies, lespedezas, and various lichens. On mid- and lower slopes, the deciduous forest includes laurel oak, tulip tree, black and sweet gum, red maple, as well as hickories and holly. Understory on the more mesic sites include vacciniums, hollies, various ferns, grapes, sassafras, dogwood, and greenbriers. Although stands comprised of predominantly deciduous species are not abundant on the SRS, there are areas located on former homestead sites (windbreaks and hedgerows) that are important for wildlife habitat.

In addition to evergreen and deciduous forest stands, there are areas with both evergreen and deciduous trees. Where more than 30% intermixture occurred on these two types, they were classified as mixed forest.

2.2.1.6 Bottomland Hardwood Forests

Bottomland hardwood forests are found along the streams of the SRS and on the "islands" or "ridges" of the Savannah River swamp. Elevations of these ridges are high enough to normally prevent thermal impacts to the forest communities established there. Typical canopy species include water oak (Quercus nigra), laurel oak (Quercus laurifolia), sweet gum (Liquidambar styraciflua), elms (Ulmus alata and U. americana), red maple (Acer rubrum), and tulip tree (Liriodendron tulipifera) (Good and Whipple, 1982; Whipple, 1981; Jensen et al. 1984b; 1986a). Holly (Ilex opaca), redbay (Persea borbonia), sweet bay (Magnolia virginiana), hackberry (Celtis laevigata), and ironwood (Carpinus caroliniana) are common in the subcanopy and understory. Greenbriers, grapes, and other vines are common in the shrub and ground layers. Herbaceous plants are less common due to the more dense shading.

2.2.2 Commercially and Recreationally Valuable Biota

The timber crop of the SRS is of prime commercial value. This resource is actively managed by the Savannah River Forest Station (SRFS) under an established timber management plan. This plan specifies management requirements for nearly 175,000 acres of commercial forest and over 16,000 acres of nonforest land. The commercial operations's primary product is pine pulpwood, but it also provides pine sawtimber, hardwood sawtimber, and pulpwood (Table 2-5). This resource has been developed since 1953 through the planting or replanting of nearly 113,000 acres with approximately 100,000 seedlings of various tree species (Tables 2-6, 2-7) (SRFS, 1988).

The commercial value of SRS standing timber in 1987, based on bids from previous years was over $118 million (Table 2-8). The cumulative value of timber sold on the SRS from 1955 through 1987 was over $23 million, and the cumulative value of timber cut for the same period was over $22 million (Tables 2-9, 2-10) (SRFS, 1988).

The existence of an established forestry management plan functioning in conjunction with reactor operations in the past indicates that continued reactor operations will have no impact upon the commercial success of the SRFS timber operations.

TABLE 2-5

Summary of SRFS Timber Management Plan, FY-1978 Through FY-1987

Timber Management Plan Data

Management plan period FY-1978 through FY-1987 completed and submitted:

Commercial forest land	- 174,322 acres
Nonforest land	- 16,625 acres
Water	- 7,397 acres
Total	198,344 acres

Net Merchantable Volume as of 9/30/87

	Sawtimber MMBF[a] Scribner	Pulpwood M Cords
Pine	417.3	1,830.2
Hardwood	380.2	860.2
Total	797.5	2,690.4

Predicted Annual Net Growth - Including Ingrowth

Pine	6%	11%
Hardwood	0.4%	0.5%

[a] MMBF - millions of board feet

Source: SRFS (1988)

TABLE 2-6

Summary of Total Acres Planted and Seeded, FY-1953-1987

Fiscal Year	Planted Loblolly	Planted Slash	Planted Longleaf	Planted Hardwood	Direct Seeded Longleaf	Cumulative Total
1953-73	11,671	38,527	14,858	-	21,948	87,004
1974	1,051	-	101	-	-	88,156
1975	702	-	350	64	-	89,272
1976	620	-	468	12	-	90,372
1977	831	-	266	-	-	91,469
1978	1,033	-	310	-	-	92,812
1979	1,985	-	-	-	-	94,797
1980	1,994	-	160	-	-	96,951
1981	2,312	-	314	-	-	99,577
1982	2,537	-	-	-	41	102,155
1983	1,450	-	402	-	41	104,048
1984	1,913	-	239	-	31	106,231
1985	2,042	-	205	-	20	108,498
1986	2,026	-	221	-	-	110,745
1987	1,649	-	559	-	-	112,953

Source: SRFS (1988)

TABLE 2-7

Planting Summary, FY-1953-FY-1987

Planting Summary

Gross seedlings planted by species (M)

Fiscal Year	Loblolly	Slash	Longleaf	Hardwood	Cumulative Total (M)
1953-73[a]	12,228[b]	40,298	50,029	-	102,555
1974	546	-	50	-	103,151
1975	391	-	210	16	103,768
1976	337	-	255	6	104,366
1977	500	-	225	-	105,091
1978	550	-	225	-	105,866
1979	1,300	-	-	-	107,166
1980	1,530	-	160	-	108,856
1981	1,574	-	311	-	110,741
1982[a]	1,578	-	41	-	112,360
1983[a]	1,465	-	350	-	114,175
1984[a]	1,550	-	279	-	116,004
1985[a]	1,500	-	146	-	117,650
1986	1,500	-	200	-	119,350
1987	1,200	-	570	-	121,120

[a] 1,000 longleaf seedlings tabulated for each acre seeded. Actual seedlings planted through FY-1987; 99,039,000.
[b] Includes 5,000 cypress planted in FY-1972.

Source: SRFS (1988)

TABLE 2-8

Summary of Standing Timber Value, FY-1962-FY-1987

Fiscal Year	Dollar Value	Fiscal Year	Dollar Value
1962	$15,976,230	1976	$ 35,822,000
1963	17,857,517	1977	36,700,000
1964	19,822,323	1978	53,310,113
1965	22,841,055	1979	63,849,134
1966	25,169,794	1980	70,234,047
1967	25,308,675	1981	83,930,420
1968	26,333,842	1982	92,108,240
1969	27,372,000	1983[a]	91,976,122
1970	28,370,995	1984	103,084,852
1971	29,200,617	1985[b]	94,812,504
1972	30,258,114	1986	117,481,333
1973	32,456,000	1987	118,898,339
1974	33,156,000		
1975	33,962,000		

[a] Value decreased due to change in unit value used. Value of products are determined by weighted average of preceding 12 months high bid.

[b] Decrease due to decrease in value of products.

Source: SRFS (1988)

TABLE 2-9

Summary of Type and Value of Timber Sold, FY-1955 Through FY-1987

	Timber Sales					
	Sold					
Fiscal Year	MBF[a] Pine S/T	MBF Hdwd S/T	Cords Pine	Cords Hdwd	Total Value	Cumulative Value
1955-72	18,802	22,314	319,020	14,525	$3,960,501	$ 3,960,501
1973	1,587	0	60,075	0	614,548	4,575,049
1974	546	0	45,792	0	686,144	5,261,193
1975	2,829	164	52,320	529	1,004,087	6,265,280
1976	542	41	62,139	773	931,870	7,197,150
1977	576	0	47,994	0	827,993	8,025,143
1978	3,901	230	34,360	738	1,096,620	9,121,763
1979	3,711	149	31,936	540	982,567	10,104,330
1980	8,338	1,362	27,641	1,565	1,369,259	11,473,589
1981	9,621	1,125	20,951	3,074	2,198,522	13,672,111
1982	8,361	958	21,432	2,976	1,701,463	15,373,574
1983	6,247	910	14,938	1,423	1,211,092	16,584,666
1984	10,756	1,532	20,789	4,661	2,380,124	18,964,790
1985	8,785	294	25,628	1,051	1,752,573	20,717,363
1986	5,519	181	15,257	1,203	1,139,573	21,856,936
1987	10,250	0	20,411	7,667	1,601,137	23,458,073

[a] MBF = thousands of board feet

Source: SRFS (1988)

TABLE 2-10

Summary of Type and Value of Timber Cut, FY-1955 Through FY-1987

Timber Sales

Cut

Fiscal Year	MBF[a] Pine S/T	MBF Hdwd S/T	Cords P/W Pine	Cords P/W Hdwd	Total Value	Cumulative Value Cut
1955-73[b]	37,584	-	340,316	-	4,245,160	4,245,160
1974	2,510	-	49,599	-	704,134	4,949,294
1975	830	-	33,762	-	538,978	5,488,272
1976	1,239	-	46,963	-	772,572	6,260,844
1977	1,598	-	60,719	-	881,805	7,142,649
1978	1,159	-	53,763	-	969,466	8,112,115
1979	3,846	-	51,255	-	1,373,737	9,485,852
1980	7,601	-	43,879	-	1,548,117	11,033,969
1981	6,355	-	23,188	-	1,468,699	12,502,668
1982	7,066	-	18,865	-	1,256,058	13,758,726
1983[a]	6,867	630	18,223	4,036	1,295,222	15,053,948
1984	12,929	2,216	15,720	4,247	2,000,451	17,054,399
1985	5,388	1,237	15,625	1,750	1,216,167	18,270,566
1986	10,279	383	25,358	4,102	2,072,245	20,342,811
1987	11,143	181	27,147	3,513	2,261,324	22,604,135

[a] MBF - thousands of board feet.
[b] Pine and hardwood for both sawtimber and pulpwood were consolidated for statistical purposes prior to FY-1983.

Source: SRFS (1988)

2.3 WILDLIFE

2.3.1 Introduction

The SRS is comprised of varied and diverse habitats. This heterogeneity provides habitat for a wide variety of terrestrial and semi-aquatic wildlife. At the time of government acquisition, approximately 67% of the SRS was forested, the remainder being in cropland and pasture. After closure to the public, former home and farm sites went through vegetational succession, being invaded primarily by pines. This succession to pine forest was aided by an extensive planting program implemented by the U.S. Forest Service. Currently, 90% of the SRS is forested (Mackey, 1982).

2.3.2 Reptiles and Amphibians

The SRS supports an abundant herpetofauna due to its temperate climate and diverse habitats. The herpetofauna of SRS includes, depending on taxonomic uncertainties, 16 or 17 salamanders, 25 or 26 frogs and toads, one crocodilian (see Section 5.5 for the current status of the American alligator on the SRS), 11 turtles, nine lizards, and 31 or 32 snakes. Table 2-11 contains a taxonomic listing of the species found on the SRS. Gibbons and Patterson (1978) provide an overview, description, and identification keys to the herpetofauna of the SRS.

The herpetofauna are one of the more extensively investigated groups of organisms on the SRS. Studies of the reptiles and amphibians of Carolina Bays have produced a base of knowledge of what species utilize the bays and peripheral areas (Table 2-12), their movements (Tables 2-13 and 2-14), and the success of refuge ponds for mitigation purposes (Tables 2-15 and 2-16). Steel Creek was sampled for herpetofauna before (Smith et al., 1981, 1982) as well as after the filling of L Lake (Gladden et al., 1988). Table 2-17 lists the species and number of animals captured in the Steel Creek study area (Figure 2-36) during 1981 and 1982. Similar data from sampling stations (Figure 2-37) in 1986 and 1987 are presented in Table 2-18. Reptiles and amphibians have been collected in the lower regions of L Lake since 1986 (Figure 2-38). The qualitative data (Table 2-19, Figure 2-39) do seem to indicate that the populations of amphibians and turtles may be declining while snakes and lizards appear to be stable (Patterson and Giffin, 1988).

The reptiles and amphibians known to inhabit Par Pond are listed in Table 2-20. Turtles and snakes in the Par Pond system and surrounding areas were studied from 1967 to 1985 (Gladden et al., 1985). Recent research is limited to ongoing projects of SREL. The turtle population of Par Pond shows some interesting effects of thermal loading in growth rates, adult size, feeding regime, and reproduction (Gibbons, 1970). Par Pond turtles have a larger body size than turtles in other SRS habitats (Figure 2-40). This larger body size and higher growth rate (Figure 2-41) are correlated with diet and feeding habits and augmented by year around activity and feeding which is likely a result of thermal effluents from P Reactor.

TABLE 2-11

Amphibians and Reptiles of the SRS[a]

CLASS AMPHIBIA	
Order Caudata - salamanders	
Family Proteidae	
Necturus punctatus	dwarf waterdog
Family Amphiumidae	
Amphiuma means	two-toed amphiuma
Family Sirenidae	
Siren lacertina	greater siren
S. intermedia	lesser siren
Family Ambystomatidae	
Ambystoma talpoideum	mole salamander
A. opacum	marbled salamander
A. maculatum[a]	spotted salamander
A. t. tigrinum	eastern tiger salamander
Family Salamandridae	
Notophthalmus v. viridescens	red-spotted newt
Family Plethodontidae	
Desmognathus f. fucus[a] and/or	northern dusky salamander
D. auriculatus[a]	southern dusky salamander
Plethodon g. glutinosus	slimy salamander
Pseudotriton m. montanus[a]	eastern mud salamander
P. ruber vioscai[a]	southern red salamander
Eurycea bislineata cirrigera	southern two-lined salamander
E. longicauda guttolineata	three-lined salamander
E. quadridigitata	dwarf salamander
Order Anura - frogs and toads	
Family Pelobatidae	
Scaphiopus h. holbrooki	eastern spadefoot toad
Family Bufonidae	
Bufo terrestris	southern toad
B. quercicus	oak toad
B. woodhousei fowleri[a]	Fowler's toad
Family Hylidae	
Acris g. gryllus	southern cricket frog
Acris c. crepitans	northern cricket frog
Hyla c. crucifer	northern spring peeper
H. cinerea	green treefrog
H. gratiosa	barking treefrog
H. femoralis	pine woods treefrog
H. squirella	squirrel treefrog
H. versicolor[a] and/or *chrysoscelis*	gray treefrog
H. avivoca ogechiensis	eastern bird-voiced treefrog

TABLE 2-11, Contd

CLASS AMPHIBIA, Contd	
Order Anura - frogs and toads, Contd	
Pseudacris triseriata feriarum	upland chorus frog
P. n. nigrita	southern chorus frog
P. ornata	ornate chorus frog
P. brimleyi[a]	Brimley's chorus frog
Limnaoedus ocularis	little grass frog
Family Microhylidae	
Gastrophryne carolinensis	eastern narrow-mouthed toad
Family Ranidae	
Rana catesbeiana	bullfrog
R. virgatipes	carpenter frog
R. c. clamitans	bronze frog
R. utricularia (=sphenocephala)	pickerel frog
R. areolata capito	Carolina gopher frog
R. grylio[a]	pig frog
CLASS REPTILIA	
Order Crocodilia - Crocodilians	
Family Alligatoridae	
Alligator mississippiensis	American alligator
Order Chelonia - turtles	
Family Chelydridae	
Chelydra s. serpentina	common snapping turtle
Family Kinosternidae	
Sternotherus odoratus	stinkpot
Kinosternon s. subrubrum	eastern mud turtle
K. bauri palmarum[a]	striped mud turtle
Family Emydidae	
Clemmys guttata	spotted turtle
Terrapene c. carolina	eastern box turtle
Chrysemys s. scripta	yellow-bellied turtle
C. c. concinna	river cooter
C. f. floridana	Florida cooter
Deirochelys r. reticularia	eastern chicken turtle
Family Trionychidae	
Trionyx spiniferus asperus	gulf coast spiny softshell
Order Squamata - snakes and lizards	
Suborder Lacertilia - lizards	
Family Iguanidae	
Anolis c. carolinensis	green anole
Sceloporus u. undulatus	southern fence lizard
Family Teiidae	
Cnemidophorus s. sexlineatus	six-lined racerunner
Family Scincidae	
Leiolopisma laterale	ground skink
Eumeces fasciatus[a]	five-lined skink
E. laticeps	broad-headed skink
E. inexpectatus	southeastern five-lined skink

TABLE 2-11, Contd

CLASS REPTILIA, Contd	
Order Squamata - snakes and lizards, Contd	
Family Anguidae	
Ophisaurus ventralis	eastern glass lizard
O. attenuatus longicaudus	slender glass lizard
Family Colubridae	
Nerodia cyclopion floridana	Florida green water snake
N. taxispilota	brown water snake
N. e. erythrogaster	red-bellied water snake
N. f. fasciata and/or	
N. sipedon pleuralis[a]	midland water snake
N. r. rigada	eastern glossy water snake
Seminatrix pygaea paludis	Carolina swamp snake
Storeria d. dekayi	northern brown snake
S. o. occipitomaculata	red-bellied snake
Thamnophis s. sirtalis	eastern garter snake
T. s. sauritus	eastern ribbon snake
Virginia v. valeriae	eastern earth snake
Heterodon platyrhinos	eastern hognose snake
H. simus	southern hognose snake
Diadophis p. punctatus	southern ringneck snake
Farancia a. abacura	eastern mud snake
F. e. erytrogramma	rainbow snake
Coluber constrictor priapus	southern black racer
Masticophis f. flagellum	eastern coachwhip
Opheodrys aestivus	rough green snake
Elaphe g. guttata	corn snake
E. o. obsoleta	black rat snake
Pituophis m. melanoleucus	northern pine snake
Lampropeltis g. getulus	eastern kingsnake
L. triangulum elapsoides	scarlet kingsnake
Cemophora coccinea copei	northern scarlet snake
Tantilla coronata	southeastern crowned snake
Family Elapidae	
Micrurus f. fulvius	eastern coral snake
Family Viperidae (=Crotalidae)	
Agkistrodon c. contortrix	southern copperhead
A. p. piscivorus	eastern cottonmouth
Sistrurus m. miliarius	Carolina pygmy rattlesnake
Crotalus horridus atricaudatus	canebrake rattlesnake

[a] Species whose presence on the SRS has been reported but not recently confirmed, or species with which taxonomic problems are associated.

Source: Gibbons and Patterson (1978)

TABLE 2-12

Reptiles and Amphibians Occurring on Sun Bay Study Area or Rainbow Bay Study Area

Amphibians

Necturus punctatus[a]	dwarf waterdog
Amphiuma means	tow-toed amphiuma
Siren intermedia	lesser siren
Ambystoma talpoideum	mole salamander
A. opacum	marbled salamander
A. maculatum[a]	spotted salamander
A. t. tigrinum	eastern tiger salamander
Notophthalmus v. viridescens	red-spotted newt
Desmognathus auriculatus	southern dusky salamander
Plethodon g. glutinosus	slimy salamander
Pseudotriton m. montanus	eastern mud salamander
P. ruber vioscai	southern red salamander
Eurycea bislineata cirrigera	southern two-lined salamander
E. longicauda guttolineata	three-lined salamander
E. quadridigitata	dwarf salamander

Frogs and Toads

Scaphiopus h. holbrooki	eastern spadefoot toad
Bufo terrestris	southern toad
B. quercicus	oak toad
B. woodhousei fowleri[a]	Fowler's toad
Acris g. gryllus	southern cricket frog
Hyla c. crucifer	northern spring peeper
H. cinerea	green treefrog
H. gratiosa	barking treefrog
H. femoralis	pine woods treefrog
H. squirella	squirrel treefrog
H. versicolor and/or chrysoscelis	gray treefrog
Pseudacris n. nigrita	southern chorus frog
P. ornata	ornate chorus frog
Limnaoedus ocularis[a]	little grass frog
Gastrophryne carolinensis	eastern narrow-mouthed toad
Rana catesbeiana	bullfrog
R. virgatipes[a]	carpenter frog
R. c. clamitans	bronze frog
R. utricularia (=sphenocephala)	southern leopard frog
R. palustris[a]	pickerel frog
R. areolata capito	Carolina gopher frog

Crocodilians

Alligator mississippiensis[a]	American alligator

TABLE 2-12, Contd

Turtles

Chelydra s. serpentina	common snapping turtle
Sternotherus odoratus	stinkpot
Kinosternon s. subrubrum	eastern mud turtle
K. bauri palmarum[a]	striped mud turtle
Clemmys guttata[a]	spotted turtle
Terrapene c. carolina	eastern box turtle
Pseudemys s. scripta	yellow-bellied turtle
P. f. floridana[a]	Florida cooter
Deirochelys r. reticularia	eastern chicken turtle

Lizards

Anolis c. carolinensis	green anole
Sceloporus u. undulatus	southern fence lizard
Cnemidophorus s. sexlineatus	six-lined racerunner
Scincella laterale	ground skink
Eumeces fasciatus	five-lined skink
E. laticeps	broad-headed skink
E. inexpectatus	southeastern five-lined skink
Ophissaurus ventralis	eastern glass lizard
O. attenuatus longicaudus	slender glass lizard

Snakes

Nerodia cyclopion floridana[a]	Florida green water snake
N. taxispilota[a]	brown water snake
N. e. erythrogaster	red-bellied water snake
N. f. fasciata	banded water snake
Regina r. rigida[a]	eastern glossy water snake
Storeria d. dekayi	northern brown snake
S. o. occipitomaculata	red-bellied snake
Thamnophis s. sirtalis	eastern garter snake
T. s. sauritus	eastern ribbon snake
Heterodon platyrhinos	eastern hognose snake
H. simus	southern hognose snake
Diadophis p. punctatus	southern ringneck snake
Farancia a. abacura	eastern mud snake
F. e. erytrogramma[a]	rainbow snake
Coluber constrictor priapus	southern black racer
Masticophis f. flagellum	eastern coachwhip
Opheodrys aestivus	rough green snake
Elaphe g. guttata	corn snake
E. o. obsoleta	black rat snake

TABLE 2-12, Contd

Snakes, Contd

Pituophis m. melanoleucus	northern pine snake
Lampropeltis g. getulus	eastern kingsnake
L. triangulum elapsoides	scarlet kingsnake
Cemphora coccinea copei	northern scarlet snake
Tantilla coronata	southeastern crowned snake
Virginia striatula[a]	rough earth snake
V. v. valeriae	eastern earth snake
Micrurus f. fulvius[a]	eastern coral snake
Agkistrodon c. contortrix[a]	southern copperhead
A. p. piscivorus	eastern cottonmouth
Sistrurus m. miliarius[a]	Carolina pygmy rattlesnake
Crotalus horridus atricaudatus	canebrake rattlesnake

[a] Species not yet found at sites but which could occur there.

Source: Vitt et al. (1982)

TABLE 2-13

Direction of Movement of All Species of Amphibians and Reptiles Captured (original and recaptured) in Drift Fence and Pitfall Traps at Rainbow Bay and Sun Bay on the Savannah River Site in South Carolina for One Year (April 1, 1981 - March 31, 1982)

Species	Rainbow Bay				Sun Bay			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS AMPHIBIA								
Order Caudata								
Ambystoma talpoideum	929	1	527	3	1970	0	697	1
Ambystoma opacum	26	2	22	12	15	3	18	30
Ambystoma t. tigrinum	123	0	97	1	26	0	14	0
Notophthalmus v. viridescens	1648	0	727	0	517	0	507	0
Plethodon g. glutinosus	2	0	3	0	2	0	1	1
Pseudotriton ruber vioscai	2	0	0	0	8	0	2	0
Pseudotriton m. montanus	0	0	0	0	0	0	0	0
Eurycea quadridigitata	166	2	30	23	1	0	1	0
Total	2896	5	1406	39	2539	3	1240	32
Order Anura								
Scaphiopus h. holbrooki	56	2	50	0	26	1	20	0
Bufo terrestris	314	0	313	0	138	0	95	0
Bufo quercicus	13	0	11	0	10	0	9	0
Acris g. gryllus	1	0	0	0	2	0	0	0
Hyla cinerea	1	0	0	0	0	0	0	0
Hyla c. crucifer	72	124	34	784	56	10	21	75
Hyla gratiosa	0	0	1	0	0	0	0	0
Hyla femoralis	3	0	0	0	2	0	1	0
Hyla chysoscelis	1	0	0	0	2	1	2	0
Pseudacris n. nigrita	109	0	72	3	3	0	1	0
Pseudacris ornata	580	57	303	3107	207	2	128	55
Gastrophryne carolinensis	2299	0	1477	0	316	0	327	0
Rana catesbeiana	0	0	1	0	1	1	0	0
Rana clamitans	2	1	2	1	40	43	28	38
Rana ultricularia	120	0	36	4	8	0	2	0
Total	3571	184	2300	3899	811	58	634	168

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TABLE 2-13, Contd

Species	Rainbow Bay				Sun Bay			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS REPTILIA								
Order Chelonia								
Chelydra s. serpentina	0	0	0	0	4	0	2	3
Sternotherus odoratus	0	0	0	0	32	2	16	7
Kinosternon s. subrubrum	20	2	11	1	0	0	0	0
Terrapene c. carolina	1	0	1	0	1	0	1	0
Pseudemys s. scripta	1	0	0	0	0	0	0	0
Deirochelys r. reticularia	3	0	1	0	1	0	1	0
Total	25	2	13	1	38	2	20	10
Order Squamata								
Suborder Lacertilia								
Anolis c. carolinensis	31	5	28	14	15	1	14	1
Sceloporus u. undalatus	2	3	0	0	3	10	6	4
Cnemidophorus s. sexlineatus	3	1	2	0	22	6	32	1
Scincella laterale	2	3	4	0	1	0	1	0
Eumeces laticeps	0	1	0	0	0	1	0	0
Total	38	13	34	14	41	18	53	6
Suborder Serpentes								
Nerodia e. erythrogaster	0	0	1	0	1	0	0	0
Nerodia f. fasciata	3	0	1	0	0	0	0	1
Storeria d. dekayi	1	3	6	0	1	0	0	0
Storeria o. occipitomaculata	24	1	11	0	5	0	3	0
Thamnophis s. sirtalis	0	3	0	3	0	0	0	0
Diadophis p. punctatus	3	1	8	0	5	0	3	0
Farancia a. abacura	3	11	0	4	-	-	-	-
Lampropeltis g. getulus	1	1	1	0	0	0	0	0

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TABLE 2-13, Contd

Species	Rainbow Bay				Sun Bay			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS REPTILIA, Contd								
Heterodon platyrhinos	00	0	0	0	3	2	1	0
Heterodon simus	0	0	0	0	6	0	2	0
Lampropeltis triangulum elapsoides	0	0	0	0	0	0	1	0
Coluber constrictor	5	3	0	2	3	1	3	1
Cemophora coccinea copei	2	0	2	0	5	0	6	0
Tantilla coronata	28	0	25	0	59	0	42	0
Virginia v. valeriae	8	0	7	0	2	0	3	0
Agkistrodon p. piscivorus	0	0	0	0	1	0	0	0
Total	78	23	62	9	91	3	64	2
Grand Total	6608	227	3815	3962	3520	84	2011	218

Source: Vitt et al. (1982)

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TABLE 2-14

Direction of Movement of All Species of Amphibians and Reptiles Captured (original and recaptured) in Drift Fence and Pitfall Traps at Peripheral Areas Associated with Rainbow Bay on the Savannah River Site in South Carolina for One Year (April 1, 1981 - March 31, 1982)

Species	Linda's Pond				Pickerel Pond			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS AMPHIBIA								
Order Caudata								
Ambystoma talpoideum	236	0	187	0	226	0	140	0
Ambystoma opacum	21	0	26	0	3	0	2	2
Notophthalmus v. viridescens	9	0	0	0	32	0	23	1
Plethodon g. glutinosus	4	0	3	0	12	8	28	1
Pseudotriton ruber vioscai	0	0	1	0	7	0	29	0
Eurycea quadridigitata	0	0	0	0	7	0	3	0
Total	270	0	217	0	287	8	225	4
Order Anura								
Scaphiopus h. holbrooki	5	0	18	0	8	0	36	0
Bufo terresrris	12	0	26	0	20	0	44	0
Bufo quercicus	0	0	1	0	0	0	0	0
Hyla c. crucifer	0	0	1	0	1	0	17	7
Hyla femoralis	0	0	1	0	0	0	1	0
Pseudacris n. nigrita	0	0	1	0	0	0	1	0
Pseudacris ornata	6	0	5	0	5	1	5	6
Gastrophryne carolinensis	89	0	456	0	19	0	103	0
Rana catesbeiana	2	3	2	5	0	0	0	0
Rana clamitans	2	0	0	0	6	1	2	1
Rana utricularia	0	0	0	0	6	0	9	0
Total	116	3	511	5	65	2	218	14

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TABLE 2-14, Contd

Species	Linda's Pond				Pickerel Pond			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS AMPHIBIA, Contd								
Order Chelonia								
Sternotherus odoratus	0	0	0	0	1	0	0	0
Kinosternon s. subrubrum	3	1	1	0	0	0	0	0
Terrapene c. carolina	0	0	2	0	4	0	1	0
Pseudemys s. scripta	0	0	0	0	0	0	0	0
Total	3	1	3	0	5	0	1	0
Order Squamata								
Suborder Lacertilia								
Anolis c. carolinensis	0	0	1	0	4	1	5	1
Sceloporus u. undulatus	1	0	6	0	0	0	2	0
Cnemidophorus s. sexlineatus	0	0	0	0	0	0	1	0
Scincella laterale	1	0	0	0	1	0	1	0
Eumeces laticeps	0	0	0	0	0	0	1	0
Total	2	0	7	0	5	1	10	1
Suborder Serpentes								
Storeria d. dekayi	0	0	0	0	1	0	0	0
Storeria o. occipitomaculata	0	0	2	0	1	0	7	0
Thamnophis s. sirtalis	0	0	0	0	0	0	0	2
Diadophis p. punctatus	1	0	1	0	3	0	5	0
Farancia a. abacura	0	1	0	3	0	0	0	0
Heterodon platyrhinos	0	0	0	0	0	0	1	0
Heterodon simus	1	0	0	0	0	0	0	0
Lampropeltis triangulum elapsoides	0	0	1	0	0	0	1	0

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TABLE 2-14, Contd

Species	Linda's Pond				Pickerel Pond			
	Entering		Exiting		Entering		Exiting	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
CLASS REPTILIA, Contd								
Order Chelonia, Contd								
Coluber constrictor	0	0	0	0	0	0	0	1
Cemophora coccineai copei	1	0	3	0	0	0	2	0
Tantilla coronata	8	0	20	1	3	0	8	0
Virginia v. valeriae	3	0	1	0	0	0	1	0
Total	14	1	28	4	8	0	25	3
Grand Total	405	5	766	9	370	11	479	22

Source: Vitt et al. (1982)

W890607O

TABLE 2-15

Number of Adult Amphibians Captured Entering the Refuge Ponds During Their Breeding Season from FY-1984 to FY-1988 (total for all four ponds)

Species	1984	1985	1986	1987	1988
Salamanders					
Ambystoma talpoideum	9	4	62	59	33
Ambystoma tigrinum	0	0	1	1	0
Notophthalmus viridescens	3	0	9	8	5
Eurycea quadridigitata	1	1	0	0	0
Total	13	5	72	68	38
Frogs and Toads					
Scaphiopus holbrooki	18	11	7	12	5
Bufo terrestris	34	156	161	53	62
Bufo quercicus	4	0	0	0	0
Hyla crucifer	17	27	121	5	28
Hyla femoralis	1	1	0	0	0
Hyla chrysoscelis/versicolor	3	2	1	3	0
Pseudacris nigrita	0	2	2	0	0
Pseudacris ornata	4	4	6	0	10
Gastrophryne carolinensis	68	69	36	34	29
Rana catesbeiana	1	0	1	0	0
Rana clamitans	13	5	7	0	0
Rana utricularia	24	14	98	20	21
Total	187	291	440	127	155
Grand total	200	296	512	195	193

Source: Scott et al. (1988)

TABLE 2-16

Number of Amphibian Juveniles Produced at DWPF Refuge Ponds During FY-1985 to FY-1988

Species	Pond A				Pond B				Pond D				Total			
	1985	1986	1987	1988	1985	1986	1987	1988	1985	1986	1987	1988	1985	1986	1987	1988
Ambystoma talpoideum	0	6	1	0	0	32	29	60	0	5	202	142	0	43	232	202
Notophthalmus viridescens	0	11	41	85	0	0	2	0	0	8	1	57	0	19	44	142
Total salamanders	0	17	42	85	0	32	31	60	0	13	203	199	0	62	276	344
Bufo terrestris	50	1	0	3	16	1	0	0	0	14	0	298	66	16	0	301
Acris gryllus	–	–	5	0	–	–	0	0	–	–	13	27	0	0	18	27
Hyla crucifer	306	0	0	97	85	3	0	147	640	1	1	8	1031	4	1	252
Hyla gratiosa	24	10	31	2	100	15	17	16	41	98	5	65	165	123	53	83
Rana catesbeiana	–	–	0	–	–	9	1	–	–	0	0	–	–	–	9	1
Pseudacris ornata	0	0	0	1	0	0	0	6	0	–	0	0	0	–	0	7
Hyla chrysoscelis/versicolor	59	0	2	0	77	0	2	0	6	1	0	1	142	1	4	1
Rana utricularia	19	1	21	287	646	6	0	72	0	7	0	0	665	14	21	359
Total frogs and toads	458	12	59	390	924	24	20	241	687	121	19	399	2069	158	106	1031

Source: Scott et al. (1988)

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TABLE 2-17

Amphibians and Reptiles Found in the Steel Creek Study Area Between September 1, 1981 and August 20, 1982 (numbers in parentheses are total captures)

Salamanders - (122)	
Siren intermedia (1)	greater siren
Siren lacertina (3)	lesser siren
Ambystoma talpoideum (17)	mole salamander
A. opacum (37)	marbled salamander
A. maculatum (6)	spotted salamander
Notophthalmus viridescens (6)	red-spotted newt
Plethodon glutinosus (30)	slimy salamander
Pseudotriton montanus (1)	eastern mud salamander
Eurycea bislineata (2)	southern two-lined salamander
E. longicauda (3)	three-lined salamander
E. quadridigitata (16)	dwarf salamander
Frogs and Toads - (+200)	
Scaphiopus holbrooki (5)	eastern spadefoot toad
Bufo terrestris (~30)	southern toad
Acris gryllus (~30)	southern cricket frog
Pseudacris ornata (11)	ornate chorus frog
Hyla crucifer (3)	northern spring peeper
H. cinerea (~40)	green treefrog
H. gratiosa (2)	barking treefrog
Gastrophryne carolinensis (1)	eastern narrow-mouthed toad
Rana catesbeiana (4)	bullfrog
R. clamitans (8)	bronze frog
R. utricularia (+100)	southern leopard frog
R. grylio (3)	pig frog
R. virgatipes (3)	carpenter frog
Turtles - (108)	
Chelydra serpentina (3)	common snapping turtle
Sternotherus odoratus (5)	stinkpot
Kinosternon sp. (7)	mud turtle
Terrapene carolina (1)	eastern box turtle
Pseudemys scripta (73)	pond slider
P. floridana (11)	Florida cooter
P. concinna (3)	river cooter
Deirochelys reticularia (5)	chicken turtle
Lizards - (33)	
Anolis carolinensis (11)	green anole
Sceloporus undulatus (2)	southern fence lizard
Cnemidophorus sexlineatus (8)	six-lined race runner
Eumeces fasciatus (5)	five-lined skink
E. laticeps (6)	broad-headed skink
E. inexpectatus (1)	southeastern five-lined skink

TABLE 2-17, Contd

Snakes (14)	
Nerodia sp. (5)	water snakes
Storeria occipitomaculata (3)	red-bellied snake
S. dekayi (1)	brown snake
Diadophis punctatus (1)	southern ringneck snake
Seminatrix pygaea (1)	swamp snake
Coluber constrictor (1)	black racer
Crotalus horridus (2)	canebrake rattlesnake

Source: Smith et al. (1982)

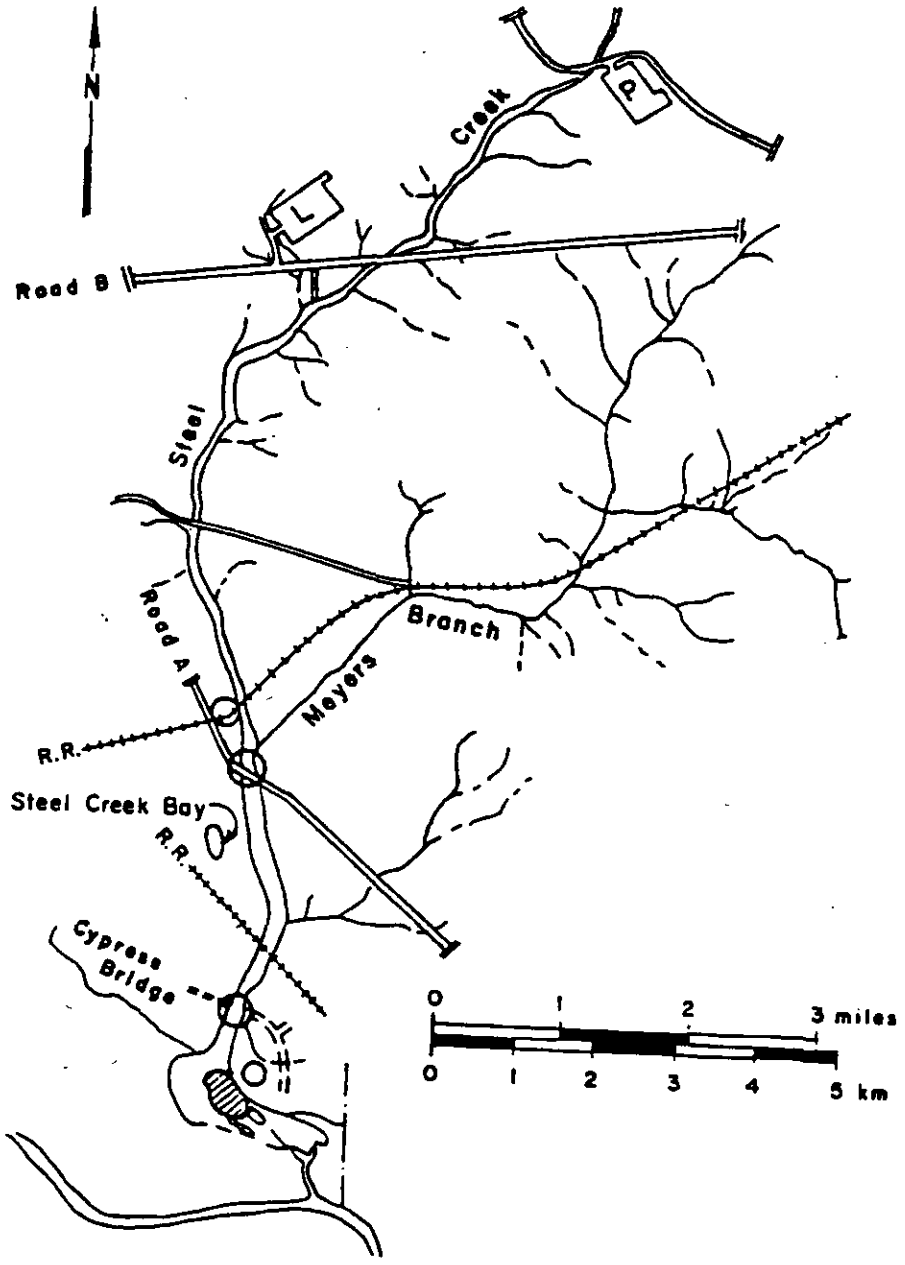

FIGURE 2-36. Location of Drift Fences and Pitfall Traps (open circles). In Steel Creek (1981-1982) Cross Hatching in Delta Indicates Area of 1982 Turtle Trapping. (Smith et al., 1982)

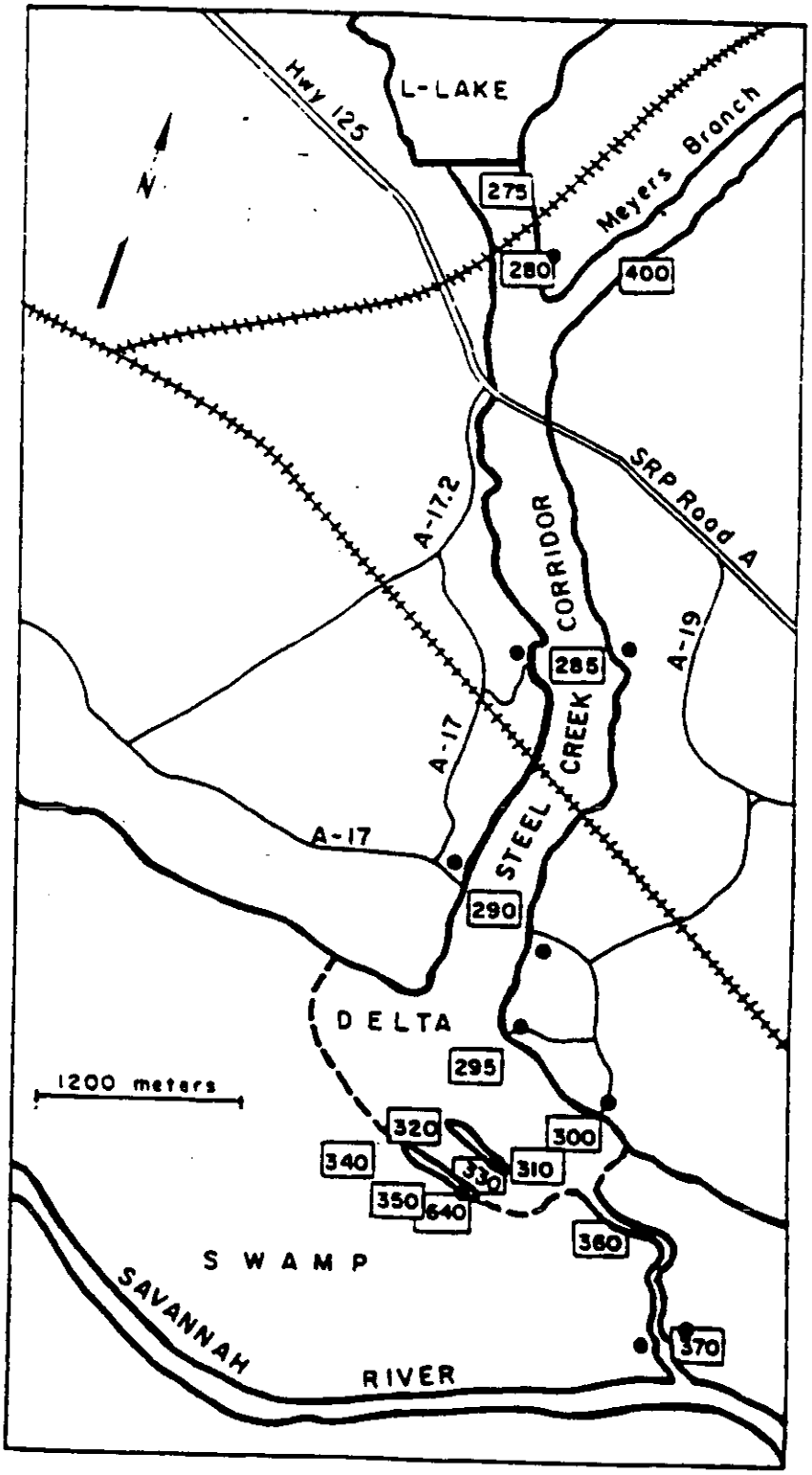

FIGURE 2-37. Location of Reptile and Amphibian Sampling Transects in the Steel Creek Corridor and Delta (•), (January 1986 - December 1987) (source: Giffin and Patterson, 1988)

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TABLE 2-18

Total Number of Each Reptile and Amphibian Species Collected from Sampling Locations in Steel Creek (January 1986 - December 1987)

Taxon	1986	1987
Marbled salamander	-	1
Mole salamander	-	1
Two-lined salamander	-	8
Slimy salamander	2	12
Lesser siren	7	14
Greater siren	1	2
Cricket frog	1	-
Green treefrog	6	5
Spring peeper	-	1
Gray treefrog	2	1
Bullfrog	7	1
Bronze frog	25	2
Leopard frog	6	24
Southern toad	8	-
Narrow-mouthed toad	2	-
Spadefoot toad	-	1
Alligator	7	13
Snapping turtle	9	5
River cooter	-	1
Chicken turtle	4	-
Striped mud turtle	-	1
Mud turtle	8	11
Florida cooter	7	10
Yellow-bellied slider	82	93
Stinkpot	8	9
Spiny softshell	3	2
Box turtle	1	-
Green anole	28	7
Six-lined racerunner	2	2
Broad-headed skink	1	-
Five-lined skink	3	-
Ground skink	7	2
Eastern glass lizard	-	1
Cottonmouth	10	24
Black racer	2	1
Corn snake	-	1
Rainbow snake	1	2
Chain king snake	-	1
Red-bellied watersnake	-	2
Banded watersnake	3	1
Brown watersnake	7	15
Brown snake	2	1
Southeastern crowned snake	-	1
Ribbon snake	1	1

Note: Only individuals identified to species are included in this table.

Source: Giffin and Patterson (1988)

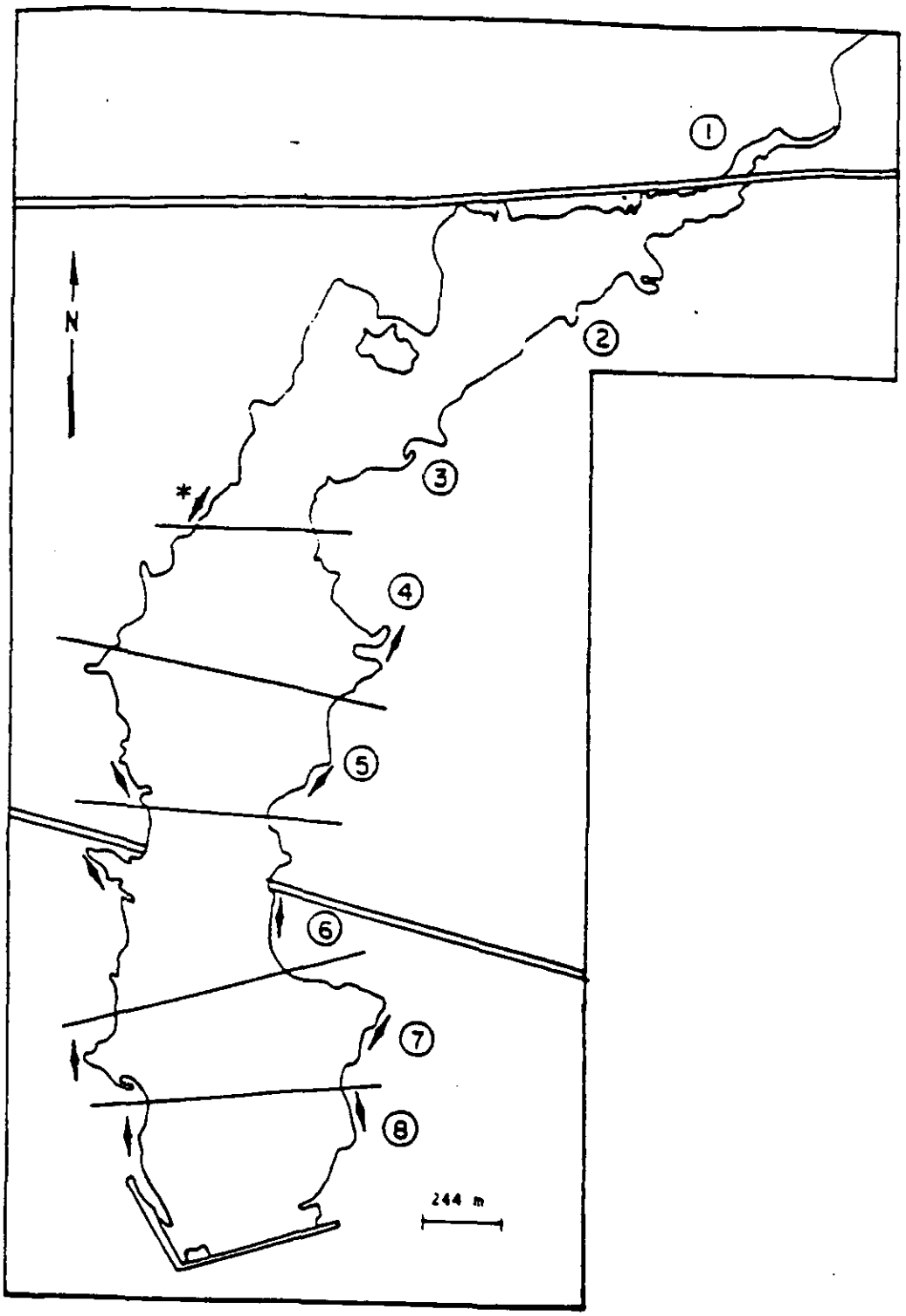

FIGURE 2-38. The Location of Reptile and Amphibian Sampling Transects on the L-Lake Shoreline. The transect in Region 3 was established before permanent markers divided the regions. It is so close to the boundary with Region 4 that it was deemed unnecessary to relocate it
(source: Patterson and Giffin, 1988)

TABLE 2-19

Total Number of Each Reptile and Amphibian Species Collected from Regions 4-8 of L Lake (January 1986 - December 1987).
Animals identified to genus were not included in the total count if a species within that genus was identified.

Taxon	1986	1987
Amphibians		
Marbled salamander	3	-
Mole salamander	5	-
Red-spotted newt	1	-
Slimy salamander	13	1
Red salamander	1	-
Lesser siren	1	-
Narrow-mouthed toad	10	7
Green treefrog	1	-
Bullfrog	4	-
Bronze frog	1	-
Leopard frog	5	2
Spadefoot frog	3	5
Southern toad	11[a]	7
Total	59	22
Reptiles		
Alligator	1	3
Mud turtle	3	1
Florida cooter	2	-
Yellow-bellied slider	47	23
Box turtle	2	3
Spiny softshell	2	1
Green anole	43	29
Six-lined racerunner	11	16
Five-lined skink	6	5
Southeastern five-lined skink	3	-
Broad-headed skink	6	4
Ground skink	17	10
Fence lizard	38	27
Cottonmouth	3	3
Black racer	1	3
Canebrake rattlesnake	1	-
Corn snake	1	-
Rainbow snake	1	-
Eastern hognose snake	5	1

TABLE 2-19, Contd

Taxon	1986	1987
Reptiles, Contd		
Southern hognose snake	-	1
Coach whip	-	1
Red-bellied watersnake	-	1
Brown watersnake	7	6
Green snake	-	1
Red-bellied snake	1	-
Southeastern crowned snake	2	6
Garter snake	-	1
Smooth earth snake	1	-
Total	204	146
Annual total	263	168

[a] Does not include recently metamorphosed juvenile captured in drift fences in July 1986

Source: Patterson and Giffin (1988)

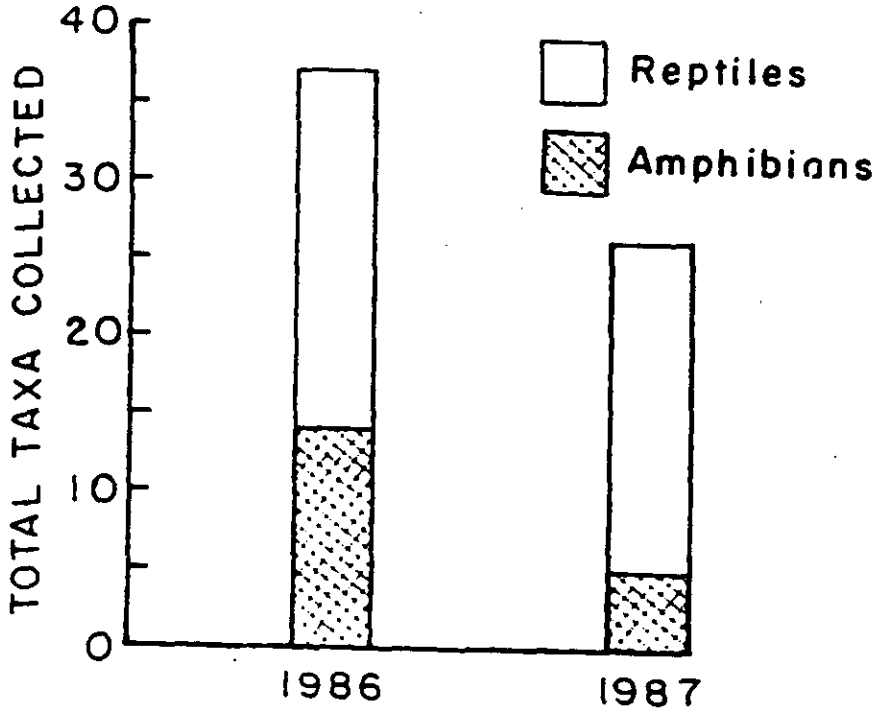

FIGURE 2-39. Total Number of Reptile and Amphibian Species Collected from All Sampling Regions of L Lake (January 1986 - December 1987 (source: Patterson and Giffin, 1988)

TABLE 2-20

Reptiles and Amphibians of Par Pond

Frogs	
Rana utricularia	leopard frog
Rana catesbeiana	bullfrog
Rana clamitans	green frog
Acris gryllus	cricket frog
Hyla cinerea	green tree frog
Hyla crucifer	spring peeper
Bufo terrestris	southern toad
Bufo quercicus	oak toad
Gastrophryne carolinensis	narrow mouthed toad
Aquatic Salamanders	
Siren intermedia	lesser siren
Amphiuma means	amphiuma
Snakes	
Nerodia fasciata	banded water snake
Nerodia cyclopion	green water snake
Nerodia taxispilots	brown water snake
Agkistrodon piscivorus	cottonmouth
Turtles	
Pseudemys scripta	slider turtle
Pseudemys floridana	Florida cooter
Sternotherus odoratus	musk turtle
Kinosterum subrubrum	mud turtle
Chelydra serpentina	snapper
Deirochelys reticularia	chicken turtle
Crocodilians	
Alligator mississippiensis	American alligator

Source: Wilde (1985)

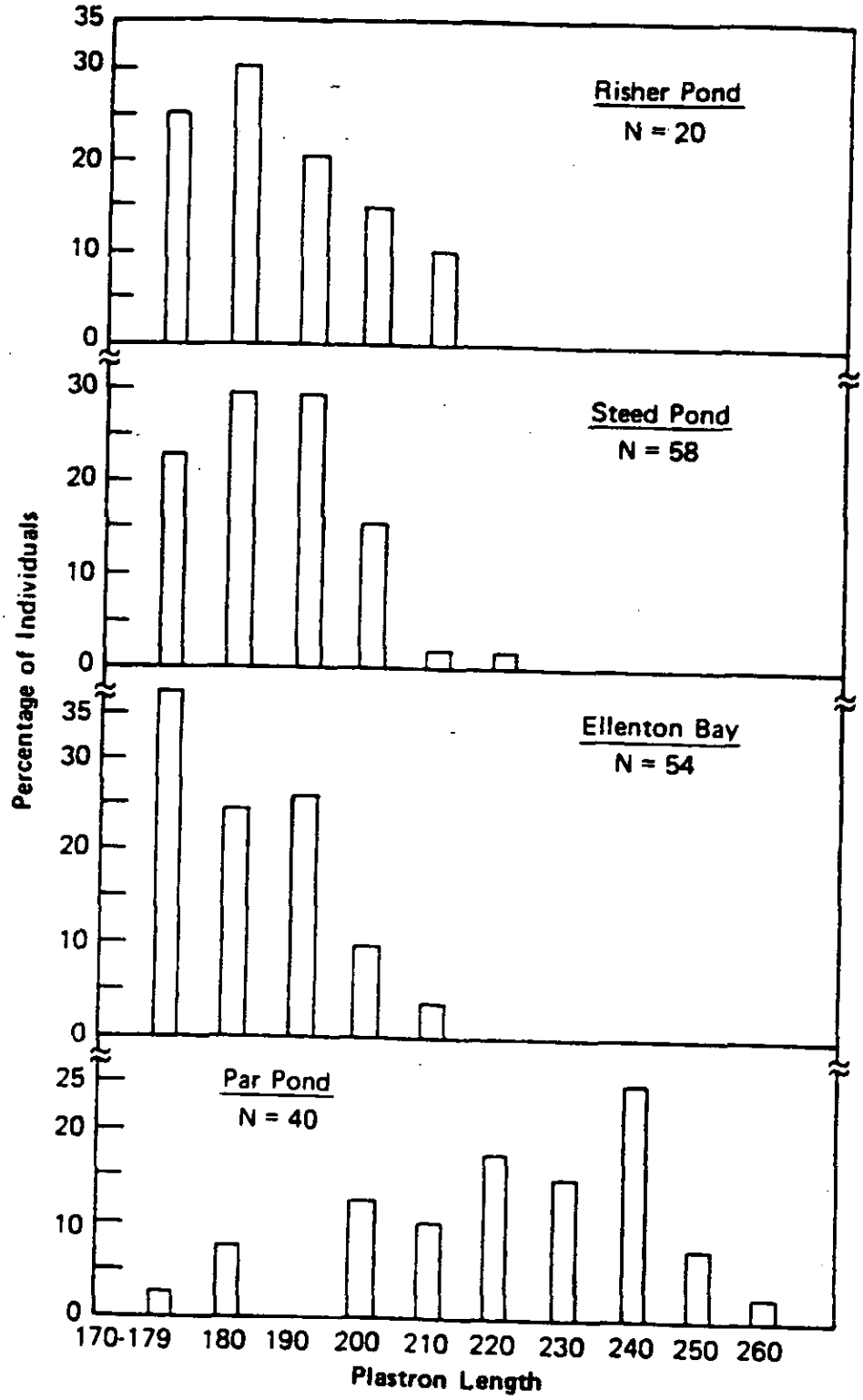

FIGURE 2-40. Size Structure of Adult Pseudemys scripta from Different Habitats on the SRS (source: Gibbons, 1970)

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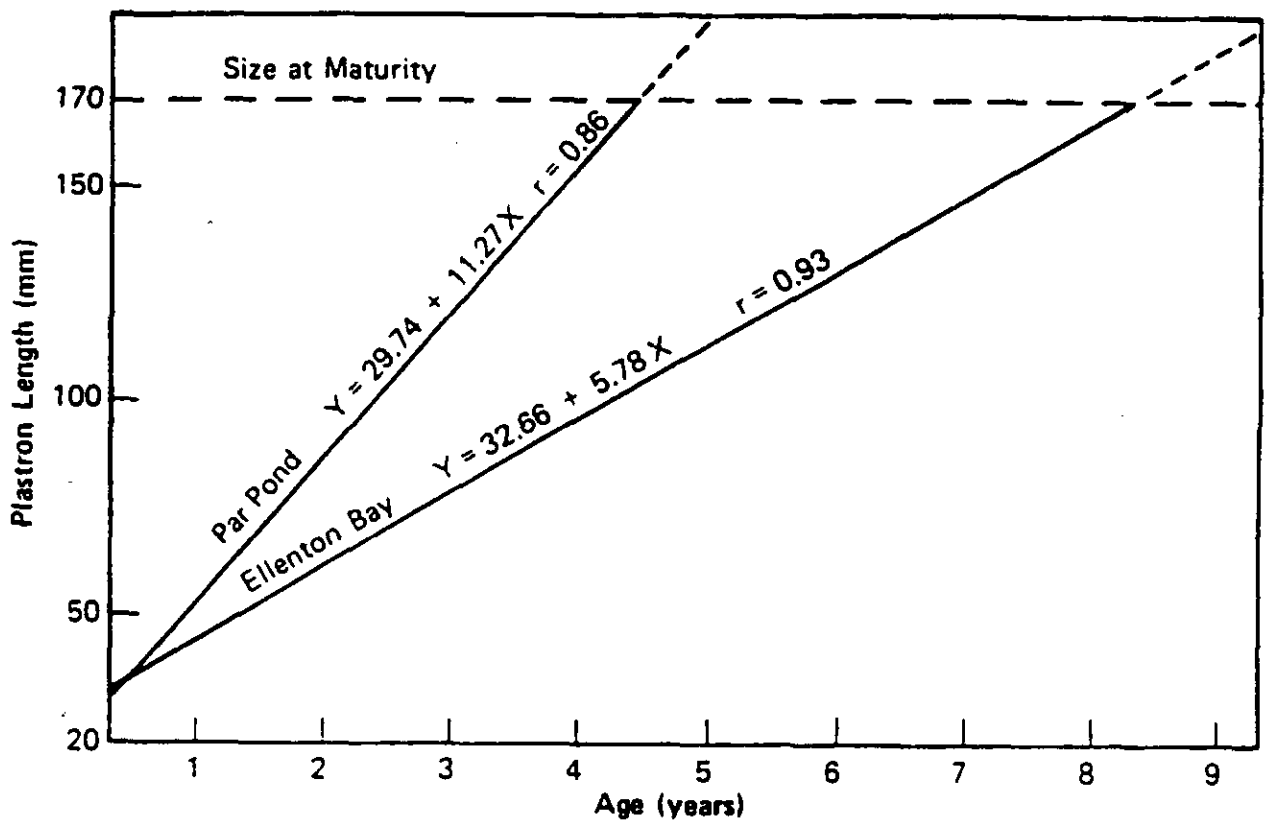

FIGURE 2-41. Growth Rates (Abscissa = Age in Years; Ordinate = Plastron Length in mm) of Juvenile Pseudemys scripta from Two Populations (Par Pond, N = 30; Ellenton Bay, N = 160) on the SRS.(Source: Gibbons, 1970)

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Male turtles in Par Pond achieve sexual maturity faster than those in other bodies of water at the SRS, while females reach a larger size at sexual maturity (Figure 2-42). Larger body size in female turtles allows for larger egg or clutch size (Gladden et al., 1985).

The herpetofauna, aside from the alligator, of Pen Branch Creek area has been little studied. During operation of K Reactor no reptiles or amphibians would be expected to inhabit areas of thermal discharge (Gladden et al., 1985). No studies of the Pen Branch herpetofauna have been instituted since the K-Reactor outage.

2.3.3 Avifauna

2.3.3.1 Introduction

The SRS supports a diverse and mobile avifauna that includes migrant, seasonal, or permanent residents. Early research (Norris, 1963) identified 213 species of birds on the SRS (Table 2-21). Information on avifauna other than waterfowl on the SRS is limited to early research (Norris, 1957, 1963), Christmas bird counts (Angerman et al., 1979, 1980), and ecological inventories (Smith et al., 1981; SREL, 1979, 1980).

Composite lists of birds observed at Rainbow Bay (Table 2-22) and Sun Bay (Table 2-23) are indicative of the wide variety of birds found on the SRS. In 1978 the numbers of birds observed at Rainbow Bay doubled in November compared to inventories in September and October indicating increased usage of the area for overwintering (SREL, 1979).

A list of birds found in the vicinity of Steel Creek appears in Table 2-24. This information was compiled from various studies conducted prior to 1981 (Smith et al., 1981).

Information regarding birds found on the SRS listed as threatened or endangered (bald eagle, red-cockaded woodpecker, wood stork) can be found in Chapter 5 of this document, and upland game birds are discussed in Section 2.3.5.1.

2.3.3.2 Waterfowl

Waterfowl utilize most of the suitable habitat available on the SRS (Table 2-25) and have been studied more than the upland birds. Mackey (1987) presents extensive information pertaining to waterfowl use of the SRS. A portion of the summary from that document follows below.

Large numbers of waterfowl have been present on the SRS since public access to the site was terminated in the early 1950s. Thirty-one species of waterfowl have been documented as occurring on the SRS. The Savannah River Ecology Laboratory (SREL) has been conducting waterfowl research

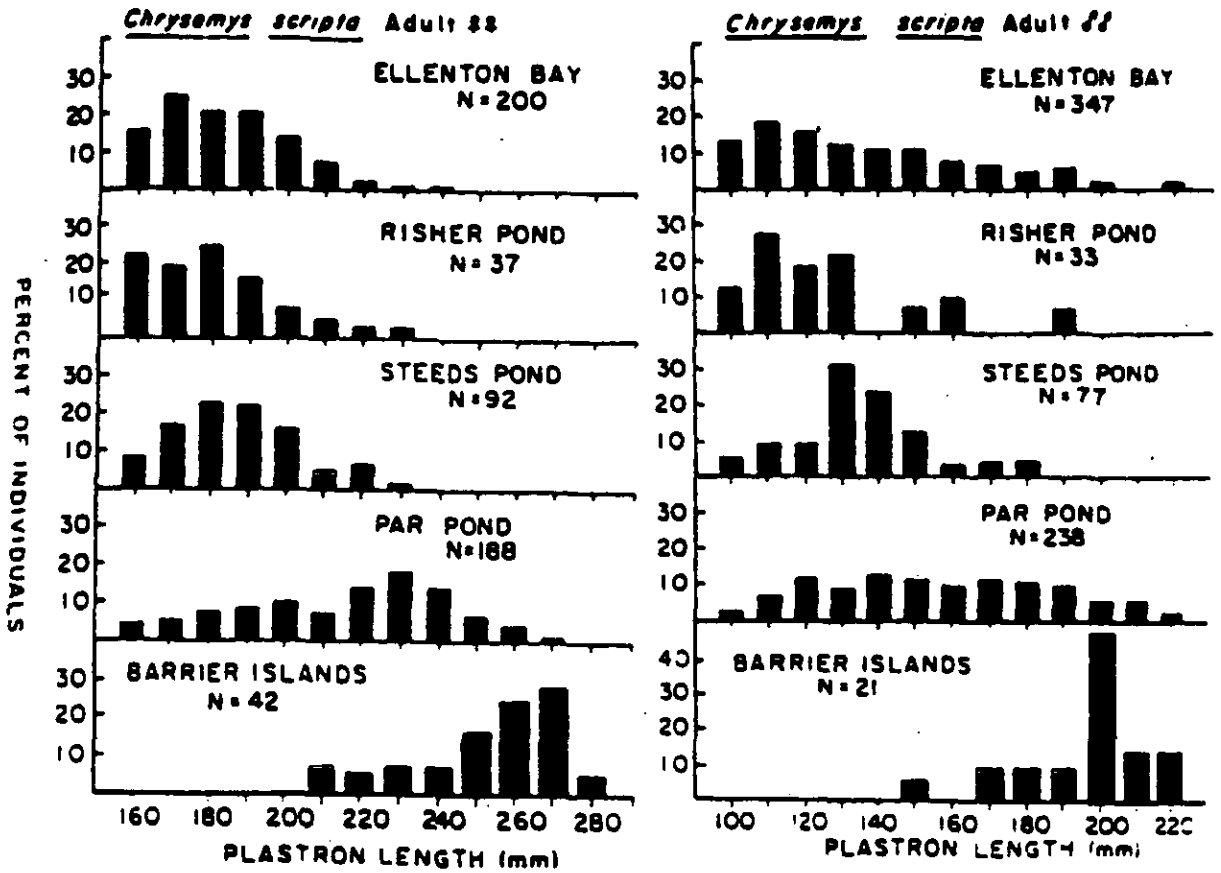

FIGURE 2-42. Comparative Population Size Structures of Adult Female and Male Pseudemys (Chrysemys) scripta from Different Habitats in South Carolina (source: Gibbons et al., 1979)

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TABLE 2-21

Birds of the SRS

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Gavia immer	Common loon	T.V.	River Swamp, Par Pond	2
Podiceps auritus	Horned grebe	W.V.	Ponds	3
Podilymbus podiceps	Pied-billed grebe	P.R.	Ponds	Common
Phalacrocorax auritus	Double-crested cormorant	W.V.	Near ponds	7
Anhinga anhinga	Anhinga	S.V.	Ponds, creeks	3
Ardea herodias	Great blue heron	P.R.	Ponds, Carolina Bays, creeks	Common
Butorides virescens	Green heron	S.R.	Creeks	Uncommon
Florida caerulea	Little blue heron	S.V.	Ponds	Common
Casmerodius albus	Common egret	P.R.	Carolina Bays, ponds	Common
Leucophoxy thula	Snowy egret	S.V.	River swamp, ponds	Uncommon
Nycticorax nycticorax	Black-crowned night heron	T.V.	Ponds	2
Nyctanassa violacea	Yellow-crowned night heron	S.V.	River swamp, Carolina Bays	2
Ixobrychus exilis	Least bittern	S.R.	Carolina Bays	Common
Botaurus lentiginosus	American bittern	W.V.	Carolina Bays	Uncommon
Mycteria americana	Wood ibis	S.V.	Near creeks	Uncommon
Guara alba	White ibis	S.V.	River and Carolina Bays	15
Branta canadensis	Canada goose	W.V.	Ponds	1
Chen hyperborea	Snow goose	T.V./W.V.	Carolina Bays	2
Chen caerulescens	Blue goose	T.V./W.V.	Carolina Bays	4
Anas platyrhynchos	Mallard duck	W.V./S.R.	Carolina Bays	Common
Anas rubripes	Black duck	W.V.	Carolina Bays	17
Anas acuta	Pintail duck	W.V.	Carolina Bays	1
Anas carolinensis	Green-winged teal	W.V.	Par Pond	Common
Anas discors	Blue-winged teal	T.V.	Ponds, Carolina Bays	Common
Mareca americana	American widgeon	W.F.	Ponds	Uncommon
Spatula clypeata	Shoveler	T.V./W.V.	Carolina Bays	3
Aix sponsa	Wood duck	P.R.	River swamp	Common
Aythya collaris	Ring-necked duck	W.V.	Ponds, Carolina Bays	Common
Aythya valisneria	Canvasback	W.V.	Ponds	1
Aythya affinis	Lesser scamp	T.V.	Ponds	Uncommon
Glaucionetta albeola	Bufflehead	T.V.	Ponds	5
Changula hyemalis	Oldsquaw	W.V.	Par Pond	1
Erismatura jamaicensis	Ruddy duck	T.V.	Ponds	Uncommon
Lophodytes cucullatus	Hooded merganser	W.V.	Ponds, streams	Uncommon to Common

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Cathartes aura	Turkey vulture	P.R.	Ubiquitous	Common
Coragyps atratus	Black vulture	P.R.	Ubiquitous	Very common
Ictinia missippiensis	Mississippi kite	S.R.	Lower terraces	Uncommon
Accipiter striatus	Sharp-shined hawk	W.V.	Ubiquitous	Infrequent
Accipiter cooperii	Coopers hawk	P.R.	Ubiquitous	Common
Buteo jamaicensis	Red-tailed hawk	P.R.	Pines, powerline poles	Common
Buteo lineatus	Red-shouldered hawk	P.R.	River swamp, lower terraces	Common
Buteo platypterus	Broad-winged hawk	S.R.	Deciduous woods	Rare
Haliaeetus leucocephalus	Bald eagle	T.V.	Near Par Pond	3
Circus cyaneus	Marsh hawk	W.V.	Old fields	Common
Pandion haliaetus	Osprey	T.V.	Ponds	16
Falco peregrinus	Peregrine falcon	W.V.	Near Par Pond	Rare
Falco columbarius	Pigeon hawk	T.V.	Lower terrace	Rare
Falco sparverius	Sparrow hawk	P.R.	Old field	Common
Colinus virginianus	Bob white	P.R.	Ubiquitous in ground cover	Common
Meleagris gallopavo	Turkey	P.R.	Near streams and swamps	Rare
Rallus elegans	King rail	S.R.	Carolina Bays	Common
Rallus limicola	Virginia rail	T.V.	-	Rare
Porzana carolina	Sora	T.V.	-	Uncommon
Porphyrula martinica	Purple gallinule	S.R.	Carolina Bays	Uncommon
Gallinula chloropus	Common gallinule	T.V.	Carolina Bays, ponds	Uncommon
Fulica americana	American coot	W.R.	Ponds, Carolina Bays	Common
Charadrius vociferus	Killdeer	P.R.	Edges of ponds, bays	Uncommon
Philohela minor	American woodcock	P.R.	-	Rare
Capella gallinago	Common snipe	W.R.	Marshes	Common
Actitis macularia	Spotted sandpiper	T.V.	Edges of ponds, streams	Common
Tringa solitaria	Solitary sandpiper	T.V.	Ponds	Uncommon
Totanus melanoleucus	Greater yellowlegs	T.V.	Ponds	Uncommon
Totanus flavipes	Lesser yellowlegs	T.V.	-	Uncommon
Erolia minutilla	Least sandpiper	T.V.	-	Uncommon
Crocethia alba	Sanderling	T.V.	-	3
Lobipes lobatus	Northern phalarope	T.V.	Bays	2
Larus delawarensis	Ring-billed gull	W.R.	River, ponds	5
Larus philadelphia	Bonaparte's gull	T.V.	Ponds	Rare
Chilidonias nigra	Black tern	T.V.	Bays	Scarce
Zenaidura macroura	Morning dove	P.R.	Fields, oak forests	Common

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Columbigallina passerina	Ground dove	-	Par Pond, streams	5
Coccyzus americanus	Yellow-billed cuckoo	S.R.	Floodplain, forests	Common
Coccyzus erythropthalmus	Black-billed cuckoo	T.V.	-	1
Tyto alba	Barn owl	P.R.	Terrace forests	2
Otus asio	Screech owl	P.R.	Trees	Few
Bubo virginianus	Great horned owl	P.R.	Pine trees	Uncommon
Strix varia	Barred owl	P.R.	Flood plain timber	Common
Asio flammeus	Short-eared owl	W.V.	Fields	Common
Caprimulgus carolinensis	Chuck-will's widow	S.R.	Forested areas	Common
Chordeiles minor	Common nighthawk	S.R.	Open pineland	Common
Chaetura pelagica	Chimney swift	S.R.	River swamp	Common
Archilochus colubris	Ruby-throated hummingbird	S.R.	Broadleaf forests	Common
Megaceryle alcyon	Belted kingfisher	P.R.	Ponds, streams	Uncommon
Colaptes auratus	Yellow-shafted flicker	P.R.	Swamp forests	Common
Hylatomus pileatus	Pileated woodpeckers	P.R.	River swamps, floodplain, forests	Common
Centurus carolinus	Red-bellied woodpecker	P.R.	River swamps, floodplain, forests	Common
Melanerpes erythrocephalus	Red-headed woodpecker	P.R.	Power poles	Common
Sphyrapicus varius	Yellow-bellied sapsucker	W.V.	Mixed forests, swamps	Common
Dendrocopus villosus	Hairy woodpecker	P.R.	Dead timber	Uncommon
Dendrocopus pubescens	Downy woodpecker	P.R.	Broadleaf and mixed forests	Common
Dendrocopus borealis	Red-cockaded woodpecker	P.R.	Pine trees	Rare
Tyrannus tyrannus	Eastern kingbird	S.R.	Open country	Abundant
Tyrannus dominicensis	Gray kingbird	-	-	1
Tyrannus verticalis	Western kingbird	-	-	1
Myiarchus crinitus	Great crested flycatcher	S.R.	Broadleaf and mixed forests	Common
Sayornis phoebe	Eastern phoebe	W.V.	Near water	Common
Empidonax virescens	Acadian flycatcher	S.R.	River swamp	Abundant
Empidonax trailli	Traill's flycatcher	T.V.	-	1
Empidonax minimus	Least flycatcher	T.V.	-	1
Contopus virens	Eastern wood pewee	S.R.	Open mixed woods	Common
Eremophila alpestris	Horned lark	W.V.	Open fields	Uncommon
Iridoprocne bicolor	Tree shallow	T.V.	-	2
Riparia riparia	Bank swallow	T.V.	Stream	1
Stelgidopteryx ruficollis	Rough-winged shallow	S.R.	Clay banks	Common
Hirundo rustica	Barn swallow	T.V.	-	Uncommon

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Progne subis	Purple martin	S.R.	Old house sites	Common
Cyanocitta cristata	Blue jay	P.R.	Woods	Common
Corvus brachyrhynchos	Common crow	P.R.	Pines and mixed forests	Abundant
Corvus ossifragus	Fish crow	S.R.	Floodplain forests, bays	Common
Parus caroninensis	Carolina chickadee	P.R.	Open wooded areas	Common
Parus bicolor	Tufted titmouse	P.R.	Open wooded areas	Common
Sitta carolinensis	White-breasted nuthatch	P.R.	River swamp	Uncommon
Sitta pusilla	Brown-headed nuthatch	P.R.	Open pine forests	Common
Certhia familiaris	Brown creeper	W.V.	-	Rare
Troglodytes aedon	House wren	W.V.	Scrubby growth	Uncommon
Troglodytes troglodytes	Winter wren	W.V.	Forest floor	Common
Thryomanes bewickii	Bewick's wren	W.V.	Brush, wood piles	Common
Thryothorus ludovicianus	Carolina wren	P.R.	Swamps, floodplain, forests	Common
Telmatodytes palustris	Long-billed marsh wren	W.V.	Carolina Bays	Uncommon
Minus polyglottos	Mocking bird	P.R.	Trees, shrubs	Abundant
Dumetella carolinensis	Catbird	W.V.	Swamp border	Common
Toxostoma rufum	Brown thrasher	P.R.	Thickets	Common
Turdus migratorius	Robin	W.V.	Ubiquitous	Common
Hylocichla mustelina	Wood thrush	S.R.	Floodplain forests	Common
Hylocichla guttata	Hermit thrush	W.V.	Broadleaf and mixed forests	Common
Hylocichla ustulata	Swainson's thrush	T.V.	-	Uncommon
Hylocichla minima	Gray-checked thrush	T.V.	-	Rare
Hylocichla fuscescens	Veery	T.V.	River swamp	Common
Sialia sialis	Eastern bluebird	P.R.	Open woodlands	Abundant
Polioptila caerulea	Blue-gray gnatcatcher	S.R.	Ubiquitous	Abundant
Regulus satrapa	Golden-crowned kinglet	W.R.	Broadleaf and mixed forests	Common
Regulus calendula	Ruby-crowned kinglet	W.R.	Forest edges, shrubs	Abundant
Anthus spinoletta	Water pipit	W.V.	Old fields	Common
Anthus spragueii	Sprague's pipit	W.V.	Fields	Rare
Bombycilla cedrorum	Cedar waxwing	W.V.	Fruit-seeking	Common
Lanius ludovicianus	Loggerhead shrike	P.R.	Open country	Common
Sturnus vulgaris	Starling	P.R.	-	Uncommon
Vireo griseus	White-eyed vireo	S.R.	Broadleaf forests	Common
Vireo flavifrons	Yellow-throated vireo	S.R.	Broadleaf and mixed forests	Common
Vireo solitarius	Solitary vireo	W.V.	River swamp	Rare
Vireo olivaceus	Red-eyed vireo	S.R.	Broadleaf forests, swamp	Abundant

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Mniotilta varia	Black-and-white warbler	T.V.	-	Uncommon
Protonotaria citrea	Prothonotary warbler	S.R.	Swamp, streams	Common
Limnothylpis swainsonii	Swainson's warbler	S.R.	Swamp, streams	Common
Helmitheros vermivorus	Worm-eating warbler	T.V.	-	Uncommon
Vermivora chrysoptera	Golden-winged warbler	T.V.	-	Uncommon
Vermivora pinus	Blue-winged warbler	T.V.	Broadleaf forests	7
Vermivora peregrina	Tennessee warbler	T.V.	-	Uncommon
Vermivora celata	Orange-crowned warbler	W.V.	-	Rare
Vermivora ruficapilla	Nashville warbler	T.V.	-	Rare
Parula americana	Parula warbler	S.R.	Broadleaf forests	Abundant
Dendroica petechia	Yellow warbler	T.V.	Willow borders	Uncommon
Dendroica magnolia	Magnolia warbler	T.V.	-	Uncommon
Dendroica tigrina	Cape May warbler	T.V.	-	Uncommon
Dendroica caerulescens	Black-throated warbler	T.V.	-	Abundant
Dendroica coronata	Myrtle warbler	W.V.	Waxmyrtle	Common
Dendroica virens	Black-throated green warbler	T.V.	-	Uncommon
Dendroica cerulea	Cerulean warbler	T.V.	-	Rare
Dendroica fusca	Blackburnian warbler	T.V.	-	Uncommon
Dendroica dominica	Yellow-throated warbler	S.R.	River swamp, streams	Uncommon
Dendroica pennsylvania	Chesnut-sided warbler	T.V.	-	Uncommon
Dendroica castanea	Bay-breasted warbler	T.V.	-	Uncommon
Dendroica striata	Blackpoll warbler	T.V.	-	Uncommon
Dendroica pinus	Pine warbler	P.R.	Pinelands	Common
Dendroica kirtlandii	Kirtland's warbler	T.V.	-	Rare
Dendroica discolor	Prairie warbler	S.R.	Open pine and scrub oaks	Common
Dendroica palmarum	Palm warbler	W.R.	Open country	Common
Seiurus aurocapillus	Ovenbird	T.V.	Broadleaf forest	Abundant
Seiurus noveboracensis	Northern waterthrush	T.V.	Ponds	Common
Seiurus motacilla	Louisiana waterthrush	S.R.	Streams	Common
Oporornis formosus	Kentucky warbler	S.R.	Pond margins, broadleaf forests	Common
Oporornis agilis	Connecticut warbler	T.V.	-	Rare
Geothlypis trichas	Yellowthroat	P.R.	Fields, streams, bays	Common
Icteria virens	Yellow-breasted chat	S.R.	Scrubby areas, lower terraces	Common
Wilsonia citrina	Hooded warbler	S.R.	River swamp	Common
Wilsonia pusilla	Wilson's warbler	T.V.	-	Rare

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Wilsonia canadensis	Canada warbler	T.V.	–	Rare
Setophaga ruticilia	American redstart	T.V.	Broadleaf forests	Common
Passer domesticus	House sparrow	P.R.	Industrial areas	Common
Dolichonyx oryzivorus	Bobolink	T.V.	Fields	Common
Sturnella magna	Eastern meadowlark	P.R.	Fields	Common
Sturnella neglecta	Western meadowlark	W.V.	–	Rare
Agelaius phoeniceus	Red-winged blackbird	P.R.	Carolina Bays	Common
Icterus spurius	Orchard oriole	S.R.	Old farm sites	Common
Icterus galbula	Baltimore oriole	T.V./W.V.	–	Rare
Euphaeus carolinus	Rusty blackbird	W.V.	River swamp	Uncommon
Quiscalus quiscula	Common grackle	P.R.	Near Bays	Common
Molothrus ater	Brown-headed cowbird	W.V.	Fields	Uncommon
Piranga olivacea	Scarlet tanager	T.V.	Broadleaf forest	Common
Piranga rubra	Summer tanager	S.R.	Mixed forest	Common
Richmondena cardinalis	Cardinal	P.R.	Edge growth, hammocks	Abundant
Pheucticus ludovicianus	Rose-breasted grosbeak	T.V.	–	Uncommon
Guiraca caerulea	Blue grosbeak	S.R.	Grassy fields	Common
Passerina cyanea	Indigo bunting	S.R.	Ubiquitous	Common
Passerina ciris	Painted bunting	S.R.	Lower terraces	Common
Carpodacus purpureus	Purple finch	W.V.	Upland areas	Common
Spinus pinus	Pine siskin	W.V.	–	Rare
Spinus tristis	American goldfinch	P.R.	Lower terraces	Uncommon to common
Pipilo erythrophthalmus	Rufous-sided towhee	P.R.	Shrub, pine-oak forests	Common
Passerculus sandwichensis	Savannah sparrow	W.R.	Old fields	Very abundant
Ammodramus savannarum	Grasshopper sparrow	W.V.	–	Uncommon
Passerherbulus caudacutus	LeConte's sparrow	W.V.	–	Rare
Passerherbulus henslowii	Henslow's sparrow	T.V.	–	Rare
Pooecetes gramineus	Vesper sparrow	W.V.	Open areas	Common
Aimophila aestivalis	Bochman's sparrow	P.R.	Pine woods	Common
Junco hyemalis	Slate-colored junco	W.V.	Upland pine-oak	Common
Spizella passerina	Chipping sparrow	P.R.	Pine	Common
Spizella pusilla	Field sparrow	P.R.	Lower terraces	Common
Zonotrichia albicollis	White-throated sparrow	W.V.	Moist areas	Abundant

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TABLE 2-21, Contd

Scientific Name	Common Name	Residency Status[a]	Location of Sighting[b]	Abundance[c]
Passerella iliaca	Fox sparrow	P.R.	Lower terraces	Common
Melospiza lincolnii	Lincoln's sparrow	T.V.	-	Rare
Melospiza georgiani	Swamp sparrow	W.V.	Bays, marshy areas	Common
Melospiza melodia	Song sparrow	W.V.	Open, brushy areas	Abundant

[a] P.R. - permanent resident
S.R. - summer resident - regular, spring to fall; breeding or presumably breeding
S.V. - summer visitant - nonbreeding
W.V. - winter visitant - usually regular, fall to spring
T.V. - transient visitant - spring and/or fall

[b] Area where the birds were most commonly observed. Location of sighting is not given for one of the following reasons: (1) Birds were seen only in migration, (2) birds were seen in areas not typical or expected of the species, (3) birds were seen only in nearby areas offsite, (4) birds were observed only as a result of road kills or kills from collision with a television tower, or (5) record was not made of location of bird sighting.

[c] Abundance is qualitative where available.

Source: Norris (1963)

W8906070

TABLE 2-22

A Composite List of All Birds Observed in the Rainbow Bay Study Area from September 1, 1978 to March 31, 1980. The status of each species is listed as follows: W = winter resident; S = summer resident; P = permanent resident; M = migrant

Species	Status	Species	Status
Great blue heron	P	Common crow	P
Green heron	S	Fish crow	P
Little blue heron	S	Black-capped chickadee	P
Cattle egret	M	Carolina chickadee	P
Yellow-crowned night heron	S	Tufted titmouse	P
White ibis	M	Brown-headed nuthatch	P
Mallard	W	Brown creeper	W
Wood duck	P	House wren	M
Turkey vulture	P	Carolina wren	P
Black vulture	P	Mockingbird	P
Sharp-shinned hawk	P	Catbird	P
Cooper's hawk	P	Brown thrasher	P
Red-tailed hawk	P	American robin	P
Red-shouldered hawk	P	Wood thrush	S
Broad-winged hawk	S	Hermit thrush	W
Marsh hawk	S	Swainson's thrush	M
American kestrel	P	Eastern bluebird	P
Bobwhite	P	Blue-gray gnatcatcher	S
Killdeer	P	Golden-crowned kinglet	W
Lesser yellowlegs	M	Ruby-crowned kinglet	W
Morning dove	P	Cedar waxwing	W
Yellow-billed cuckoo	S	Loggerhead shrike	P
Screech owl	P	White-eyed vireo	S
Great horned owl	P	Yellow-throated vireo	S
Barred owl	P	Solitary vireo	W
Chuck-will's widow	S	Red-eyed vireo	S
Common nighthawk	S	Black-and-white warbler	S
Chimney swift	S	Prothonotary warbler	S
Ruby-throated hummingbird	S	Orange-crowned warbler	W
Belted kingfisher	P	Nashville warbler	M
Common flicker	P	Parula warbler	S
Pileated woodpecker	P	Yellow-rumped warbler	W
Red-bellied woodpecker	P	Yellow-throated warbler	S
Red-headed woodpecker	P	Pine warbler	P
Yellow-bellied sapsucker	W	Prairie warbler	W
Hairy woodpecker	P	Palm warbler	W
Downy woodpecker	P	Northern waterthrush	M
Eastern kingbird	S	Louisiana waterthrush	M
Great-crested flycatcher	S	Kentucky warbler	S
Eastern phoebe	W	Nashville warbler	M
Acadian flycatcher	S	Yellowthroat	P

TABLE 2-22, Contd

Species	Status	Species	Status
Least flycatcher	M	Yellow-breasted chat	S
Eastern wood pewee	S	Hooded warbler	S
Rough-winged swallow	S	American redstart	M
Purple martin	S	Eastern meadowlark	P
Blue jay	P	Red-winged blackbird	P
Orchard oriole	S	Rufous-sided towhee	P
Brewer's blackbird	W	Savannah sparrow	W
Common grackle	P	Bachman's sparrow	P
Brown-headed cowbird	P	Dark-eyed junco	W
Scarlet tanager	M	Chipping sparrow	P
Summer tanager	S	Field sparrow	P
Cardinal	P	White-crowned sparrow	M
Blue gosbeak	S	White-throated sparrow	W
Indigo bunting	S	Fox sparrow	W
Pine siskin	W	Swamp sparrow	W
American goldfinch	W	Song sparrow	W

[a] W = winter resident
[b] S = summer resident
[c] P = permanent resident
[d] M = migrant

Source: SREL (1980)

TABLE 2-23

A Composite List of All Birds Observed in the Sun Bay Study Area from March 1, 1980 to March 31, 1980

Species	Status[a]	Species	Status
Cattle egret	M	Wood thrush	S
Great egret	S	Hermit thrush	W
Turkey vulture	P	Eastern bluebird	P
Black vulture	P	Blue-gray gnatcatcher	S
Sharp-shinned hawk	P	Golden-crowned kinglet	W
Cooper's hawk	P	Ruby-crowned kinglet	W
Red-tailed hawk	P	Cedar waxwing	W
Red-shouldered hawk	P	Logerhead shrike	P
Broad-winged hawk	S	White-eyed vireo	S
American kestrel	P	Yellow-throated vireo	S
Bobwhite	P	Solitary vireo	W
Solitary sandpiper	M	Red-eyed vireo	S
White-rumped sandpiper	M	Black-and-white warbler	S
Mourning dove	P	Prothonotary warbler	S
Yellow-billed cuckoo	S	Parula warbler	S
Screech owl	P	Yellow-rumped warbler	W
Common nighthawk	S	Pine warbler	P
Belted kingfisher	P	Prairie warbler	S
Chimney swift	S	Palm warbler	W
Common flicker	P	Kentucky warbler	S
Pileated woodpecker	P	Yellowthroat	P
Red-bellied woodpecker	P	Yellow-breasted chat	S
Red-headed woodpecker	P	Hooded warbler	S
Yellow-bellied sapsucker	W	American redstart	M
Hairy woodpecker	P	Red-winged blackbird	P
Downy woodpecker	P	Orchard oriole	S
Eastern kingbird	S	Northern oriole	S
Great-crested flycatcher	S	Rusty blackbird	W
Eastern phoebe	W	Common grackle	P
Acadian flycatcher	S	Brown-headed cowbird	P
Barn swallow	S	Scarlet tanager	M
Blue jay	P	Summer tanager	S
Common crow	P	Cardinal	P
Fish crow	P	Blue gosbeak	S
Carolina chickadee	P	Indigo bunting	S
Tufted titmouse	P	American goldfinch	W
Brown-headed nuthatch	P	Rufous-sided towhee	P
Brown creeper	W	Bachman's sparrow	P
House wren	M	Chipping sparrow	P
Carolina wren	P	Field sparrow	P
Mockingbird	P	White-throated sparrow	W
Catbird	P	Swamp sparrow	W
Brown thrasher	P	Song sparrow	W
American robin	P		

[a] W = winter resident
S = summer resident
P = permanent resident
M = migrant

Source: SREL (1980)

TABLE 2-24

Bird Species Recorded in the Vicinity of Steel Creek

Pied-billed grebe	Anhinga	Great blue heron
Green heron	Little blue heron	Great egret
White ibis	Wood duck	Turkey vulture
Black vulture	Sharp-shinned hawk	Red-tailed hawk
Red-shouldered hawk	Broad-winged hawk	Bobwhite
Wild turkey	Purple gallinule	Northern phalarope
Black tern	Morning dove	Yellow-billed cuckoo
Screech owl	Great horned owl	Barred owl
Chuck-will's widow	Common nighthawk	Chimney swift
Ruby-throated hummingbird	Belted kingfisher	Yellow-shafted flicker
Pileated woodpecker	Red-bellied woodpecker	Red-headed woodpecker
Yellow-bellied sapsucker	Hairy woodpecker	Downy woodpecker
Red-cockaded woodpecker	Eastern kingbird	Great crested flycatcher
Eastern phoebe	Acadian flycatcher	Eastern wood pewee
Bank swallow	Barn swallow	Blue jay
Common crow	Fish crow	Caroling chickadee
Tufted titmouse	White-breasted nuthatch	Brown-headed nuthatch
House wren	Carolina wren	Long-billed marsh wren
Mockingbird	Gray catbird	Brown thrasher
American robin	Wood thrush	Hermit thrush
Eastern blackbird	Blue-gray gnatcatcher	Water pipit
White-eyed vireo	Yellow-throaded vireo	Red-eyed vireo
Black-and-white warbler	Prothonotary warbler	Northern parula
Yellow-rumped warbler	Yellow-throated warbler	Pine warbler
Prairie warbler	Ovenbird	Northern waterthrush
Kentucky warbler	Common yellowthroat	Yellow-breasted chat
Hooded warbler	American redstart	Eastern meadowlark
Red-winged blackbird	Orchard oriole	Common grackle
Brown-headed cowbird	Summer tanager	Cardinal
Blue-grosbeak	Indigo bunting	Painted bunting
Rufous-sided towhee	LaConte's sparrow	Bachman's sparrow
Chipping sparrow	Field sparrow	White-throated sparrow

Source: Smith et al. (1981)

and surveys on the site for the past 15 years. This research has included work on waterfowl use of the SRS, wood duck reproductive biology, and waterfowl wintering ecology.

With the continued drainage of wetlands in the plains region of western Canada and the United States, continental waterfowl numbers are likely to continue to decrease because of reduced productivity and recruitment each year. Waterfowl numbers on the SRS will probably reflect these declines, but not to the extent that will probably be observed in other wintering areas in the southeast, because of the low human disturbance of wintering waterfowl on the SRS. Reduced disturbance allows the wetland areas of the SRS to serve as a refuge for these birds (Mayer et al., 1986).

Waterfowl use of the SRS has been assessed through aerial surveys of the Par Pond system and Savannah River swamp and through roost counts in the Steel Creek drainage. Aerial surveys have proven to be the most successful method of estimating waterfowl numbers each winter. The most abundant waterfowl species in the Savannah River swamp were consistently mallards and wood ducks, as determined by numbers counted. Both of these species have increased on the SRS over the four-year period (1981-1985) during which these surveys were conducted. Midwinter mallard numbers in both the Atlantic Flyway and in South Carolina have decreased during the same time period. In the SRS Savannah River swamp, the Steel Creek Delta and the sloughs between the Four Mile Creek and Pen Branch Deltas had more mallards than did the Beaver Dam Creek Delta or the Pen Branch Delta. No differences were found between wood duck counts on the Four Mile Creek Delta sloughs, the Steel Creek Delta, or the Beaver Dam Creek Delta. The Savannah River swamp was used extensively for foraging by both mallards and wood ducks (Mayer et al., 1986).

Aerial surveys over the Par Pond system were conducted during the winter and early spring from 1981 to 1985. Twenty species were identified during these surveys. Lesser scaup were the most numerous species observed, followed by ringneck ducks, ruddy ducks, and buffleheads. Over this four-year period, waterfowl numbers on the Par Pond system have increased, while midwinter numbers have declined in the Atlantic Flyway and South Carolina. Lesser scaup, buffleheads, and ruddy ducks were found in fewer numbers in the North Arm of Par Pond than in all four other areas of Par Pond. Ruddy ducks were more frequently observed in the Hot Arm of Par Pond than in the Intake Arm. The other three species were significantly more abundant in the West Arm (Mayer et al., 1986).

The completion of L Lake has provided additional habitat for wintering waterfowl on the SRS. Waterfowl and other water birds began using L Lake after its completion and data for two partial and one complete migratory season is shown in Table 2-26. As littoral zone plant communities and invertebrate populations increase in this system, waterfowl use will likely increase and become more diversified. No decrease in the use of the Par Pond system has been noted in conjunction with the beginning use of L Lake. If this trend continues, the waterfowl use of the SRS will increase as a result of the increase in wintering habitat (Mayer et al., 1986).

TABLE 2-25

Locations on the SRS where Waterfowl Have been Observed Between 1952 and 1985

Species - Common Name[a]	Par Pond	Pond C	Pond B	Beaver Dam Creek	Four Mile Creek	Pen Branch	Steel Creek	Upper Three Runs Creek	Carolina Bays	Basins
Tundra swan	+	o	o	o	o	o	o	o	o	o
Canada goose	+	+	o	o	o	o	o	o	o	+
Blue/snow goose[b]	o	o	o	o	o	o	o	o	+	+
Mallard	+	o	+	+	+	+	+	o	+	+
American black duck	+	o	+	+	+	o	+	o	+	o
Gadwall	+	+	+	+	+	o	+	o	o	o
Pintail	+	o	o	o	o	o	+	o	+	o
Green-winged teal	+	o	o	o	o	o	+	o	o	o
Blue-winged teal	+	o	o	+	+	o	+	o	+	+
American wigeon	+	o	o	+	+	o	+	o	+	o
Northern shoveler	+	o	+	o	o	o	+	o	+	o
Wood duck	+	+	+	+	+	+	+	+	+	+
Redhead	+	o	o	o	o	o	o	o	o	o
Ringneck duck	+	+	+	+	o	o	+	o	+	+
Canvasback	+	o	o	o	o	o	o	o	o	o
Greater scaup	+	o	o	o	o	o	o	o	o	o
Lesser scaup	+	+	+	o	o	o	o	o	o	+
Common goldeneye	+	o	o	o	o	o	o	o	o	o
Bufflehead	+	+	+	o	o	o	+	o	o	+
Oldsquaw	+	o	o	o	o	o	o	o	o	o
White-winged scoter	+	o	o	o	o	o	o	o	o	o
Ruddy duck	+	+	o	o	o	o	o	o	+	o
Hooded merganser	+	+	+	+	+	o	+	+	o	+
Red-breasted merganser	+	o	o	o	o	o	o	o	o	o
Common loon	+	o	o	o	o	o	o	o	o	o
Horned grebe	+	o	o	o	o	o	o	o	+	o
Pied-billed grebe	+	+	+	o	o	o	+	o	+	+
King rail	o	o	o	o	o	+	o	o	+	o
Common gullinule	+	o	o	o	o	o	o	o	+	o
Purple gallinule	+	o	o	o	o	o	o	o	+	o
American coot	+	+	+	o	o	o	+	o	+	+

[a] See for a listing of common names and scientific names of waterfowl species in this volume.

[b] Identification as to blue or snow goose was uncertain.

+ Observed.

o Not observed.

Source: Mayer et al. (1986)

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TABLE 2-26

Number of Waterfowl and Water Birds Observed in Regions 4-8 of L Lake During Migratory Season 1 (January-March 1986), Season 2 (October 1986-March 1987), and Season 3 (October-December 1987)

Species	Region 4 Season 1	Region 4 Season 2	Region 4 Season 3	Region 5 Season 1	Region 5 Season 2	Region 5 Season 3	Region 6 Season 1	Region 6 Season 2	Region 6 Season 3	Region 7 Season 1	Region 7 Season 2	Region 7 Season 3	Region 8 Season 1	Region 8 Season 2	Region 8 Season 3
Common loon	-	9	1	-	10	-	-	1	1	-	6	-	-	7	-
Pied-billed grebe	-	57	24	3	48	20	-	22	24	-	84	60	-	268	164
Horned grebe	-	4	7	-	5	-	-	3	1	-	17	3	-	29	4
Double-crested cormorant	58	251	220	-	37	4	30	66	4	3	13	121	15	53	41
Anhinga	-	10	-	-	-	-	-	6	8	-	1	2	-	-	-
Great blue heron	-	9	21	-	17	25	1	30	11	1	30	60	-	10	24
Great egret	1	15	14	-	4	21	1	8	15	1	-	31	1	-	14
Cattle egret	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-
Green-backed heron	-	-	-	-	3	-	-	2	-	-	-	-	-	-	-
White ibis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Canada goose	-	-	-	-	-	-	-	-	-	6	-	8	1	-	-
Wood duck	-	4	10	-	15	-	6	14	20	1	-	22	-	1	-
Mallard	-	-	1	-	-	64	-	-	-	-	-	-	-	-	-
Blue-winged teal	-	3	-	-	-	-	2	1	1	10	19	9	4	19	1
Lesser scaup	-	-	-	-	11	-	-	-	-	-88	1	-	5	-	-
Bufflehead	72	-	-	12	-	-	10	7	-	64	16	1	19	22	-
Hooded merganser	-	1	-	2	2	-	-	14	-	-	-	-	-	2	-
Common merganser	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Ruddy duck	-	9	-	-	-	-	-	-	-	-	5	-	-	14	-
Unknown water fowl	4	-	86	1	-	-	-	-	-	19	87	34	-	154	24
American coot	342	411	8	75	275	49	2	185	239	4	135	37	5	230	25
Number of species	4	13	10	4	11	6	7	14	10	9	11	11	7	11	8

Source: Patterson and Giffin (1988)

Waterfowl and water associated bird use of L Lake has been monitored from 1986 until present. Species observed from January 1986 through December 1987 are presented in Table 2-27. Comparison of abundance by lake region and season appear in Figure 2-43. Increased use by waterfowl species and increasing cumulative taxa richness (Figure 2-44) suggests that L Lake is becoming similar to Par Pond as habitat for waterfowl use (Patterson and Giffin, 1988).

Lesser scaup and ringneck duck counts fluctuated within reactor cycles on Par Pond, although no discernible trends could be attributed to thermal influence (Mayer et al., 1986). Only the ruddy ducks showed differences between the warm and ambient areas of Par Pond during the reactor cycles. Pond C has limited use by waterfowl during the wintering season. The majority of this use is during periods when the reactor is not operating. The abundance of waterfowl species is different on Pond B than on Par Pond, with buffleheads being most frequently sighted, followed by ruddy ducks, lesser scaups, and ringneck ducks

Wood ducks are the only waterfowl species to breed commonly on the SRS. Nest box surveys were conducted on the SRS between 1973 and 1985 (Mayer et al., 1986). In the 1985 nesting season, nest initiations and duckling production were down from 1984, because of lower water levels at the nest sites. Dump nesting was found to be a common behavior among wood duck hens on the SRS. Use of nest boxes by other species, such as the red-headed woodpecker, has only slightly reduced nest box availability for wood ducks. Mark-recapture studies of wood ducks in the Steel Creek Delta were used to estimate a population size of 29 to 63 breeding females and recruitment at 10 to 37 females per year.

2.3.4 Mammals

Forty-eight of the 57 species of mammals found in South Carolina (Golley, 1966) that may occur on the SRS are listed in Table 2-28 (Cothran et al., 1989). The variety of available habitat contributes to the diversity of mammal species. The distribution of species by habitat type for the five major habitats on the SRS is shown in Table 2-29. There are eight species that potentially could occur on the SRS whose presence has not been confirmed. They include the cougar, white-footed mouse, swamp rabbit, big brown bat, hoary bat, Brazilian free-tailed bat, little brown bat, and the southeastern myotis bat. Several introduced mammal species are present on the SRS. These include the feral dog, feral cat, feral pig, house mouse, Norway rat, and black rat. The feral pig is the only one of these species that occurs in large numbers and it is hunted to aid in control of its population. Further information on the feral pig is in Section 2.3.5 of this report.

Commercially or recreationally valuable mammals include game, edible, and fur-bearing species. These are listed in Table 2-30 and are covered in greater detail in Section 2.3.5 of this report.

TABLE 2-27

Waterfowl and Associated Avian Species Observed on L Lake (January - December 1987)

Scientific Name	Common Name
Branta canadensis	Canada goose
Anas platyrhynchos	Mallard
Anas discors	Blue-winged teal
Aix sponsa	Wood duck
Aythya affinis	Lesser scaup
Bucephala albeola	Bufflehead
Lophodytes cucullatus	Hooded merganser
Mergus serrator	Red breasted merganser
Casmerodius albus	Great egret
Bubulcus ibis	Cattle egret
Ardea herodias	Great blue heron
Fulica americana	American coot
Podilymbus podiceps	Pied-billed grebe
Podiceps auritus	Horned grebe
Phalacrocorax auritus	Double-crested cormorant
Anhinga anhinga	Anhinga
Gavia immer	Common loon

Source: Patterson and Giffin (1988)

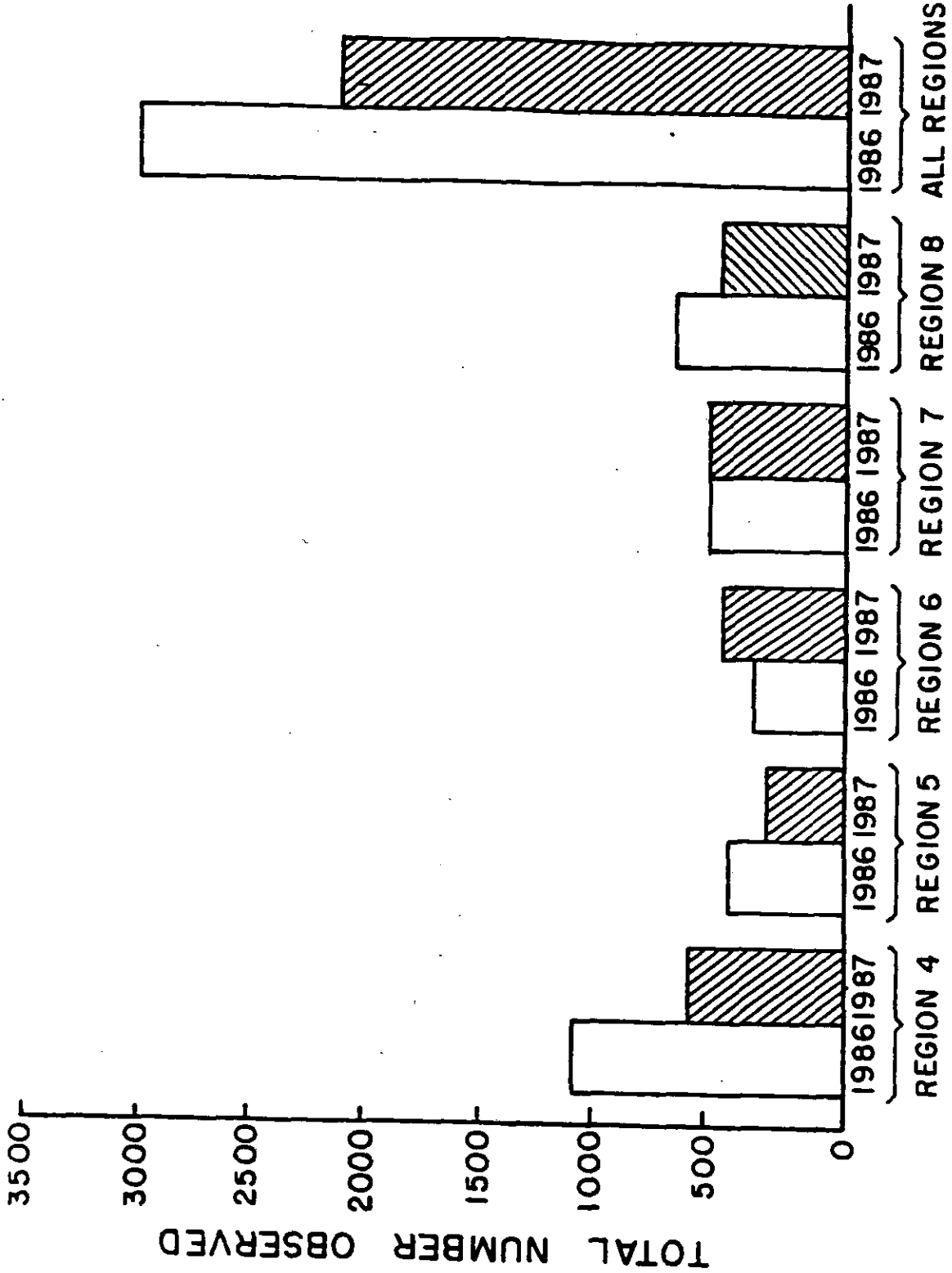

FIGURE 2-43. Total Number of Waterfowl and Associated Avian Species Observed in Regions 4-8 of L Lake
(source: Patterson and Giffin, 1988)

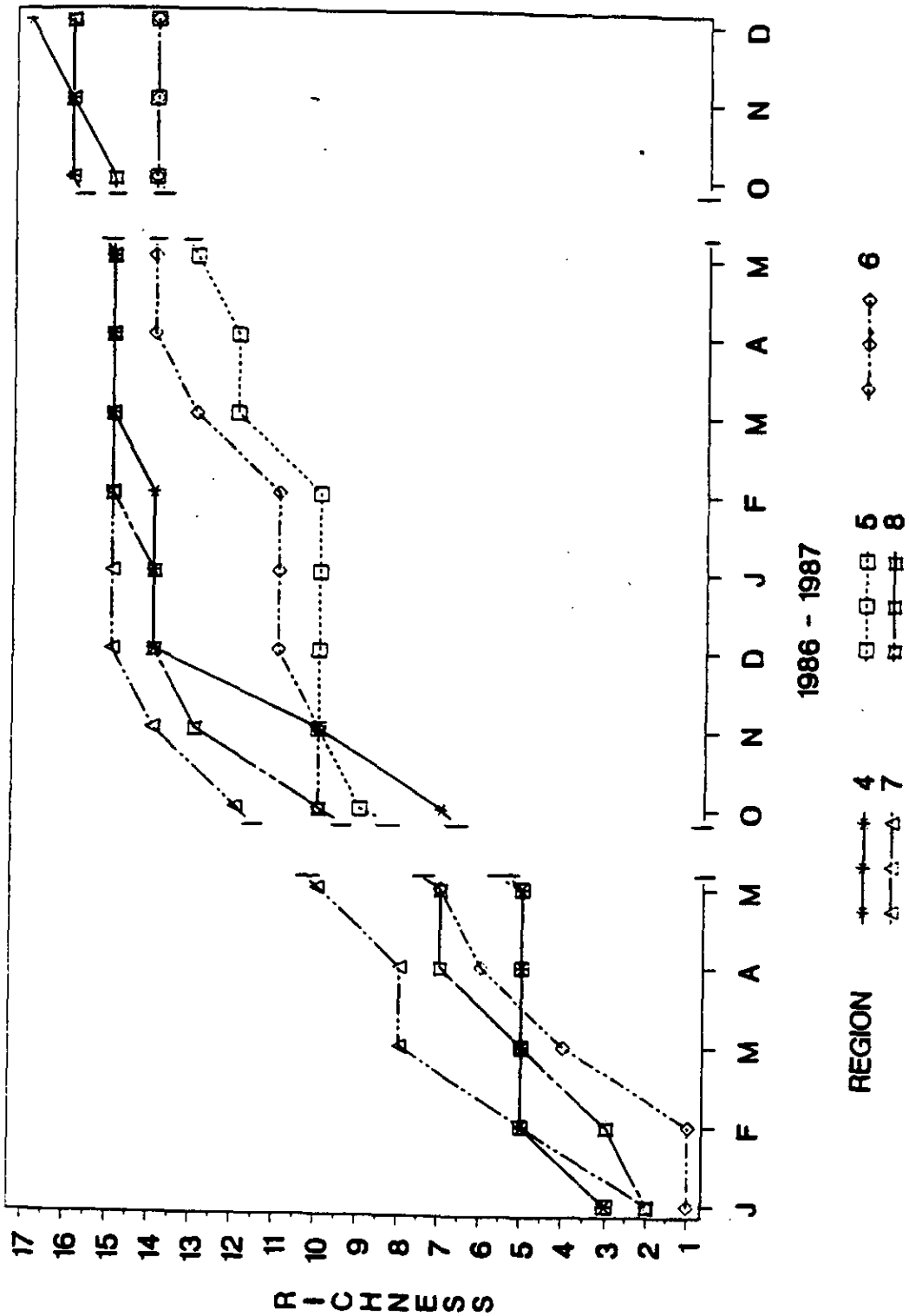

FIGURE 2-44. Cumulative Waterfowl and Associated Avian Species Taxa Richness in Regions 4-8 of L Lake (January 1986 - December 1987) (source: Patterson and Giffin, 1988)

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TABLE 2-28

Mammals of the Savannah River-Site Phylogenetic Listing[a]

Class-Mammalia
- Subclass-Theria
  - Infraclass-Metatheria
    - Order-Marsupialia
      - Family-Didelphidae
        - *Didelphis virginiana virginiana* (Kerr) - opossum
  - Infraclass-Eutheria
    - Cohort-Uniguiculata
      - Order-Insectivora
        - Family-Soricidae
          - *Blarina carolinensis carolinensis* (Bachman) - short-tailed shrew
          - *Cryptotis parva parva* (Say) - least shrew
          - *Sorex longirostris longirostris* (Bachman) - southeastern shrew
        - Family-Talpidae
          - *Condylura cristata parva* (Paradiso) - star-nose mole
          - *Scalopus aquaticus howelli* (Jackson) - eastern mole
      - Order-Chiroptera
        - Family-Vespertilionidae
          - *Lasionycteris noctivagans* (Le Conte) - silver-haired bat
          - *Lasiurus borealis borealis* (Mueller) - red bat
          - *Lasiurus intermedius floridana* (Miller) - northern yellow bat
          - *Lasiurus seminolus* (Rhoads) - Seminole bat
          - *Nycticeius humeralis humeralis* (Rafinesque) - evening bat
          - *Pipistrellus subflavus subflavus* (F. Cuvier) - eastern pipistrelle
          - *Plecotus rafinesquii macrotis* (Le Conte) - big-eared bat
    - Cohort-Glires
      - Order-Lagomorpha
        - Family-Leporidae
          - *Sylvilagus aquaticus aquaticus* (Bachman) - swamp rabbit
          - *Sylvilagus floridanus mallurus* (Thomas) - eastern cotton-tail
          - *Sylvilagus palustris palustris* (Bachman) - marsh rabbit
      - Order-Rodentia
        - Suborder-Myomorpha
          - Family-Cricetidae
            - Subfamily-Cricetinae
              - *Neotoma floridana floridana* (Ord) - eastern wood rat
              - *Ochrotomys nuttalii aureolus* (Audubon & Bachman) - golden mouse
              - *Oryzomys palustris palustris* (Harlan) - rice rat or marsh rice rat
              - *Peromyscus gossypinus gossypinus* (Le Conte) - cotton mouse
              - *Peromyscus leucopus leucopus* (Rafinesque) - wood mouse or white-footed mouse
              - *Peromyscus polionotus lucubrans* (Schwartz) - old field mouse
              - *Reithrodontomys humulis humulis* (Audubon & Bachman) - eastern harvest mouse

TABLE 2-28, Contd

Sigmodon hispidus komareki (Gardner-Hispid) - cotton rat
Subfamily-Microtinae
Microtus pinetorum pinetorum (Le Conte) - pine vole
Ondatra zibethicus zibethicus (Linnaeus) - muskrat
Family-Muridae
Mus musculus brevirostris (Waterhouse) - house mouse
Rattus norvegicus norvegicus (Berkenhout) - Norway rat
Rattus rattus rattus (Linnaeus) - roof rat or black rat
Suborder-Sciuromorpha
Family-Castoridae
Castor canadensis carolinensis (Rhoads) - beaver
Family-Sciuridae
Glaucomys volans saturatus (Howell) - southern flying squirrel
Sciurus carolinensis carolinensis (Gemlin) - eastern gray squirrel
Sciurus niger niger (Linnaeus) - eastern fox squirrel
Cohort-Ferungulata
Order-Carnivora
Family-Canidae
Canis familiaris (Linnaeus) - feral dog
Urocyon cinereoargenteus cinereoargenteus (Schreber) - gray fox
Vulpes vulpes fulva (Desmarest) - red fox
Family-Felidae
Felis catus (Linnaeus) - feral cat
Felis concolor coryi (Bangs) - mountain lion (puma, cougar, panther)
Lynx rufus floridanus (Rafinesque) - bobcat
Family-Mustelidae
Lutra canadensis lataxina (F. Cuvier) - river otter
Mephitis mephitis elongata (Bangs) - striped skunk
Mustela frenata olivacea (Howell) - long-tailed weasel
Mustela vison mink (Peale & Palisot de Beauvois) - mink
Spilogale putorius putorius (Linnaeus) - eastern spotted skunk
Family-Procyonidae
Procyon lotor solutus (Nelson & Goldman) - raccoon
Family-Ursidae
Ursus americanus americanus (Pallas) - black bear
Order-Artiodactyla
Suborder-Ruminantia
Family-Cervidae
Odocoileus virginianus virginianus (Zimmerman) - white-tailed deer
Suborder-Suiformes
Family-Suidae
Sus scrofa (Linnaeus) - feral swine

[a] Modified from Simpson (1945)

Source: Cothran et al. (1989)

TABLE 2-29

Five Major Habitats of the SRS and the Mammal Species Found There[a]

Mammal Species	Old-Fields and Clearcuts	Pine Plantations	Scrub Oak Longleaf Pine	Upland and Lowland Hardwoods	Aquatic
Blarina carolinensis	X	X		X	
Castor canadensis	X				X
Condylura cristata	X				X
Cryptotis parva	X	X		X	
Didelphis virginiana	X	X	X	X	
Glaucomys volans				X	
Lasionycteris noctivagens				X	
Lasiurus borealis	X	X		X	
Lasiurus intermedius				X	
Lasiurus seminolus		X		X	
Lutra canadensis					X
Lynx rufus	X	X	X	X	
Mephitis mephitis	X	X		X	
Microtus pinetorum	X	X		X	
Mustela frenata	X			X	
Mustela vison				X	X
Neotoma floridana	X			X	
Nycticeius humeralis		X		X	
Ochrotomys nuttalli	X	X	X	X	
Odocoileus virginianus	X	X	X	X	
Ondatra zibethicus					X
Oryzomys palustris	X			X	X
Peromyscus gossypinus	X	X		X	
Peromyscus polionotus	X	X	X		
Pipistrellus subflavus		X		X	
Plecotus rafinesquii				X	
Procyon lotor	X	X	X	X	X
Reithrodontomys humilis	X	X			
Scalopus aquaticus	X		X	X	
Sciurus carolinensis		X	X	X	
Sciurus niger		X	X		
Sigmodon hispidus	X				
Sorex longirostris	X	X			
Spilogale putorius	X	X		X	
Sus scrofa	X	X		X	
Sylvilagus floridanus	X	X	X	X	
Sylvilagus palustris				X	X
Urocyon cineroargenteus	X	X	X	X	
Ursus americanus				X	
Vulpes vulpes	X				

[a] X indicates that a species is likely to be found in the habitat.

Source: Cothran et al. (1989)

TABLE 2-30

Game, Edible, and Fur-Bearing Mammals of the SRS

Odocoilus virginianus	white-tailed deer
Sylvilagus floridanus	cotton-tail rabbit
Sciurus carolinensis	gray squirrel
Sciurus niger	fox squirrel
Urocyon cinereoargentus	gray fox
Vulpes vulpes	red fox
Lynx rufus	bobcat
Procyon lotor	raccoon
Didelphis virginiana	opossum
Ursus americana	black bear
Sus scrofa	feral pig
Mustela vison	mink
Lutra canadensis	otter
Castor canadensis	beaver
Ondatra zibethica	muskrat

Source: Cothran et al. (1989)

Biological inventories of mammals have been conducted in two areas of the SRS: the DWPF site (SREL, 1980) and the proposed AFR site (SREL, 1979). In addition, data from collections and sightings of mammals in the Steel Creek area during the summer of 1981 were summarized in Smith et al. (1981). Table 2-31 lists the mammals of the Steel Creek area taken from drift fences, pitfall traps, and board transects; species collected or observed; and species expected to inhabit the area.

The mammals found in the Sun Bay and Rainbow Bay study areas are shown in Tables 2-32, 2-33, and 2-34. Table 2-32 summarizes capture data and rank of species of small mammals caught in drift fences in the areas of the two Carolina Bays studied during the biological inventory of the DWPF site (Smith et al., 1981). Table 2-33 shows data on bats collected in areas near Sun Bay and Rainbow Bay. The larger mammals actually trapped, observed or whose tracks were observed are shown in Table 2-34. Data for small mammal numbers and rank by season and habitat type are shown in Tables 2-35 and 2-36, respectively.

2.3.5 Commercially and Recreationally Valuable Biota

2.3.5.1 Unexploitable Resources

Many potentially valuable commercial and recreational wildlife resources on the SRS are not exploited due to restricted access of the site. Animals that could be commercially trapped or recreationally hunted include bobcat, beaver, fox, mink, muskrat, opossum, otter, rabbit, raccoon, skunk, squirrel, migratory waterfowl, bobwhite, dove, turkey, snipe, and woodcock.

In 1972, the South Carolina Wildlife and Marine Resources Department (SCWMRD) began a wild turkey breeding program on the SRS to provide stock turkeys for other areas of the state. The SCWMRD released 36 turkeys on the SRS during the winter periods of 1972-1974 and began planting openings with food crops to supplement natural forage and facilitate trapping. A total of approximately 50 openings were provided by 1986 when the plantings were discontinued. Trapping of turkeys began in 1977 and continued annually until 1986 when demand for stock turkeys dropped. No trapping occurred in 1987 and 1988. An increase in demand brought about a resumption of trapping in 1989. A total of 262 turkeys have been trapped on the SRS since 1977, 248 have been removed. A summary of turkey trapping and removal is shown in Table 2-37 (Caudell, 1989).

The fur-bearing mammals of the SRS, although not an exploitable resource, have been extensively studied through a census program begun in 1954. The annual numbers of animals captured for four species appears in Figure 2-25. Annual numbers of the six most commonly captured species appears in Table 2-38. There have been wide fluctuations in both numbers of individuals and species composition over the years of the survey and may be a function of the change in habitat type since the closure of the site to the public (Cothran et al., 1989).

TABLE 2-31

Mammals of Steel Creek Area

Blarina brevicauda	short-tailed shrew
Oryzomys palustrus	rice rat
Cryptotis parva	least shrew
Sorex longirostris	southeastern shrew
Condrylura cristata	star-nosed mole
Microtus pinetorum	pine vole
Ochrotomys nuttalli	golden mouse
Peromyscus sp.	mouse species
Scalopus aquaticus	eastern mole
Neotoma floridana	eastern wood rat
Sigmodon hispidus	hispid cotton rat
Sciurus carolinensis	gray squirrel
Sciurus niger	fox squirrel
Glaucomys volans	flying squirrel
Odocoilus virginianus	white-tailed deer
Sus scrofa	feral pig
Ursus americana	black bear
Procyon lotor	raccoon
Didelphis virginiana	opossum
Urocyon cinereoargentus	gray fox
Castor canadensis	beaver
Lutra canadensis	otter
Mustela frenata	weasel
Mustela vison	mink
Mephitis mephitis	striped skunk
Sylvilagus palustris	marsh rabbit
Ondatra zibethica	muskrat
Lynx rufus	bobcat
Vespertilionidae	bat species

Source: Smith et al. (1981)

TABLE 2-32

Species, Number of Individuals, and Rank of Small Mammals Caught in Drift Fences at the Rainbow Bay and Sun Bay Study Areas. Each species is ranked according to its relative abundance in samples; species of equal abundance are ranked the same.

Species	Rainbow Bay No. of Captures	Rainbow Bay Rank	Sun Bay No. of Captures	Sun Bay Rank
Shrews				
Sorex l. longirostris southeastern shrew	5	4	0	-
Blarina brevicauda short-tailed shrew	32	2	2	2
Cryptotis p. parva least shrew	3	5	0	-
Unid. shrew	89	-	29	-
Moles				
Scalopus aquaticus eastern mole	2	6	0	-
Condylura cristata parva star-nosed mole	1	7	0	-
Cricetids				
Reithrodontomys h. humulis eastern harvest mouse	157	1	1	3
Ochrotomys nuttali aureolus golden mouse	2	6	0	-
Peromyscus polionotus old-field mouse	1	7	0	-
Peromyscus g. gossypinus cotton mouse	0	-	1	3
Neotoma floridana eastern wood rat	0	-	1	3
Sigmodon hispidus hispid cotton rat	14	3	4	1
Microtus p. pinetorum pine vole	5	4	4	1
Unid. mouse	21	-	26	-
Total	332	-	68	-

Source: Smith et al. (1981)

TABLE 2-33

Species and Number of Bats Collected at or Near the Rainbow Bay (R-Bay) and Sun Bay (S-Bay) Study Areas During Two Sampling Periods, June 26 - July 1, 1979 and August 20-24, 1979

Species	Area			
	R-Bay	Dick's Pond	S-Bay	Beaver Pond
Pipistrellus subflavus subflavus eastern pipistrelle	0	4	0	4
Lasiurus seminolus Seminole bat	1	5	1	2
Lasiurus b. borealis red bat	1	0	0	0
Lasiurus sp. Unknown *Lasiurus*	1	1	1	1
Nycticeius h. humeralis evening bat	0	1	0	1
Total	3	11	2	8

Source: Smith et al. (1981)

TABLE 2-34

Large Mammal Species on the Rainbow Bay and Sun Bay Study Areas[a]

Species	Rainbow Bay			Sun Bay		
	Trapped	Visual Obs.	Track Obs.	Trapped	Visual Obs.	Track Obs.
Procyon lotor raccoon	x	x	x	x		x
Sylvilagus sp. rabbit		x	x		x	x
Sylvilagus floridanus eastern conttontail rabbit	x	x		x		
Sciurus niger eastern fox squirrel					x	
Sciurus carolinesis eastern gray squirrel	x	x		x		
Vulpes fulva red fox	x		x			x
Urocyon cinereoargenteus gray fox	x	x	x			x
Odocoileus virginianus whitetail deer		x	x		x	x
Spilogale putorius spotted skunk		x				
Mephitis mephitis striped skunk	x	x				
Castor canadensis beaver			x			
Lynx rufus bobcat	x	x	x			
Didelphis virginiana opossum				x		
Mustela vison mink						x

[a] X indicates that at least one individual was trapped, sighted, or that its tracks were observed.

Source: Smith et al. (1981)

TABLE 2-35

Species, Number of Individuals, and Rank of Small Mammals Trapped Each Season for 10-day Periods at the Sun Bay Study Area. Each species is ranked according to its relative abundance in samples; species of equal abundance are ranked the same.

Species	Winter No. of Captures	Winter Rank	Spring No. of Captures	Spring Rank	Summer No. of Captures	Summer Rank
Shrews						
Blarina brevicauda short-tailed shrew	1	4	1	2	6	3
Oryzomys palustris palustris rice rat	1	4	0	–	0	–
Peromyscus polionotus old-field mouse	5	2	1	2	0	–
Peromyscus gossypinus gossypinus cotton mouse	15	1	9	1	16	1
Ochrotomys nuttali aureolus golden mouse	2	3	1	2	7	2
Sigmodon hispidus hispid cotton rat	1	4	0	–	0	–
Total	25		12		29	

Source: Smith et al. (1981)

TABLE 2-36

Species and Number of Individuals of Small Mammals Trapped in Four Habitats for 10-day Periods During Three Seasons at the Sun Bay Study Area. Each habitat is ranked according to the abundance of species in samples; habitats of equal abundance are ranked the same.

Species	Habitat			
	Clearcut	Lowland Hardwoods	Upland Hardwoods	Pine Plantation
Shrews				
Blarina brevicauda short-tailed shrew	1	3	3	1
Oryzomys palustris palustris rice rat	0	1	0	0
Peromyscus polionotus old field mouse	5	0	0	1
Peromyscus gossypinus gossypinus cotton mouse	2	26	8	4
Ochrotomys nuttali aureolus golden mouse	1	8	1	0
Sigmodon hispidus hispid cotton rat	1	0	0	0
Total	10	38	12	6
Habitat rank	3	1	2	4

Source: Smith et al. (1981)

TABLE 2-37

Summary of Numbers of Turkeys Trapped and Removed by the SRS Turkey Trapping Program (1977 to 1989)

Year	Turkeys Trapped			Turkeys Removed		
	Male	Female	Total	Male	Female	Total
1977	12	8	20	12	4	16
1978	12	-	12	12	-	12
1979	10	6	16	6	6	12
1980	7	4	11	7	4	11
1981	6	-	6	6	-	6
1982	0	1	1	0	0	0
1983	44	19	63	44	19	63
1984	27	38	65	26	38	64
1985	12	13	25	11	11	22
1986	4	8	12	4	8	12
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	9	22	31	9	21	30
Total	143	119	262	137	111	248

Source: Caudell (1989)

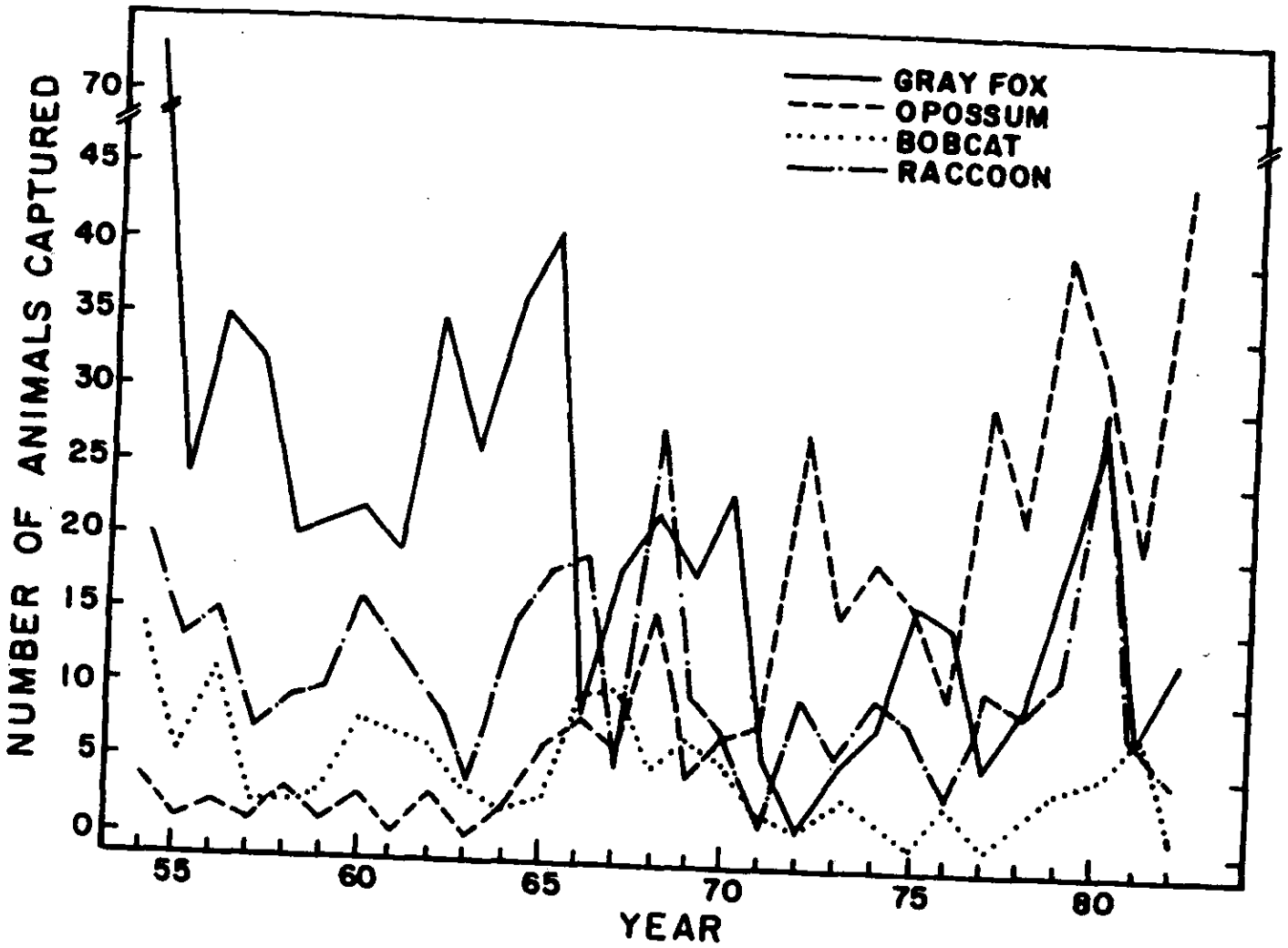

FIGURE 2-45. Numbers of Furbearers Captured Yearly from 1954 Through 1982 (source: Cothran et al., 1989)

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TABLE 2-38

Number of Furbearers Captured Yearly During the Annual Furbearers Census

Year	Total Number	Gray Fox	Bobcat	Raccoon	Opossum	Striped Skunk	Red Fox
1954	123	73	14	20	4	2	10
1955	48	24	5	13	1	5	0
1956	71	35	12	15	2	0	7
1957	47	32	2	7	1	2	3
1958	36	20	2	9	3	1	1
1959	38	21	3	10	1	2	1
1960	56	22	8	16	3	3	4
1961	45	19	7	12	0	0	7
1962	58	35	6	9	3	2	3
1963	35	26	3	4	0	1	1
1964	56	36	2	14	2	2	0
1965	70	41	3	18	6	0	2
1966	46	8	10	19	8	0	1
1967	39	18	10	5	6	0	0
1968	72	22	5	28	15	2	0
1969	49	18	7	10	4	9	1
1970	47	24	5	7	7	4	0
1971	18	6	2	1	8	1	0
1972	48	1	1	10	28	8	0
1973	29	5	3	6	15	0	0
1974	42	8	2	10	19	3	0
1975	40	16	0	8	16	0	0
1976	33	15	3	3	10	1	0
1977	47	5	0	11	30	1	1
1978	42	9	2	9	22	0	0
1979	77	18	4	12	41	2	0
1980	138	45	5	38	47	3	0
1981	50	9	8	8	25	0	0
1982	65	2	1	5	56	1	0
Total	1565	613	135	337	383	55	42

Source: Cothran et al. (1989)

2.3.5.2 Exploitable Resources

Public hunts of deer and feral hogs are the only available public recreational use of the SRS. The purpose of the hunts is to aid in control of the deer and hog populations. Domestic hogs, abandoned in 1952, reverted to a semi-wild state, reproduced, and became detrimental to young forest plantations (Langley and Marter, 1973). The deer herd of SRS, estimated to be 10 animals in 1951, increased rapidly after the site was closed to the public. The onsite deer heard in 1972 was estimated to be between 10 and 11 thousand animals (Urbston and Rabon, 1972). Annual estimates of the deer herd from 1965-1983 appear in Table 2-39. By the early 1960's deer-vehicle collisions were a frequent occurrence. This and the potential for habitat degradation prompted the institution of controlled public hunts in 1965 (Langley and Marter, 1973). The hunts were managed by the SRFS from 1965 to 1980, after 1980 E. I. du Pont conducted the hunt program. A summary of hunt statistics is shown in Table 2-40. From 1965 to 1987 a total of 25,097 deer and 1,293 hogs were killed during organized public hunts, the average kill per year was 1,091 deer and 56 hogs. Kill per hunter day of deer and hogs from 1965 to 1980 was approximately .22, hunter days per kill was 4.6 (SRFS, 1988).

TABLE 2-39

Annual Estimated SRS Deer Population
(1965-1983)

Year	Estimated Population
1965	5,000
1966	5,500
1967	6,000
1968	6,000
1969	6,500
1970	7,000
1971	7,500
1972	8,000
1973	8,500
1974	9,000
1975	7,000
1976	6,500
1977	6,500
1978	5,500
1979	5,500
1980	5,000
1981	4,000
1982	3,500
1983	3,500

Source: Dukes (1984)

TABLE 2-40

Summary of Public Hunt Data, 1965-1987

Public Deer Hunts

CY Year	Days Still Hunts	No. Sat. Hunts	Week Day Hunts	Hunters: Paid Hunters	Hunters: Dog Handlers	Hunters: Total	Total Hunt Income
1965-70	13	50	61	8,482	5,521	15,653	$ 55,097

Kill

Dog: Buck	Dog: Doe	Still: Buck	Still: Doe	Hogs
1,894	2,133	101	194	36

CY Year	No.	Dog Hunts Hunter Days: Standers	Dog Hunts Hunter Days: Dog Handlers	Still Hunts: Hunt Days	Still Hunts: Hunter Days	Total Hunter Days	Total Hunt Income
1971-80	182	14,933	13,811	129	31,931	60,530	$423,257

Kill

Dog	Deer Still	Hogs
8,009	3,715	473

Kill by Hunts Conducted by E. I. du Pont

CY Year	Deer	Hogs
1981	1,791	33
1982	2,063	189
1983	1,597	133
1984	1,038	104
1985	1,019	79
1986	940	123
1987	603	123

Note: In 1981 SRFS discontinued conducting the deer hunt program.

Source: SRFS (1988)

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3.0 WETLAND RESOURCES

3.1 SITE WIDE

3.1.1 Introduction

The SRS is bordered on the southwest for 16 km by the Savannah River swamp. Six streams drain the SRS and are bordered primarily by bottomland hardwood forests. The remainder of the SRS wetlands consists of Carolina Bays, cooling water canals, cooling lakes, former farm ponds, and freshwater marshes. The main streams on the SRS are Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek. All of these streams except Upper Three Runs Creek have been influenced by SRS cooling water discharges. These discharges, 10 to 20 times the natural stream flows, cause the streams to overflow their original banks along much of their length. The original bottomland forests have been reduced or modified along much of Four Mile Creek, Pen Branch, and Steel Creek.

3.1.2 The SRS Savannah River and Stream Floodplains

To inventory the SRS wetlands, a 1:48,000 scale map of the SRS was developed from aerial photography (February 22, 23, and March 8, 1982). This map was updated in 1985 to include wetlands west of Upper Three Runs Creek and to add L Lake to the map (Mackey et al., 1985). Wetlands cover over 21% of the SRS. About 64% of the SRS wetlands are bottomland hardwood forests which occur primarily along SRS streams and in the Savannah River swamp (Table 3-1). Fourteen percent of SRS wetlands are Cypress-Tupelo swamp forest, located predominantly within the Savannah River swamp. Scrub-shrub and emergent marsh areas are found commonly in thermal and post-thermal areas of the Savannah River swamp. Table 3-2 lists typical plant species found in SRS thermally influenced wetlands (Mackey, 1987).

Wetlands areas of the SRS include a mosaic of vegetation forms and species. Species that are characteristically dominant for a given wetland type may differ depending on whether the wetland is undisturbed, currently receiving thermal effluents, or undergoing revegetation following cessation of cooling water releases. For example, there is little similarity in the dominant species in the Nonpersistent Emergent Wetland class between thermal and post-thermal areas.

TABLE 3-1

Land Cover Types and Wetlands of the SRS

Land Cover Types	Hectares	Percentage of Total
Roads	1,665	2.1
Production Areas	1,289	1.6
Utility Corridors	1,110	1.4
Upland Pine/Hardwood	58,955	73.3
Subtotal	63,019	78.4
Wetlands		
Bottomland Hardwoods	11,208	13.9
Cypress-Tupelo	2,379	3.0
Scrub-Shrub	877	1.1
Emergent Marsh	697	0.9
Water[a]	2,246	2.8
Subtotal	17,407	21.7
Total	80,426	100.1

[a] Includes the Savannah River.

Source: Mackey (1987)

TABLE 3-2

Classification of the SRS Wetlands and Dominant Plant Species

Classification or Wetlands Cover Type	Dominant Plant Species of Selected SRS Wetlands		
	Nonthermal	Thermal	Post-Thermal
Open Water			
Aquatic Bed			
Algal		Blue-green algae	
Submerged Vascular			*Ceratophyllum demersum* *Myriophyllum brasiliense*
Emergent Wetland			
Persistent			*Typha latifolia* *Scrious cyperinus* *Aneilema keisak* *Leersia* spp. *Boehmeria cylindrica* *Panicum agrostoides*
Nonpersistent		*Ludwigia* spp. *Ammannia coccinea* *Cyperus* spp. *Echinodorus* spp. *Aeschynomene indica*	*Hydrolea quadrivalvis* *Aneilema keisak* *Polygonum hydropiperoides* *Ludwigia palustris* *Sagittaria latifolia*
Scrub-Shrub Wetland			
Broad-Leaved Deciduous		*Cephalanthus occidentalis* *Salix* spp. *Planera aquatica*	*Cephalanthus occidentalis* *Salix* spp. *Planera aquatica*
Forested Wetland			
Deciduous Bottomland Hardwoods	*Quercus* spp. *Liquidambar styraciflua* *Acer rubrum* *Carya aquatica*	*Quercus* spp. *Liquidambar styraciflua* *Ulmus* sp. *Carpinus caroliniana*	*Salix* spp. *Fraxinus* spp. *Quercus* spp. *Liquidambar styraciflua* *Acer rubrum* *Carya aquatica*
Deciduous Swamp Forest	*Taxodium distichum* *Nyssa aquatica*	*Taxodium distichum* *Nyssa aquatica*	*Taxodium distichum* *Nyssa aquatica*
Mixed Forest/Scrub-Shrub Wetland			*Taxodium distichum* *Nyssa aquatica* *Cephalanthus occidentalis*
Mixed Forest/Scrub-Shrub/ Nonpersistent Emergent Wetland			*Taxodium distichum* *Nyssa aquatica* *Cephalanthus occidentalis* *Polygonum lapathifolium*

Source: Mackey (1987)

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3.2 SAVANNAH RIVER SWAMP

3.2.1 General Wetland Patterns

About 3,800 ha of the Savannah River swamp lies within the SRS between Upper Three Runs Creek and Steel Creek. The SRS swamp area borders the Savannah River for approximately 16 km and has an average width of about 2.2 km (Figure 3-1). An embankment or natural levee has built up along the north side of the river from sediments deposited during periods of flooding (Figure 3-1). 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 Branch enter the river near the southeast corner of SRS.

On the landward side of the levee, the ground elevation decreases forming the river swamp, which contains stands of cypress and tupelo trees, bottomland hardwoods, and open marsh areas. During periods of flooding, river water overflows the levee and floods the swamp area, leaving only isolated islands. The river overflows into the swamp when river elevations are between 27 and 28 m above mean sea level (MSL). During flooding, the water from these streams flows through the swamp parallel to the river and enters the river offsite.

The wetlands community structure of the Savannah River swamp on the SRS has been influenced by a variety of environmental perturbations. Like most riverine swamps of the southeastern United States, this forest has been selectively logged. Virtually all of the swamp was dominated by second-growth timber in the early 1950s. When the SRS initiated operations, the swamp was characterized by a closed canopy forest of bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica) in the deep water sites and poorly drained sloughs and hardwoods on the island ridges (Sharitz et al., 1974a; Mackey, 1987; Tinney et al., 1986).

The Savannah River swamp receives thermal effluent from C Reactor (until late June 1985), K Reactor, L Reactor, and the D-Area power plant. The discharge of cooling water effluents from the SRS production reactors and the coal-fired power plant modified the SRS Savannah River swamp in several ways. Deposition of sediment from erosion associated with increased flows to creeks formed sedimentation deltas in the swamp (Ruby et al., 1981). In addition, water temperatures in portions of the swamp near the areas where effluents entered the swamp exceeded the thermal tolerances of most vascular plant species and resulted in extensive forest mortality (Sharitz et al., 1974b; Tinney et al., 1986; Mackey, 1987). Finally, the input of increased volumes of cooling water from the creeks into the SRS swamp modified the hydrology of the system. This change in hydrology was further influenced by flood control activities on the Savannah River (Figure 3-2). Examination of long term discharge fluctuations in the Savannah River (Repaske, 1981) reveals that water levels in the river following construction of Clarks Hill Dam in the early 1950s are neither as high, nor as low as those occurring prior to dam construction. The SRS effluent discharges maintain relatively high

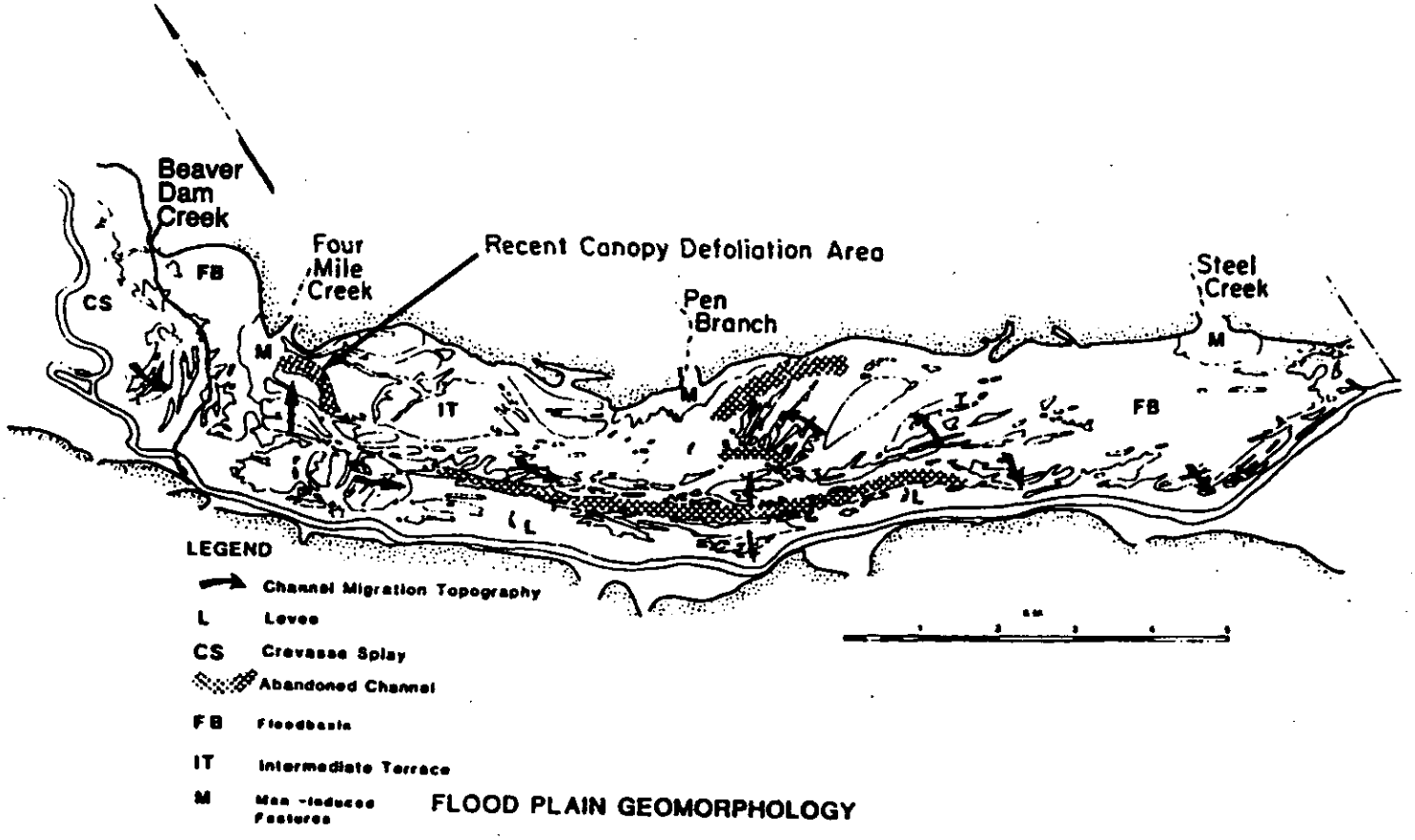

FIGURE 3-1. Geomorphology of the SRS Savannah River Swamp Showing Numerous Hardwood Islands and a Natural Levee Along the Savannah River (source: Stevenson, 1982)

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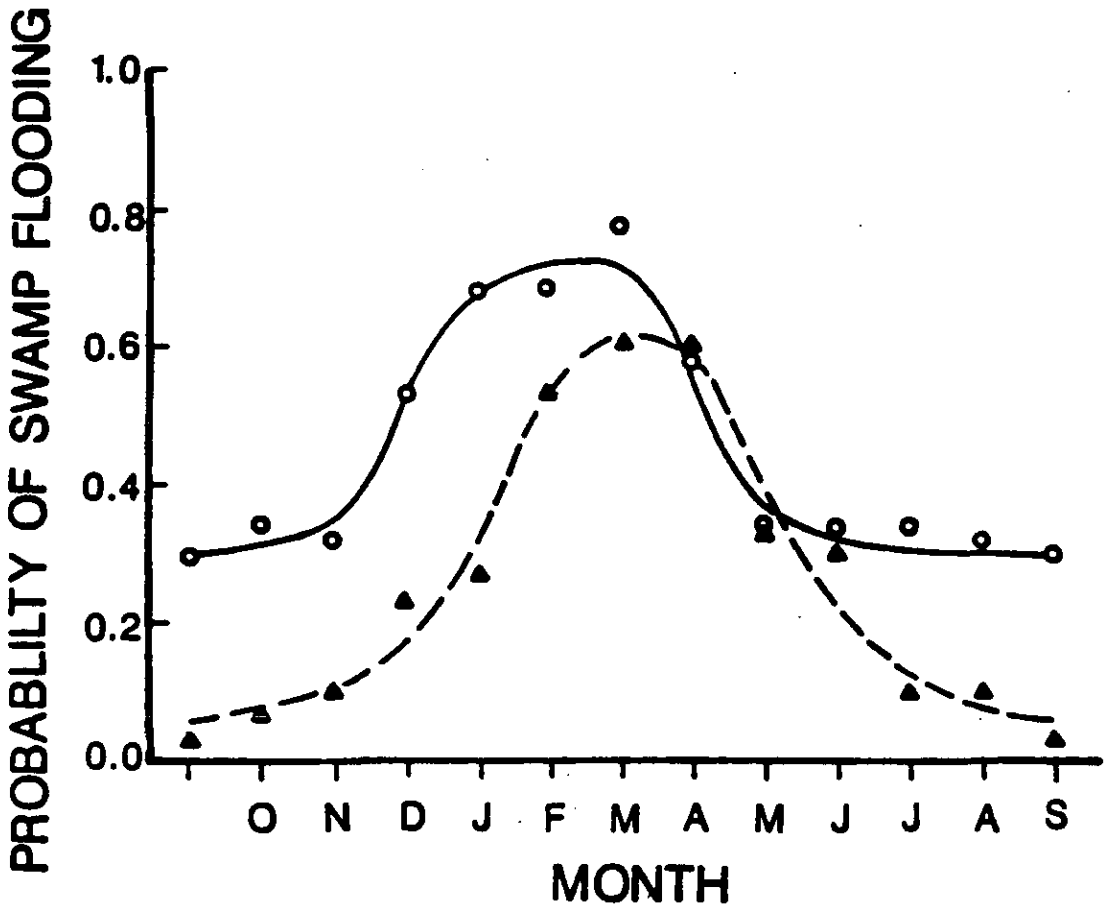

FIGURE 3-2. **Monthly Probabilities of the Savannah River Flooding.** Flood frequencies prior to the completion of the Clarks Hill Dam in 1954 are shown in open circles and as a solid line. Flood frequencies after 1954 are shown as triangles and a dashed line (source: Aho et al., 1986)

water levels in the SRS swamp throughout the year near the deltas. Dry periods necessary for extensive regeneration of the dominant woody swamp forest species seldom occur under the current hydrologic regime (Sharitz et al., 1986).

The composition of the SRS Savannah River swamp forest has been extensively examined. Summaries of the wetland community structure are given below from studies by Repaske (1981), Whipple et al. (1981); and Smith et al. (1981, 1982). Additional areas of the swamp were sampled in 1983 and 1984 (Gladden et al., 1985). Standard vegetation sampling techniques were used in these studies (Mueller-Dombois & Ellenberg, 1974). These data provided information on density, size class (relative basal area), and importance values of woody species distributed throughout disturbed and relatively undisturbed portions of the SRS Savannah River swamp.

The data were analyzed using standard plant community analysis procedures. Importance values were calculated using relative density and relative dominance (basal area). Detrended correspondence analysis ordination was employed to array the data along axes calculated using the importance values of the plant species (Hill, 1979a; Smith et al., 1981, 1982). This technique grouped the wetland communities along gradients that can be interpreted to reflect plant community responses to environmental perturbations (Hill & Gauch, 1980). A two-way indicator species analysis was then used to separate the data into major plant community types, based upon importance of dominant wood species (Hill, 1979b). Comparisons of species arrays or groupings and community types with environmental characteristics provided an indication of the major environmental variables responsible for woody species distribution in the SRS swamp (Gladden et al., 1985).

The ordination of woody plant communities developed using this detrended correspondence analysis (DCA) is given in Figure 3-3. Sample sites occurring in close proximity on DCA axes 1 and 2 show greater similarity in species importance than do sites located at greater distances from each other along these axes. Each site was assigned a relative value of 1 to 3 on a hydrologic scale (1 = deeply and continuously flooded, 2 = shallowly and continuously flooded, 3 = occasionally flooded) and on a perturbation scale (1 = tree mortality characteristic of natural swamp, 2 = low perturbation with slight tree mortality, 3 = high perturbation and high tree mortality). A comparison of these scalars with the data shown in Figure 3-3 shows that the swamp forest communities are distributed along two major environmental axes: a water depth or hydrologic regime gradient and a perturbation or disturbance gradient. Quadrats symbolized by squares or triangles show no perturbation or low levels of perturbation. Those symbolized by circles are highly disturbed and contain no or almost no species representative of the original swamp forest. Open symbols represent sites occurring in areas where there is only occasional flooding. Partially darkened or completely darkened symbols represent quadrats sampled at shallow or deeply flooded sites (Gladden et al., 1985).

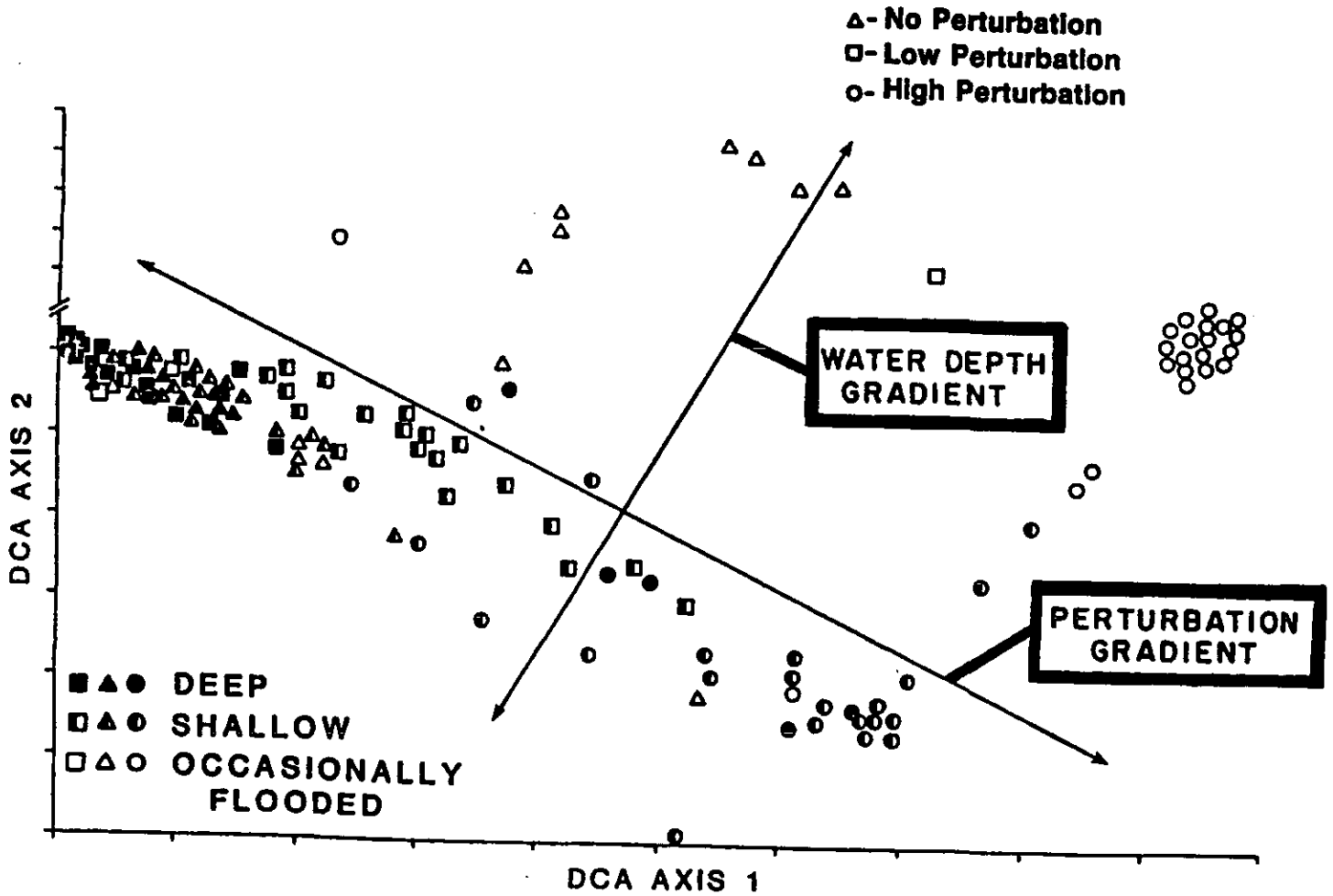

FIGURE 3-3. Detrended Correspondence Analysis (DCA) Ordination of Forested and Shrub Dominated Sites in the SRS Savannah River Swamp (source: Gladden et al., 1985)

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The two-way indicator species analysis (Hill, 1979b) separate the swamp forest into the major wetlands community types (Figure 3-4). Deciduous bottomland hardwood forests occur in areas that are slightly elevated and better drained and that are flooded only occasionally during the year. These communities are dominated by a mixture of oak species (Quercus nigra, Q. laurifolia, Q. michauxii, Q. lyrata) as well as red maple (Acer rubrum), sweetgum (Liquidambar styraciflua), ash (Fraxinus caroliniana and F. americana), and other hardwood species. The species composition of the understory appears to be controlled by the wetness of the substrate. Sweet bay (Magnolia virginiana), tulip poplar (Liriodendron tulipifera), and hollies (Ilex spp.) are found in drier localities, while red bay (Persea borbonia) and ironwood (Carpinus caroliniana) occur in stands with longer periods of soil saturation. Smilax spp. and other woody vines are common (Gladden et al., 1985).

The deciduous swamp forest, which occurs in deeper water and on continuously flooded sites, is characterized by two canopy dominants: bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica). The understory is typically sparse and is composed of ash, bald cypress, occasional black gum (Nyssa sylvatica), water tupelo, red maple, and water elm (Planera aquatica). Most saplings are restricted to stumps, logs, or accumulated sediments and debris at the bases of the trees. The ground cover is limited in the swamp forest by continuous flooding and low light penetration through the canopy. In areas of slow current, duckweed (Lemna spp. and Spirodela spp.), waterweed (Egeria densa), and coontail (Ceratophyllum demersum) are found. St. John's wort (Hypericum spp.), Virginia willow (Itea virginica), false neetle (Boehmeria cylindrica), and woody vines such as poison ivy (Rhus radicans) and pepper-vine (Ampelopsis arborea) occur in the understory on stumps and fallen logs (Gladden et al., 1985). Importance values for the dominant woody species in the SRS swamp are presented in Table 3-3.

Woody plant community types occurring in the most highly disturbed areas are dominated by successional shrub species, such as willow (Salix spp.) and buttonbush (Cephalanthus occidentalis). These scrub-shrub communities occur where the original swamp forest has been eliminated, but where water temperatures are not too high to preclude the growth of woody species.

Willow dominated scrub-shrub communities tend to occur on sand bars or on occasionally flooded sites; whereas, buttonbush dominated communities represent the early successional invasion of deeper water sites (Gladden et al., 1985). The understory of the buttonbush community is comprised by nonpersistent emergent wetland species such as hydrolea (Hydrolea quadrivalvis), aneilema (Aneilema keisak), waterpepper (Polygonum hydropiperoides), water purslane (Ludwigia palustris), and wapato (Sagittaria latifolia). Climbing hemp (Mikania scandens) and pepper-vine also occur (Gladden et al., 1985). Herbaceous vegetation in the willow community is often sparse due to the dense canopy. Small patches of herbs include redtop panicgrass (Panicum agrostoides), waterpepper, false nettle, St. John's wort, sensitive fern (Onoclea sensibilis), climbing hemp, and pepper-vine (Gladden et al., 1985).

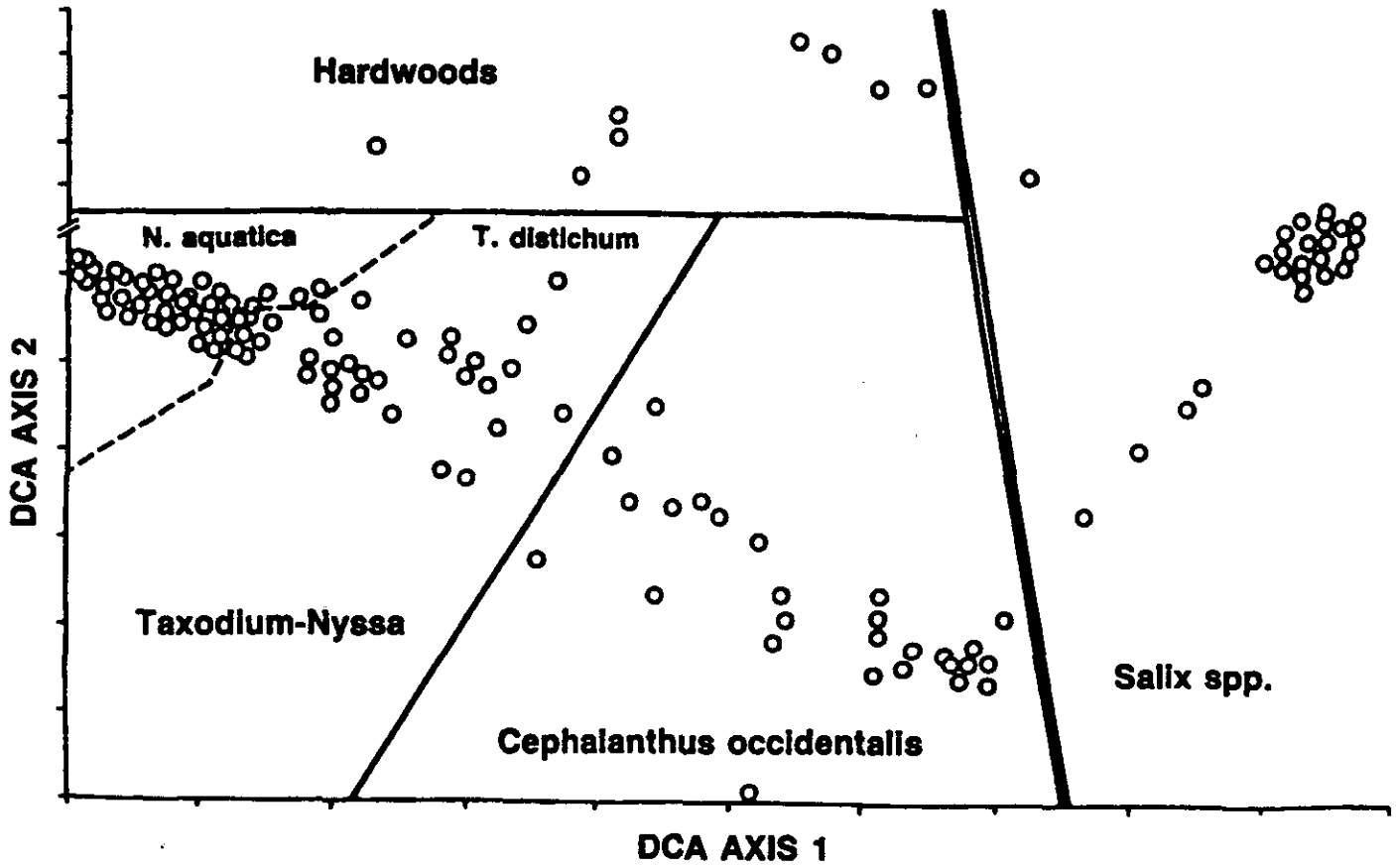

FIGURE 3-4. Two-Way Indicator Species Analysis of the SRS Savannah River Swamp Forest Data Indicated on DCA Ordination (source: Gladden et al., 1985)

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TABLE 3-3

Importance Values of Dominant-Woody Species in the SRS Savannah River Swamp[a]

Species	Deciduous Swamp Forest			Scrub-Shrub Revegetated (N=49)	Deciduous Bottomland Forest (N=24)
	Natural (N=34)[b]	Thermal (N=20)	Post-Thermal (N=21)		
Nyssa aquatica	103	126	75	<1	7
Taxodium distichum	68	54	64	11	11
Fraxinus spp.	10	12	44	12	7
Itea virginica	3	3	--	5	<1
Planera aquatica	2	2	5	9	4
Cephalanthus occidentalis	<1	1	9	76	1
Liquidambar styraciflua	<1	--	--	--	25
Quercus laurifolia	<1	--	1	--	16
Salix spp.	--	<1	--	82	<1
Carpinus caroliniana	--	--	--	--	28
Quercus nigra	--	--	--	--	17

[a] Importance value (Curtis & McIntosh, 1950) = relative density + relative dominance (as percentage).
[b] N = number of plots sampled.

Source: Gladden et al. (1985)

3.2.2 Remote Sensing Wetlands Map of the SRS Savannah River Swamp

In addition to wetlands surveys of individual sites in the SRS Savannah River swamp, remote sensing overflights were conducted in 1981 to provide a wetlands map of the entire SRS Savannah River swamp (Jensen et al., 1984a, 1984b). Smaller, individual maps of the delta areas were also prepared in order to quantify wetland areas and to establish a data base to evaluate future changes in the swamp (Christensen et al., 1986).

Airborne, high-resolution, multispectral scanner data were obtained from altitudes of 1220 m and 2440 m above ground level (AGL) on March 31, 1981 (Figure 3-5). At 2440 m, the data have an effective spatial resolution of approximately 5.6 m x 5.6 m, after geometric correction. At 1220 m, the effective spatial resolution is 2.8 m x 2.8 m. The high altitude (2440 m) imagery was used to map the entire SRS Savannah River swamp and the low altitude (1220 m) imagery was used to map individual delta areas.

3.2.2.1 Wetlands Classification from the Remote Sensing MSS Data

The Savannah River swamp contains areas of diverse cover types, such as vegetation, mud flats, and open water. In order to use remotely sensed data to map these cover types, a classification scheme was developed which was comparable with ground survey data collected from the swamp. The classification scheme selected was adopted with minor modifications from the wetlands classification system developed by the U.S. Fish and Wildlife Service (Cowardin et al., 1979), and used for the National Wetland Maps (Stewart et al., 1980). Six of the wetland classes commonly identified in the SRS Savannah River swamp are given below (Jensen et al., 1984b).

Persistent Emergent Wetland (PE) is dominated chiefly by perennial herbaceous species, including cattail (Typha latifolia), knotweed (Scirpus cyperinus), cutgrass (Leersia spp.) and false nettle (Boehmeria cylindrica). Aneilema keisak, an annual, is also locally abundant. Nonpersistent Emergent Wetland (NPE) contains several species of smartweed (Polygonum spp.), as well as hydrolea (Hydrolea quadrivalvis) in the deeper water areas. The NPE vegetation type is characterized by water primrose (Ludwigia spp.) on shallow sandbars and mudflats. Scrub-Shrub Wetland (SS) is dominated by willow (Salix nigra and S. caroliniana) on the sandbars, and buttonbush (Cephalanthus occidentalis) in deeper water. Typically, SS represents a transition from emergent marsh to swamp forest. The Deciduous Swamp Forest (DSF) is dominated by bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica). Deciduous Bottomland Forest (DBF) is characterized by oaks (Quercus sp.), red maple (Acer rubrum), sweetgum (Liquidambar styraciflua), and hickory (Carya spp.). DBF vegetation is less water tolerant than species in the DSF. An algal bed (AB) cover class was found in the thermal delta areas, such as the Four Mile Creek Delta, and the class was dominated by thermally tolerant blue-green algae (Jensen et al., 1984b).

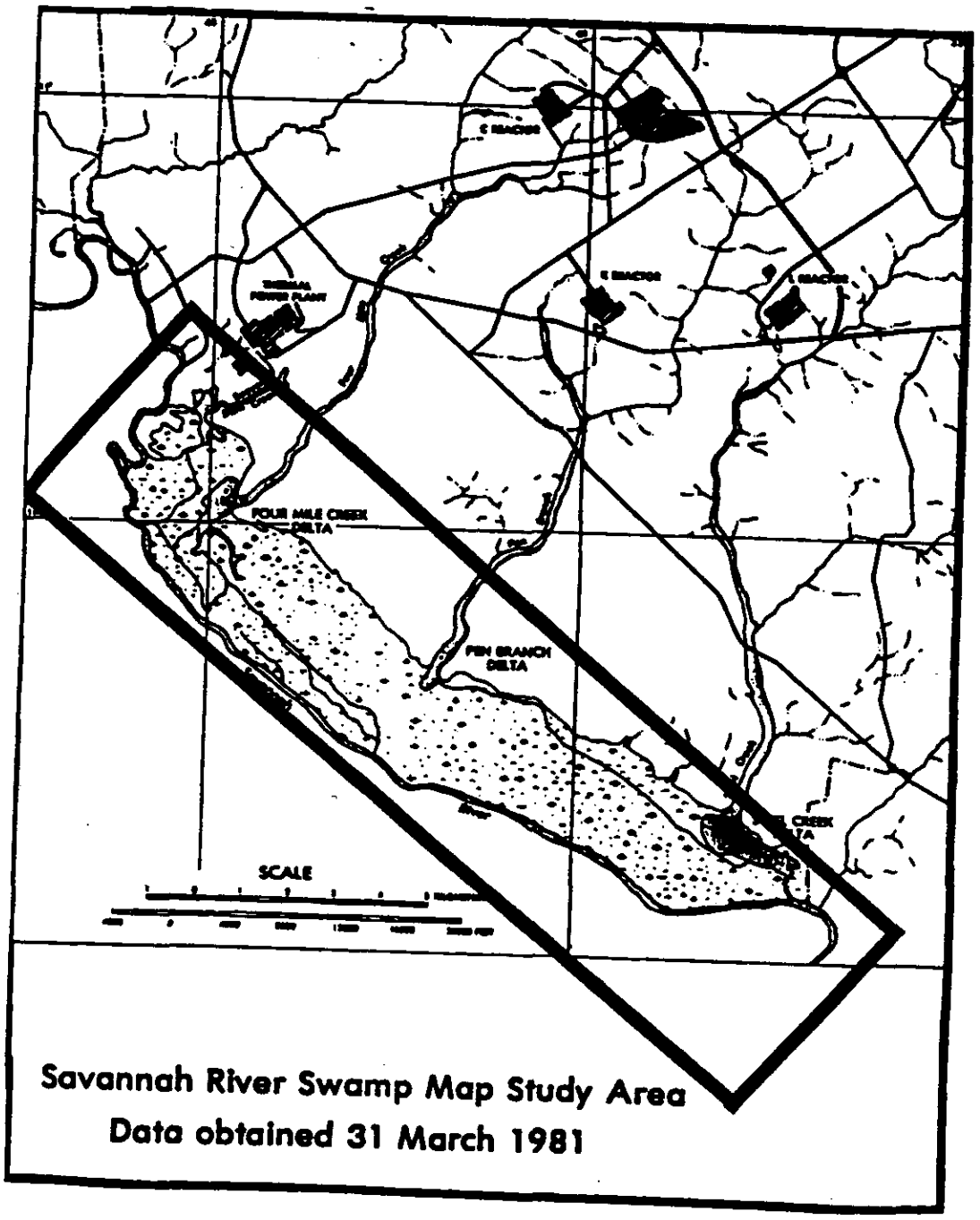

FIGURE 3-5. Aerial MSS Survey Coverage of the SRS Savannah River Swamp, March 31, 1981 (source: Jensen et al., 1984b)

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3.2.2.2 SRS Savannah River Swamp Wetlands MSS Map

The SRS Savannah River swamp is primarily covered by cypress-tupelo forest (47%) and drier bottomland-hardwood islands (40%) (Table 3-4). A few pine trees are also found in the islands (2.2%). The remainder of the SRS swamp is composed of scrub-shrub and marsh wetland communities which are found near the entry points of the SRS thermal and post-thermal streams. Cypress-tupelo forest has been replaced by a mixture of scrub-shrub and persistent and nonpersistent marsh vegetation in these delta areas. Because these delta areas have more wetland heterogeniety, a higher spatial resolution was used for mapping the wetland communities in the deltas than was used for the entire SRS Savannah River swamp (Jensen et al., 1984b).

3.2.2.3 Wetland Maps of the Delta Areas

The wetland vegetation areas for the Steel Creek, Pen Branch, Four Mile Creek, and Beaver Dam Creek deltas are listed in Tables 3-5 through 3-8. Discussions of classification methods, accuracy assessment, and phenology problems are presented in Christensen et al. (1986) and Jensen et al. (1984b, 1986a). The data for the Steel Creek and Pen Branch deltas will be presented later to estimate change since 1981 in these two deltas.

3.3 K REACTOR AND THE PEN BRANCH CORRIDOR

Pen Branch follows a path roughly parallel to Four Mile Creek until it enters the Savannah River swamp. The only significant tributary is Indian Grave Branch, which flows into Pen Branch about 8 km upstream from the Savannah River swamp. Pen Branch flow enters the swamp about 5 km from the river and flows southeast toward the Steel Creek Delta area.

Pen Branch and Indian Grave Branch drain about 55 km^2 above the swamp. Indian Grave Branch receives effluent cooling water from K Reactor. Above the K-Area discharge, Indian Grave Branch flow averages about 0.03 m^3/sec. Above the confluence of Indian Grave Branch, Pen Branch is also a small stream, with a flow averaging 0.14 to 0.28 m^3/sec (Newman et al., 1986).

The headwaters of Pen Branch consist of a largely unperturbed blackwater stream. Downstream from K Area, thermal effluent from K Reactor joins Pen Branch via Indian Grave Branch. When K Reactor is operating, discharged cooling water from K Area accounts for over 98% of the stream volume. Since the reactor cooling water originates from the Savannah River, it changes the water quality as well as the temperature and flow regimes in Pen Branch (Newman et al., 1986). Pen Branch discharges into the Savannah River floodplain swamp rather than flowing directly into the Savannah River. Where Pen Branch discharges into the swamp, it has formed a delta. The flow from Pen Branch usually spreads over the delta and continues through the swamp as shallow sheet flow until entering the lower reaches of Steel Creek and discharging into the Savannah River. However, when the Savannah River inundates the floodplain swamp, the flow from Pen Branch is forced against the northern border of the swamp, crosses the Steel Creek Delta, and is discharged into the Savannah River downstream from the mouth of Steel Creek.

Emergent marsh and open water are common below the K-Reactor discharge. Some hardwoods exist on the outer perimeter of the thermally affected areas, but most occur in nonthermal tributaries or upstream of the K-Area discharge (Ezra et al., 1986).

Pen Branch receives thermal effluent from K Reactor. Temperatures of the reactor effluents at the point of release into Pen Branch commonly exceed 65°C. The reactor cooling water effluent also substantially increases stream discharges. The direct impacts to SRS streams as a result of reactor operations are of two types: (1) elevation of stream water temperatures above ambient levels and (2) stream discharge increases that are greater than an order of magnitude above normal flow. The increased stream discharges also accelerate upstream erosion and subsequent downstream sedimentation (Ruby et al., 1981; Mackey, 1987; Tinney et al., 1986).

TABLE 3-4

Area of Wetland Classes Found Within the SRS Savannah River Swamp, March 31, 1981[a]

Wetland Cover Class	Hectares	Percentage of Swamp
Open Water in Swamp (W)[b]	27	0.7
Nonpersistent Emergent Marsh (NPE)	152	4.0
Persistent Emergent Marsh (PE)	55	1.4
Scrub-Shrub (SS)	155	4.1
Deciduous Swamp Forest (DSF)	1793	47.2
Deciduous Bottomland Forest (DBF)	1528	40.2
Needle-Leaved Evergreen Forest (NEF)	83	2.2
Unclassified (U)	8	0.2
Total	3801	100.0

[a] Obtained by analyzing multispectral scanner data (2440 meters AGL) collected by the Energy Measurements Group of EG&G, Las Vegas, Nevada.

[b] Does not include 221 ha of Savannah River water adjacent to the SRS Savannah River swamp; probably includes some area of algal beds.

Source: Jensen et al. (1984a)

TABLE 3-5

Steel Creek Delta and Vicinity Wetland Classification Based on March 31, 1981, MSS Data

Wetland Cover Class[a]	Hectares	Acres	Percentage
W	6.34	15.68	3
NPE	17.93	44.30	9
PE	20.32	50.21	10
SS	34.37	84.93	18
DSF	64.68	159.83	34
DBF	16.95	41.88	9
U	0.06	0.15	1
Masked[b]	32.03	79.15	16
Total	192.68	476.13	100

[a] W = Open Water
NPE = Nonpersistent Emergent
PE = Persistent Emergent
SS = Scrub-Shrub
DSF = Deciduous Swamp Forest
DBF = Deciduous Hardwood Forest
U = Unclassified

[b] Upland (nonswamp) area.

Source: Mackey (1987)

TABLE 3-6

Pen Branch Delta and Vicinity Wetland Classification Based on March 31, 1981, MSS Data

Wetland Cover Class[a]	Hectares	Acres	Percentage
W	2.40	5.93	1
AB	11.91	29.42	3
NPE	43.44	107.35	11
PE	4.07	10.07	1
SS	37.36	92.34	10
DSF	166.83	412.23	43
DBF	51.23	126.61	13
U	0.07	0.17	0
Masked[b]	68.04	168.11	18
Total	385.35	952.23	100

[a] W = Open Water
AB = Aquatic Bed
PE = Persistent Emergent
NPE = Nonpersistent Emergent
SS = Scrub-Shrub
DSF = Deciduous Swamp Forest
DBF = Deciduous Hardwood Forest
U = Unclassified

[b] Upland (nonswamp) area.

Source: Mackey (1987)

TABLE 3-7

Four Mile Creek Delta and Vicinity Wetland Classification Based on March 31, 1981, MSS Data

Wetland Cover Class[a]	Hectares	Acres	Percentage
W	9.44	23.33	5
AB	19.54	48.29	10
NPE	19.20	47.46	10
PE	3.65	9.02	2
SS	12.62	31.18	7
DSF	68.16	168.43	35
DBF	50.96	125.92	26
U	1.20	2.97	1
Masked[b]	7.90	19.51	4
Total	192.67	476.11	100

[a] W = Open Water
AB = Aquatic Bed
PE = Persistent Emergent
NPE = Nonpersistent Emergent
SS = Scrub-Shrub
DSF = Deciduous Swamp Forest
DBF = Deciduous Hardwood Forest
U = Unclassified

[b] Upland (nonswamp) area.

Source: Mackey (1987)

TABLE 3-8

Beaver Dam Creek Delta and Vicinity Wetland Classification Based on March 31, 1981, MSS Data

Wetland Cover Class[a]	Hectares	Acres	Percentage
W	50.05	123.67	8.7
NPE	15.61	38.57	2.6
PE	42.35	104.65	7.4
SS	59.82	147.81	10.4
DSF	141.79	350.36	24.7
DBF	264.55	653.69	46.2
Total	574.17	1418.75	100.0

[a] W = Open Water
NPE = Nonpersistent Emergent
PE = Persistent Emergent
SS = Scrub-Shrub
DSF = Deciduous Swamp Forest
DBF = Deciduous Hardwood Forest

Source: Mackey (1987)

3.3.1 Aquatic Plant Surveys of the Pen Branch Corridor and Delta

Water temperatures throughout the length of the thermal portion of Pen Branch typically exceed 40°C in the summer months. Therefore, vascular plants do not survive in the water or the associated sediments. The original flora of the stream and associated floodplains has been destroyed and the present flora is depauperate. Sharitz et al. (1974a) found only 34 species of vascular plants in the stream corridor of Pen Branch at a site immediately above the delta where the stream enters the Savannah River swamp. All of the plants grew above the water on sandbars or small islands formed by fallen logs and stumps of trees (Table 3-9). Only 56% of the floodplain area sampled supported vascular plant life. The Pen Branch floodplain flora was characterized by herbaceous plants. The dominant species was Ludwigia leptocarpa, which grew on stumps, logs, and emergent sandbars. This species has been shown to have a relatively high tolerance to the elevated thermal conditions of the SRS swamp (Christy and Sharitz, 1980). The other species were mostly perennial herbaceous plants, that are characteristic of disturbed areas. Perennial herbs constituted 60% of the species typical of the Pen Branch flora and annual herbs another 20%. Woody plants are relatively intolerant of the elevated temperature and substrate conditions.

In another early survey, Irwin (1975) sampled the vegetation of stump communities at three sites in the thermal portion of Pen Branch. Fifteen stumps from each of three areas corresponding to mean annual water temperatures of approximately 50°C, 45°C, and 40°C were evaluated. The vegetation of the stump communities in Pen Branch included old-field species, roadside weeds and aquatic herbs (Table 3-10). Twenty-six of the species were herbaceous, and of the nine woody species, three were tree seedlings. There was no clearly distinguishable relationship between stream water temperature and stump community composition, although the upstream sites (water temperature approximately 50°C) were dominated by several old-field species, including Eupatorium spp. and Andropogon virginicus. Downstream sites (water temperatures approximately 40-45°C) had a greater dominance of aquatic species, such as Ludwigia leptocarpa and Ammannia coccinea.

Information on the in-stream habitat formers of the thermal and non-thermal streams of SRS are summarized from the Comprehensive Cooling Water Study and other studies at SRS from 1983 to 1985. Figure 3-6 gives the locations of sampling stations from these surveys. The methods used to analyze macrophytes included: area or volume measurements of biomass or macrophyte standing crop, using AFDW (Firth et al., 1986). Both living and dead plant material were included in standing crop measurements. During 1983-1984, macrophyte samples were collected from each site (Table 3-11). For the biomass and standing crop determinations, only swamp and delta stations were sampled. At the delta sites (Stations 5 and 6), twenty 0.3 m^2 random samples were collected. The swamp stations (Stations 9 and 10) were mapped to determine area and volume of the macrophyte beds, and quantitatively sampled to determine biomass and standing crop using dry weight and AFDW analysis. In 1984-1985, macrophyte beds were measured at all mapped stations. Area, volume, percent cover, and

TABLE 3-9

Dominant Plant Species in the Pen Branch Corridor and Floodplain

Importance Value[a]	Species
48	*Ludwigia leptocarpa*
28	*Boehmeria cylindrica*
24	*Cyperus strigosus*
21	*Arundinaria gigantea*
20	*Ammannia coccinea*
17	*Fimbristylis* spp.
16	*Paspalum* spp.
15	*Ampelopsis arborea*
11	*Panicum* spp.
11	*Sabal minor*
11	*Panicum dichotomiflorum*
11	*Ludwigia decurrens*
9	*Cassia fasciculata*
8	*Eclipta alba*
7	*Eupatorium* spp.
7	*Erianthus giganteus*
6	*Hypericum walteri*
5	*Saururus cernuus*
<5	Remaining 16 species

[a] Importance Value (Curtis & McIntosh, 1950) = relative density + relative dominance + relative frequency (as percentage).

Source: Sharitz et al. (1974a)

TABLE 3-10

Importance Values[a] of Plant Species on Stumps at Three Sites in the Pen Branch Corridor and Floodplain

Species	Average Annual Water Temperature 50°C	45°C	40°C
Eupatorium capillifolium	38	*	–
Eupatorium sp.	43	26	*
Ludwigia leptocarpa	17	63	35
Fimbristylis spadicea	45	*	–
Andropogon virginicus	19	*	–
Cyperus strigosus	12	32	32
Paspalum dilatatum	36	35	39
Galium tinctorium	22	*	–
Lycopus sp.	10	45	–
Ptilimnium capillaceum	11	*	–
Ilex opaca	*	–	*
Acer rubrum	*	–	*
mbrosia artemisiifolia	*	*	–
drolea quadrivalvis	*	–	–
Juncus marginatus	*	–	–
Myrica cerifera	*	–	–
Itea virginica	*	–	–
Boehmeria cylindrica	*	10	*
Ludwigia decurrens	*	13	*
Polygonum hydropiperoides	*	–	*
Lespedeza cuneata	*	–	*
Ammannia coccinea	–	14	23
Panicum anceps	–	*	51
Cassia nictitans	–	10	14
Cephalanthus occidentalis	–	*	*
Liquidambar styraciflua	–	*	–
Alnus serrulata	–	*	–
Ampelopsis arborea	–	–	28
Eclipta alba	–	–	*

[a] Importance value (Curtis & McIntosh, 1950) = relative density + relative frequency + relative dominance (as percentage). A "*" equals an importance value less than 10; a "–" indicates that the species is absent.

Source: Irwin (1975)

CORRESPONDING STATION NUMBERS

1983-1984	1984-1985
1	5
2	not sampled
3	14
4	21
5	22
6	23
7	26
8	28
9	33
10	35
11	39
12	40

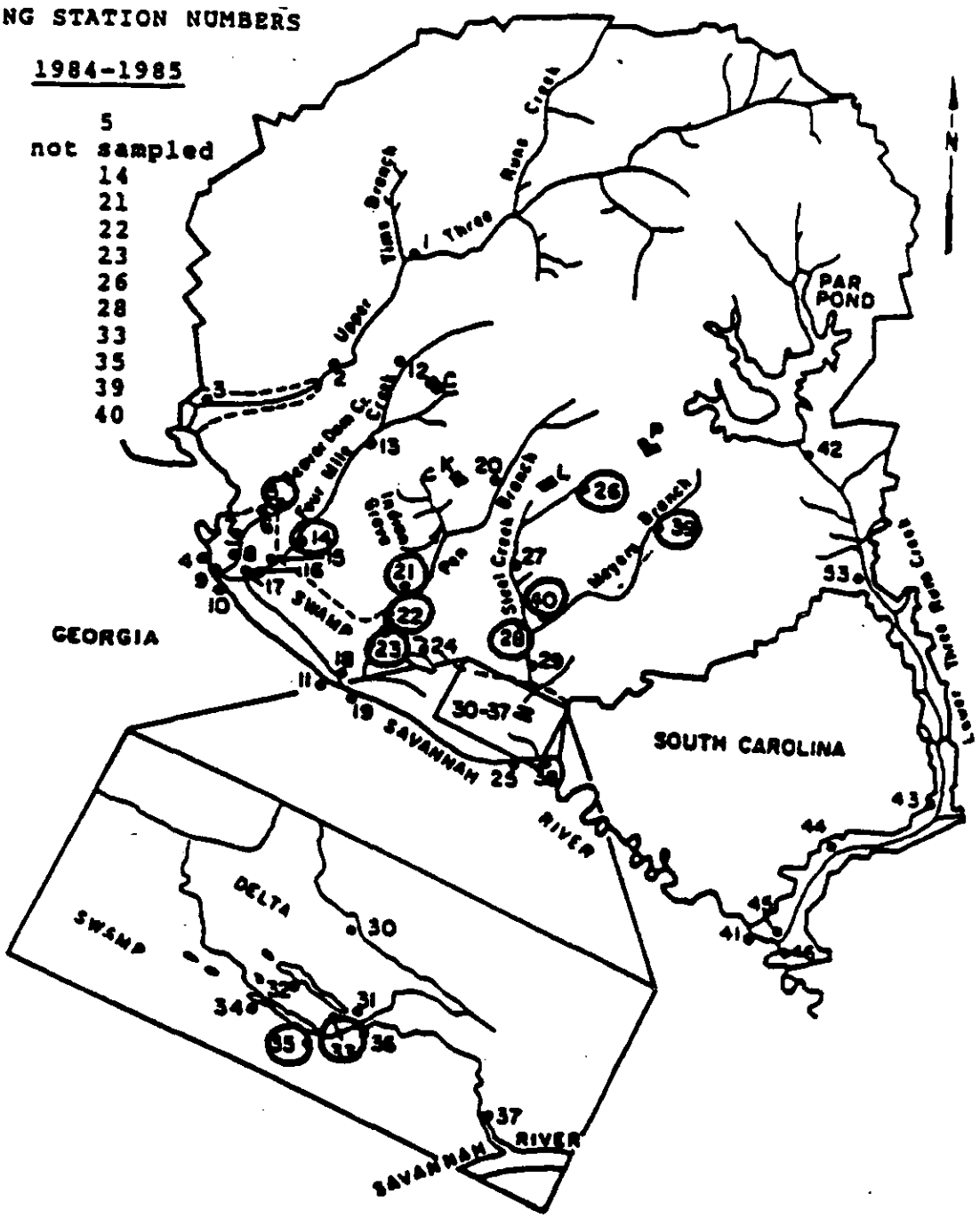

FIGURE 3-6. Map of Savannah River Plant Study Area Showing 1984-1985 Aquatic Ecology Program Locations. Reactors are indicated by letters. Corresponding numbers for stations sampled in 1984-1985 and 1983-1984 are shown above.

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TABLE 3-11

A Checklist of the Aquatic and Semi-Aquatic Vascular Macrophytes and Riparian Flora of the Lower Food Chain Study Sites

Family	Genus - Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Osmundaceae	*Osmunda regalis*	Royal fern										X		X
	O. cinnamomea	Cinnamon fern												X
Azollaceae	*Azolla caroliniana*	Mosquito fern					X				X	X		
Blechnaceae	*Woodwardia areolata*	Netted chain fern	X	X						X		X		X
Pinaceae	*Pinus taeda*	Loblolly pine	X		X				X					
Taxodiaceae	*Taxodium distichum*	Bald cypress					X			X	X			X
Typhaceae	*Typha latifolia*	Common cattail							X					
Potamogetonaceae	*Potamogeton pusillus*										X	X	X	
Alismataceae	*Echinodorus cordifolius*	Creeping burhead					X	X		X				
	Sagittaria graminae					X								
	S. latifolia	Duck potato					X	X		X			X	
Poaceae	*Arundinaria gigantea*	Cane			X			X					X	X
	Panicum agrostoides	Redtop panicgrass												X
	Panicum sp.		X		X									
	Leersia sp.	Cutgrass	X	X	X					X				
	Elymus sp.	Wild ryegrass	X		X									
Cyperaceae	*Cyperus* sp.	Sedge	X	X										
	Carex sp.			X										
Arecaceae	*Sabal minor*	Palmetto		X		X								
Araceae	*Orontium aquaticum*	Golden club												X
	Arisaema triphyllum	Jack-in-the-pulpit											X	X
Lemnoceae	*Lemna valdiviana*	Duckweed					X	X			X	X		
	Spirodela oligorrhiza	Great duckweed						X				X		
Bromeliaceae	*Tillandsia usneoides*	Spanish moss					X	X			X	X		X
Juncaceae	*Juncus effusus*	Common rush		X					X	X			X	
Liliaceae	*Smilax rotundifolia*	Greenbriar			X				X			X	X	
	S. bona-nox	Catbriar				X	X				X			
Saururaceae	*Saururus cernuus*	Lizard's tail										X		X
Salicaceae	*Salix nigra*	Black willow		X		X			X	X	X			

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TABLE 3-11, Contd

Family	Genus - Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Myricaceae	Myrica cerifera	Wax myrtle	X	X		X				X				X
Juglandaceae	Carya aquatica	Water hickory			X						X			
Betulaceae	Alnus serrulata	Tag alder		X					X	X			X	X
Fagaceae	Quercus nigra	Water oak			X									
	Q. phellos	Willow oak	X						X				X	
Ulmaceae	Planera aquatica	Water elm									X	X		
	Ulmus americana	American elm				X					X		X	
Urticaceae	Boehmeria aquatica	False nettle	X		X				X	X			X	
Polygonaceae	Polygonum lapathifolium	Knotweed									X	X	X	
Phytolaccaceae	Phytolacca americana	Pokeweed												X
Ceratophyllaceae	Ceratophyllum demersum	Hornwort										X	X	
Magnoliaceae	Liriodendron tulipifera	Tulip tree								X				
Lauraceae	Sassafrass albidum	Sassafrass		X					X					
Nymphaceae	Nuphar luteum	Spatter dock										X	X	
Saxifragaceae	Itea virginica	Tassel white	X							X	X	X	X	
Hamamelidaceae	Liquidambar styraciflua	Sweet gum	X	X	X					X				X
Platanaceae	Platanus occidentalis	Sycamore							X				X	
Rosaceae	Rubus argutus	Blackberry	X	X		X			X	X	X	X	X	X
	Prunus sp.	Wild cherry							X					
Fabaceae	Wisteria frutescens	Wisteria			X		X					X	X	X
	Gleditsia aquatica	Water locust			X									
Callitrichaceae	Callitriche heterophylla	Water starwort									X	X		X
Anacardiaceae	Toxicodendron radicans	Poison ivy	X	X		X		X	X	X	X	X	X	X
Aquifoliaceae	Ilex opaca	American holly			X								X	
	I. decidua	Possum haw												
Aceraceae	Acer rubrum	Red maple	X	X		X							X	X
Hippocastanaceae	Aesculus pavia	Red buckeye				X		X			X			X

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TABLE 3-11, Contd

Family	Genus - Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Balsaminaceae	*Impatiens capensis*	Jewel weed								X	X		X	X
Vitaceae	*Vitis aestivalis*	Summer grape	X		X				X	X		X	X	
	Ampelopsis arborea	Pepper vine	X	X	X	X			X	X	X	X	X	
	Parthenocissus quinquefolia	Virginia creeper		X		X			X	X			X	X
Malvaceae	*Hibiscus militaris*	Marsh mallow										X		
Violaceae	*Viola* sp.	Violet												X
Onagraceae	*Ludwigia palustris*	Water purslane	X	X		X			X			X	X	
	L. decurrens	Primrose willow					X							
	L. leptocarpa						X	X						
	Ludwigia sp. 1								X	X				
	Ludwigia sp. 2		X								X			
Haloragaceae	*Myriophyllum brasiliense*	Parrot feather								X	X	X		
Apiaceae	*Hydrocotyle ranunculoides*	Water pennywort									X	X		
	Hydrocotyle sp.	March pennywort	X				X						X	X
	Cicuta maculata	Water hemlock								X		X		X
Nyssaceae	*Nyssa aquatica*	Water tupelo											X	
Cornaceae	*Cornus florida*	Dogwood								X			X	X
Ericaceae	*Oxydendrum aboreum*	Sourwood							X				X	
Loganiaceae	*Gelsemium sempervirens*	Yellow jessamine			X	X			X				X	
Asclepiadaceae	*Asclepias* sp.	Milkweed							X	X				
Convolvulaceae	*Cuscuta* sp.	Dodder								X				
Lamiaceae	*Scutellaria lateriflora*	Skullcap			X									
Scrophulariaceae	*Bacopa egensis*	Water hyssop											X	
	Bacopa sp.		X		X				X					

biomass were determined for total macrophytes and for each of the species present at the site. At other stations, macrophytes were sampled to determine species-specific biomass. Biomass was calculated from dry weight and AFDW (Firth et al., 1986).

During the first-year study, only the delta and swamp stations were quantitatively sampled for macrophytes, although a species list was prepared using specimens from all first year stations. Macrophyte sampling was done between November 1983 and May 1984. The site at 1983-1984 Station 9 was sampled both in the channel and in the adjacent smartweed (Polygonum) beds. Table 3-11 lists all species of macrophytes found in the first year of sampling. Species richness was highest at the post-thermal and nonthermal locations (Table 3-12).

During the winter sampling, most of the material collected at the Pen Branch delta sites (1983-1984 Stations 5 and 6), and from the Polygonum beds at 1983-1984 Station 9 was dead. The material in the stream channels at 1983-1984 Stations 9 and 10 was living, but not growing rapidly (Gladden et al., 1985). The flooding that occurred between the winter and spring sampling affected the Pen Branch Delta stations by retarding macrophyte growth. However, macrophytes at 1983-1984 Stations 9 and 10 were not affected by the flooding.

During the spring sampling, macrophytes were absent from the open canopy Pen Branch Delta site (1983-1984 Station 5; Table 3-12). Samples from the closed canopy Pen Branch site (1983-1984 Station 6) included sparse, but living macrophytes. In the winter, the thermal, open canopy areas (1983-1984 Station 5) supported a significantly greater ($p < 0.001$) standing crop than the nonthermal, open canopy channel areas (1983-1984 Station 9; Table 3-13). The thermal, closed canopy site (1983-1985 Station 6) had a significantly greater ($p < 0.001$) standing crop than the nonthermal closed canopy site (1983-1984 Station 10) in the winter. In the spring, there were no significant ($p > 0.05$) differences between the two sites: flooding had decreased macrophyte production at 1983-1984 Station 6 while macrophyte production had increased at 1983-1984 (Gladden et al., 1985).

Most of the 1984-1985 data are from the mapped sites. At each site, four vegetation parameters: area, volume, biomass, and percentage cover, were measured for total and species-specific macrophyte development (Tables 3-14 and 3-15). The reference stream sites (1984-1985 Stations 1, 39, 40, 42, and 43) had few macrophytes (Table 3-15). With the exception of Station 42, the annual means for the reference stream sites did not differ for any of the parameters measured.

The two mapped thermal stream sites were Station 21 on Pen Branch and Station 7 on Beaver Dam Creek. The Pen Branch site was hot enough to exclude macrophytes from the channel. Mildly thermal Station 7 had high means for plant area, volume, and percentage cover. Vegetation characteristics resembled those in the main channels of the Steel Creek delta stations described below (Firth et al., 1986).

TABLE 3-12

Number of Macrophyte Taxa at Each 1983-1984 Sampling Station (November 1983 - May 1984)

	Station											
	Mildly Thermal	Thermal Streams			Thermal Swamp		Nonthermal Stream		Nonthermal Swamp		Reference Stream	
	1	2	3	4	5	6	7	8	9	10	11	12
Total number of taxa	28	20	24	16	19	17	28	32	22	32	35	26
Taxa growing in stream channel	4	0	0	0	8	4	1	2	9	12	6	2
Taxa growing on floodplain	0	0	0	0	6	10	0	18	11	18	0	17
Taxa growing in other riparian areas	24	20	24	16	5	3	27	12	2	2	29	7
Channel + floodplain taxa	4	0	0	0	14	14	1	20	20	30	6	19

Source: Gladden et al. (1985)

TABLE 3-13

Macrophyte Standing Crop (g AFDW/m^2) at Delta and Swamp 1983-1984 Stations During Winter and Spring 1984. Mean, Standard Deviations (s), Coefficient of Variation (CV), and Number of Samples (n) for Samples Collected January-May 1984.

	Station				
	5	6	9	9P[a]	10
	PBD-t	PBD-t	SCS-n	SCS-n	SCS-n
			Winter		
Mean	452.75	73.31	5.02	449.54	3.21
s	196.16	105.74	2.75	175.86	3.41
CV	43.4	144.2	19.93	39.12	106.03
n	20	20	32	15	41
			Spring		
Mean	b	13.63	115.60	229.47	31.27
s		17.37	69.16	81.22	23.13
CV		126.46	59.83	35.39	73.97
n		20	75	15	50

Note: PBD-t = Pen Branch Delta thermal
SCS-n = Steel Creek Stream nonthermal

[a] Station 9P was located in the Polygonum beds adjacent to the Station 9 channel.
[b] Macrophyte beds were absent due to extensive spring flooding.

Source: Gladden et al. (1985)

TABLE 3-14

Aquatic Vascular Plant (AVP) Area (m^2/m^2); AVP Volume (m^3/m^2); AVP Biomass (g/m^2) and AVP Percent Cover (October 1984 - September 1985)

Station	Location/ Thermal Regime	AVP Area		AVP Volume		AVP Biomass		Percent Cover		N
		Mean	s	Mean	s	Mean	s	Mean	s	
1	UTR-n	0.0245	-	0.0030	-	3.326	-	2.449	-	1
7	BD-t	0.1167	0.0692	0.0242	0.0192	17.68	12.07	12.16	8.131	20
14	FMD-t	0.0010	0.0031	-	-	0.0047	0.0189	0.0189	0.3070	16
15	FMD-t	0.0127	0.0288	0.0055	0.0156	4.107	13.04	1.268	2.880	15
24	PBS-n	0.0002	0.0004	-	-	0.0288	0.0625	0.0162	0.0351	20
26	SC-n	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
27	SC-n	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
28	SC-n	0.0423	0.0675	0.0010	0.0015	16.75	28.83	4.026	6.736	16
29	SC-n	0.0002	0.0004	<0.0001	<0.0001	0.0855	0.1949	0.0202	0.0430	12
33	SCD-n	0.3958	0.1434	0.1807	0.1349	82.18	48.70	39.61	14.17	20
34	SCS-n	0.2786	0.2968	0.1196	0.1666	84.01	113.4	29.87	29.85	20
35	SCS-n	0.2331	0.3229	0.0832	0.1267	59.62	78.83	23.32	32.31	20
39	MB-n	0.0001	0.0002	<0.0001	<0.0001	0.0002	0.0007	0.0054	0.0167	20
40	MB-n	0.0009	0.0030	0.0002	0.0005	0.0111	0.0331	0.0916	0.2998	20
42	LTR-n	0.0335	0.0558	0.0017	0.0029	1.929	3.437	3.349	5.584	20
53	LTR-n	0.0000	-	0.0000	-	0.0000	-	0.0000	-	9
43	LTR-n	0.0060	0.0185	<0.0001	<0.0001	0.0284	0.1121	0.5429	1.834	20

s = standard deviation

Source: Firth et al. (1986)

TABLE 3-15

Area (m^2/m^2); Volume (m^3/m^2); Biomass (g/m^2); Percent Cover (percent of mapped area covered by species in question) (October 1984 - September 1985)

List of Species Abbreviations:

ALT	Alternanthera philoxeroides
AZ	Azolla caroliniana
BA	Bacopa sp.
CAL	Callitriche heterophylla
CER	Ceratophyllum demersum
EG	Egeria densa
GRAS	Unidentified grass (Poaceae)
HLA	Hydrolea quadrivalvis
HY	Hydrocotyle ranunculoides
LEE	Leersia sp.
LEM	Lemna spp. (and occasional Spirodela fronds)
LUD	Ludwigia sp.
MISC	Unidentified
MYR	Myriophyllum spicatum
NU	Nuphar luteum
POL	Polygonum spp.
POT	Potamogeton pusillus
VAL	Vallisneria americana (and/or Sparangium sp.)

Species	Area Mean	Area s[a]	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 1 (UTR-n)					
BA	0.0017	-	0.0003	-	-	-	0.1690	-	1
POT	0.0228	-	0.0027		3.326	-	2.280	-	1
				Station 7 (BD-t)					
ALT	0.0133	0.0310	0.0015	0.0035	1.437	3.269	1.333	3.097	20
CAL	0.0008	0.0015	0.0002	0.0003	0.0905	0.1731	0.1048	0.1905	20
CER	0.0849	0.0464	0.0220	0.0167	11.62	9.322	8.824	6.067	20
HY	0.0001	0.0002	<0.0001	<0.0001	0.0015	0.0058	0.0062	0.2444	20
LEE	0.0026	0.0063	0.0002	0.0007	0.3085	0.7610	0.2643	0.6326	20
LEM	0.0038	0.0062	-	-	0.5661	1.113	0.4621	0.7724	20
MISC	0.0033	0.0060	-	-	-	-	0.3305	0.6017	20
POL	0.0078	0.0161	-	-	3.486	7.210	0.8340	1.696	20

TABLE 3-15, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 14 (MFD-t)					
GRAS	0.0010	0.0031	-	-	-	-	0.0956	0.3077	16
LEM	<0.0001	0.0001	-	-	0.0047	0.0189	0.0026	0.0105	16
				Station 15 (FMD-t)					
ALT	<0.0001	0.0001	0.0008	0.0030	1.766	6.841	0.0039	0.0152	15
CER	0.0126	0.0287	0.0047	0.0127	2.340	6.327	1.264	2.866	15
LEM	<0.0001	<0.0001	-	-	0.0003	0.0011	0.0001	0.0005	15
				Station 21 (PB-t)					
				No vegetation in channel					
				Station 22 (PBD-t)					
				No vegetation in channel					
				Station 24 (PBS-n)					
LEM	0.0002	0.0004	-	-	0.0288	0.0625	0.0162	0.0351	20
				Station 26 (SC-n)					
MISC	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
				Station 27 (SC-n)					
MISC	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
				Station 28 (SC-n)					
ALT	0.0012	0.0041	0.0001	0.0004	0.2847	0.9330	0.1235	0.4130	16
BA	0.0001	0.0002	<0.0001	<0.0001	0.0010	0.0041	0.0063	0.0250	16
LUD	0.0001	0.0004	0.0001	0.0003	0.0334	0.1335	0.0102	0.0408	16
MISC	0.0003	0.0012	-	-	-	-	0.0308	0.1233	16
MYR	0.0063	0.0108	0.0008	0.0012	0.9620	2.258	0.4261	0.6815	16
POL	0.0341	0.0631	-	-	15.30	28.33	3.406	6.304	16
POT	0.0002	0.0008	<0.0001	0.0001	0.0240	0.0930	0.0230	0.0806	16
				Station 29 (SC-n)					
MISC	<0.0001	0.0001	-	-	-	-	0.0016	0.0055	12
POL	0.0002	0.0004	-	-	0.0837	0.1957	0.0186	0.0434	12

TABLE 3-15, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 33 (SCD-n)					
AZ	0.0010	0.0038	0	0	0.1706	0.6763	0.0955	0.3785	20
CAL	0.0065	0.0139	0.0025	0.0073	1.306	3.769	0.8090	1.576	20
CER	0.0965	0.0561	0.0502	0.0295	62.24	38.38	9.649	5.611	20
HLA	0.0014	0.0050	-	-	0.3548	2.669	0.1445	0.4958	20
HY	0.0023	0.0057	0.0007	0.0021	0.9281	2.669	0.2296	0.5698	20
LEM	0.0028	0.0074	-	-	0.0858	0.1419	0.2802	0.7396	20
MYR	0.0248	0.0407	0.0132	0.0232	8.941	14.06	2.346	4.093	20
POL	0.0011	0.0030	-	-	0.4941	1.334	0.1103	0.2971	20
VAL	0.2594	0.1572	0.1140	0.1201	7.665	8.016	0.1103	0.2971	20
				Station 34 (SCS-n)					
CAL	0.1391	0.2398	0.0726	0.1287	37.50	66.99	13.91	23.98	20
CER	0.0329	0.0396	0.0133	0.0187	16.73	23.14	3.287	3.956	20
HY	0.0002	0.0010	0.0001	0.0005	0.1478	0.6430	0.0234	0.0980	20
LEM	0.0092	0.0273	-	-	0.2646	0.5258	0.9217	2.732	20
MYR	0.0111	0.0314	0.0031	0.0087	2.921	8.884	3.112	10.08	20
NU	0.0167	0.0269	0.0056	0.0103	0.1712	0.3243	1.668	2.692	20
POT	0.0607	0.0728	0.0214	0.0384	25.85	47.13	6.073	7.278	20
VAL	0.0087	0.0243	0.0034	0.0094	0.2251	0.6058	0.8746	2.433	20
				Station 35 (SCS-n)					
AZ	0.0002	0.0007	-	-	0.0278	0.1241	0.0155	0.0693	20
CAL	0.1682	0.3223	0.0575	0.1214	29.81	62.93	16.82	32.24	20
CER	0.0381	0.0453	0.0185	0.0260	23.02	34.41	3.804	4.535	20
DG	0.0049	0.0083	0.0020	0.0041	1.846	3.428	0.4878	0.8311	20
HY	0.0006	0.0013	0.0001	0.0001	0.2961	1.147	0.0583	0.1255	20
				Station 35 (SCS-n)					
LEM	0.0056	0.0108	-	-	0.2057	0.5313	0.5594	1.077	20
MISC	0.0001	0.0002	-	-	-	-	0.0056	0.0218	20
MYR	0.0013	0.0028	0.0006	0.0017	0.5947	1.748	0.1256	0.2772	20
NU	0.0040	0.0095	0.0010	0.0029	0.0048	0.1343	0.4016	0.9544	20
POT	0.0089	0.0161	0.0031	0.0054	3.750	6.615	0.8943	1.608	20
VAL	0.0014	0.0032	0.0004	0.0012	0.0268	0.0764	0.1445	0.3255	20
				Station 39 (MB-n)					
MISC	<0.0001	0.0001	-	-	-	-	0.0030	0.0134	20
VAL	<0.0001	0.0001	<0.0001	<0.0001	0.0002	0.0007	0.0024	0.0107	20

TABLE 3-15, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 40 (MB-n)					
NU	0.0001	0.0003	<0.0001	0.0001	0.0003	0.0014	0.0076	0.0338	20
VAL	0.0008	0.0030	0.0002	0.0005	0.0108	0.0332	0.0840	0.3002	20
				Station 42 (LTR-n)					
CAL	0.0002	0.0008	<0.0001	<0.0001	0.0005	0.0021	0.0180	0.0805	20
CER	0.0025	0.0042	0.0003	0.0005	0.3474	0.5316	0.2540	0.4207	20
MISC	0.0022	0.0087	-	-	-	-	0.2226	0.8693	20
MYR	0.0003	0.0011	<0.0001	<0.0001	0.0068	0.0201	0.0343	0.1148	20
POL	0.0004	0.0016	-	-	0.1890	0.7137	0.0420	0.1580	20
POT	0.0270	0.0558	0.0011	0.0028	1.369	3.373	2.696	5.578	20
VAL	0.0008	0.0032	0.0003	0.0011	0.0159	0.0685	0.0818	0.3200	20
				Station 53 (LTR-n)					
				No vegetation in mapped channel					
				Station 43 (LTR-n)					
MISC	0.0049	0.0184	-	-	-	-	0.4851	1.839	20
NU	0.0011	0.0040	<0.0001	<0.0001	0.0284	0.1121	0.0578	0.1996	20

[a] s = standard deviation

Macrophyte development at the Steel Creek sites was similar to that of the reference streams (Table 3-14). The fourth site, Station 28, is a clear, shallow stream with a partial to open canopy. Its macrophyte development was greater than the other Steel Creek sites. When the Steel Creek sites were compared as a group to the pooled reference sites, macrophyte biomass was greater at the Steel Creek sites; however, area, volume, and percent cover were not significantly different.

The site at 1984-1985 Station 28 had at least seven aquatic plant taxa, but only water milfoil (Myriophyllum) and smartweed (Polygonum) grew in any abundance (Table 3-15). Pondweed (Potamogeton) grew in moderate abundance there. The other nonthermal stations had zero to two taxa per site.

3.4 L REACTOR, L LAKE, AND STEEL CREEK CORRIDOR

3.4.1 Steel Creek Watershed Characteristics

Steel Creek is located in the eastern half of SRS. Steel Creek and its major tributary, Meyers Branch, drain approximately 91 km^2 of upland before entering the swamp and flowing to the Savannah River. The drainage basin for Meyers Branch constitutes over half of the overall watershed area (50.85 km^2). The stream slope changes from 4.6 m/km at the head to 0.8 m/km as it enters the Savannah River (Newman, 1986).

3.4.2 Wetland Characteristics of the Steel Creek Drainage Area

The wetlands of the Steel Creek drainage have been studied extensively since 1981. Smith et al. (1981, 1982) summarize the results of many of the early studies. These initial studies were expanded during the Comprehensive Cooling Water Study that continued into 1985, immediately prior to the restart of L Reactor. The results of these studies are reported in Mackey (1987).

Generally, these studies document that the Steel Creek ecosystem was in a state of secondary successional revegetation prior to the restart of L Reactor. Earlier releases of thermal effluents into Steel Creek resulted in the elimination of most stream biota and substantial erosion of the floodplain area in the stream corridor between L Reactor and the Savannah River swamp. Sedimentation of material eroded upstream resulted in the creation of a large open delta where Steel Creek enters the river swamp. Tree kill also occurred in deeper water areas of the swamp beyond the sedimentary delta. Biological succession in the stream corridor and delta/swamp areas began with the cessation of thermal effluent release in 1968 (Mackey, 1982).

With long-term reactor shutdown, such as that experienced on the Steel Creek Delta, plant succession proceeds unimpeded. The initial flora of the emergent sandbars was dominated by fimbristylis (Fimbristylis autumnalis), water primrose (Ludwigia leptocarpa), primrose willow (L. decurrens), sedges (Cyperus spp.), and echinochloa (Echinochloa walteri) (McCaffrey, 1982). Smartweed (Polygonum punctatum), wapato (Sagittaria latifolia), and cut grass (Leersia oryzoides) became dominant plants four to eight years after reactor shutdown. Seven years after shutdown, aneilema (Aneilema keisak) became an additional dominant; cut grass increased and P. punctatum decreased in dominance.

Begger ticks (Bidens spp.), marsh St. John's-wort (Hypericum walteri), false nettle (Boehmeria cylindrica), and knot grass (Scirpus cyperinus) have an intermediate ranking in importance four to eight years after reactor shutdown with the addition of redtop panicgrass (Panicum agrostoides) at the later date. Buttonbush (Cephalanthus occidentalis) and willow (Salix spp.) appeared during this time while seedlings of other woody species were ephemeral. According to Martin et al. (1977), the

Steel Creek Delta was covered with water and resembled a freshwater marsh in 1975. The vegetation was characterized by a low, dense herbaceous cover with numerous clumps of large graminoids and widely spaced shrubs. In 1981, there were three major stages of succession in the Persistent Emergent Wetland. There were areas of abundant knot grass that generally fit Martin's description; areas in which numerous small buttonbush and willow plants were nearly as tall as the knot grass (approximately 1.5 m); and other areas that had become dominated by a mixture of willow and buttonbush shrubs which exceeded the height of the knot grass.

In 1981-1982, following 14 years of revegetation, cut grass remained dominant in habitats similar to those described by Martin et al. (1977) with knot grass of increased importance and redtop panicgrass commonly occurring. Wapato (Aneilema keisak) and waterpepper (Polygonum hydropiperoides) were still abundant, especially in the more deeply flooded areas.

The major difference in vegetative cover after 15 years of successional revegetation was the increase in woody vegetation. The dominant species was willow (Salix spp.). However, seedlings of bald cypress (Taxodium distichum), water ash (Fraxinus spp.), water elm (Planera aquatica), and red maple (Acer rubrum) occurred, especially toward the delta periphery. The survival and growth of these plants are largely dependent upon the duration and timing of flooding (Broadfoot and Williston, 1973; Whitlow and Harris, 1979; Sharitz et al., 1986; McLeod et al., 1986; Scott et al., 1985).

Most of the deltaic fans have a raised substrate where hardwood species may become established. It is likely that the deltaic fan will eventually become more like the Deciduous Bottomland Hardwood Forest (Quercus lyrata--Carya aquatica--Nyssa aquatica) than the original Deciduous Swamp Forest.

Succession in the areas of deeper water is dependent upon water depth and flow. Here submerged aquatic plants (Ceratophyllum demersum and Myriophyllum brasiliense) colonize under-water logs. These species are joined by numerous emergent aquatic species, including smartweed (Polygonum lapathifolium) and aneilema (Aneilema keisak) in deeper water with low flow. Hydrolea (Hydrolea quadrivalvis) dominates the periphery of the deltaic fan and occurs over a wide range of water depths, along with parrot-feather (Myriophyllum brasiliense) and water purslane (Ludwigia palustris). The shallower areas allow the presence of wapato with abundant rhynchospora (Rhynchospora corniculata). Waterpepper occurs in similar habitats. Both wapato and waterpepper are transitional species occurring in both the Nonpersistent Emergent Wetlands and in the Persistent Emergent Wetlands.

3.4.3 L Lake

3.4.3.1 Macrophyte Planting Program

The Savannah River Ecology Laboratory (SREL) of the University of Georgia conducted a wetlands planting program in L Lake in 1987. Transplants, shrub branches, and commercial plants were planted in L Lake from January to April 1987. More than 4,270 meters (14,000 ft) of shoreline were planted. Approximately 100,000 plants were planted. Details on species planted, source of plant material, and planting density are provided in Table 3-16 (Wein et al., 1987).

3.4.3.2 Status of L-Lake Plant Communities

A variety of plants, some of which have been reported from thermal areas of SRS (Irwin, 1975; Sharitz et al., 1974a, 1974b), were present in L Lake in 1987. Because the development of the littoral plant community in L Lake is in an early successional stage, the diversity of the littoral plant community in L Lake was low in 1987 compared with Par Pond and other older lakes of similar morphometry and environmental characteristics (Grace, 1985a, 1985b; Dames and Moore, 1984; Barry, 1980). Diversity will continue to increase as new species colonize the littoral zone. Productivity of aquatic macrophytes was low during 1987, but will increase as plant beds continue to develop (Firth, 1988).

3.4.4 Steel Creek Below L Lake

The species composition of wetland plant communities is largely determined by the tolerance of individual species to soil saturation and/or inundation. The increased discharge in Steel Creek was expected to result in shifts in plant community composition toward more flood-tolerant species.

Emergent, floating leaved and submerged macrophytes varied considerably in their abundance in the stream channel habitats in the Steel Creek drainage. Macrophyte coverage of channel habitats was generally highest in the open-canopy delta sites (300, 310, 320, 330), intermediate in the swamp (340, 350), and downstream channel sites (360, 370), and minimal at the upstream channel sites (280, 285, 290), Meyers Branch (400), and Station 295 on the delta (Figure 3-7 and Table 3-17). Of the Steel Creek Delta sites that had substantial macrophyte cover, only Station 300 exhibited a large change in percentage cover from 1986 to 1987, decreasing from 99.8% to 21.7%. Other stations exhibited relatively small changes in macrophyte cover from 1986 to 1987.

Limited data for macrophyte cover are available from summer 1985. Station 280, closest to L-Lake Dam, had a substantial reduction in macrophyte cover from 1985 to 1986 as a result of scouring of the stream channel at this site (Table 3-17; Firth et al., 1988). Station 330 in the delta had higher macrophyte coverage in 1986 and 1987 than in 1985, while other sampling sites exhibited only small changes.

TABLE 3-16

Description of Plant Material Planted at L Lake

Zone	Plant Species	Density[a]	Type of Plant Material Transplanted
1	*Vallisneria americana*	4	Cheesecloth bombs
2	*Brasenia sclueiberi*	4	Bare root section of rhizome
	Nelumbo lutea	4	Bare root section of rhizome
	Nymphaea ororata	4	Bare root section of rhizome
	Potamogeton diversifolia	4	Bare root section of rhizome
3	*Eleocharis quadrangulata*	2	Bare root section of rhizome
	Panicum hemitomon	2	Bare root clump with six stems
	Pontederia cordata	2	Bare root section of rhizome
	Saqittaria latifolia	2	Bare root plants[b]
	Scirpus cyperinus	2	Bare root clumps
	Typha latifolia	2	Bare root rhizome
	Bacopa caroliniana	2	Bare root plants
	Eleocharis equisetoides	2	Bare root section of rhizome
	Juncus effusus	2	Bare root clump
	Juncus acuminatus	2	Bare root clump
	Carex comosa	2	Bare root clump
	Lycopus rubellus	2	Bare root rhizome
	Polygonum spp.	2	Bare root clump
4	*Leersia oryzoides*	1.5	Bare root stems
	Panicum hemitomon	-	3-ft strips
	Panicum spp.	-	Seed[b]
	Glyceria spp.	-	Seed[b]
5	*Cephalanthus occidentalis*	10	Wands
	Salix nigra	10	Wands
	Alnus serrulata	Cluster	Wands
	Nyssa sylvatica	10	2-3 ft bare root plants[b]
	Taxodium distichum	10	2-3 ft bare root plants[b]

[a] Density number is distance in feet between individual plants.
[b] Commercial source for plant material.

Source: Wein et al. (1987)

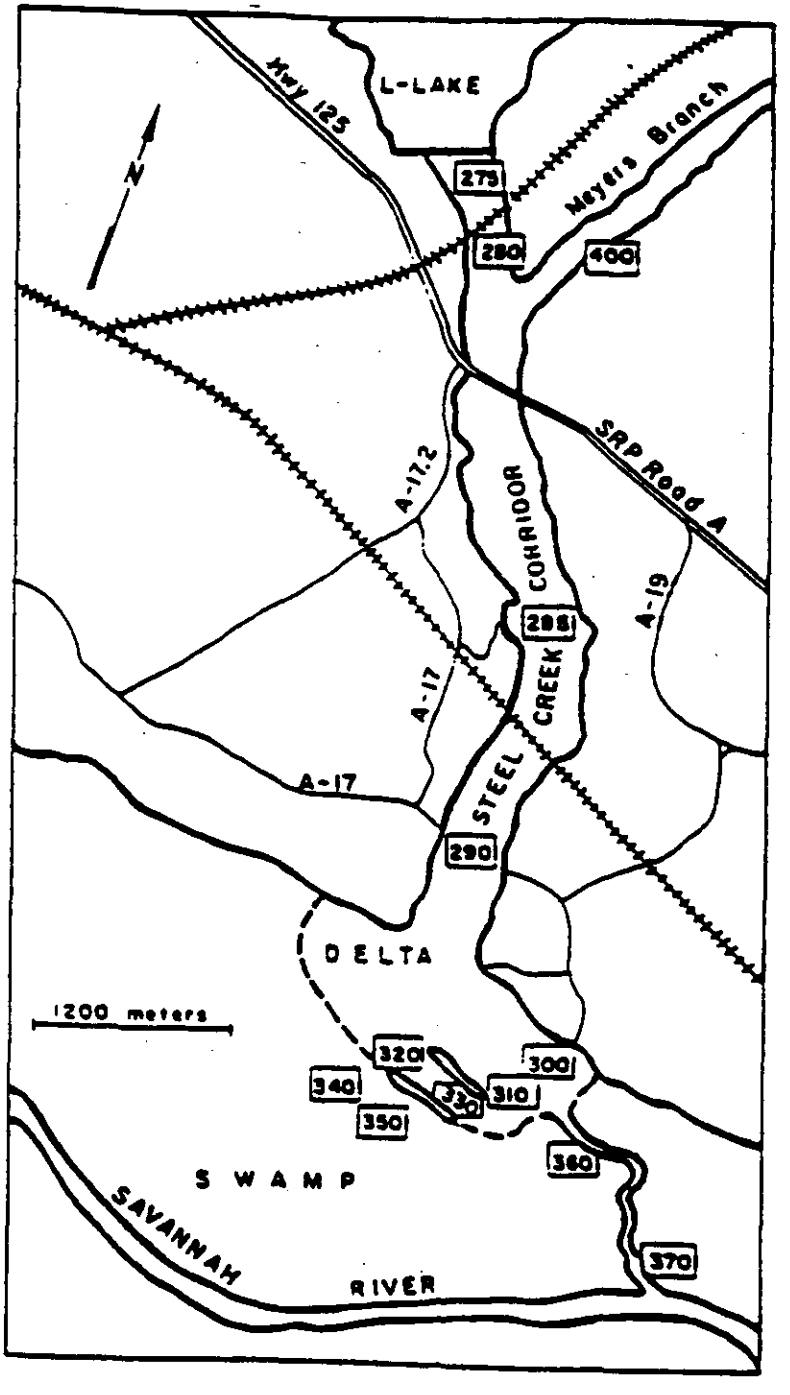

FIGURE 3-7. Sampling Locations in Steel Creek, Meyers Branch, and the Steel Creek Delta/Swamp

W8906070

M890070

TABLE 3-17

Percentage Cover[a] of Aquatic Macrophyte Taxa in Stream Channels of Steel Creek and Meyers Branch, July-September 1985, 1986 and 1987

	Upstream Corridor									Meyers Branch			Downstream Channel					
	280			285[b]			290			400			360[b]			370[b]		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Plant Taxa																		
Alternanthera philoxeroides	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Azolla caroliniana	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Callitriche sp.	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Ceratophyllum demersum	–	–	–		–	–	–	–	–	–	–	–		4.9	5.9		5.8	5.3
Egeria densa	–	–	–		–	–	–	–	–	–	–	–		10.9	14.5		13.4	5.3
Hydrocotyle ranunculoides	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Lemna spp.	–	–	–		–	–	–	–	–	–	–	–		2.9	–		–	–
Murdania keisak	–	–	–		–	–	–	–	–	–	–	–		2.3	1.7		–	–
Myriophyllum aquaticum	–	–	–		–	–	–	–	–	–	–	–		1.2	–		–	–
Nuphar luteum	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Paspalum repens	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Polygonum spp.	11.4	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Potamogeton spp.	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Sparganium americanum	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Vallisneria americana	–	–	–		–	–	–	–	–	–	–	–		–	–		–	–
Other[c]	0.8	0	<1.0		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0	1.0		0.5	1.0		0.9	1.0
(No. Species <1%)														(3)	(8)		(5)	(9)
Total	12.2	0	<1.0		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0	<1.0		22.7	23.1		20.1	11.6
Length of Stream Reach Mapped (m)	100	75	75		75	75	75	75	75	75	75	75		75	75		75	75

Note: Modified from Firth et al. (1988b).

[a] Calculated as [(m^2 of macrophyte cover/m^2 of mapped channel)* 100]
[b] Location not sampled in 1985
[c] Sum of percent cover for taxa having less than 1% cover that were not reported individually; number of taxa not reported for Steel Creek corridor stations

TABLE 3-17, Contd

	Delta 295[b]			300[b]			310[b]			320[b]			330			Swamp 340			350		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	19
Plant Taxa																					
Alternanthera philoxeroides	-	-		-	-		-	-		6.2	-		-	-	-	-	-	-		-	-
Azolla caroliniana	-	-		1.5	-		-	-		-	-		-	-	-	-	-	-	-	-	-
Callitriche sp.	-	-		-	-		-	-		-	-		2.8	-	-	-	-	-	-	-	-
Ceratophyllum demersum	-	-		61.0	18.6		25.9	7.3		41.5	53.4		15.9	19.0	23.4	7.7	4.2	3.2	8.2	3.1	-
Egeria densa	-	-		-	-		2.4	29.8		-	-		-	-	8.3	-	5.0	13.4	1.8	18.4	18
Hydrocotyle ranunculoides	-	-		-	-		-	-		-	2.2		-	-	-	-	-	-	-	-	-
Lemna spp.	-	-		-	-		-	-		1.8	1.9		1.0	-	3.8	3.5	2.4	2.8	1.9	1.9	1
Murdanis keisak	6.2	-		-	-		-	-		-	-		-	-	-	-	-	-	-	-	-
Myriophyllum aquaticum	-	-		12.7	-		-	-		2.1	-		1.2	1.8	-	-	-	-	-	-	-
Nuphar luteum	-	-		-	-		-	-		-	-		-	-	-	-	1.4	-	-	-	-
Paspalum repens	-	-		-	-		-	-		-	-		-	6.4	-	-	-	-	-	-	-
Polygonum spp.	-	-		3.7	1.5		3.4	-		-	-		-	-	-	-	-	-	-	-	-
Potamogeton spp.	-	-		18.1	-		-	-		2.4	-		-	1.6	1.1	5.7	2.7	-	2.5	-	-
Sparganium americanum	-	-		-	-		-	-		-	-		-	37.1	18.0	-	2.3	-	-	-	2
Vallisneria americana	-	-		-	-		-	-		-	-		10.8	-	-	2.2	-	-	-	-	-
Other[c]	0.1	<1.0		2.8	1.6		1.0	1.6		0.3	0.3		0.8	2.1	1.0	0.8	0.8	1.8	1.3	0.8	0
(No. Species <1%)	(2)			(7)	(4)		(2)	(4)		(2)	(4)		(2)	(9)	(3)	(4)	(4)	(5)	(4)	(3)	(7
Total	6.3	<1.0		99.8	21.7		32.7	38.7		53.4	57.8		32.5	68.0	55.6	19.9	18.8	21.2	15.7	24.2	22
Length of Stream Reach Mapped (m)	75	75		75	75		75	75		75	75		125	125	125	125	125	125	125	125	125

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The distribution of macrophyte biomass among sites in Steel Creek and Meyers Branch exhibited the same patterns observed for macrophyte percentage cover. Plant biomass was highest at the open-canopy delta sites, intermediate at the swamp and downstream channel sites, and minimal in the upstream corridor sites, Meyers Branch, and Station 295 on the delta. Differences in macrophyte biomass among years also followed the patterns noted earlier for macrophyte percentage cover.

The community of submerged, floating leaved and emergent vascular macrophytes was depauperate in channel areas of the upstream corridor region of Steel Creek. Only Polygonum spp. occurred with greater than 1% cover at any sampling station during any of the years (Table 3-17). The small amount of Polygonum spp. was sampled in 1985, but was scoured from the location in 1986. The downstream channel area of Steel Creek (Stations 360, 370) had substantially larger macrophyte communities, with a larger number of species contributing to the total plant cover. Although these areas were not sampled in 1985, sampling during 1986 and 1987 revealed that Egeria densa and Ceratophyllum demersum were the dominant aquatic macrophytes at the downstream channel sites.

Ceratophyllum demersum and Egeria densa were also dominant aquatic macrophytes at many of the delta/swamp sites that were sampled (Table 3-17). C. demersum tended to be more abundant at the open-canopy delta areas while E. densa was more abundant at the closed-canopy swamp areas. Other aquatic macrophyte taxa that were dominant (>5% cover) during summer sampling at one or more delta/swamp locations included Murdania keisak, Myriophyllum aquaticum, Paspalum repens, Potamogeton spp., Sparganium americanum, and Vallisineria americana.

Sampling stations with well-defined stream channels and floodplains (corridor: 280, 285, 290; lower channel: 360, 370; Meyers Branch: 400) generally had higher vascular plant taxa richness than delta and swamp stations (Table 3-18). The highest overall taxa richness occurred at Stations 285, 290, and 370 (91 taxa each) in 1986 and Stations 370, 360, and 290 (100, 87, and 86 taxa, respectively) in 1987. Lowest taxa richness occurred at Stations 300, 330, 340, and 350, 49, 49, 49, and 47 taxa, respectively) in 1986 and at Stations 330 and 350 (44 and 47 taxa, respectively) in 1987.

Herbaceous taxa constituted the highest proportion of total taxa richness at all sites (Table 3-18). However, the relative proportions of herbaceous taxa to woody taxa (trees, shrubs, vines) were higher in the corridor (280, 285, 290), lower channel (360, 370), and Meyers Branch stations than in the delta and swamp stations. These differences are likely a result of the more frequent and persistent flooding that naturally occurs in the delta and swamp habitats.

Overall changes in taxa richness from 1986 to 1987 were small at most sampling sites (Table 3-18). The largest changes in overall species richness occurred at Station 285 (loss of 12 taxa), 295 (gain of 10 taxa), 360 (gain of 11 taxa), and 370 (gain of 9 taxa). However, all stream corridor sites, including Meyers Branch, exhibited a net decline in taxa

TABLE 3-18

Total Number of Taxa at Each Site and Numbers of Trees, Shrub, Vine, and Herb Taxa, (January 1986 - December 1987)

Location	Station	Total No. of Taxa		No. of Tree Taxa		No. of Shrub Taxa		No. of Vine Taxa		No. of Herb Taxa	
		1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
Corridor											
	280	80	78	7	6	8	7	13	8	52	57
	285	91	79	9	8	13	10	12	8	57	53
	290	91	86	10	11	12	10	9	6	60	59
Delta	295	59	69	5	5	5	5	9	8	40	51
	300	49	56	4	4	2	2	2	4	41	46
	310	53	53	5	7	3	3	4	4	41	39
	320	56	56	5	5	2	2	5	5	44	44
	330	49	44	5	6	3	3	4	1	37	34
Swamp	340	49	53	5	6	1	2	5	4	38	41
	350	47	47	4	5	3	2	4	3	36	37
Lower channel	360	76	87	14	17	6	6	14	13	42	51
	370	91	100	18	17	6	8	14	14	53	61
Meyers Branch	400	82	78	14	10	11	14	12	11	45	43

Source: Firth et al. (1988).

richness ranging from 2 to 12 species. At the stream corridor floodplain stations (280, 285, 290), shrub and vine taxa richness declined at all sites, while tree and herb taxa richness exhibited no consistent pattern of increase or decrease. Firth et al. (1988) attribute this pattern to a relatively lower flood tolerance among shrub and vine taxa at the stream corridor sites than at the delta and swamp sites that have historically been more frequently and severely flooded.

Tree density was highest at the stream corridor sites, Station 295 on the delta, and Meyers Branch (Table 3-19). Tree densities were generally lowest at the open-canopy delta sites (300, 310, 320, and 330), while the swamp and lower channel sites were intermediate in tree density. In contrast, tree basal area was highest at the swamp sites (340, 350), the lower channel (360, 370), and Meyers Branch (400). These differences reflect the species composition and relative maturity of the different areas in the Steel Creek drainage. Stream corridor and delta sites continue to exhibit the effects of succession since cessation of reactor operations in 1968. Woody plant communities are dominated by shrub-scrub vegetation such as Salix spp., Cephalanthus occidentalis, Myrica cerifera, and Alnus serrulata (Firth et al., 1988). However, specimens of the dominant mature swamp taxa (Nyssa aquatica, Taxodium distichum, and Fraxinus spp.) are beginning to appear at these sites. The swamp sites (340, 350) are dominated by mature specimens of these taxa, and the large stand basal area values reflect the maturity of these sites. The downstream channel sites are also mature stands and include Liquidambar styraciflua and Ulmus americana, reflecting the more mesic nature of these floodplain habitats.

Tree density increased at most sites from 1986 to 1987 (Table 3-19). Although some tree mortality occurred at most sites sampled, recruitment offset these losses (Firth et al., 1988). Only Stations 280 and 285 in the upstream corridor had net reductions in tree densities from 1986 to 1987. Tree losses at these two sites were primarily among small individuals of the dominant taxa: Alnus serrulata, Cephalanthus occidentalis, Myrica cerifera, and Salix spp. However, the growth and recruitment of remaining individuals into the tree size class ($\geq$2.5 cm diameter) resulted in little change in stand basal area. All other sites exhibited modest increases in stand basal area.

Shrub stem densities were higher in the upstream corridor and at Meyers Branch than at any of the delta, swamp, or downstream channel sites (Table 3-20). Myrica cerifera and Alnus serrulata dominated the shrub flora at the upstream corridor sites, while Cephalanthus occidentalis and Itea virginica dominated the delta and swamp sites, respectively. Shrub density increased slightly at most sites from 1986 to 1987, but there were no substantial changes in either density or taxonomic composition at any of the sites.

Herbaceous plant cover exhibited clear differences among sampling sites within the Steel Creek drainage (Figure 3-8). Sampling sites in the upstream corridor (280, 285, 290), lower channel (360, 270), and Meyers Branch (400) had substantially lower herbaceous plant cover than sites in

TABLE 3-19

Tree Density and Basal Area at Sampling Stations in Steel Creek and Meyers Branch in 1986 and 1987

Location	Station	Density (no./ha) 1986	Density (no./ha) 1987	Basal Area (m^2/ha) 1986	Basal Area (m^2/ha) 1987
Corridor	280	5,459	3,954	17.4	17.2
	285	5,310	4,667	15.6	15.9
	290	2,833	2,833	10.6	11.8
Delta	295	3,017	3,050	5.6	6.5
	300	350	483	0.8	1.2
	310	665	826	7.9	8.5
	320	388	431	1.1	1.3
	330	593	670	5.9	6.9
Swamp	340	1,683	1,733	60.1	68.2
	350	847	868	59.2	59.2
Lower channel	360	1,450	1,483	46.7	47.0
	370	783	817	28.6	31.1
Meyers Branch	400	2,253	2,253	39.5	41.8

Note: Modified from Firth et al. (1988).

TABLE 3-20

Shrub Density (no./m^2) at Sampling Stations in Steel Creek and Meyers Branch in 1986 and 1987

Location	Station	1986	1987	Dominant Taxa[a]
Corridor	280	1.11	1.44	*Myrica cerifera*, *Alnus serrulata* *Itea virginica*
	285	1.77	2.37	*Alnus serrulata*, *Myrica cerifera*
	290	0.95	1.37	*Alnus serrulata*, *Itea virginica*
Delta	295	0.49	0.53	*Cephalanthus occidentalis*
	300	0.14	0.12	*Cephalanthus occidentalis*
	310	0.27	0.32	*Cephalanthus occidentalis*, *Itea virginica*
	320	0.27	0.18	*Cephalanthus occadentalis*
	330	0.06	0.07	*Cephalanthus occadentalis*, *Foresteria* sp., *Itea virginica*
Swamp	340	0.13	0.10	*Itea virginica*
	350	0.13	0.21	*Itea virginica*
Lower channel	360	0.12	0.31	*Foresteria* spp., *Rubus* spp., *Ilex* spp., *Itea virginica*
	370	0.13	0.29	*Ilex* spp., *Itea virginica*
Meyers Branch	400	1.74	1.94	*Itea virginica*, *Leucothoe* sp.

Note: Modified from Firth et al. (1988).

[a] Greater than 15% of total stem density.

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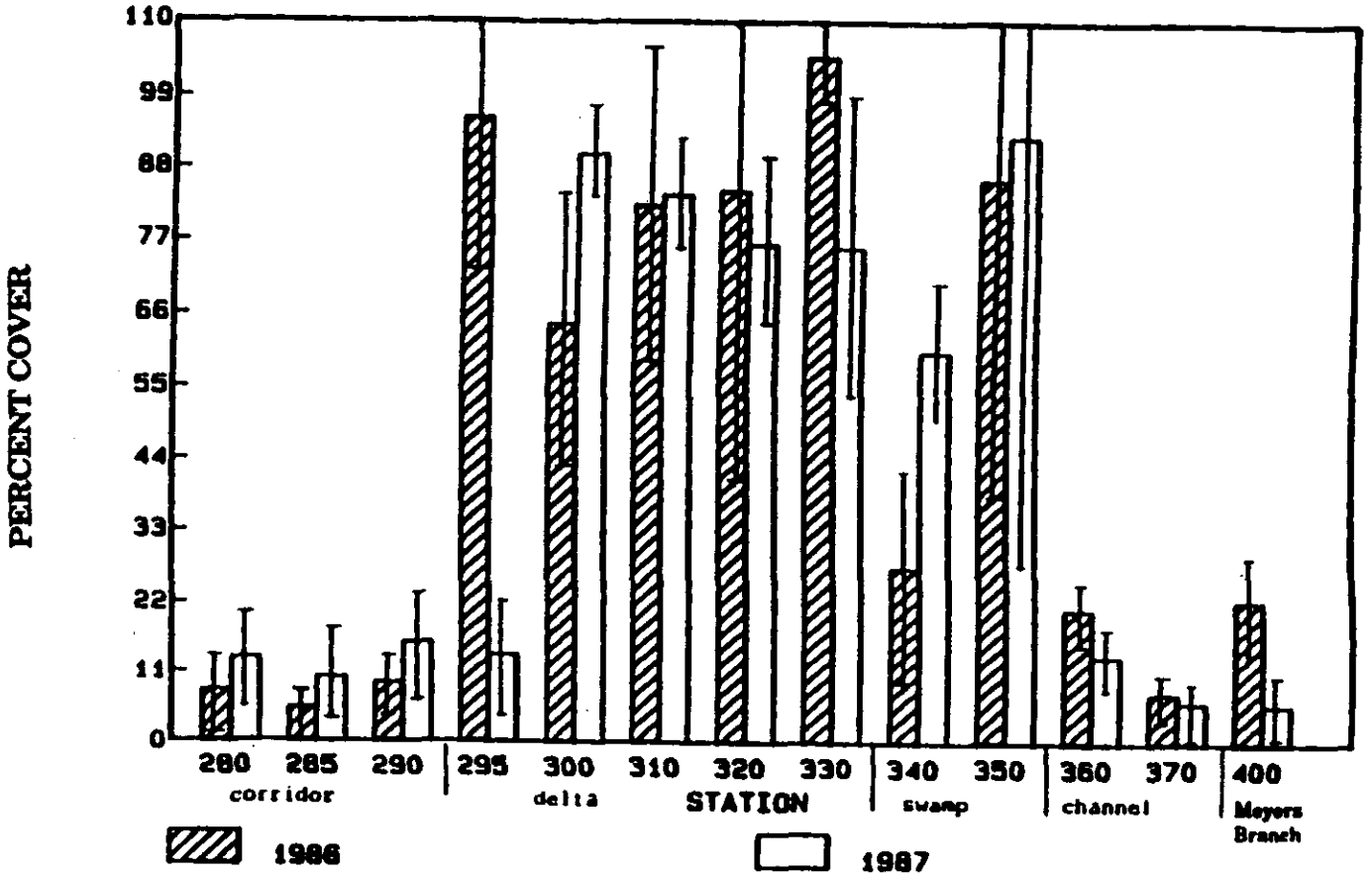

FIGURE 3-8. Annual Mean Percentage Herb Cover at Steel Creek Corridor, Delta, Swamp, and Channel at Meyers Branch Stations (January 1986 - December 1987) (Firth et al., 1988)

the delta (295, 300, 310, 320, 330) and swamp (340, 350). These differences are primarily related to differences in the density of the tree canopy at these various sites (Figure 3-9). The exceptions to this pattern are the swamp sites where canopy cover was high and herbaceous cover was also high.

Differences in percentage herbaceous plant cover occurred at all sites from 1986 to 1987 (Figure 3-8). Herbaceous plant cover increased slightly at the stream corridor and swamp sites, decreased at the downstream channel and Meyers Branch sites, and exhibited varying patterns at the delta sites. The most dramatic difference occurred at Station 295, the only delta site with high tree density, where herbaceous cover declined from 95.6% in 1986 to 13.7% in 1987 (Firth et al., 1988).

3.4.5 Remote Sensing Surveys Below L Lake, 1985-1987

The Steel Creek corridor and delta/swamp areas were surveyed in spring 1985, 1986, and 1987 using airborne multispectral scanner techniques. Data obtained during the remote sensing overflights were processed to obtain estimates of the areal coverage of major wetland vegetation classes for each year so that estimates of wetland change could be made following the restart of L Reactor.

Bottomland hardwood and scrub-shrub vegetation dominate the Steel Creek corridor area between L-Lake Dam and the Savannah River swamp (Table 3-21). The only trends evident across the three sampling periods are a shift from bottomland hardwood to emergent wetland vegetation types. This change indicates that portions of the hardwood forest canopy are likely opening along the Steel Creek corridor, and herbaceous vegetation is invading the areas where light penetrates through the canopy. Although changes have occurred in coverage by both scrub-shrub and open-water classes, there do not appear to be consistent trends during the first 2 years.

Vegetation cover changes in the delta/swamp habitats have been small since the restart of L Reactor (Table 3-21). Neither deciduous bottomland forest nor deciduous swamp forest vegetation classes exhibited changes that would indicate substantial community alteration from 1985 to 1987. Scrub-shrub, nonpersistent emergent marsh, persistent emergent marsh, parrots feather, and open-water cover classes appear to have undergone changes related to increased flooding resulting from L-Reactor operations. Specifically, there appears to have been a decline in cover of scrub-shrub and persistent emergent marsh vegetation, while nonpersistent emergent marsh, parrots feather, and open-water cover classes have increased in areal extent from 1985 to 1987.

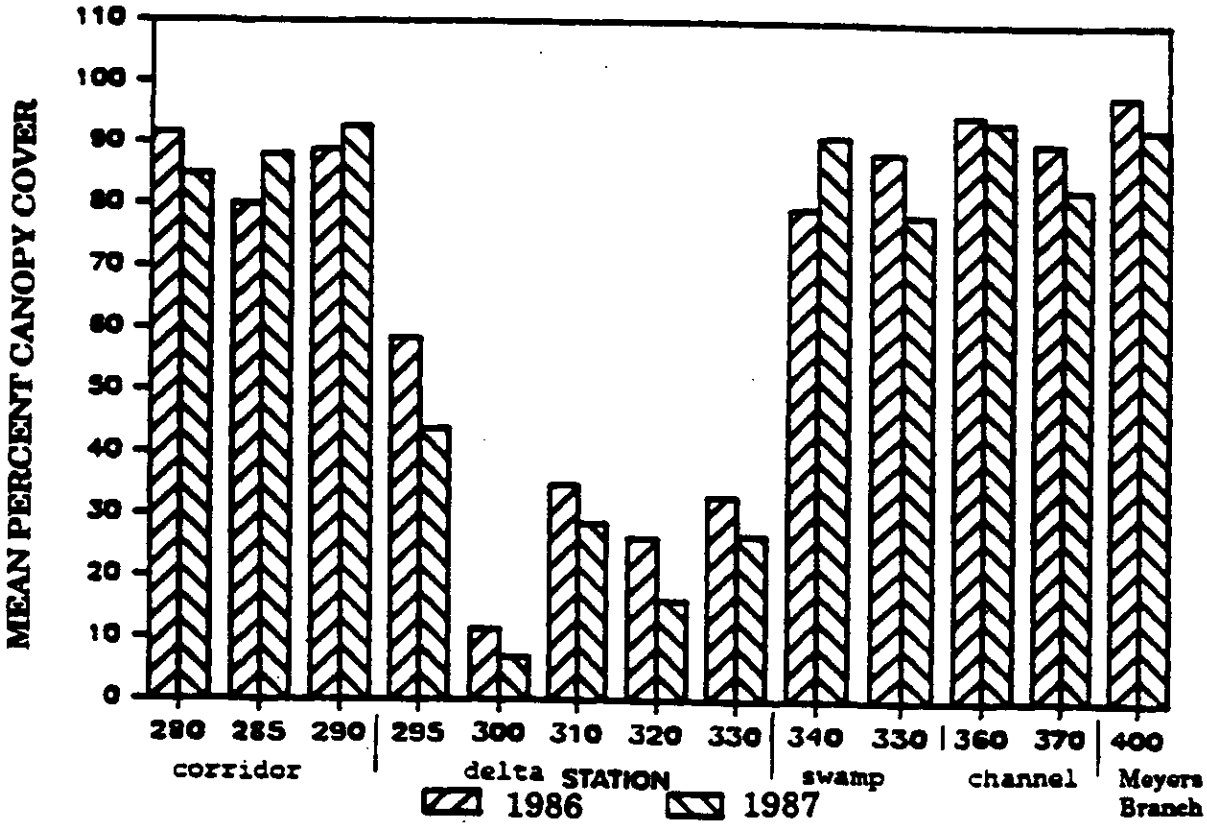

FIGURE 3-9. Mean Summer Percentage Canopy Cover at Steel Creek Corridor, Delta, Swamp, and Channel and at Meyers Branch Stations (January 1986 - December 1987) (Firth et al., 1988)

TABLE 3-21

Changes in Area of Wetland Vegetation Classes in Steel Creek Corridor from L-Lake Dam to Steel Creek Delta. Estimates of Areas Covered (in hectares) by Wetland Vegetation Types in Steel Creek Corridor in 1985, 1986, and 1987

Vegetation	1985	1986	1987
Bottomland hardwood	162	160	151
Scrub-shrub	106	95	105
Emergent wetland	3	11	14
Open water	1	7	2
Total	272	273	272

Changes in Area of Wetland Vegetation Classes in Steel Creek Delta/Swamp in 1985, 1986, and 1987

Vegetation	1985	1986	1987
Deciduous bottomland forest	77	72	80
Deciduous swamp forest	108	100	105
Scrub-shrub	68	69	58
Nonpersistent emergent marsh	9	19	19
Persistent emergent marsh	14	<1	0
Parrots feather	0	13	8
Open water	11	13	15
Total	287	287	285

3.5 P REACTOR AND PAR POND

3.5.1 Macrophytes

Several studies of the macrophytes of Par Pond were conducted during the 1970's (Wilde and Tilly, 1985). Conclusions derived from these studies were: (1) a well developed macrophyte community occurs in Par Pond, (2) relatively stable water levels maintained by reactor operation enhance macrophyte development, and (3) the dominant macrophyte species in Par Pond are typical of this geographical region.

Grace (1985a) provided a series of maps on wetlands vegetation at several sites throughout the reservoir in July 1984 (Table 3-22). Most of the species had been reported in earlier studies (Wilde and Tilly, 1985). Grace (1985a) concluded that Par Pond wetlands were principally middle-to-late successional and relatively homogeneous.

In another study by Grace (1985b), aerial photographs from 1975, 1980, and 1983 were examined to evaluate the changes that have occurred in the wetland vegetation of Par Pond. This evaluation of the aerial photographs included comparisons with ground-level vegetation maps developed from the field surveys conducted during July 1984 (Grace, 1985a). Comparisons of photographs from August and December of 1983 to evaluate seasonal changes showed that the main seasonal change in the coverage of wetland vegetation was the wintertime loss of nonpersistent emergent species such as Nelumbo lutea and Nymphaea odorata. Comparisons between September 1980 and August 1983 showed that the lakeward extent of nonpersistent macrophytes has increased by an average of 8.2 m, although not all sites have changed equally. For persistent macrophytes (principally Typha spp.), the average increase in lakeward extent between December 1975 and August 1983 was 3.5 m. An extensive development of wetland vegetation in Par Pond and a substantial spread of vegetation between 1975 and 1983 indicates the high suitability of habitat in Par Pond for the growth of wetland plants (Grace, 1985b).

Ezra and Tinney (1985) prepared vegetation maps of floating-leaved and emergent macrophytes in Par Pond using aerial photography and multispectral scanner (MSS) data from a September 21, 1984 survey. These vegetation maps were compared with multispectral scanner thermal data to determine the distribution of these macrophytes in different thermal regions of Par Pond. No major patterns were noted in either the relative amount or composition of macrophyte vegetation in different thermal regions of the pond.

3.6 LONG TERM TRENDS AND EFFECTS OF COOLING WATER RELEASES ON SRS STREAMS AND THE SRS SAVANNAH RIVER SWAMP

3.6.1 Introduction

Since 1953, cooling water discharges from the SRS reactors and the D-Area powerhouse have altered wetland vegetation in the SRS stream floodplains and the Savannah River swamp. High effluent flows have eroded streambanks and deposited sediments, forming four deltas at the junction of each stream and the swamp. To assess the status and predict future changes of the SRS swamp deltas, past aerial photographs were analyzed using photo-interpretation and computer techniques to provide the following information:

- past and current expansion rates,
- location and changes of impacted areas, and
- estimates of total areas affected.

The period of analyses covered aerial photography from 1951 through 1985 (Tinney et al., 1986). In addition, multispectral remote sensing data were available from 1981 to 1985 for the SRS swamp delta areas. These multispectral data allow estimation of changes by wetland community types for the delta areas (Christensen et al., 1986).

The wetlands changes in the Steel Creek system are particularly interesting because thermal discharge temperatures and flows have varied markedly. Both L and P reactors discharged effluents to the stream from 1954 to 1963. L Reactor continued to discharge thermal effluent to Steel Creek from 1963 to 1968. Besides a varied discharge history, the Steel Creek system has also experienced early successional revegetation (Smith et al., 1981, 1982). When P Reactor stopped releasing thermal effluents to the stream in 1963, the upper Steel Creek corridor began to revegetate. In 1968, thermal discharges into the creek ceased and the lower Steel Creek floodplain and delta region has been undergoing post-thermal succession (Smith et al., 1981, 1982; Christensen et al., 1986).

Pen Branch and Four Mile Creek began receiving reactor effluents in 1954 and 1955, respectively. In contrast to Steel Creek, neither stream has received effluents from more than one reactor. Additionally, both reactors have operated with only minor changes in operating conditions since the initial startup. C Reactor has been shutdown since late June 1985 and the Four Mile Creek corridor and delta are now undergoing early successional revegetation. A fourth source of thermal effluents to the SRS Savannah River swamp is from D Area, which contained a heavy water production facility (placed on standby in 1982) and a coal-fired power plant (currently operating). Effluents from D Area have consistently been lower in both volume and temperature than effluents from the reactor areas.

TABLE 3-22

Species List of Par Pond Wetlands Vegetation Observed in a July 1984 Survey

Species	Common Name	Sites Where Observed
Acer rubrum L.	Red maple	2,3,4,6,7,8,9,18,11,15
Alnus serrulata (Ait.) Willd.	Tag alder	3
Alternanthera philoxeroides (Mart.) Griseb.	Alligator weed	
Bacopa caroliniana (Walt.) Robins.	Carolina bacopa	3,7
Betula nigra L.	River birch	
Boehmeria cylindrica (L.) Sw.	False nettle	3
Brasenia schreberi Gmel.	Water shield	9,14
Cephalanthus occidentalis L. var. occidentalis	Button bush	8,14
Echinodorus cordifolius (L.) Grisebach	Creeping water plantain	
Eleocharis quadrangulata (Michx.) R. & S.	Square stem spike rush	1,15
Erianthus giganteus (Walt.) Muhl.	Giant plume grass	3,4,6,7,8,14
Hydrocotyle sp.	Pennywort	1,3,4
Juncus effusus var. solutus Fern. & Wieg.	Rush	3,5,14
Myrica gale L.	Sweet gale	1,6,8,10,14
Nelumbo lutea (Willd.) Pers.	Water lotus	1,2,6,7,9,10,11,14
Nymphaea odorata Ait.	Water lily	7,8,9,14
Panicum hemitomon Schult.	Panic-grass	1,2,9,11,14,15
Peltandra virginica (L.) Schott & Endl.	Arrow-arum	
Polygonum sp.	Smartweed	4,7
Pontedaria cordata L. var. cordata	Pickerelweed	9,14
Salix nigra Marsh.	Black willow	3,4,6,8,11,12
Scirpus americanus Pers.	Three-angled bullrush	7
Scirpus cyperinus (L.) Kunth	Bullrush	3,5,6,7,8
Sphagnum sp.	Sphagnum moss	4
Typa domingensis Pers.	Southern cattail	4,5,6,7,8,10,11,12
Typha latifolia L.	Common cattail	2,3,4,5,6,7,8,11,12,14,18
Woodwardia virginica (L.) Smith	Virginia chain fern	3

Source: Grace (1985a)

3.6.2 Photographic Surveys

Aerial photographs of the SRS thermal creeks and Savannah River swamp were evaluated for years between 1951 and 1985. These photographs provide a visual record of the history of the deltas and creek and allow assessment of wetlands vegetation changes. The photographs were interpreted using standard photogrammetric techniques (Wolf, 1974; Burnside, 1979; Christensen et al., 1984a; Tinney et al., 1986). Impact area boundaries from each year were registered to a common scale in a Geographic Information System (GIS) (Howland, 1980; Borrell, 1982). The GIS was queried using Boolean logic to document the condition of the creek and delta wetland forests at each date and the change between dates (Townshend, 1981). The date and spectral sensitivity for each stream system are summarized in Table 3-23. Most of the aerial photography was panchromatic (0.4-0.7 μm), acquired at scales larger than or equal to 1:20,000. All aerial photography had a standard 60% endlap and 30% sidelap, which facilitated stereoscopic analysis.

Quantitative estimates of wetland losses were based on identification of areas in the creek floodplains and the SRS Savannah River swamp where indigenous bottomland hardwood and cypress-tupelo swamp forest had been damaged from exposure to thermal effluents and sediment. Forest areas were classified as:

- no damage,
- partial damage (5-95% canopy loss), or
- complete damage (95-100% canopy loss).

This classification scheme was useful for identifying areas where damage had occurred or was under way, and/or where succession had taken place (Christensen et al., 1984a, 1984b, 1986; Tinney et al., 1986).

3.6.3 Long Term Trends, 1951-1985

3.6.3.1 Steel Creek Corridor and Delta

In 1951, a closed canopy forest extended throughout the Savannah River swamp and Steel Creek corridor. Although portions of the forest had been previously logged, a second-growth forest of bald cypress, water tupelo, and bottomland hardwoods was present. In 1954, both L and P reactors began releasing thermal effluents to Steel Creek. The discharge volume (approximately 200 cfs total) and temperature (30 to 40°C) were relatively low (Table 3-24). Approximately one year after startup, 48 ha of bottomland forest had been partially defoliated in the Steel Creek corridor below both L and P Reactors (Table 3-25 and Figure 3-10). Canopy loss continued into 1956 with 132 ha of corridor floodplain forest damaged (Table 3-25 and Figure 3-10). At the same time, the first signs of canopy loss also appeared in the swamp (Figure 3-11). In a one-year period, 73 ha of cypress-tupelo canopy were partially defoliated in the swamp (Figure 3-11 and Tables 3-24 and 3-26). Canopy loss in the swamp

TABLE 3-23

Aerial Photography Used to Document Wetlands Change

Date	Spectral Sensitivity	Format	Steel Creek	Pen Branch	Four Mile Creek	Beaver Dam Creek
04-04-51	Panchromatic	B&W positive	X	o	o	X
05-01-55	Panchromatic	B&W positive	X	X	X	X
03-21-56	Panchromatic	B&W positive	X	X	X	X
03-15-61	Panchromatic	B&W positive	X	X	X	X
05-05-66	Near infrared	B&W positive	X	X	X	X
03-18-73	Panchromatic	B&W positive	X	X	o	o
02-13-74	Panchromatic	B&W positive	X	o	X	X
10-27-78	Panchromatic	B&W positive	o	o	o	X
02-20-82	Color	Positive	X	X	X[a]	X
04-06-84	Near infrared	Color positive	X	X	X	X
04-25-85	Color infrared	Color print	X	X	X	X

o Photography was not available.
[a] Photography was not used for area estimates because of poor quality.

TABLE 3-24

Estimated Impacts and Discharge Conditions to Steel Creek from Reactor Discharges, 1954-1985

Year	Steel Creek -- Savannah River Swamp: Total Affected Area[a] (ha)	Steel Creek -- Savannah River Swamp: Expansion and Revegetation Rate (ha/yr)	Steel Creek -- Floodplain Corridor: Total Affected Area[a] (ha)	Steel Creek -- Floodplain Corridor: Expansion Rate of Forest Canopy Mortality (ha/yr)	Annual Average Reactor Discharge: Flow (cfs)[d]	Annual Average Reactor Discharge: Temperature (°C)
1954	0		0	-	200	32
				48.1		
1955	0	-	48.1	-	200	44
		72.8		84.1		
1956	72.8	|	132.2	_	257	64
		-		|		
1957		|		|	270	71
1958		|		|	386	69
		10.1		2.2		
1959		|		|	557	72
1960		|		|	649	72
1961	122.6	_	143.4	-	758	67
1962		|		|	763	68
1963		|		|	372	66
		0.4		0.5		
1964		|		|	376	67
1965		|		|	371	69
1966	124.2	-	146.0	_	370	70
1967		|		|	368	69
1968[b]		|	0.1	|	370	67
		0.4[c]		|		
1973		|		|		
1974	120.6	-	147.0	_		
1975		|		|		
1976		1[c]		|		
1978		|		|		
1979		|		|		
1980		|		|		
1981		-		5.9[c]		
1982	113.3	|		|		
		7.8[c]		|		
1983		|		|		
1984	90.1	-		|		
1985	81.9	8.1†	76.1	_		

[a] Greater than 5% canopy loss.
[b] L Reactor discharged for two months before shutdown.
[c] Revegetation rate.
[d] 35.32 cfs = 1 cms.

TABLE 3-25

Area in Each Impact Category for the Steel Creek Corridor[a]

Year	Partial Canopy Loss[b]	Total Canopy Loss[c]	Total Canopy Loss Area	Average Expansion Rate of Forest Canopy Mortality (ha/yr)
1955	47.6	0.5	48.1	-
1956	129.9	2.3	132.2	84.1
1961	8.7	134.7	143.4	2.2
1966	3.8	142.2	146.0	0.5
1973	27.0	120.0	147.0	0.1
1985	51.7	24.4	76.1	-5.9

[a] Areas are in hectares (ha).
[b] 5 to 95% loss.
[c] 95 to 100% loss.

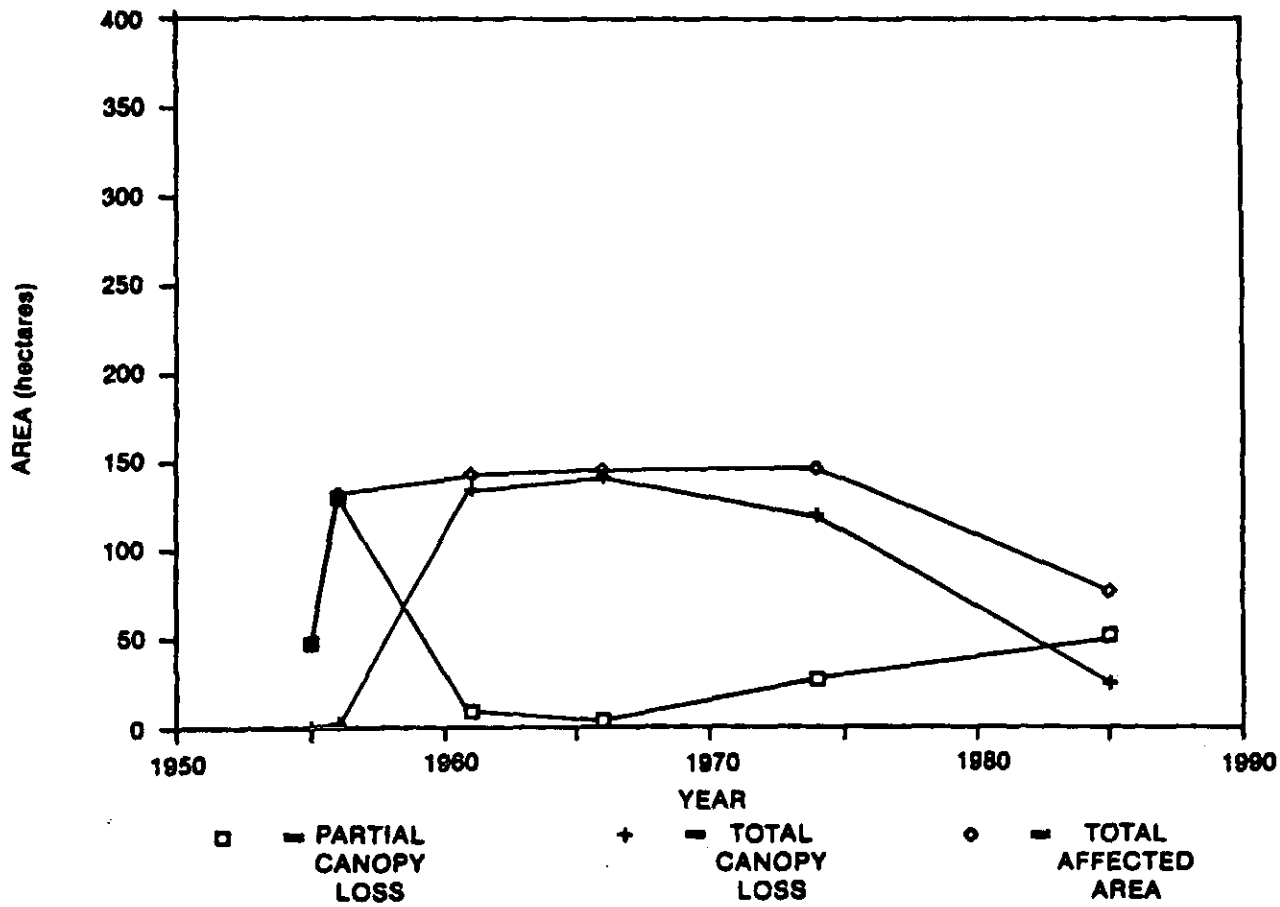

FIGURE 3-10. Steel Creek Corridor Wetland Changes, 1955-1985 (Tinney et al., 1986)

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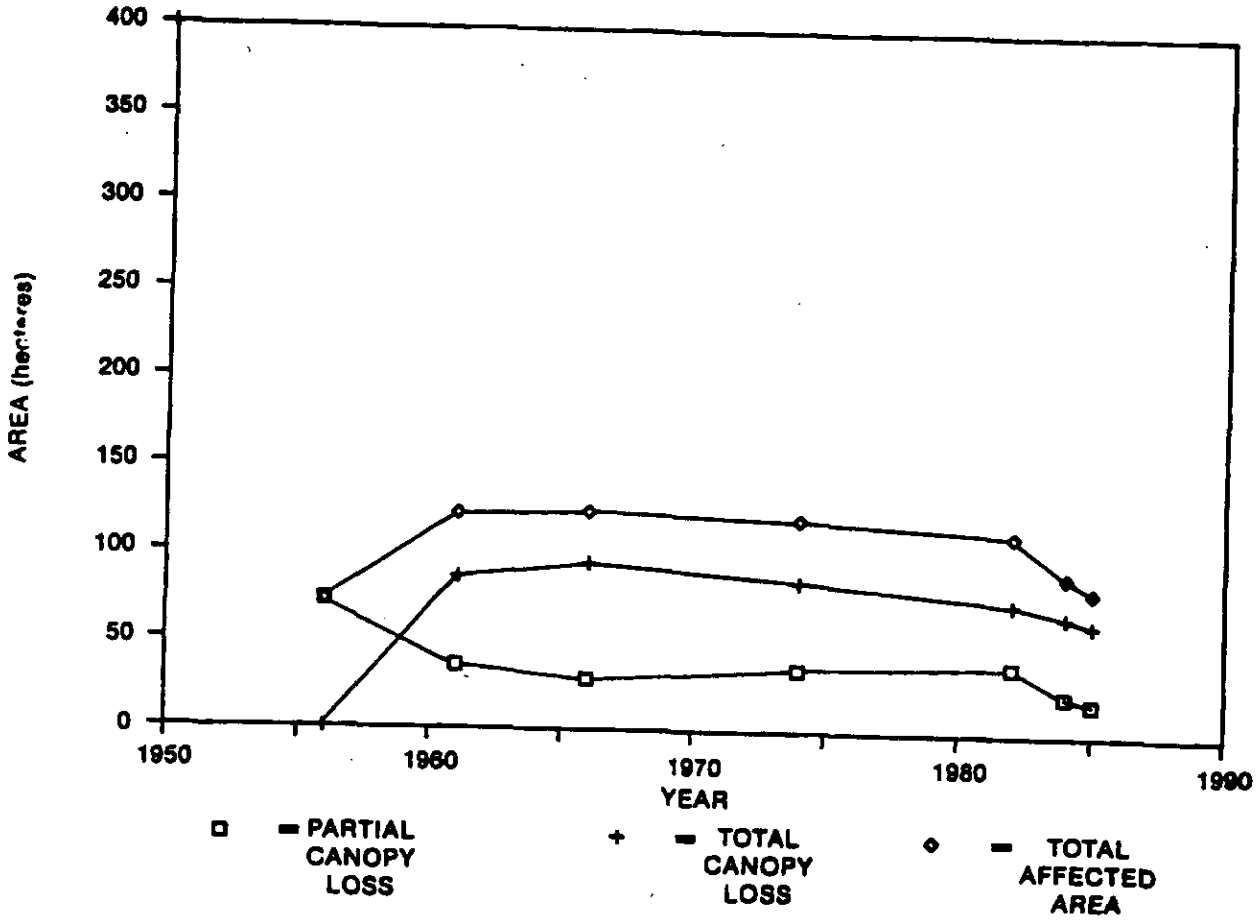

FIGURE 3-11. Steel Creek Delta Growth and Revegetation Trends, 1951 to 1985 (Tinney et al., 1986)

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TABLE 3-26

Area in Each Impact Category for the Steel Creek Delta[a]

Year[b]	Partial Canopy Loss[c]	Total Canopy Loss[d]	Total Canopy Loss Area	Average Expansion Rate of Forest Canopy Mortality (ha/yr)
1951	-	-	-	-
1956	72.8	-	72.8	10.1
1961	36.0	86.6	122.6	0.4
1966	29.1	95.1	124.2	-0.5
1974	35.6	85.0	120.6	-0.9
1982	38.8	74.5	113.3	-11.6
1984	22.4	67.7	90.1	-8.2
1985	18.7	63.2	81.9	-

[a] Areas are in hectares (ha).
[b] Data from 1982 and earlier are from Gladden et al. (1985).
[c] 5 to 95% loss.
[d] 95 to 100% loss.

continued at an overall rate of 10 ha/yr while in the Steel Creek floodplain defoliation slowed to 2.2 ha/yr from 1956 to 1961 (Table 3-24). During this period, reactor discharge temperatures averaged approximately 70°C (Table 3-24).

Maximum flow in Steel Creek occurred between 1960 and 1963 (Table 3-24). However, from 1961 to 1966, the floodplain and the swamp impact zones grew at a rate of about 0.5 ha/yr (Figures 3-10 and 3-11). The lower growth rate probably occurred because P-Reactor thermal effluents were diverted to Par Pond in 1963. From 1961 to early 1963, reactor discharges to Steel Creek averaged 760 cfs, but dropped to about 370 cfs from 1963 to 1968 (Table 3-24). Water temperatures remained relatively constant. In 1966, the total impact area was near maximum size at 124 ha in the swamp and 146 ha in the Steel Creek corridor (Tables 3-25 and 3-26).

In 1963, P-Reactor thermal effluents were diverted to Par Pond, allowing the revegetation of bottomland forest to begin in the upper portion of the Steel Creek corridor. When L Reactor discontinued operations in 1968, the swamp and remainder of the floodplain forest also began to revegetate. Between 1968 and 1982, forest canopy revegetated in about 11 ha of the delta impact zone. New canopy cover was established in the swamp at a rate of less than one ha/yr (Figure 3-11). After 1982, the canopy recovery rate accelerated to about 8 ha/yr as young hardwoods matured. However, most new regrowth of woody species was by Salix spp. (willow) and not the original cypress-tupelo swamp forest (Repaske, 1981; Smith et al., 1981). Some cypress-tupelo regeneration occurred in fringe areas of the swamp impact zone where thermal exposure had been less extreme and root and stump sprouting took place (Tinney et al., 1986).

One area where cypress-tupelo regeneration occurred was offsite in the Creek Plantation Swamp (southeast of SRS). Thermal effluents from Steel Creek entered the area sometime after 1956, particularly when the swamp was flooded in late winter and early spring. By 1961, about 5 ha of swamp canopy offsite had been altered. After 1963, the canopy began to recover and by 1966 the impact area visible from aerial photographs had been reduced to 4 ha. Currently, a closed forest canopy exists in the previously impacted offsite area (Christensen et al., 1984a; Tinney et al., 1986).

3.6.3.2 Pen Branch Corridor and Delta

In 1951, the Savannah River swamp and Pen Branch corridor had a closed canopy forest. In 1954, K Reactor began discharging thermal effluent to Pen Branch. The discharge volume (approximately 100 cfs) and temperature were low (Table 3-27). However, canopy change in the corridor was visible as early as 1955 and 1956 in the aerial photographs (Figure 3-12).

About 11 hectares of bottomland hardwood forest along the corridor were partially defoliated by May 1955 (Tables 3-27 and 3-28). Since discharge temperatures were relatively low, flooding from reactor effluents was probably the major cause of damage. Reactor discharge temperatures began

TABLE 3-27

Estimated Impacts and Discharge Conditions to Pen Branch from Reactor Discharges, 1954-1985

Year	Pen Branch--Savannah River Swamp: Total Impacted Area[a] (ha)	Pen Branch--Savannah River Swamp: Expansion Rate (ha/yr)	Pen Branch Corridor: Total Affected Area[a] (ha)	Pen Branch Corridor: Expansion Rate of Forest Canopy Mortality (ha/yr)	Annual Average Reactor Discharge: Flow (cfs)[b]	Annual Average Reactor Discharge: Temperature (°C)
1954		|			100[c]	26
1955	0	|	11.0	–	100[c]	42
		|		42.8		
1956	0	–	53.8	–	131	63
1957		0.9		|	183	64
1958		|		|	214	66
1959		|		11.8	277	70
1960		|		|	334	66
1961	4.5	–	112.9	–	398	63
1962		|		|	399	63
1963		|		|	394	66
1964		9.4		0.6	394	67
1965		|		|	392	62
1966	51.4	–	115.7	–	389	53
1967		|		|	389	58
1968		|		|	389	63
1969		|		|	389	57
1970		1.7		-1.2	386	46
1971		|		|	388	57
1972		|		|	390	55
1973	63.1	–		|	388	59
1974		|		|	324	61
1975		|		|	373	58
1976		6.6		|	376	57
1977		|		|	375	57
1978		|		|	378	57
1979	102.4	–		|	379	61
1980		|		|	380	64
1981		6.2		|	380	64
1982	121.0	-		|	381	67
1983		13.2		|	380	-
1984	147.4	|		|	370	59
1985	151.8	4.4	92.6	-	-	-

[a] Includes greater than 5% canopy loss.
[b] Approximate.
[c] 35.82 cfs = 1 cms.

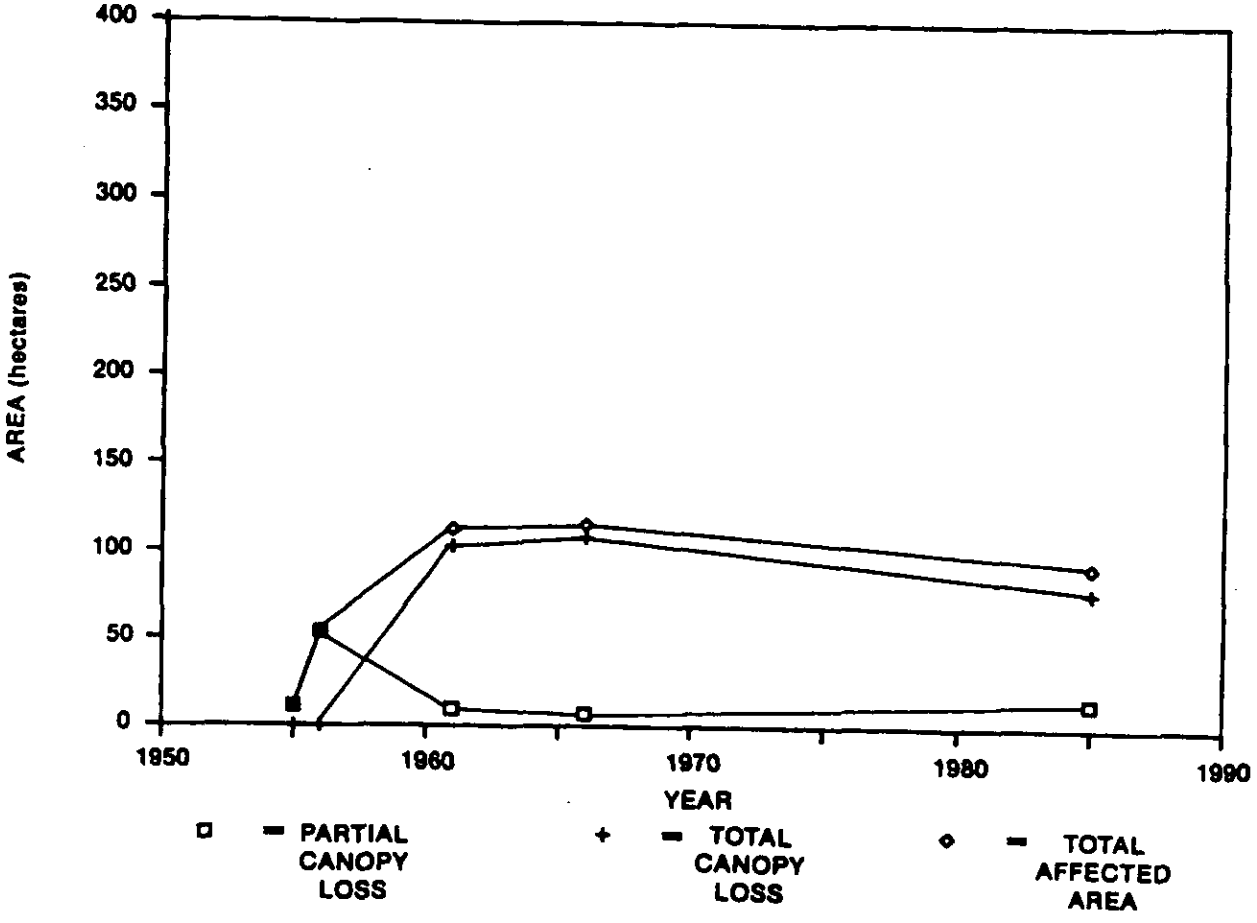

FIGURE 3-12. Wetland Changes in the Pen Branch Corridor, 1955-1985 (source: Tinney et al., 1986)

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TABLE 3-28

Area in Each Impact Category for the Pen Branch Corridor[a]

Year	Partial Canopy Loss[b]	Total Canopy Loss[c]	Total Canopy Loss Area	Average Expansion Rate of Forest Canopy Mortality (ha/yr)
1955	11.0	-	11.0	-
1956	53.8	-	53.8	42.8
1961	9.7	103.2	112.9	11.8
1966	7.2	108.5	115.7	0.6
1985	14.7	77.9	92.6	-1.2

[a] Areas are in hectares (ha).
[b] 5 to 95% canopy loss.
[c] 95 to 100% canopy loss.

a steady rise during 1955 and 1956, and by the end of March 1956, 54 ha along the corridor had been affected. By 1961, canopy defoliation was apparent throughout the corridor (113 ha) and had reached the Savannah River swamp (4.5 ha) (Tables 3-27 and 3-29, Figure 3-13). Most of the trees were affected, probably due to the increasing temperatures (x = 65°C) and flows (x = 338 cfs). During the next five years, the Pen Branch corridor impact area stabilized (116 ha). At the same time, a delta formed in the swamp at a rate of 9 ha/yr, and reached a size of 51 ha by 1966 (Table 3-27 and Figure 3-13). Average flow (395 cfs) and temperature (64°C) remained relatively high (Christensen et al., 1984b).

In 1965, an experimental program resulted in lower K-Reactor power levels, and discharge temperatures were reduced to 53°C by 1966 (Table 3-27). The delta expansion rate also decreased to 1.6 ha/yr. Reduced power operations and discharge temperatures continued through 1974 when SRS began an energy conservation program in all reactor areas. Since less cooling water was used, K-Reactor discharges dropped an average of 20 cfs (Table 3-27). However, delta growth accelerated to 6.6 ha/yr after 1973 despite the reduced flows and temperatures. After 1979, reactor power levels began to return to higher levels. Effluent temperatures increased (x = 65°C) and the Pen Branch Delta growth continued. In 1985, the impact zone was about 152 ha and was expanding at a rate of about 4 ha/yr (Christensen et al., 1984b; Tinney et al., 1986).

As of 1985, approximately 245 ha of forested wetlands were impacted by thermal discharges from K Reactor. Defoliated canopy is visible in both the stream floodplain (93 ha) and SRS swamp (152 ha). The Pen Branch Delta continues to expand at a rate of 4 to 5 ha/yr, whereas no additional wetlands losses are expected in the stream corridor (Tinney et al., 1986).

Much of the recent swamp canopy loss near Pen Branch Delta has been occurring in the southeasterly direction, adjacent to the upland terrace along the Savannah River swamp (Figure 3-14) (Sharitz et al., 1986; Christensen et al., 1986; Jensen et al., 1987). Over the years, cypress-tupelo canopy has been replaced by open water and willow. The historic aerial photographs, aerial multispectral scanner vegetation maps and ground observations from 1981-1985 have confirmed these changes. Recent EG&G thermal infrared surveys have shown that during river flooding, thermal effluents from both Four Mile Creek and Pen Branch are channeled along the northeast bank of the swamp away from the river (Figure 3-15) (Shines and Tinney, 1983). River flooding seems to correlate with the southeastern progression of the Pen Branch Delta. From 1966 to March 1973, the southeastern "tail" changed little (Figure 3-14). Spring flooding frequency and duration were also low during this period. After 1973, the "tail" began to increase in size along with springtime flooding frequency. The channeling of thermal effluents during the spring and summer growing season may be occurring when the cypress-tupelo forest is most sensitive, resulting in increased mortality (Sharitz et al., 1986). The post-1973 increase in flooding intensity may have caused the increase in the delta expansion rate from 1.7 to 6.6 ha/yr, while reactor discharge temperatures and flows remained relatively constant (Christensen et al., 1984b).

TABLE 3-29

Area in Each Impact Category for the Pen Branch Delta[a]

Year	Partial Canopy Loss[b]	Total Canopy Loss[c]	Total Affected Area	Average Expansion Rate of Forest Canopy Mortality (ha/yr)
1961	4.5	-	4.5	-
1966	39.7	11.7	51.4	9.4
1973	33.2	29.9	63.1	1.7
1979	27.9	74.5	102.4	6.6
1982[d]	39.3	81.7	121.0	6.2
1984	70.8	76.6	147.4	13.2
1985	72.1	79.7	151.8	4.4

[a] Areas are in hectares (ha).
[b] 5 to 95% canopy loss.
[c] 95 to 100% canopy loss.
[d] Data for 1982 and earlier are from Gladden et al. (1985).

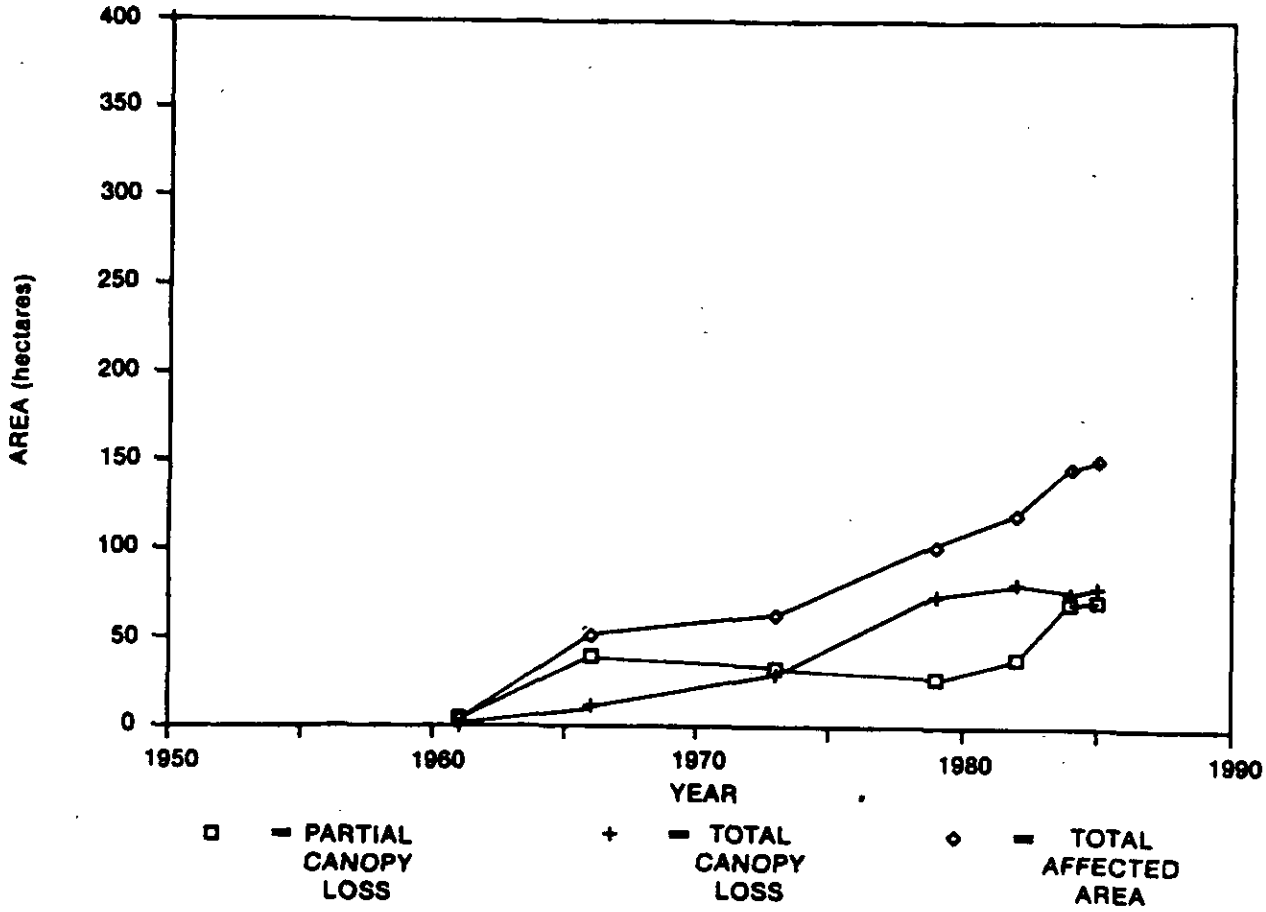

FIGURE 3-13. Pen Branch Delta Expansion (Tinney et al., 1986)

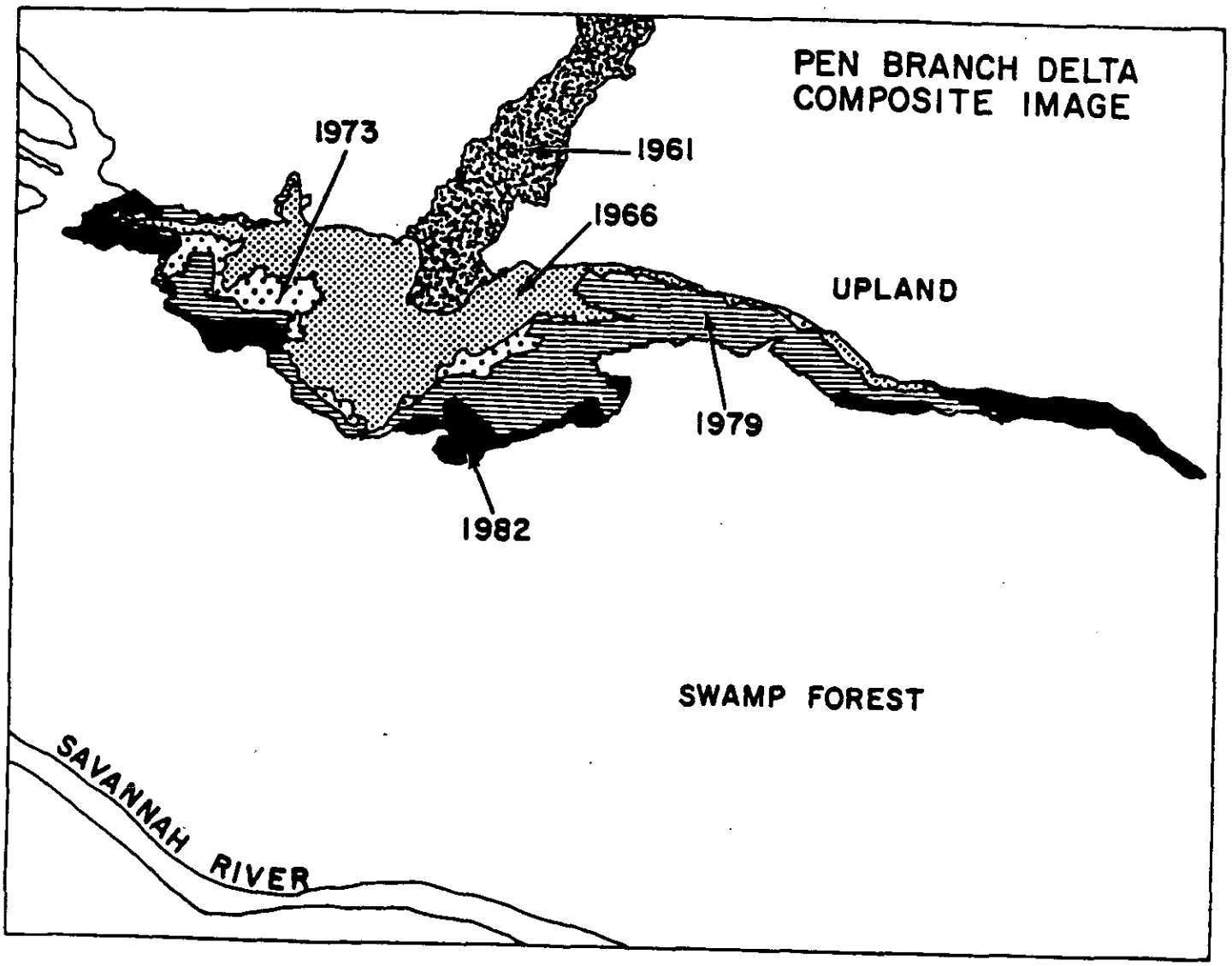

FIGURE 3-14. Pen Branch Delta Expansion Composite Image, 1961 to 1982 (source: Christensen et al., 1984b)

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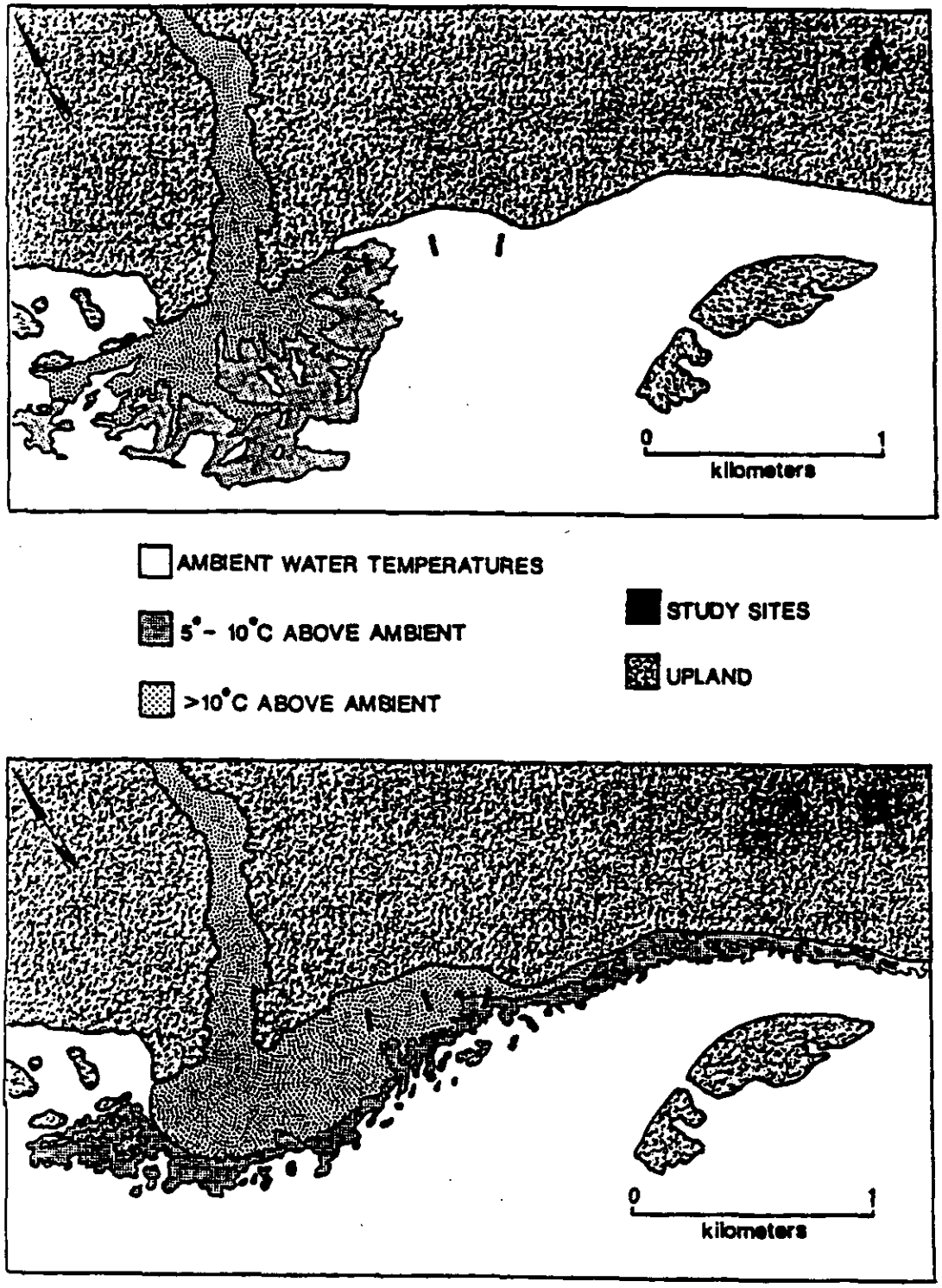

FIGURE 3-15. Thermal Patterns in the Pen Branch Delta Under Non-Flood (A) and Under Flood (B) Conditions of the Savannah River (source: Scott et al., 1986)

3.6.3.3 Four Mile Creek Corridor and Delta

A similar evaluation of the photographic data of the Four Mile Creek Corridor and Delta were conducted (Tables 3-30 and 3-31 and Figures 3-16 and 3-17). As of 1985, the Four Mile Creek impact area covered 450.3 ha (Table 3-31). Impacted Savannah River swamp canopy totaled 357.3 ha and the area in the Four Mile Creek corridor totaled 93 ha. Since late June 1985, C Reactor has been shutdown and early successional revegetation is occurring in the Four Mile Corridor and Delta areas.

The shape and expansion history of the Four Mile Creek Delta impact area are different from other areas of the swamp receiving reactor effluents. Even though Four Mile Creek had a similar flow and temperature history as Pen Branch, the Four Mile Creek impact zone is more than twice as large (357 ha) as the Pen Branch Delta (152 ha).

One explanation of the size different is that the geomorphology of the Four Mile Creek Delta area is unlike the other two deltas (Stephenson, 1982). Hardwood islands and former river channels are common in the Savannah River swamp where the Four Mile Creek thermal effluent dispersed. Steel Creek and Pen Branch deltas have fewer hardwood islands and former river channels in the immediate vicinity. As a result of the local geomorphology, Four Mile Creek discharges to the swamp have spread not only in the traditional deltaic form (similar to Pen Branch and Steel Creek deltas), but also between elevated hardwood ridges in the Savannah River swamp (Figure 3-18).

3.6.3.4 Beaver Dam Creek Delta

In 1952, D Area began discharging heated effluents via a canal to the Beaver Dam Creek area of the SRS river swamp (Figure 3-19). Both the D-Area heavy water facility and the coal-fired powerhouse used Savannah River water for cooling. In addition, water was pumped for the extraction of heavy water (Gladden et al., 1985). Tables 3-32 and 3-33 and Figure 3-20 summarize the history of discharges to and changes in the Beaver Dam Creek Delta area. Canopy decline was observed in 1956 aerial photography. The affected area totaled 19.0 ha and received an average flow of about 120 cfs. During the next eleven years, the Beaver Dam Creek Delta area expanded at variable rates with a maximum rate of 10 ha/yr during 1961-1966. The effluent temperature began to decrease in 1973 and continued to decline until 1978; a concurrent net decline of delta expansion occurred. By 1985, a total of about 14 ha had revegetated in the Beaver Dam Creek area. The annual average effluent temperature declined from 38°C to 27-28°C (Table 3-32). The affected Savannah River swamp delta area of Beaver Dam Creek in 1985 totaled about 160 ha and is revegetating at a rate of about 4.2 ha/yr. In addition to thermal discharges, the Beaver Dam Creek Delta area has also received coal fly ash basin effluent discharge (Evans and Giesy, 1978); coal fly ash deposition appears to have affected at least 8 to 10 ha of swamp (Gladden et al., 1985).

TABLE 3-30

Estimated Impacts and Discharge Conditions to Four Mile Creek Delta from Reactor Discharges, 1955-1985

Year	Total Impacted Area[a] (ha)	Average Expansion Rate of Forest Canopy Mortality (ha/yr)	Average Annual Reactor Discharge (cfs)[b]	Average Annual Temperature (°C)
1955			100[c]	47
1956	0.0		156	60
1957	0.0		220	66
1958		3.2	200	71
1959			273	71
1960			327	71
1961	15.8		384	66
1962			389	67
1963			385	68
1964		16.4	390	66
1965			385	30
1966	97.9		390	67
1967			391	71
1968			395	71
1969			390	70
1970			387	64
1971		18.6	388	65
1972			387	67
1973			387	58
1974	246.8		316	62
1975			352	59
1976			376	62
1977			376	62
1978			376	62
1979		10.4	376	61
1980			377	63
1981			376	63
1982			376	64
1983			375	68
1984	350.8		375	
1985	357.3	6.5		

[a] Greater than 5% canopy loss
[c] Approximate
[b] 35.32 cfs = 1 cms

TABLE 3-31

Area in Each Damage Category for the Four Mile Creek Corridor and Delta[a]

Year	Partial Damage Zone[b]	Savannah River Swamp Total Damage Zone[c]	Total Affected Area
Four Mile Creek Corridor			
1961	7.9	97.9	105.8
1966	10.2	96.5	106.7
1985	32.0	61.0	93.0
Four Mile Creek Delta			
1961	15.8	0.0	15.8
1966	35.2	62.7	97.9
1974	148.9	97.9	246.8
1984	206.7	144.1	350.8
1985	208.7	148.6	357.3

[a] Areas are in hectares (ha).
[b] 5 to 95% canopy loss.
[c] 95 to 100% canopy loss.

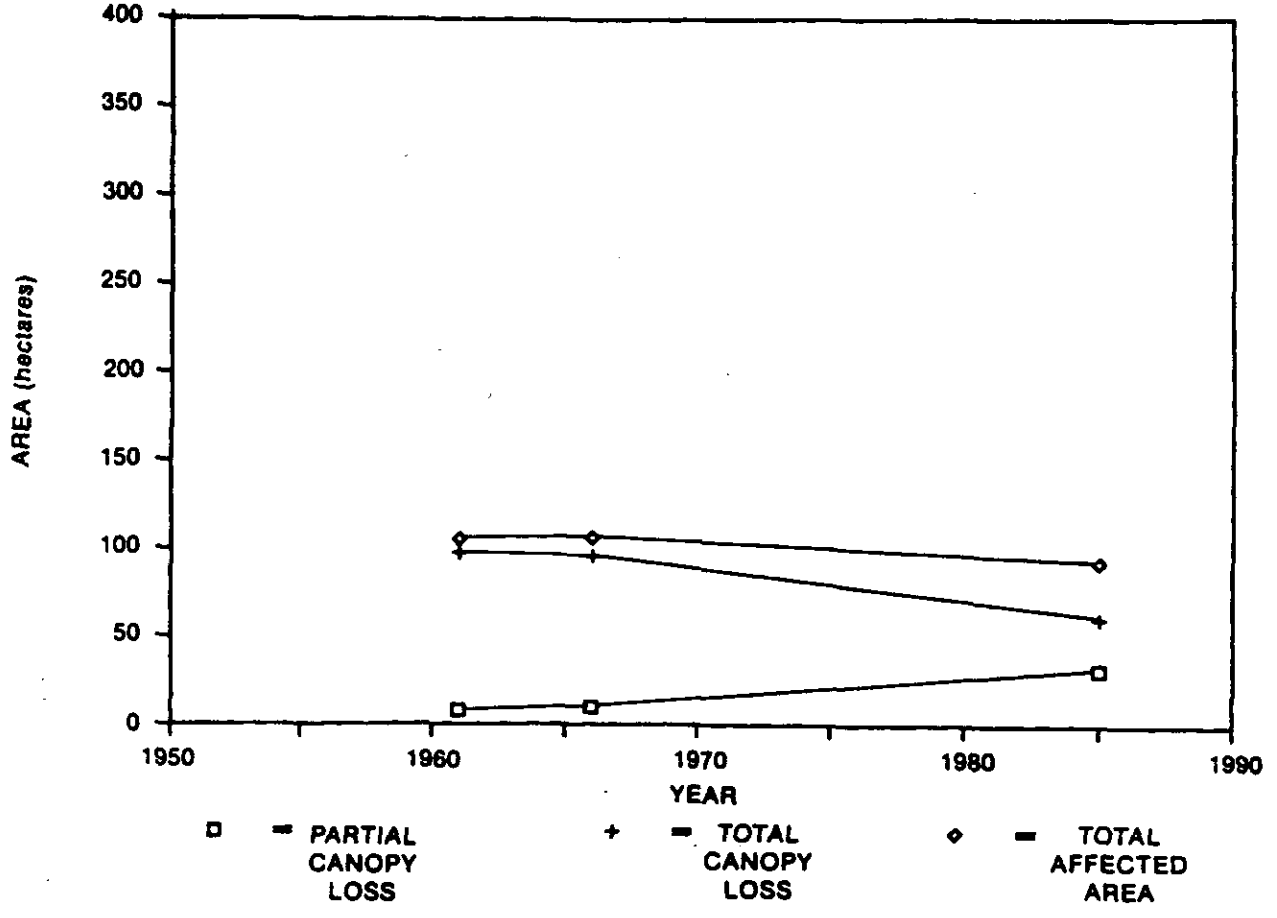

FIGURE 3-16. Four Mile Creek Corridor Changes (Tinney et al., 1986)

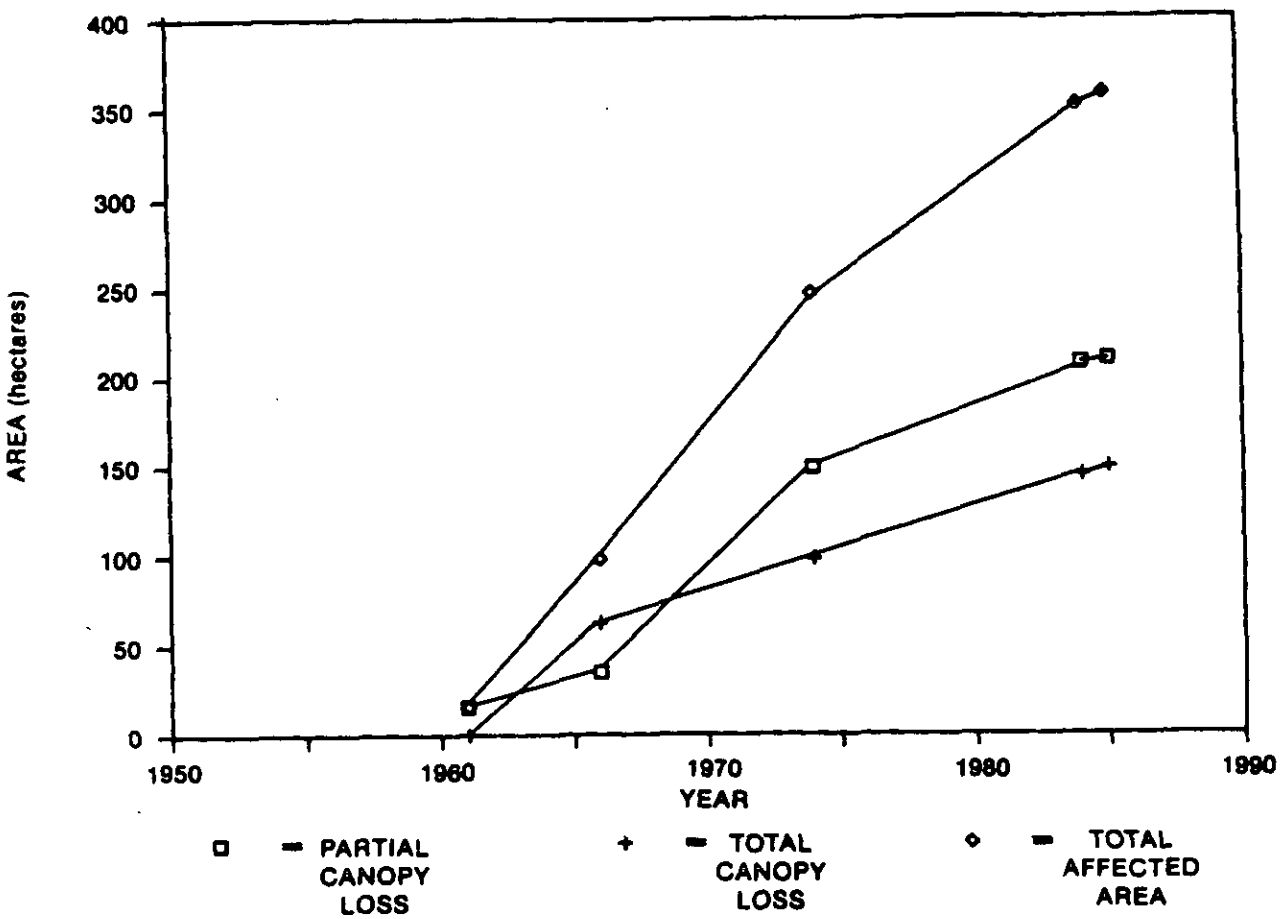

FIGURE 3-17. Four Mile Creek Delta Growth (Tinney et al., 1986)

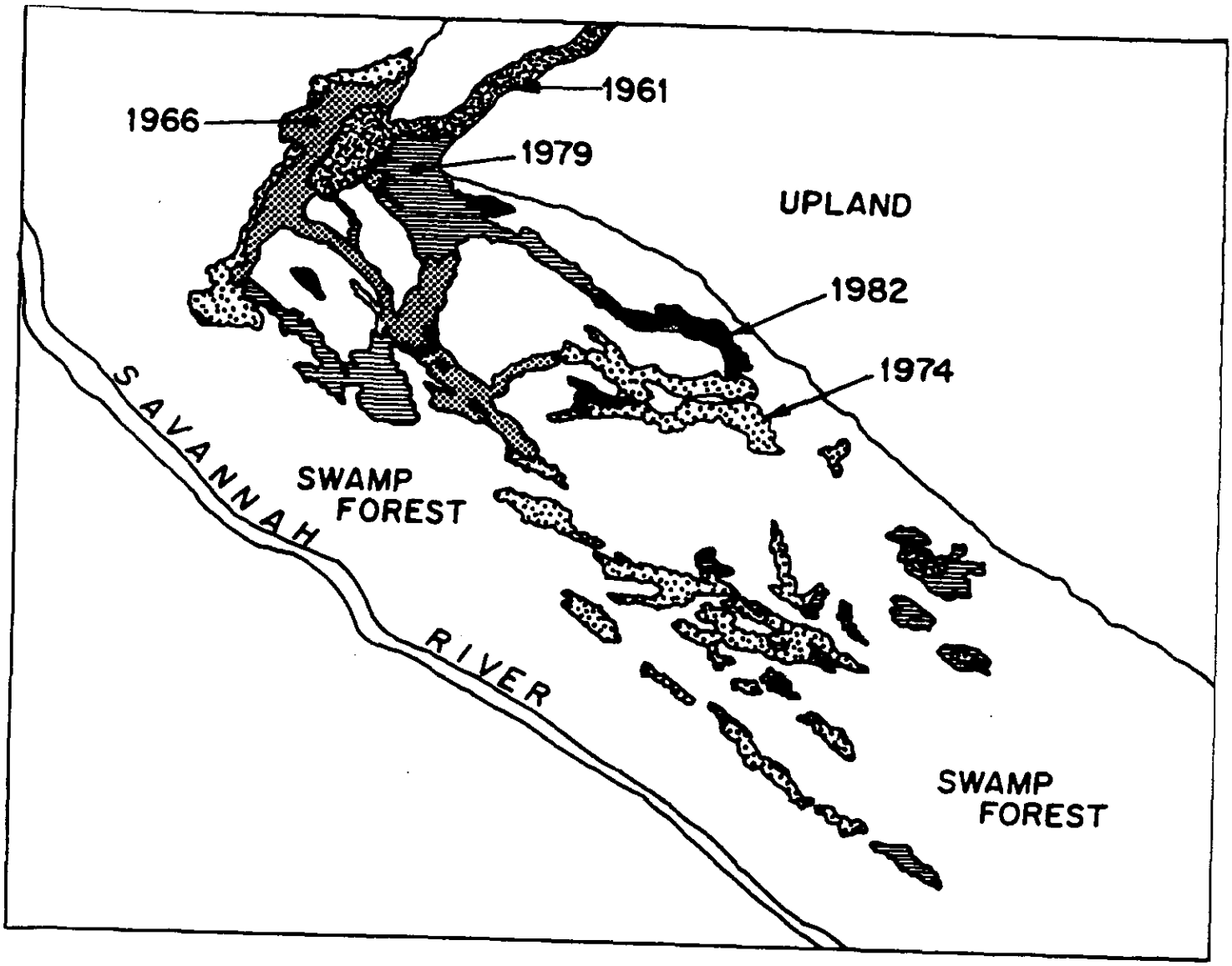

FIGURE 3-18. Four Mile Creek Delta Expansion Composite Image, 1961-1982 (source: Gladden et al., 1985)

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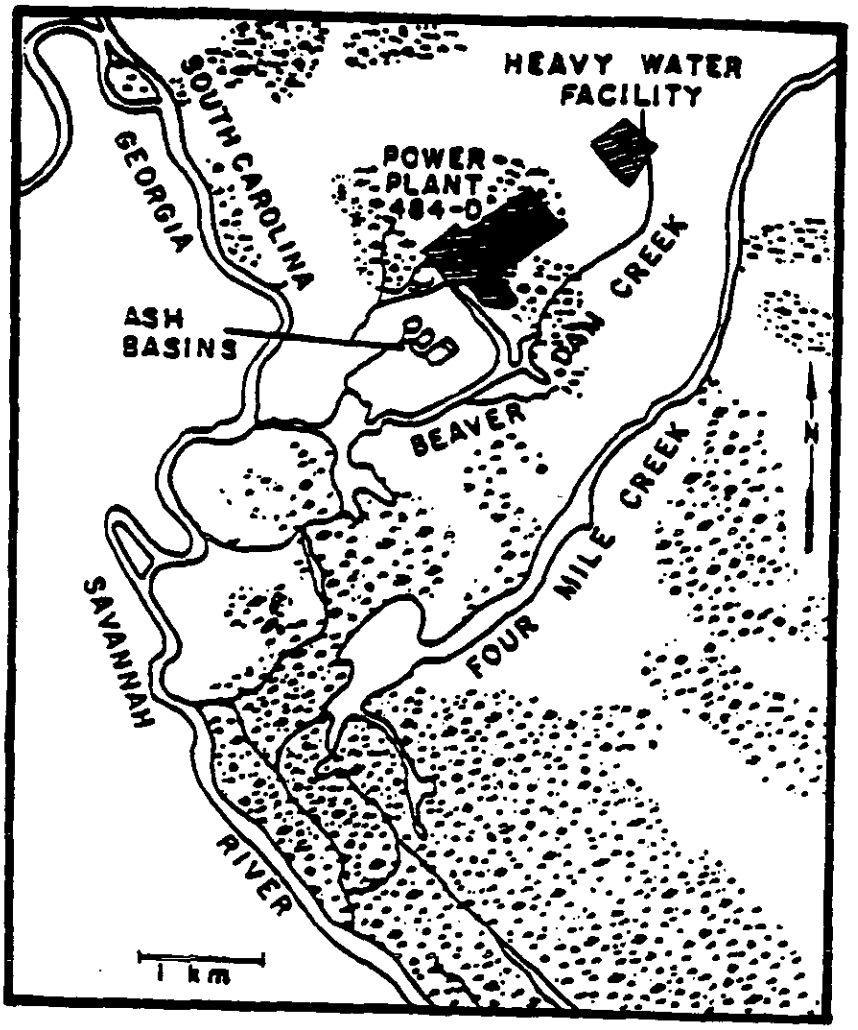

FIGURE 3-19. Savannah River Swamp in the Vicinity of Beaver Dam Creek Showing D Area

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TABLE 3-32

Estimated Impacts and Discharge Conditions to Beaver Dam Creek from D-Area Discharges, 1952-1985

Year	Total Impacted Area (ha)	Average Expansion Rate of Forest Canopy Mortality (ha/yr)	Average Annual Discharge (cfs)[a]	Average Annual Temperature (°C)[b]
1952		|		-
1953		3.6	-	-
1954		|	-	-
1955		|	-	-
1956	19.0	-	121	-
1957		|	123	-
1958		7.0	108	-
1959		|	104	-
1960		|	91	-
1961	54.0	-	88	-
1962		|	89	-
1963		|	74	-
1964		9.9	88	-
1965		|	-	-
1966	103.7	-	-	-
1967		|	-	-
1968		|	-	-
1969		|	-	-
1970		7.9	-	-
1971		|		
1972		|	-	38
1973		|	-	38
1974	167.0	-	-	36
1975		|	92	34
1976		-0.6[c]	78	32
1977		|	78	28
1978	164.8	-	74	27
1979		|	79	28
1980		-2.0[c]	82	27
1981		|	113	27
1982	157.0	-	90	27
1983		3.6	-	27
1984	164.1	|	-	-
1985	159.9	-4.2[c]	-	-

[a] For the years 1956-1964, the data are for the 681-5G pumphouse, which supplies river water to D Area. For the years 1975-1982, the data are flow measurements at the Health Protection Monitoring Station on Beaver Dam Creek before the flow discharges into the Savannah River swamp on SRP. 35.32 cfs = 1 cms.

[b] For the years 1972-1983, the temperature data are annual average data at the Health Protection Monitoring Station on Beaver Dam Creek before the flow enters the Savannah River swamp on SRP.

[c] Revegetation rate.

TABLE 3-33

Area in Each Impact Category for the Beaver Dam Creek Delta[a]

Year	Partial Canopy Loss Zone[b]	Total Canopy Loss Zone[c]	Total Affected Area	Average Expansion Rate of Forest Canopy Mortality Rate (ha/yr)
1956	19.1	-	19.1	4.8
1961	40.4	13.6	54.0	7.0
1966	76.9	26.8	103.7	9.9
1974	77.1	89.9	167.0	7.9
1978	67.3	97.5	164.8	-0.6
1982[d]	76.1	80.9	157.0	-2.0
1984	84.0	80.1	164.1	3.6
1985	85.4	74.5	159.9	-4.2

[a] Areas are in hectares (ha).
[b] 5 to 95% canopy loss.
[c] 95 to 199% canopy loss.
[d] Data for 1982 and earlier are from Gladden et al. (1985).

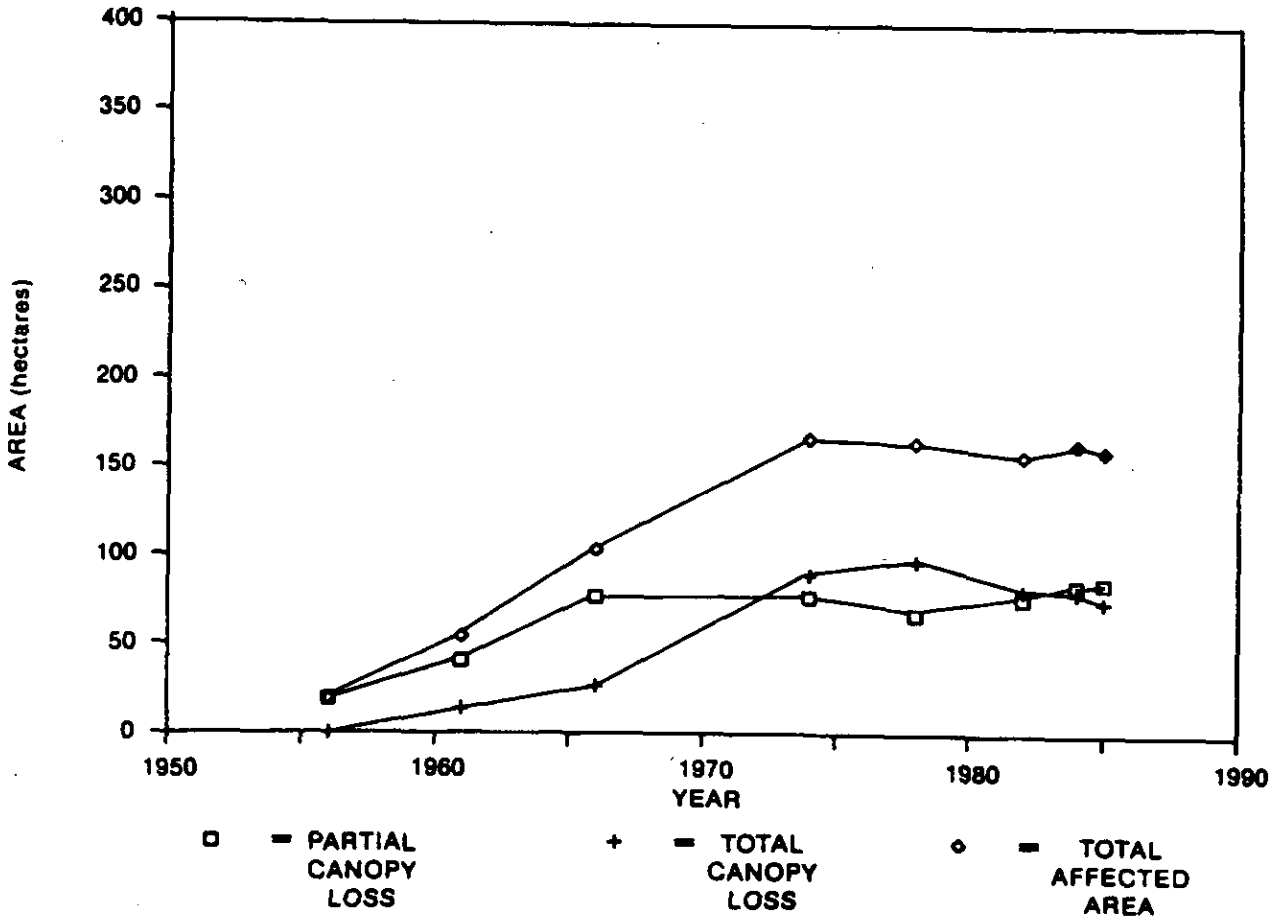

FIGURE 3-20. Beaver Dam Creek Delta Growth (source: Tinney et al., 1986)

3.6.3.5 Summary of Photographic Surveys, 1951-1985

Thermal loading, flooding, and siltation resulting from SRS operational discharges have visibly altered about 1020 ha of former SRS creeks and the Savannah River swamp (Table 3-34). Most of the affected areas include former bottomland hardwood and cypress-tupelo forest. Cypress-tupelo losses in the swamp are being partially offset by revegetation primarily with bottomland hardwood scrub-shrub species in the Beaver Dam and Steel Creek delta areas. Revegetation and initial invasion of scrub-shrub species has begun in the Four Mile Creek corridor and delta areas since C-Reactor shutdown in late June 1985.

3.6.4 Multispectral Scanner (MSS) Surveys

Portions of the Pen Branch, Four Mile Creek, Steel Creek, and Beaver Dam Creek deltas in the Savannah River swamp were evaluated for wetlands vegetation change using aircraft multispectral scanner (MSS) data acquired at 1220 m and 2440 m altitude from 1981 to 1985. The MSS data for each delta were registered and classified, and wetlands vegetation change detection categories were determined (Christensen et al., 1986; Jensen et al., 1983; Jensen et al., 1984b; Jensen et al., 1986a; Jensen et al., 1986b; Jensen et al., 1987). Portions of the Pen Branch and Four Mile Creek deltas each continued to lose additional swamp forest from 1981 to 1985. However, successional wetland communities regrew on portions of the Beaver Dam Creek, Four Mile Creek, and Steel Creek deltas.

One of the most powerful uses of digital remote sensing data is to evaluate land-use/land cover changes through time. Remote sensing change detection combines multiple-date data and image analyses to identify both temporal and spatial changes. Multispectral scanner (MSS) data analysis is a quantitative method that discriminates among a variety of vegetation types (Jensen, 1986). Baseline vegetation maps of the Savannah River swamp and the four delta swamp areas (Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek) have been prepared using aircraft MSS data (Jensen et al., 1984a, 1984b; Gladden et al., 1985) (Figure 3-21). However, maps from different years had not been compared to detect wetlands vegetation change. Satellite MSS data (Landsat and Thematic Mapper) are commonly used to detect and monitor change. For the most part, satellite data are useful for large-scale change detection, because the ground resolution currently available with Thematic Mapper is 30 x 30 meters. Aircraft-based sensors fly lower and have ground resolutions of a few meters. At this scale, much more detailed discrimination of vegetation types and area estimates can be made. However, change detection using high-resolution, aircraft MSS data is seldom conducted. Classification consistency and registration difficulties are probably the two major reasons that aircraft MSS data are infrequently used for change detection studies. Recent research on the Savannah River swamp deltas has addressed both of these considerations (Christensen et al., 1986; Jensen et al., 1987).

TABLE 3-34

Estimated Impacted Wetland Areas in the SRS Thermal Creeks and Savannah River Swamp, 1985

	Area (hectares)		
	Stream Corridors	Swamp Deltas	Total
Steel Creek	82.9	81.9	164.8
Pen Branch	92.6	151.8	244.4
Four Mile Creek	93.0	357.3	450.3
Beaver Dam Creek	-	159.9	159.9
Total	268.5	750.9	1019.4

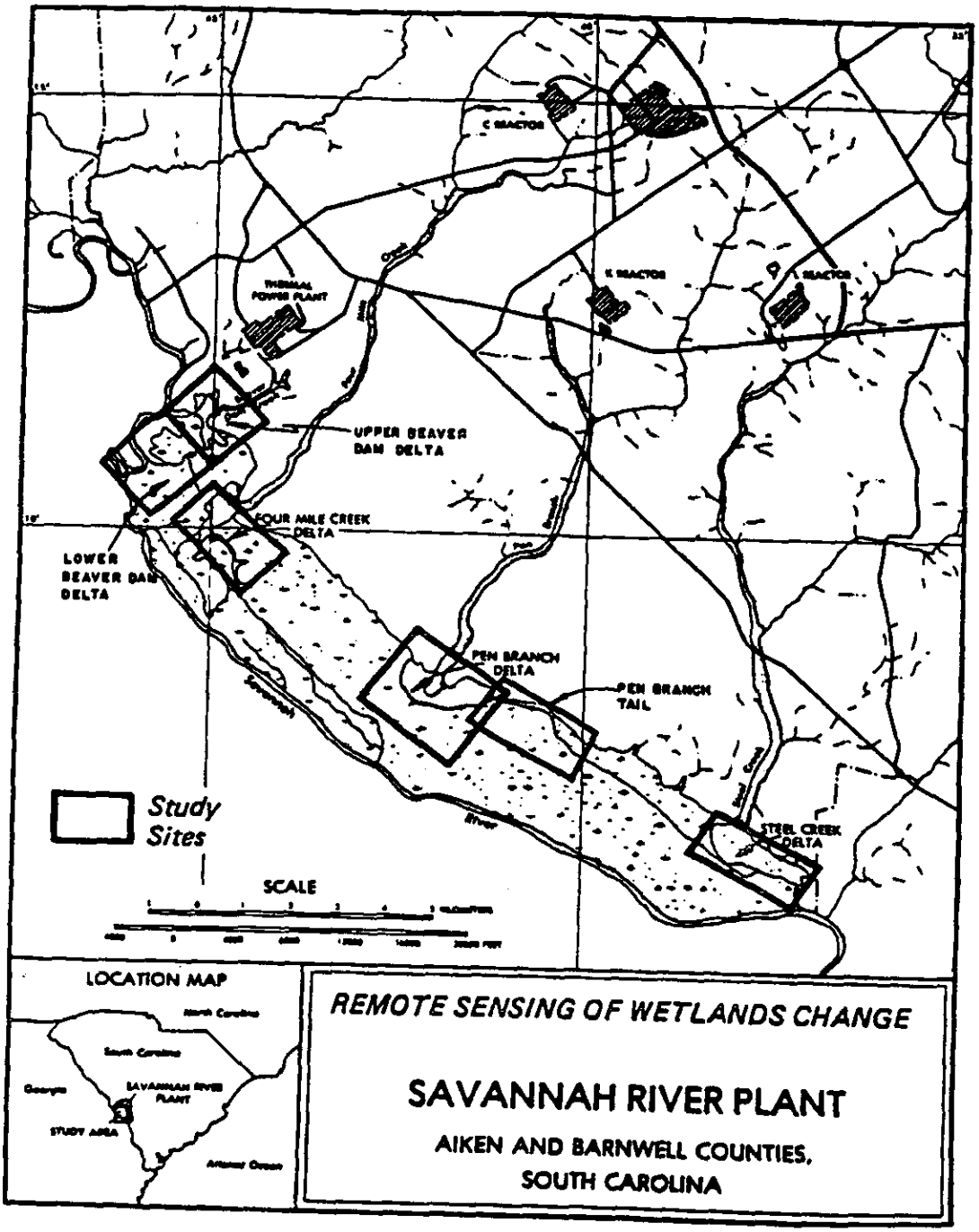

FIGURE 3-21. Multispectral Scanner Survey Areas for the Wetlands Change Detection Studies in the SRS Savannah River Swamp

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3.6.4.1 Multispectral Scanner (MSS) Data

A Daedalus AADS-1260 multispectral scanner acquired data of the Savannah River swamp on April 31, 1981, May 25, 1983, and April 6, 1984. Another Daedalus scanner, the AADS-1268, which contains spectral bands similar to those on the Thematic Mapper satellite was used to collect data on April 29, 1985. The data were collected in mid-morning at an altitude of either 1220 m and 2440 m above ground level (AGL) and an instantaneous-field-of-view (IFOV) of 2.5 milliradians, producing ground pixel sizes of either 2.8 x 2.8 m or 5.6 x 5.6 m, respectively.

3.6.4.2 Registration Procedures

For change detection, accurate image-to-image alignment, or registration, is essential. In registration, common points in one image are geographically matched to the coordinate grid (x,y locations) of another image. Rectification is basically the same process, but an image is registered to a map instead.

Both satellite and aircraft data contain varying degrees of image distortion. The distortion is generally caused by satellite or aircraft movements (roll, pitch, and yaw) while the sensor is scanning. As a result, the raw data from one flyover may not match the data of the same area on another date. Consequently, a series of geometric correction steps are performed on the raw MSS data before the data can be evaluated for change. Compensation for sensor platform movements can be made by using ground control points (GCPs). A GCP is a surface feature visible on the image and identifiable on a reference map or image. Highway, powerline, and railroad intersections, small water bodies, and buildings are good GCPs. The process involves relating GCP coordinates (row and column, pixel locations) from the image to the base image (or map) coordinate counterparts. Each pixel can then be referenced by the same coordinate in both sets of data (Christensen et al., 1986).

Typical of large wetland areas, few identifiable GCPs are visible on planimetric maps covering the Savannah River swamp. Consequently, the 1983, 1984, and/or 1985 MSS data of each study area were registered to the 1981 data, and not rectified to a map. Ground control points from each image were used in a least-squares regression analysis to calculate six coefficients for two, first-order, linear transformation equations. Coordinates from the same GCPs on the registered images were compared to the base image coordinates as a quantitative measure of registration accuracy. If GCPs did not match, the registration procedure was repeated using the new output image GCP coordinates. Common points such as tips of hardwood islands, isolated trees, tree lines, and road intersections were identified, and row and column coordinates recorded from both images. Thus, distributed GCPs were selected throughout the image scenes (Christensen et al., 1986).

Studies have found that best geometric correction results are achieved when image size is minimized (Ethridge and Mikhail, 1977; Leicke, 1980; McClone and Mikhail, 1985). Therefore, small 190 to 250 ha subscenes of the delta areas were selected and repeated registrations where attempted (Figure 3-21). The areas matched reasonably well after the second registration (Christensen et al., 1986).

3.6.4.3 Wetlands Classification and Change Detection Analyses

Even though 11 spectral bands were available for analysis on each date, only four were used in each unsupervised classification. Based on transformed divergence statistics computed by Jensen et al. (1984b) and Jensen (1986), band 5 (0.55-0.60 μm), band 7 (0.65-0.70 μm), band 8 (0.70-0.79 μm), and band 10 (0.92-1.10 μm) account for most of the variance in the AADS-1260 aircraft MSS data when performing wetland classification in this area. For the AADS-1268, band 3 (0.52-0.60 μm), band 5 (0.63-0.69 μm), band 8 (0.91-1.05 μm), and the middle-infrared band 9 (1.55-1.75 μm) are optimum. Other wetland mapping studies have found that one green, one red, and at least one infrared band are usually optimal (Best et al., 1981).

Using unsupervised methods, up to 50 natural clusters were identified for each date and assigned using minimum distance criteria to one of six possible vegetation and landcover classes (Table 3-35) determined from previous studies of the Savannah River swamp (Jensen et al., 1984b; Christensen et al., 1985, 1986; Jensen et al., 1986). Independently classified images were evaluated for change using a post-classification, cross-tabulation approach (Weismiller et al., 1977; Wickware and Howarth, 1981). Wetlands vegetation change areas were confirmed with vertical and oblique aerial photography. Images of wetlands vegetation change and statistics were produced.

3.6.4.4 Wetlands Change Detection Results

3.6.4.4.1 Pen Branch Delta--Central Portion, 1981-1984

The April 1984 MSS data were registered to both the May 1983 and March 1981 data for a 190-ha area centered on the Pen Branch Delta (Figure 3-21). The 1984 to 1981 data registrations (image registrations) were better (Figure 3-22). Details of registration procedures, ground control points, and classification procedures are given in Mackey et al., 1987.

The most obvious difference between 1981 and 1984 is the emergent marsh expansion into thinned cypress-tupelo areas. About 12 ha of cypress-tupelo were replaced by NPE and PE (Table 3-36). The majority of the cypress-tupelo loss area is adjacent to the existing thermal delta or southeast along the Savannah River swamp terrace edge.

TABLE 3-35

Classification Scheme for the Pen Branch, Four Mile Creek, Beaver Dam Creek, and Steel Creek Delta MSS Wetland Maps

Class	Representative Species	
	Common Name	Scientific Name
Open-Water (W)	-	-
Persistent Emergent Marsh (PE)	Knotweed	*Scirpus cyperinus*
	Cutgrass	*Leersia* spp.
	False nettle	*Boehmeria cylindrica*
Nonpersistent Emergent Marsh (NPE)	Water primrose	*Ludwigia* spp.
	Hydrolea	*Hydrolea quadrivalvis*
Scrub-Shrub (SS)	Willow	*Salix* spp.
	Buttonbush	*Cephalanthus occidentalis*
Deciduous Swamp or Cypress-Tupelo Forest (DSF)	Bald cypress	*Taxodium distichum*
	Tupelo gum	*Nyssa aquatica*
Deciduous Bottomland Forest (DBF)	Oak	*Quercus* spp.
	Loblolly Pine	*Pinus taeda*
	Sweetgum	*Liquidambar styraciflua*
	Red maple	*Acer rubrum*
	Hickory	*Carya* spp.

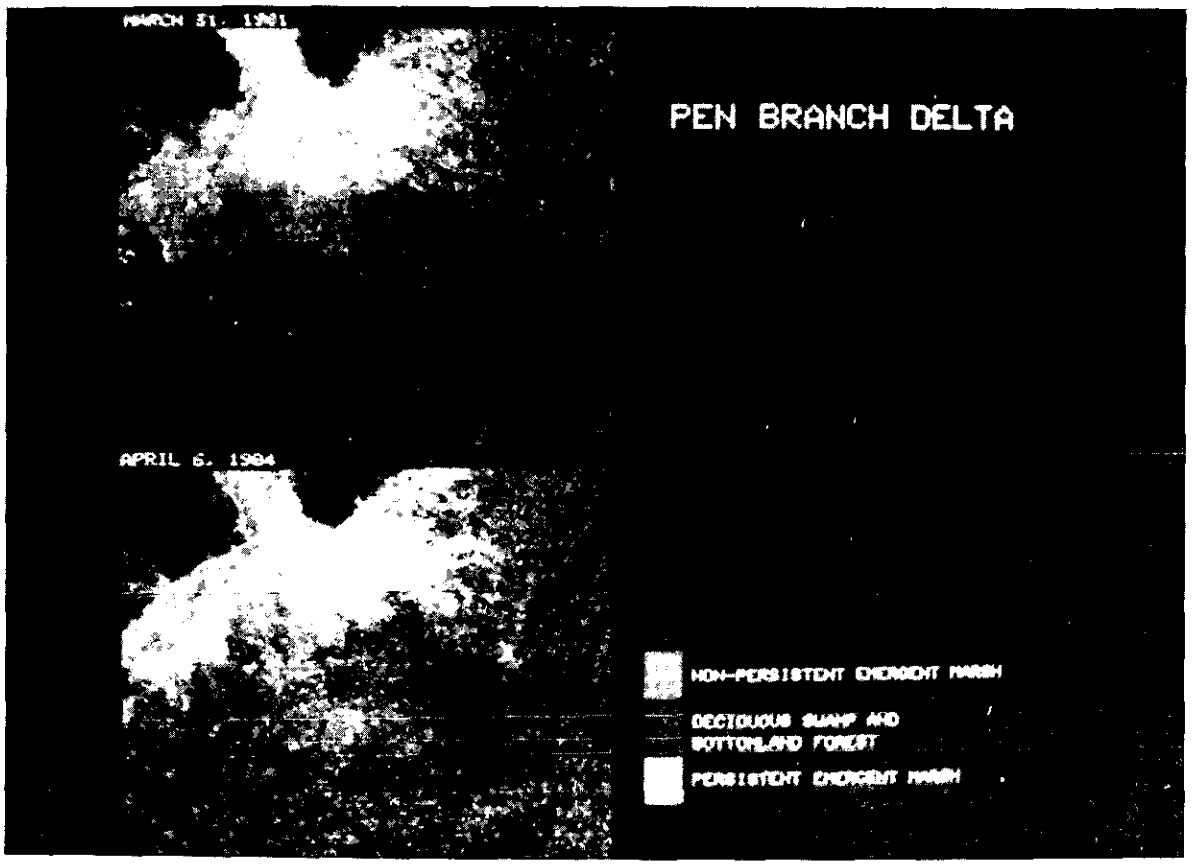

FIGURE 3-22. Wetlands Classification of the Pen Branch Delta for March 1981 and April 1984

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TABLE 3-36

The SRS Savannah River Swamp Delta Wetlands Change Detection

Wetland Vegetation Change Classes	Delta Areas, Hectares			
	Pen Branch[a]	Four Mile Creek[a]	Upper Beaver Dam Creek[b]	Steel Creek[c]
DSF to SS	NA	3.2	5.3	NC
DSF to PE	1.2	1.6	NC	NC
DSF to NPE	10.9	9.3	NC	NC
SS+PE to NPE	NA	NA	1.6	NA
SS to DBF	NA	0.8	10.1	NC
PE to SS	NA	1.6	6.9	NC
PE to DBF	NA	1.6	5.3	NC
NPE to W	NA	NA	2.8	NC
NPE to PE	NA	NC	NC	4.0
NPE to SS	NA	NC	NC	5.7
NPE to DSF	NC	NC	NC	5.3

[a] Total analysis area 190 ha from 1981-1984.
[b] Total analysis area 190 ha from 1981-1983.
[c] Total analysis area 240 ha from 1981-1984.

DBF - Deciduous Bottomland Forest
DSF - Deciduous Swamp Forest (cypress-tupelo)
SS - Scrub-Shrub
NPE - Nonpersistent Emergent Marsh
PE - Persistent Emergent Marsh
W - Open Water
NA - Not applicable because of limited vegetation classes
NC - No change (<0.5 ha)

Source: Mackey (1987)

3.6.4.4.2 Pen Branch Delta--Tail Portion, 1981-1985

Expansion of the Pen Branch Delta has occurred southeast of the main portion of the delta along the SRS Savannah River swamp terrace edge. The Pen Branch "tail" extends southeast for approximately 3 km along an upland terrace adjacent to the Savannah River swamp. This area is influenced by thermal effluents, especially during flood events (Figure 3-15). A separate evaluation of this area was conducted using aircraft MSS data taken March 31, 1981, and April 29, 1985. Two 375-ha subsets from the 1981 and 1985 MSS data were evaluated (Figure 3-23).

It was possible to classify the MSS data into the following wetland vegetation classes once the 1981 and 1985 imagery were registered to one another (Table 3-37):

- W - Open Water
- EM - Emergent Marsh (persistent and nonpersistent)
- DSF - Deciduous Swamp Forest, and
- DBF - Deciduous Bottomland Forest

One additional class of Deciduous Swamp Forest, referred to as Transition Deciduous Swamp Forest (T-DSF), was found in both the 1981 and 1985 imagery. T-DSF consists of cypress-tupelo swamp forest that had a sparse, stressed canopy which allowed radiant flux from emergent marsh below to be integrated within a typical pixel. The stressed cypress-tupelo was documented in situ in the Pen Branch tail by Scott et al. (1986) and radiometrically by Jensen et al. (1986b).

The wetlands classification maps of the 1981 and 1985 data sets are shown in Figure 3-24. The two maps were compared to document the change taking place from 1981 to 1985. The stressed cypress-tupelo (T-DSF) present in 1981 and 1985 is shown in Figure 3-24. Areas that did not change are shown in black. The change from Deciduous Swamp Forest (DSF) to Transition-DSF, Emergent Marsh, or Open Water are shown in Figure 3-25. The statistics associated with these changes are summarized in Table 3-38.

3.6.4.4.3 Steel Creek Delta

3.6.4.4.3.1 Steel Creek Delta--1981-1984

The Steel Creek Delta was formed between 1954 and 1968 by cooling water discharges from L and P reactors. The visibly impacted zone covers about 140 ha and is shaped in the traditional deltaic form, with an extended tail stretching parallel to the adjacent upland terrace and Savannah River (Tinney et al., 1986).

MSS data for an area of 240 ha for 1981 and 1984 centered on the Steel Creek Delta was registered (Figures 3-21 and 3-26). Descriptions of wetlands classification techniques used with these data are described in Christensen et al., 1986.

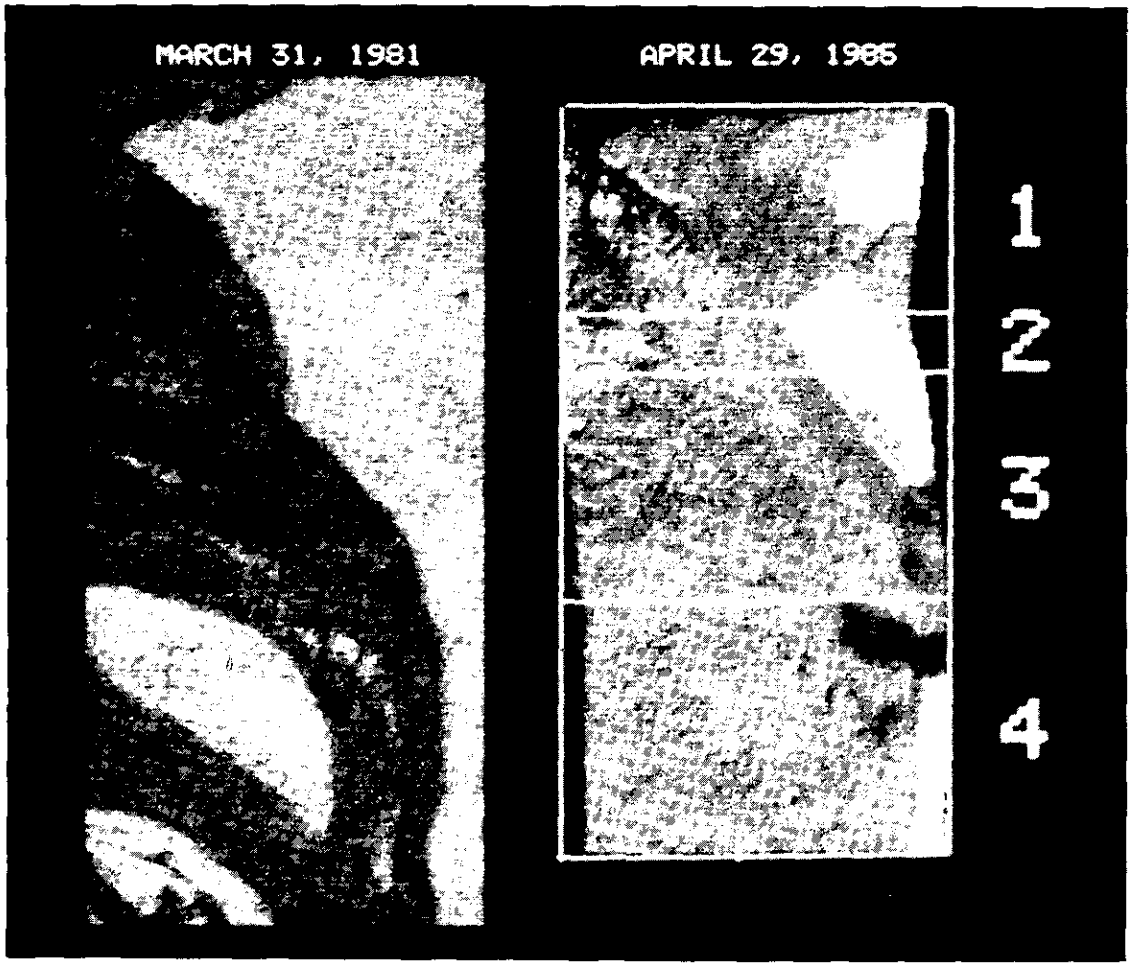

FIGURE 3-23. April 29, 1985, Aircraft MSS Data of the Pen Branch "Tail" Area were Registered to the March 31, 1981, Data Using Piecewise-Linear, Image-to-Image Registration Procedure.

TABLE 3-37

Wetland Classification Scheme for the Pen Branch "Tail" Using March 31, 1981, and April 29, 1985, Aircraft MSS Data

Wetlands Class	Representative Species	
	Common Name	Scientific Name
W - Open Water		
EM - Emergent Marsh	Knotweed	*Scirpus cyperinus*
	Cutgrass	*Leersia* spp.
	False Nettle	*Boehmeria cylindrica*
	Water Primrose	*Ludwigia* spp.
	Hydrolea	*Hydrolea quadrivalvis*
DSF - Deciduous Swamp Forest	Bald Cypress	*Taxodium distichum*
	Tupelo Gum	*Nyssa aquatica*
DBF - Deciduous Bottomland Forest	Oak	*Quercus* spp.
	Sweetgum	*Liquidambar styraciflua*
	Red Maple	*Acer rubrum*
	Hickory	*Carya* spp.

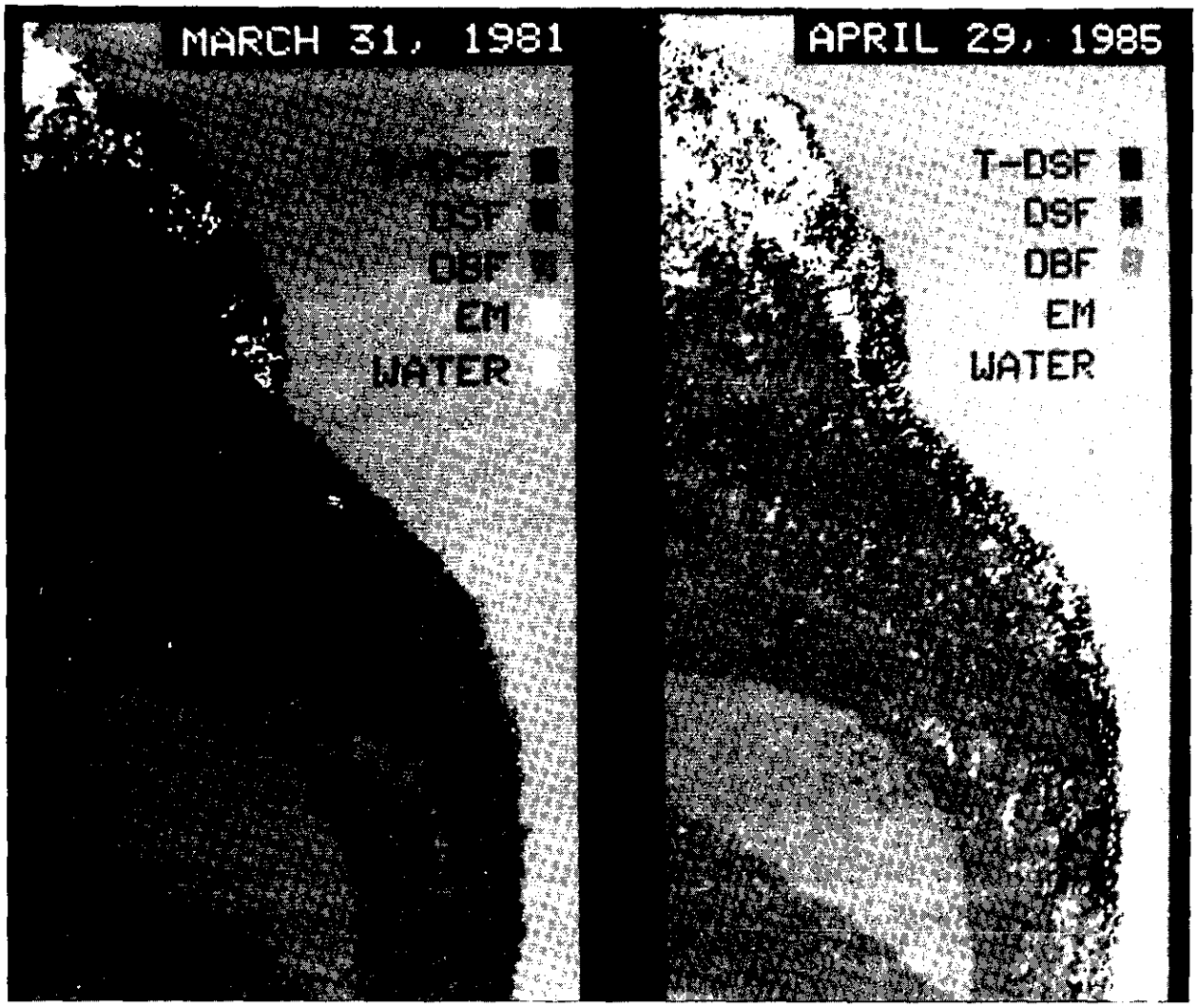

FIGURE 3-24. Wetland Maps Derived from Classification of the March 31, 1981, and April 29, 1985, Aircraft MSS Data of the Pen Branch "Tail" Area. The classes are Transition Deciduous Swamp Forest (T-DSF) composed of stressed Cypress-Tupelo, Deciduous Swamp Forest (DSF), Deciduous Bottomland Forest (DBF), Emergent Marsh (EM), and Water (W) (source: Jensen et al., 1987)

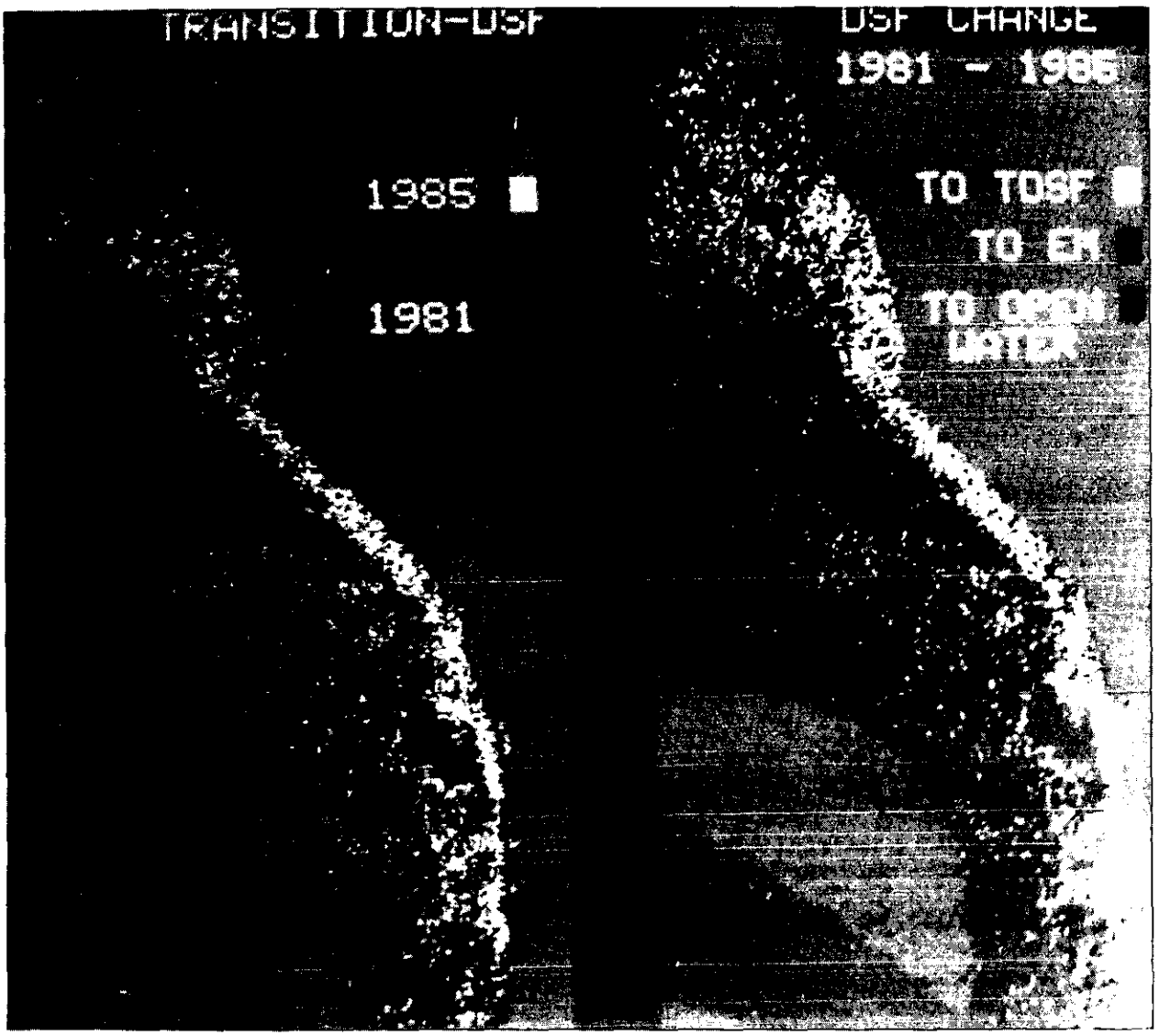

FIGURE 3-25. Change Between the March 31, 1981, and April 29, 1985, Wetland Maps of the Pen Branch "Tail" Area as Determined by a Post-Classification Comparison. The stressed Cypress-Tupelo class (Transition-DSF) existed in 1981. However, it had expanded by 1985. The transition from indigenous Deciduous Swamp Forest (DSF) to the stressed wetland vegetation (T-DSF) or to other land cover (Emergent Marsh or Open Water) is shown.

TABLE 3-38

Pen Branch "Tail" Wetlands Change Detection Using March 31, 1981, and April 29, 1985, Aircraft MSS Data

Wetlands Change Class	Hectares
Deciduous Swamp Forest (DSF) to Emergent Marsh (EM)	3.64
Deciduous Swamp Forest (DSF) to Transition-DSF (T-DSF)	12.14
Deciduous Swamp Forest (DSF) to Open Water (W)	9.30
Transition-DSF (T-DSF) to Emergent Marsh (EM)	2.42
Transition-DSF (T-DSF) to Open Water	1.21
Transition-DSF (T-DSF) No Change	5.66

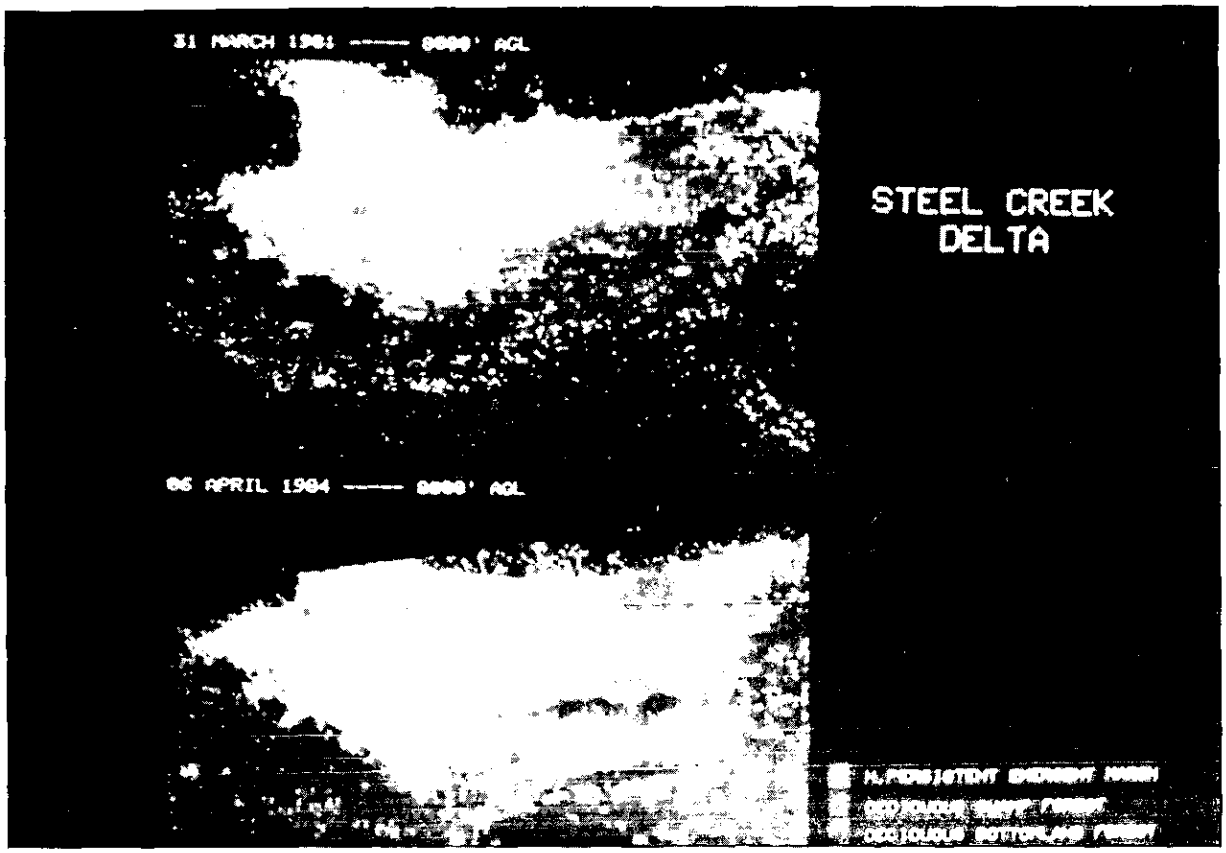

FIGURE 3-26. Wetlands Classification of the Steel Creek Delta in March 1981 and April 1984 (Source: Christensen et al., 1986)

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Steel Creek Delta revegetation has been well documented (Sharitz et al., 1974b; Smith et al., 1981; Mackey, 1982; Jensen et al., 1984b; Christensen et al., 1984b, 1986; Gladden et al., 1985; Mackey et al., 1987). Earlier Steel Creek Delta wetland maps based on ground surveys and vertical aerial photographic interpretation show fairly distinct communities, distributed according to sedimentation patterns and water levels (Smith et al., 1981). Successional vegetation changes since 1981 continue to proceed on the Steel Creek Delta (Table 3-36). The most obvious change observed with the MSS data was the extensive replacement of PE with SS (11.3 ha) in the center portion of the delta (Figure 3-27). Sediment accumulations from past reactor discharges have raised this part of the delta, keeping water depths lower and favoring SS invasion and establishment. SS also expanded in the water marsh areas, replacing 5.7 ha of NPE. Four additional hectares of PE colonized former NPE areas. Most of the thinned cypress-tupelo (DSF) canopy consolidated outside the major delta area and hardwood islands (5.3 ha of NPE to DSF) (Christensen et al., 1986).

3.6.4.4.3.2 Steel Creek Delta--1981-1985

To evaluate changes in the Steel Creek Delta further, MSS data were collected on April 26, 1985 and compared to the March 31, 1981 data. The 1981 and 1985 data were classified into the following wetland vegetation classes:

- W - Water
- EM - Emergent Marsh (Persistent and Nonpersistent)
- DSF - Deciduous Swamp Forest, and
- DBF - Deciduous Bottomland Forest

The wetlands classification maps of the March 31, 1981 and April 26, 1985 data sets are shown in Figure 3-28. The black areas in the swamp are Deciduous Bottomland Forest (DBF). The upland areas of the 1981 and 1985 classification maps were "masked out" by overlaying a digitized boundary onto both classification maps. The wetland acreage statistics for the 1981 and 1985 classification maps are shown in Tables 3-39 and 3-40, respectively.

The classification maps were compared to document the change from 1981 to 1985. A map of this change is shown in Figure 3-29. The results are summarized in Table 3-41. It is important to remember that with the restart of L Reactor, additional water is present in the Steel Creek Delta in 1985. Also, the delta wetlands vegetation changed rapidly from 1981 to 1985. Approximately 1.9 ha of Persistent Emergent March (PE) changed to Nonpersistent Emergent Marsh (NPE). About 14 ha of PE changed into Scrub-Shrub. Approximately 1.1 ha of NPE changed into Persistent Emergent Marsh (PE). Also 8.6 ha of NPE changed into Scrub-Shrub (SS). Some NPE changed into water (3.3 ha). Some Scrub-Shrub (SS) (3.3 ha) changed into PE and 1.4 ha of NPE in certain regions of the delta.

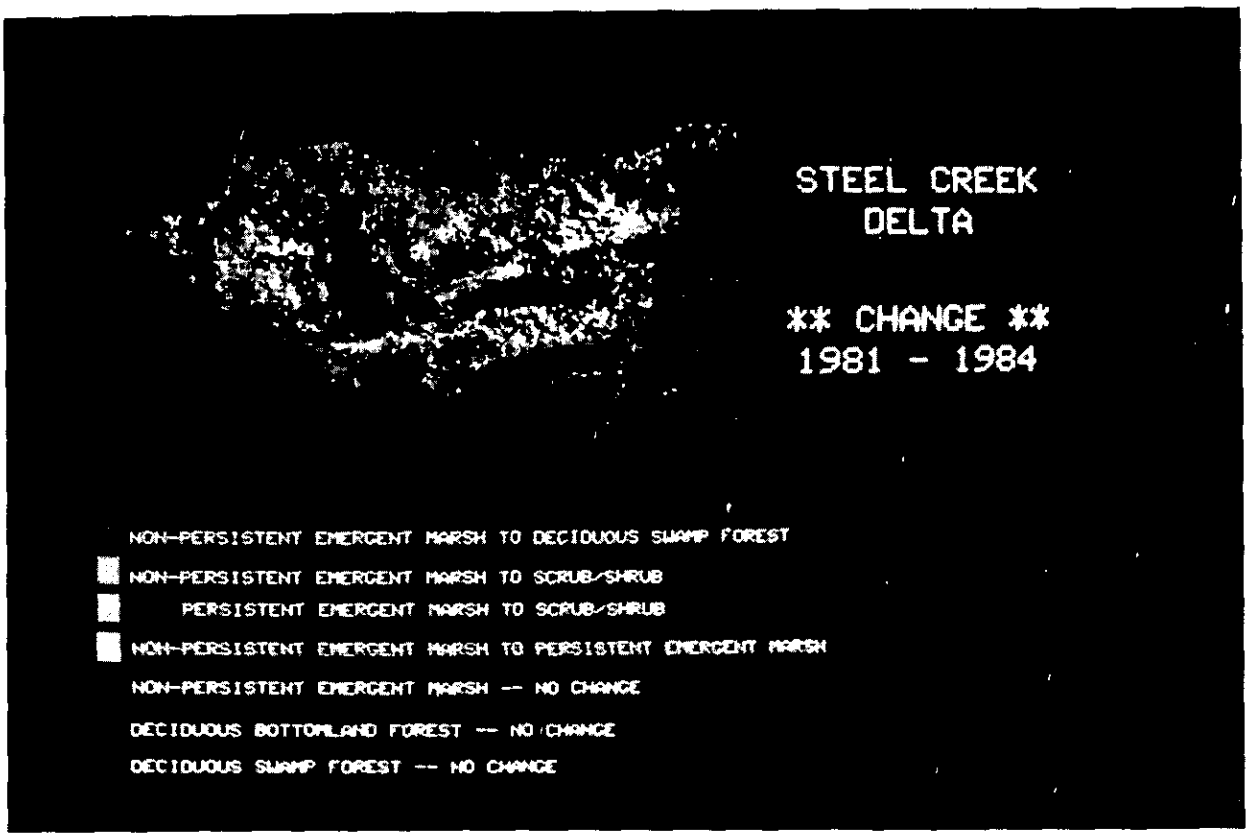

FIGURE 3-27. Steel Creek Delta Wetlands Change from 1981 to 1984. Black represents areas of no change. Invasion and establishment of Scrub/Shrub (SS) and Persistent Emergent Marsh (PE) Accounted for most of the wetlands change.

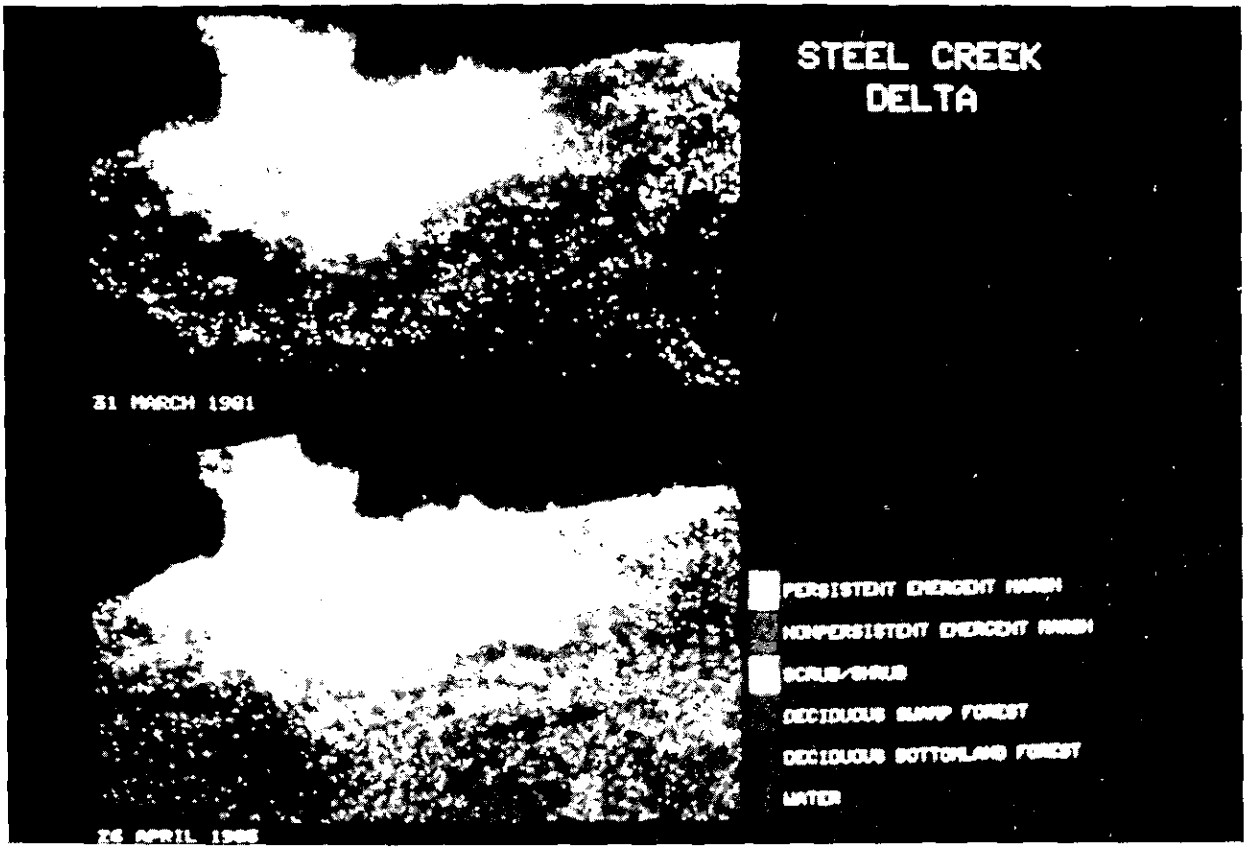

FIGURE 3-28. **Wetland Map Derived from Unsupervised Classification of the March 1981 and April 1985 Aircraft MSS Data.** The April 26, 1985 classification represents a grouping of the two Scrub/Shrub (SS) categories, willow and buttonbush, and the two Deciduous Swamp Forest (DSF) categories Tupelo and Cypress, into SS and DSF, respectively.

TABLE 3-39

Steel Creek Delta Wetland Areas on March 31, 1981, and April 26, 1985, Using Aircraft MSS Data

Wetland Classes	March 31, 1981		April 26, 1985	
	Hectares	Percentage	Hectares	Percentage
Water	0.00	0.00	4.26	1.79
NPE	29.75	12.53	16.33	6.84
PE	27.07	11.40	11.32	4.74
SS	28.17	11.87	56.82	23.81
DSF	82.04	34.56	80.57	33.75
DBF	14.40	6.07	13.47	5.64

TABLE 3-40

Steel Creek Delta Wetland Areas on April 26, 1985, Using Aircraft MSS Data with Improved Discrimination of Scrub-Shrub and Deciduous Swamp Forest

Wetland Classes	Hectares	Percentage
Water	4.26	1.79
NPE	16.33	6.84
PE	11.32	4.74
SS-Buttonbush	38.63	16.18
SS-Willow	18.20	7.62
DSF-Tupelo	36.26	15.19
DSF-Cypress	44.31	18.56
DBF	13.47	1.79

FIGURE 3-29. Wetland Change of the Steel Creek Delta Between March 1981 and April 1985

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TABLE 3-41

Steel Creek Delta Wetlands Change Using March 1981 and April 1985 Aircraft MSS Data

From	To	Hectares
Nonpersistent Emergent Marsh	Water	1.10
Nonpersistent Emergent Marsh	Persistent Emergent Marsh	3.26
Nonpersistent Emergent Marsh	Scrub-Shrub	8.62
Persistent Emergent Marsh	Nonpersistent Emergent Marsh	1.87
Persistent Emergent Marsh	Scrub-Shrub	13.79
Scrub-Shrub	Persistent Emergent Marsh	3.26
Scrub-Shrub	Nonpersistent Emergent Marsh	1.40

3.6.4.4.4 Four Mile Creek Delta--1981-1984

A 190-ha area of the Four Mile Creek Delta for 1981 and 1984 was evaluated for wetlands change (Table 3-36). The April 1984 image was registered to March 1981. Similar to the Pen Branch Delta, the major change category was change of swamp forest (cypress-tupelo) to NPE (9.3 hectares). Most of the change occurred along the northern and western delta fringes, where a thinned cypress community existed in 1981. Two areas of PE (1.6 ha) also replaced swamp forest toward the southern edge of the delta. Swamp forest loss totals were similar to the Pen Branch Delta (Table 3-36), and loss rates from 1981 to 1984 are similar to previous findings using aerial photographic techniques (Gladden et al., 1985; Tinney et al., 1986).

3.6.4.4.5 Beaver Dam Creek Delta

3.6.4.4.5.1 Upper Beaver Dam Creek Delta--1981-1983

The April 1984 MSS swamp survey did not cover all of the Beaver Dam Creek Delta area due to a flightline direction. Consequently, the March 1981 data had to be compared to the May 25, 1983, MSS data for the Beaver Dam Creek area.

Two different effluent sources from D Area have affected the Beaver Dam Creek Delta area (Evans and Giesy, 1978; Gladden et al., 1985). Cooling water discharges from the D-Area powerhouse and heavy-water facilities have been primarily responsible for vegetation damage in the middle and lower parts of the delta. The upper portion was also affected by ash basin overflow (Evans and Giesy, 1978). Since the early 1970s, cooling water temperature and flows along with sediment basin discharges have decreased. Portions of the delta have begun to revegetate, especially in the upper part, which no longer receives discharges. An area of 190 ha, centered on the upper portion of the Beaver Dam Creek Delta was selected for wetlands vegetation change detection analysis for 1981 to 1983 (Table 3-36).

Of all four deltas, the most change for different categories was found on the Beaver Dam Creek Delta, even though the change period was the shortest. Almost the entire upper portion of the delta experienced extensive regrowth from March 31, 1981, to May 25, 1983. Due to a discharge reduction, the upper delta remains dry most of the year (except during flooding of the Savannah River). As a result, less water-tolerant scrub-shrub (willow and buttonbush) and deciduous bottomland forest species (sycamore, ash, poplar, and oak) have colonized the former marsh (PE and NPE). In two and one-half growing seasons (1981, 1982, and part of 1983), 6.9 ha of PE were replaced by SS, and 5.3 ha by DBF (Table 3-36). About 10 ha of young bottomland hardwoods present in March 1981 as scrub-shrub also matured.

The loss of 5.3 ha of swamp forest (DSF) was unexpected. One explanation is that as water levels began to drop, thinned-canopy cypress areas were invaded by less water-tolerant, scrub-shrub (willow, buttonbush, and young hardwoods). Even though most of the cypress probably remained, much of the area was intermixed with SS. In late May, SS infrared reflectance is high compared to mature cypress, and thus SS signatures would dominate the spectral signature of mixed scrub-shrub/cypress-tupelo pixels. Consequently, most of the mixed pixels were probably classified as SS.

3.6.4.4.4.2 Upper and Lower Beaver Dam Creek Delta--1981-1985

Multispectral scanner (MSS) data of the Beaver Dam Creek Delta were acquired at 2440 m above ground level (AGL) on March 31, 1981, and at 1220 m on April 26, 1985. The change in landcover from March 31, 1981 to April 26, 1985, is listed in Tables 3-42 and 3-43. For the Upper Beaver Dam Creek Delta, the most noticeable decreases in landcover type were Nonpersistent Emergent Marsh (-60.0%), Persistent Emergent Marsh (-52.2%), and Deciduous Swamp Forest (-12.6%). Conversely, the area experienced increases in Deciduous Bottomland Forest (35.7%), Scrub-Shrub (10.0%), and water (13.5%). Thus, the Upper Beaver Dam Creek area returned to a more wooded condition.

In the Lower Beaver Dam Creek Delta, the Nonpersistent Emergent Marsh (99.9% reduction). This wetlands type probably changed into Persistent Emergent Marsh, which showed a substantial increase of 24.4%. Deciduous Swamp Forest, Scrub-Shrub, and water all decreased in area (-7.4%, -3.5%, and -1.1%, respectively). The Deciduous Bottomland Forest increased (5.5%). These statistics suggest that while change is taking place in the Lower Beaver Dam Creek Delta, it is not as marked as the revegetation taking place in the Upper Beaver Dam Creek Delta.

3.6.5 Comparison of the Photographic and MSS Surveys

In general, the wetland community trends in the delta areas of the SRS Savannah River swamp observed with the MSS surveys from 1981 to either 1984 or 1985 agree with the changes noted in the photographic surveys; even though the data are analyzed with different approaches and criteria for wetland change detection. For example, in the thermally influenced deltas of Four Mile Creek (until 1985) and Pen Branch, expansion of these deltas into the deciduous swamp forest (DSF) was still occurring. From 1981 to 1984 using photographic techniques, about 30 ha of cypress-tupelo forest were estimated to have been converted to open water marsh and/or scrub-shrub wetlands in the Four Mile Creek Delta area. Using MSS data to analyze about one-half of the same Four Mile Creek Delta area, an estimated 14.1 ha of swamp forest were converted to either marsh and/or scrub-shrub wetland communities (Table 3-36). When evaluated with photographic methods, the thermally influenced Pen Branch Delta showed a decline in cypress-tupelo forest of about 37 ha from 1981 to 1985 with

TABLE 3-42

Wetlands Change in the Upper Beaver Dam Creek Area from 1981-1985 Based on Aircraft MSS Data

Wetlands Type	Number of Hectares 1981	Number of Hectares 1985	Difference	Percentage Change
Water	14.8	16.8	+2.0	+13.5
Nonpersistent Emergent Marsh	8.5	3.4	-5.1	-60.0
Persistent Emergent Marsh	32.9	15.7	-17.2	-52.2
Scrub-Shrub	35.7	39.3	+3.6	+10.0
Deciduous Swamp Forest	65.8	57.5	-8.3	-12.6
Deciduous Bottomland Forest	70.3	95.4	+25.1	+35.7

TABLE 3-43

Wetlands Change in the Lower Beaver Dam Creek Area from 1981-1985 Based on Aircraft MSS Data

Wetlands Type	Number of Hectares 1981	Number of Hectares 1985	Difference	Percentage Change
Water	35.2	34.8	-0.4	-1.1
Nonpersistent Emergent Marsh	7.1	0.0	-7.1	-99.9
Persistent Emergent Marsh	9.4	11.7	+2.3	+24.4
Scrub-Shrub	8.5	8.8	-0.3	-3.5
Deciduous Swamp Forest	76.0	70.4	-5.6	-7.4
Deciduous Bottomland Forest	194.2	204.8	+10.6	+5.5

most of the decline occurring in the Pen Branch "tail" area. MSS data analyses of the "tail" region showed a decline of swamp forest of 28.7 ha from 1981 to 1985.

In contrast to the thermally influenced deltas, evaluation of both the photographic and MSS data demonstrate either stabilization and/or successional revegetation in the Beaver Dam Creek and Steel Creek deltas from 1981 through 1984. Most of the revegetation has taken place as open water and marsh wetland communities have shifted to scrub-shrub and/or young bottomland hardwood communities (Tables 3-36, 3-39, 3-41, 3-42, and 3-43).

3.7 WETLANDS UPDATE FOR THE PEN BRANCH DELTA

The Pen Branch Delta, as with the other delta areas of the SRS Savannah River swamp, are dynamic areas undergoing both year-to-year changes, as well as seasonal changes (Christensen, 1987; Christensen et al., 1988; Jensen et al., 1987; Tinney et al., 1986). The extent of the development of the Pen Branch Delta area and the vegetation types (wetland community types) are dependent on a variety of factors, including K-Reactor operations and thermal conditions on the delta (Tinney et al., 1986; Jensen et al., 1987; Repaske, 1981; Christy and Sharitz, 1980; Irwin, 1975; Sharitz et al., 1974a, 1984b) and flooding patterns of the Savannah River (Scott et al., 1985; Sharitz and Lee, 1985; Jensen et al., 1987). In addition to these influences, once reactor operations are halted, rapid colonization and/or revegetation of exposed mud flats and/or sand bar islands occurs on the delta areas of the SRS Savannah River swamp (Jensen et al., 1986a; Sharitz et al., 1974a, 1974b). These revegetation patterns consist of a variety of annual herbaceous plants, including both persistent and non-persistent wetland communities, as well as the development of scrub-shrub wetland communities within a few years following reactor shutdown (Sharitz et al., 1974a, 1974b; Tinney et al., 1986; Smith et al., 1981, 1982). Therefore, very heterogeneous mixtures of wetland communities can be found in the SRS Savannah River swamp, especially on the delta areas within a few years following reactor shutdowns (Christensen, 1987; Jensen et al., 1983, 1986a; Christensen et al., 1988).

Several evaluations of the wetland patterns of the Pen Branch Delta area have been conducted in recent years using aerial photographic surveys (Sharitz et al., 1974b; Repaske, 1981; Tinney et al., 1986), multispectral scanner (MSS) aircraft surveys (Christensen, 1987; Christensen et al., 1986, 1988; Jensen et al., 1986a; Jensen et al., 1987), and ground based surveys (Dunn and Scott, 1987; Huenneke and Sharitz, 1986; Scott et al., 1985, 1986; Sharitz and Lee, 1985; Gladden et al., 1985; Christy and Sharitz, 1980). These surveys indicate in general that the Pen Branch Delta, at least through 1985, was continuing to expand at a rate of about 5 to 10 hectares per year (Tinney et al., 1986) primarily along a terrace bordering the northern edge of SRS Savannah River swamp (Jensen et al., 1987; Scott et al., 1986). Expansion into this Pen Branch Delta "tail" area may be primarily related to thermal effluent from Pen Branch being directed along the terrace edge in a southeastern direction by flood waters during late spring and summer months (Scott et al., 1985, 1986; Jensen et al., 1987; Tinney et al., 1986).

3.7.1 Recent Wetlands Evaluation

3.7.1.1 Wetland Community Patterns, 1985-1989

Relatively few followup evaluations have been conducted on the Pen Branch Delta wetland communities since the photographic and aircraft MSS surveys of 1985. In 1985, a series of phenological observations were begun on the Pen Branch Delta. One location was at the Pen Branch Delta "boardwalk"

and the second location was at the Pen Branch Delta "tail" area (Figure 3-30). Data on percent leaf emergence and/or expansion primarily of cypress trees in these locations and data on the principal herbaceous wetland plants at each location was recorded. These data included such items as relative height, flowering status, emergent status, as well as reference photography for each site. Tables 3-44 and 3-45 show the months and dates for which phenology data were collected from 1985 to June 1989. Figure 3-31 shows a summary of the status of cypress leaf expansion for that time period, as well as the relative height of the Ludwigia spp. (water primrose (non-persistent herbaceous community) and cattail (Typha spp. (persistent herbaceous community) which occur at the Pen Branch "boardwalk". Ludwigia spp. is a common annual dominant on the elevated mudflats and sandbar islands of the thermally influenced streams and deltas of the SRS (Sharitz et al., 1974; Irwin, 1975; Christy and Sharitz, 1980; McCaffrey, 1982). Since 1985 a band of cattails has developed along the Pen Branch Delta from the "boardwalk" southeast along the Pen Branch "tail". In addition to ground based phenological data, vertical aerial photography of the Pen Branch Delta area were available and are listed in Tables 3-44 and 3-45.

As can be seen from Figure 3-31, cypress (Taxodium distichum) undergoes leaf emergence and expansion mid-to-late March each year and is typically fully leafed out by mid-April of each year. Cypress is deciduous and along with water tupelo (Nyssa aquatica) loses its leaves in mid-fall of each year.

The Ludwigia spp. community tends to emerge later than the cattail community by three to four weeks with both reaching about 2 meters in height. Neither the cattails, nor Ludwigia spp. appeared to emerge as soon, nor develop as tall in 1987 as in the other years shown in Figure 3-31. An evaluation of the flows in the Savannah River from 1985 to mid-1989 (Figure 3-32) indicates that frequent flooding of the SRS Savannah River swamp occurred from February through late March of 1987. Flooding of the SRS Savannah River swamp occurs at a flow rate of about 15,000 cubic feet per sec (cfs) in the Savannah River. This frequent flooding of the Savannah River in the spring of 1987 combined with a startup of K-Reactor operations in early March of 1987 (Figure 3-33) probably lead to a delay in the development of herbaceous wetland communities of the Pen Branch Delta in 1987. McCaffrey (1982) in a series of field observations and greenhouse experiments indicated that germination of seeds of Ludwigia leptocarpa (the principal dominant water primrose of the thermal deltas of the SRS) is delayed by flooding and/or slight burial by sediments. Once seeds of Ludwigia germinate and the plants become established, they are more resistant to changing conditions of flooding and sedimentation (McCaffrey, 1982). Note from Figure 3-31 that development of both the Ludwigia and cattail communities at the "boardwalk" area were not as suppressed in 1986, 1988, and 1989 as in 1987. Both Ludwigia and the cattails began to enter fall senesence in mid-fall of each year.

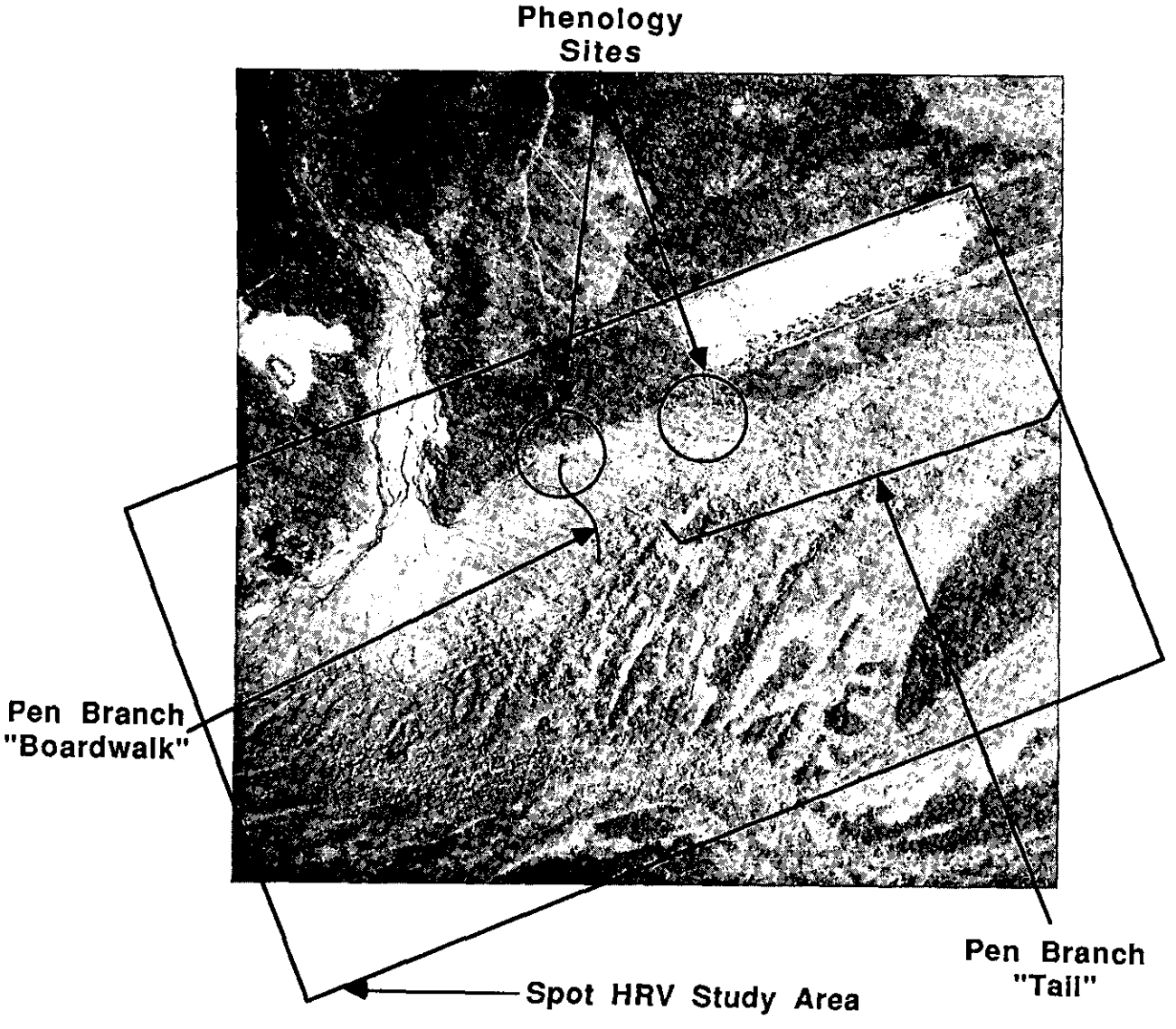

FIGURE 3-30. Pen Branch Delta Area Evaluated for Wetlands Using SPOT HRV Data for 1987, 1988, and 1989. Locations of phenology stations are shown also.

TABLE 3-44

Months for Which SPOT HRV Data, Vertical Aerial Photography, and Phenology Data are Available for the Pen Branch Delta Wetlands Update, 1985 Through Mid-1989

Year/Month		SPOT HRV Data	Vertical Aerial Photography	Phenology Data
1985	Jan	-	-	-
	Feb	-	X	-
	Mar	-	-	X
	Apr	-	X	-
	May	-	X	X
	Jun	-	X	-
	Jul	-	-	-
	Aug	-	-	-
	Sep	-	-	-
	Oct	-	-	-
	Nov	-	-	X
	Dec	-	-	X
1986	Jan	-	-	X
	Feb	-	-	X
	Mar	-	-	X
	Apr	-	X	X
	May	-	-	X
	Jun	-	-	X
	Jul	-	-	X
	Aug	-	-	X
	Sep	-	-	X
	Oct	-	-	X
	Nov	-	-	-
	Dec	-	-	-
1987	Jan	-	-	-
	Feb	-	-	-
	Mar	-	X	X
	Apr	X	X	X
	May	X	-	X
	Jun	-	-	X
	Jul	-	-	-
	Aug	X	-	X
	Sep	-	-	-
	Oct	X	X	X
	Nov	-	-	-
	Dec	-	-	-

TABLE 3-44, Contd

Year/Month		SPOT HRV Data	Vertical Aerial Photography	Phenology Data
1986	Jan	-	-	-
	Feb	-	-	X
	Mar	-	X	X
	Apr	X	X	X
	May	X	X	X
	Jun	-	-	X
	Jul	-	-	-
	Aug	-	-	-
	Sep	-	-	X
	Oct	X	-	-
	Nov	-	-	X
	Dec	-	-	-
1989	Jan	X	X	-
	Feb	-	-	-
	Mar	-	-	-
	Apr	-	X	X
	May	X	X	-
	Jun	-	-	X
	Jul	-	-	X

TABLE 3-45

Dates of SPOT HRV Data, Vertical Aerial Photography and Phenology Data Used to Assess the Pen Branch Delta Wetlands Update for 1987 Through Mid-1989

Year	SPOT HRV Data	Vertical Aerial Photography	Phenology Data
1985	-	Feb 15	-
	-	-	Mar 01
	-	-	Mar 15
	-	Apr 29	-
	-	May 14	May 16
	-	May 18	-
	-	May 19	-
	-	Jun 21	-
	-	-	Nov 01
	-	-	Nov 18
	-	-	Dec 12
1986	-	-	Jan 16
	-	-	Feb 13
	-	-	Feb 27
	-	-	May 13
	-	Apr 17	Apr 03
	-	Apr 23	Apr 21
	-	-	May 02
	-	-	May 21
	-	-	Jun 06
	-	-	Jun 23
	-	-	Jul 25
	-	-	Aug 18
	-	-	Sep 14
	-	-	Oct 03
1987	-	Mar 02	Mar 04
	-	-	Mar 17
	Apr 09	Apr 20	Apr 04
	Apr 24	Apr 21	Apr 17
	May 04	-	May 04
	-	-	May 22
	-	-	Jun 19
	Aug 22	-	Aug 24
	Oct 22	Oct 27	Oct 22

TABLE 3-45, Contd

Year	SPOT HRV Data	Vertical Aerial Photography	Phenology Data
1988	-	-	Feb 01
	-	Mar 17	Mar 10
	-	Mar 21	-
	Apr 17	Apr 29	Apr 14
	May 02	-	May 09
	May 18	May 18	-
	-	-	Jun 24
	-	-	Sep 08
	Oct 25	-	-
	-	-	Nov 18
1989	Jan 28	Jan 28	-
	-	Apr 14	Apr 03
	-	Apr 17	Apr 12
	-	Apr 19	-
	-	Apr 24	-
	-	Apr 26	-
	-	Apr 27	-
	-	May 02	-
	May 17	May 08	-
	-	-	Jun 01
	-	-	Jul 21

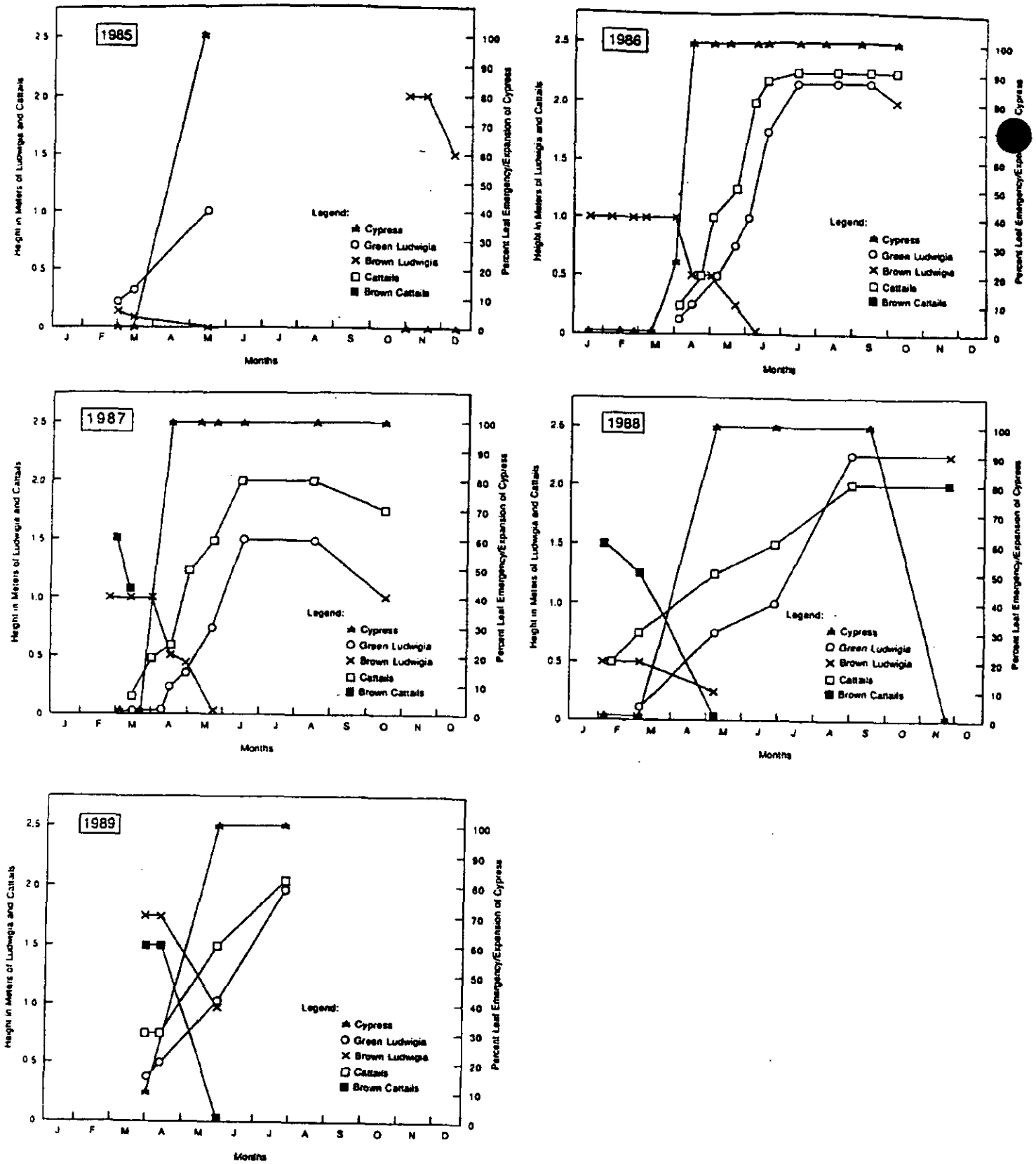

FIGURE 3-31. Summary of Phenology Data for the Primary Wetland Communities Near the Pen Branch Delta "Boardwalk" for 1985 Through Mid-1989

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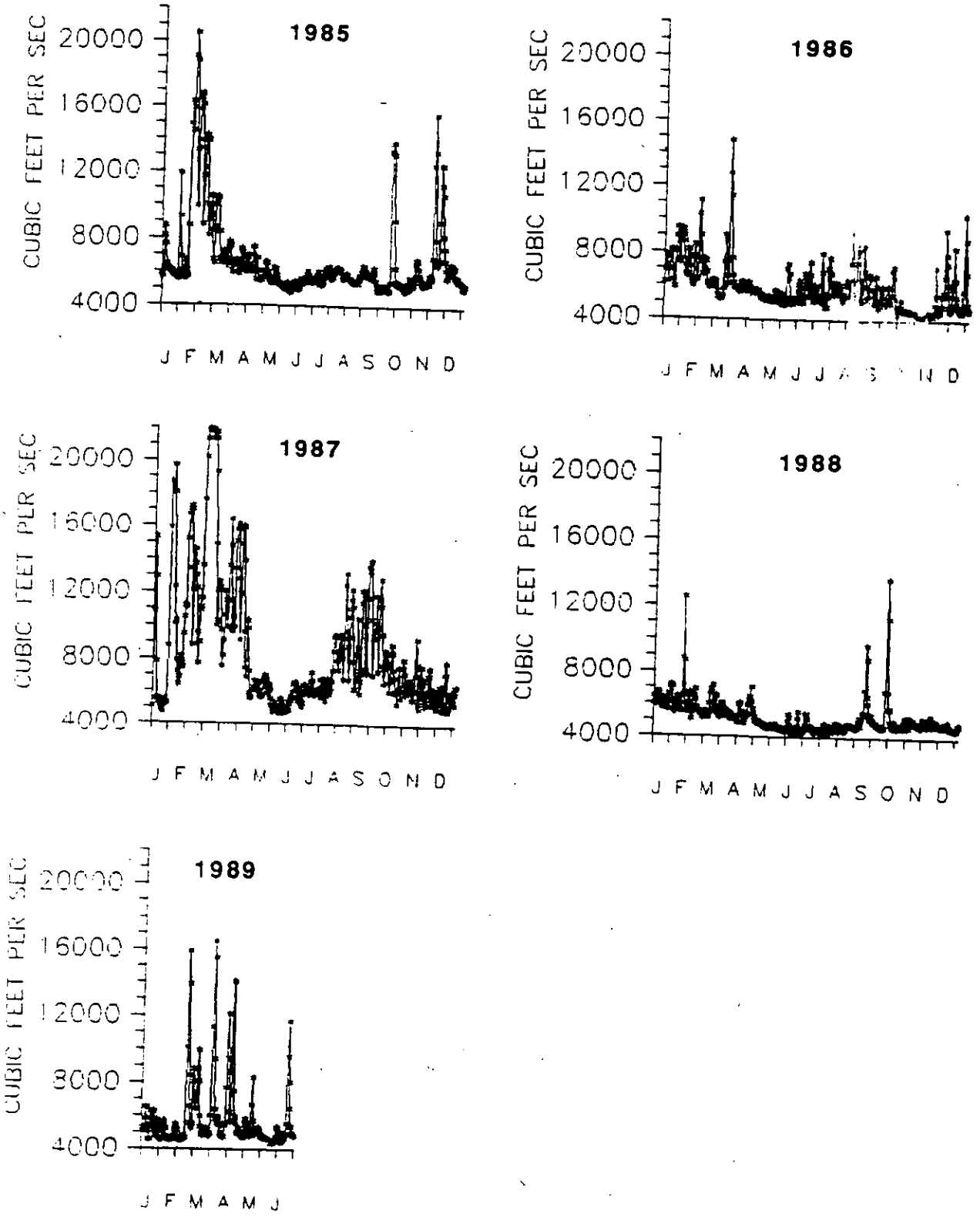

FIGURE 3-32. Flow in Savannah River from January 1985 Through June 1989

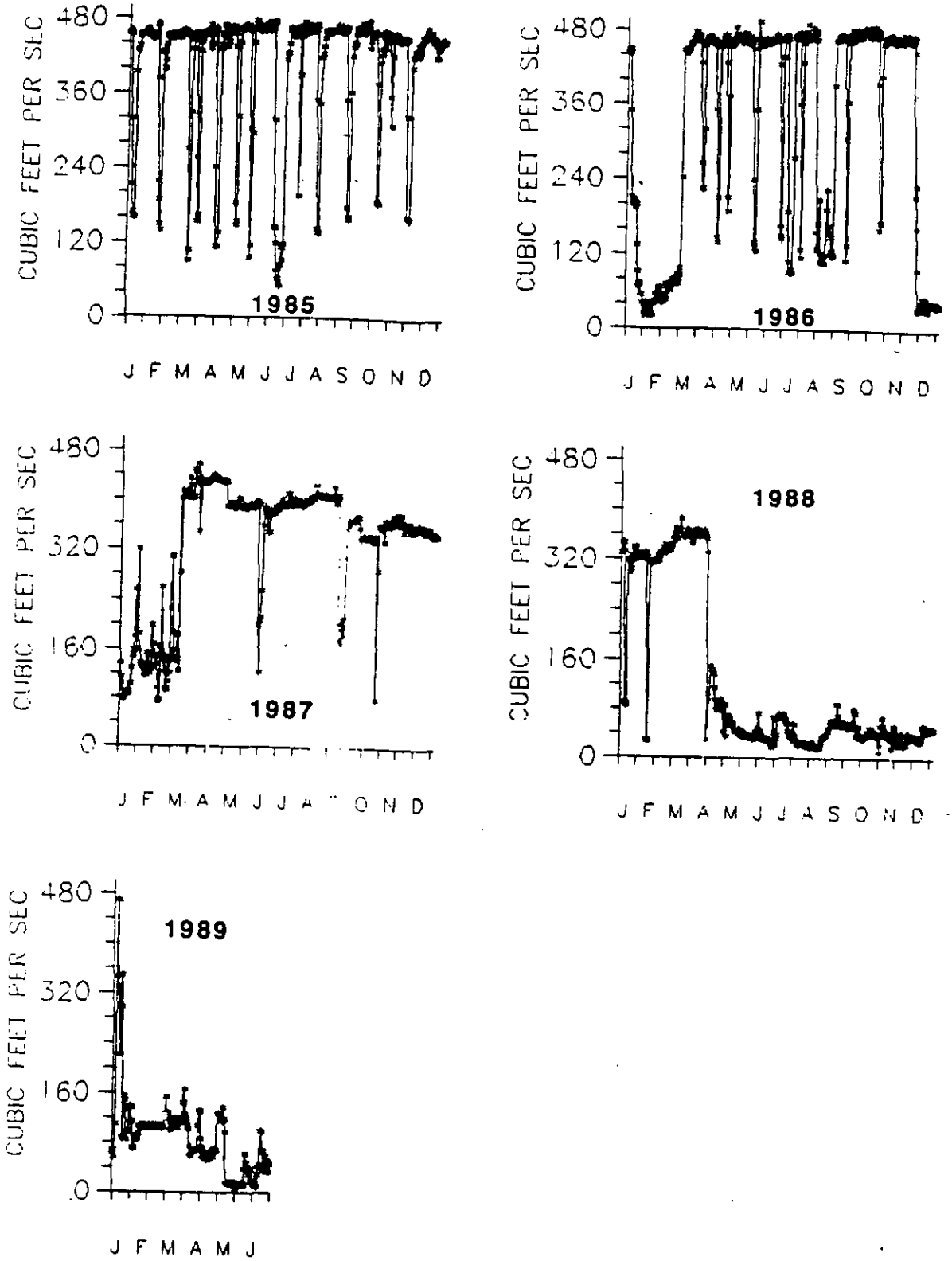

FIGURE 3-33. Flow to Pen Branch Creek from January 1985 Through June 1989

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3.7.1.2 Wetland Areal Estimates 1987-1989

In order to estimate the relative quantities of wetlands in the Pen Branch Delta area both seasonal and annual SPOT HRV satellite scanner data were obtained for this area. Tables 3-44 through 3-46 show the dates of SPOT HRV data which were available, as well as the dates and types of vertical aerial photography and phenological data which were available to assist in evaluation of the wetlands mapping with the SPOT HRV data. The SPOT HRV data were collected in the green (0.50 - 0.59 μm), red (0.61 - 0.68 μm), and near-infrared (0.79 - 0.89 μm) bands, with a nominal pixel size of 20 meters. All data were obtained at the 1B processing level. Subsets of the data were processed for an area of the Pen Branch Delta as shown in Figure 3-30, using unsupervised classification techniques (Jensen, 1986). Cluster maps were generated for each date of SPOT HRV data, grouped, and recoded to one of several landcover types with special interest given to those tabulated in Tables 3-47 and Figure 3-34. Comparisons to aerial photography were made where possible (Table 3-46). The use of satellite thematic mapper data and/or aircraft MSS data (especially in the green, red, and mean-infrared bands) to provide wetlands data on swamp areas of the SRS has proven valuable in the past (Jensen et al., 1986a) and accuracies of 70 to 85% for mapping wetland cover types from open water, marsh, scrub-shrub, to cypress-tupelo swamp forest have been realized (Jensen et al., 1983; Christensen et al., 1986, 1988; Jensen et al., 1986a; Christensen, 1987; Brewster and Tinney, 1984). Similar accuracies would be expected with SPOT HRV data (Tateishi and Mukouyama, 1987).

Other than bottomland hardwood and cypress-tupelo, three types of wetland cover types dominate the Pen Branch Delta area. These included deep and/or open water areas, non-persistent emergent marsh (NPE), and persistent marsh. Since Ludwigia frequently overgrows shallow water, mudflats, and sand bars on the Pen Branch Delta by late summer or early fall, these cover types were included with the NPE cover class along with areas of duckweed. April-May proved to be the best time of year to distinguish the wetland cover types from each other with discrimination in the summer and early fall more difficult (Ernst-Dottavio et al., 1981; Jensen et al., 1986a). In 1987, K Reactor operated at nominal half-power and there was a clear increase in the expansion of the Ludwigia and cattail communities. Ludwigia expanded into the shallow-water mudflat areas of the central delta and the cattails expanded primarily the "tail" area. In mid-April 1988, K Reactor was shut down and flows to Pen Branch decreased markedly (Figure 3-33 and 3-35). This difference in flow is reflected in a decrease in deep/open water landcover type as evaluated with the SPOT HRV data and shown in Table 3-47 and Figure 3-34. The continued "drying" of the delta is also seen in the 1989 landcover evaluation (Table 3-47 and Figure 3-34). As the Pen Branch Delta area became drier in 1988 and 1989, it also became more difficult to distinguish areas of Ludwigia dominance from cattail beds. Furthermore, some areas in the lower Pen Branch stream corridor near the upper delta are beginning to resemble "old field" sites with the SPOT HRV classified data. Similar invasion

TABLE 3-46

Dates of SPOT HRV Data and Supplementary Vertical Aerial Photography Used for Classification of Pen Branch Delta Wetlands

Year	SPOT HRV Data	Vertical Aerial Photography			
		Data	Type	Scale	Source
1987	Apr 09	Apr 20	NC	1:16700	EG&G
	Apr 24	Apr 21	NC	1:20500	EG&G
	May 04	Apr 21	NC	1:20700	EG&G
	Aug 22	-	-	-	-
	Oct 22	Oct 27	FCIR	~1:20000	NASA
1988	Apr 17	Apr 29	NC	1:15900	EG&G
	May 02	Apr 29	NC	1:19900	EG&G
	-	Apr 29	NC	1:7960	EG&G
	May 18	May 18	NC	1:19900	EG&G
	Oct 25	-	-	-	-
1989	Jan 28	Jan 28	NC	~1:20000	FS
	May 17	May 02	NC	~1:19900	EG&G

NC = natural color
FCIR = false color infrared
EG&G = EG&G Energy Measurements, Inc., Las Vegas, NV
FS = Forest Service, SRS, Aiken, SC

TABLE 3-47

Major Wetland Cover Types Based on Classification of SPOT HRV Data for the Pen Branch Delta, 1987 Through Spring 1989 (units in hectares)

Wetland Cover Type	Date and Year of HRV Data Used										
	1987					1988				1989	
	Apr 09	Apr 24	May 04	Aug 22	Oct 22	Apr 17	May 02	May 08	Oct 25	Jan 28	May 17
1. Deep/Open Water	10.4	13.1	13.6	1.5	11.8	4.8	4.0	1.2	0.6	0.0	0.0
2. Non-Persistent Emergent Marsh (NPE)											
2a. Shallow-Water/Mud Flats	82.1	65.5	33.4	12.7	75.0	44.4	29.0	0.2	56.2	0.1	0.4
2b. *Ludwigia* spp.	13.6	34.0	43.5	55.4	-	30.9	56.8	88.2	53.9	155.9[a]	97.4[a]
2c. Duckweed	-	3.2	-	-	0.3	7.5	10.1	0.3	-	-	3.6
Total NPE	95.7	102.8	76.9	68.1	75.3	82.8	95.9	88.7	110.1	156.0	101.4
3. Persistent Emergent Marsh (PE)											
3a. Cattails	10.7	31.2	28.5	65.7	21.0	23.0	38.5	*	*	*	*
4. Total	116.8	147.0	119.0	135.3	108.1	110.6	138.4	89.9	110.7	156.0	101.4

[a] After mid-May 1988, it was not possible to distinguish between the non-persistent beds of *Ludwigia* spp. and stands of cattails with the SPOT HRV data.

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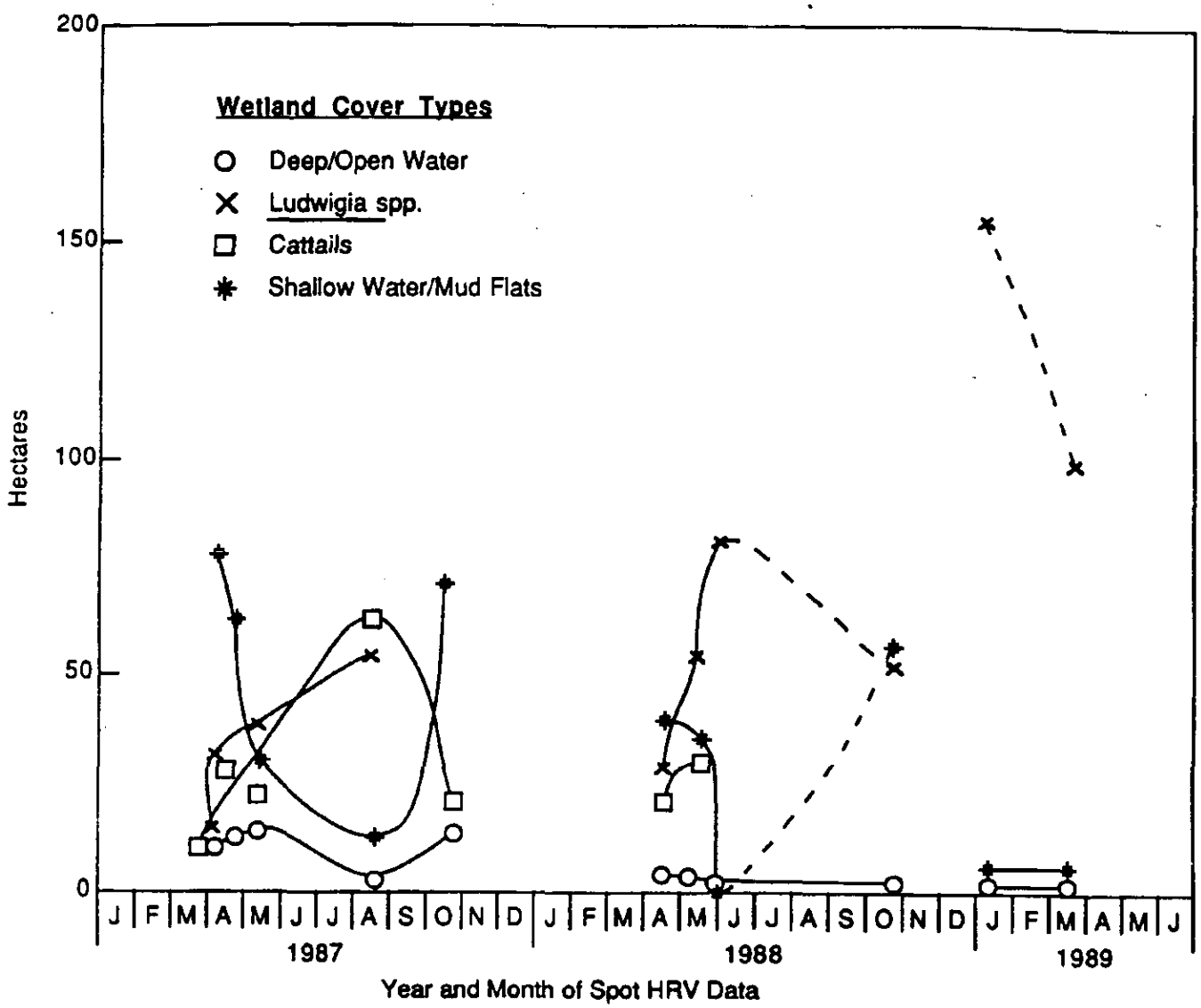

FIGURE 3-34. Major Wetland Cover Types Based on Classification of SPOT HRV Data for the Pen Branch Delta Vicinity, 1987 Through Spring 1989

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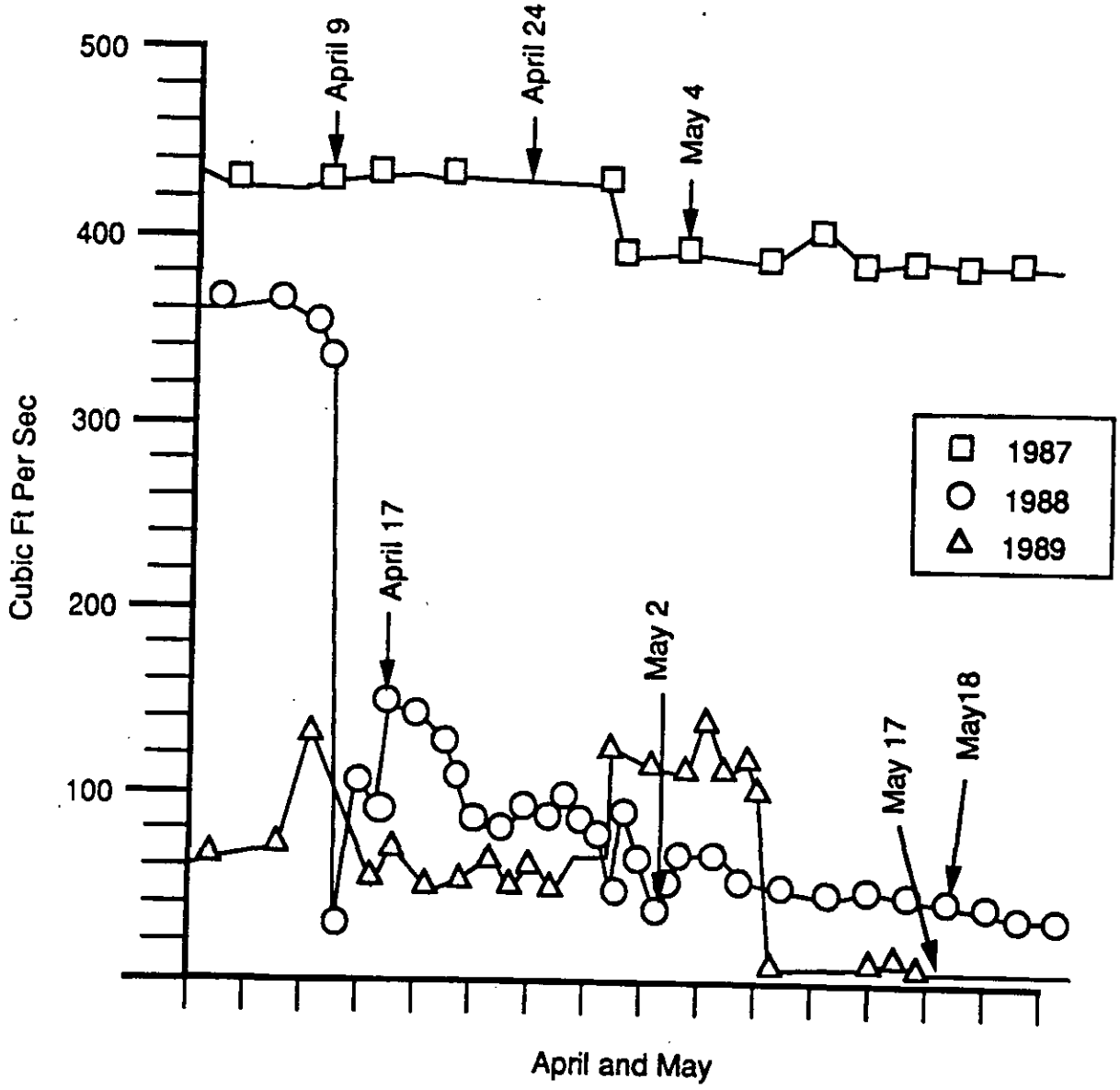

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FIGURE 3-35. Pen Branch Flow During April and May of 1987, 1988, and 1989
Dates of SPOT HRV data shown

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data. Similar invasion of "old field" species has been observed in the drier portions of the Four Mile stream corridor and delta since C-Reactor shutdown in late June 1985. The preliminary data indicate that the Pen Branch Delta is likely to develop into drier more persistent wetland communities with invasion of scrub-shrub species [i.e., willow (Salix spp.) and buttonbush (Cephalanthus occidentalis)] occurring as this delta remains drier.

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4.0 AQUATIC RESOURCES

4.1 DRAINAGE DESCRIPTIONS

Five main drainage basins are located on the SRS (Figure 4-1). The five streams that originate on, or pass through the SRS before flowing into the Savannah River are: Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs creeks. A sixth stream, Pen Branch, does not flow directly into the Savannah River but joins Steel Creek in the floodplain swamp. The upper reaches of Lower Three Runs Creek were impounded in 1958 to form Par Pond (Specht, 1987). L Lake was formed in 1985 by damming Steel Creek above the Meyers Branch confluence.

Four Mile, Beaver Dam, and Steel creeks along with Pen Branch, flow into a contiguous 30.2 km^2 (3,020 ha) river floodplain swamp which drains into the Savannah River. The swamp is separated from the main flow of the Savannah River by a natural levee along the river bank. Water moves through the swamp in a shallow sheet flow with well-defined channels where streams enter the upper side of the swamp, and exits through natural breaks in the levee. Throughout most of the year, water levels are maintained in the swamp by flow from the creeks. Periodically (usually during winter and spring), the Savannah River floods and spills over the levee, causing a reversal in the flow in the creeks and substantially altering many physiochemical features of the swamp (Specht, 1987).

The water used to cool the SRS reactors and to provide cooling water to the D-Area power plant is withdrawn from the Savannah River at three pumphouses located at River Miles (RM) 157.1, 155.3, and 155.2. The withdrawal rate of river water by the SRS varies from approximately 8.5 m^3/sec to 26.0 m^3/sec, depending on the number of reactors operating and the corresponding reactor power levels. After the cooling water flows through the reactor heat exchangers, the heated water is discharged to the river via Pen Branch (K Reactor), L Lake and Steel Creek (L Reactor), or discharged into Par Pond via a series of canals and precooling ponds (P Reactor) (Specht, 1987).

The following descriptions of the streams, Par Pond, and the Savannah River are taken from the Comprehensive Cooling Water Study (Specht, 1987). The description of L Lake is from the Clean Water Act Section 316(a) demonstration for the L-Reactor cooling system (Gladden et al., 1988).

4.1.1 Upper Three Runs Creek

Upper Three Runs Creek is a large, cool (annual maximum of 26.1°C), blackwater stream located in the northern part of the SRS. It drains an area of approximately 5,266 km^2, and has an average discharge of 9.3 m^3/sec at the mouth of the creek. Upper Three Runs Creek is approximately 40 km long, with the lower 28 km located within the boundaries of the SRS. Upper Three Runs receives more water from underground sources (the Tuscaloosa aquifer) than the other SRS streams and as such, has low conductivity, hardness, and pH values.

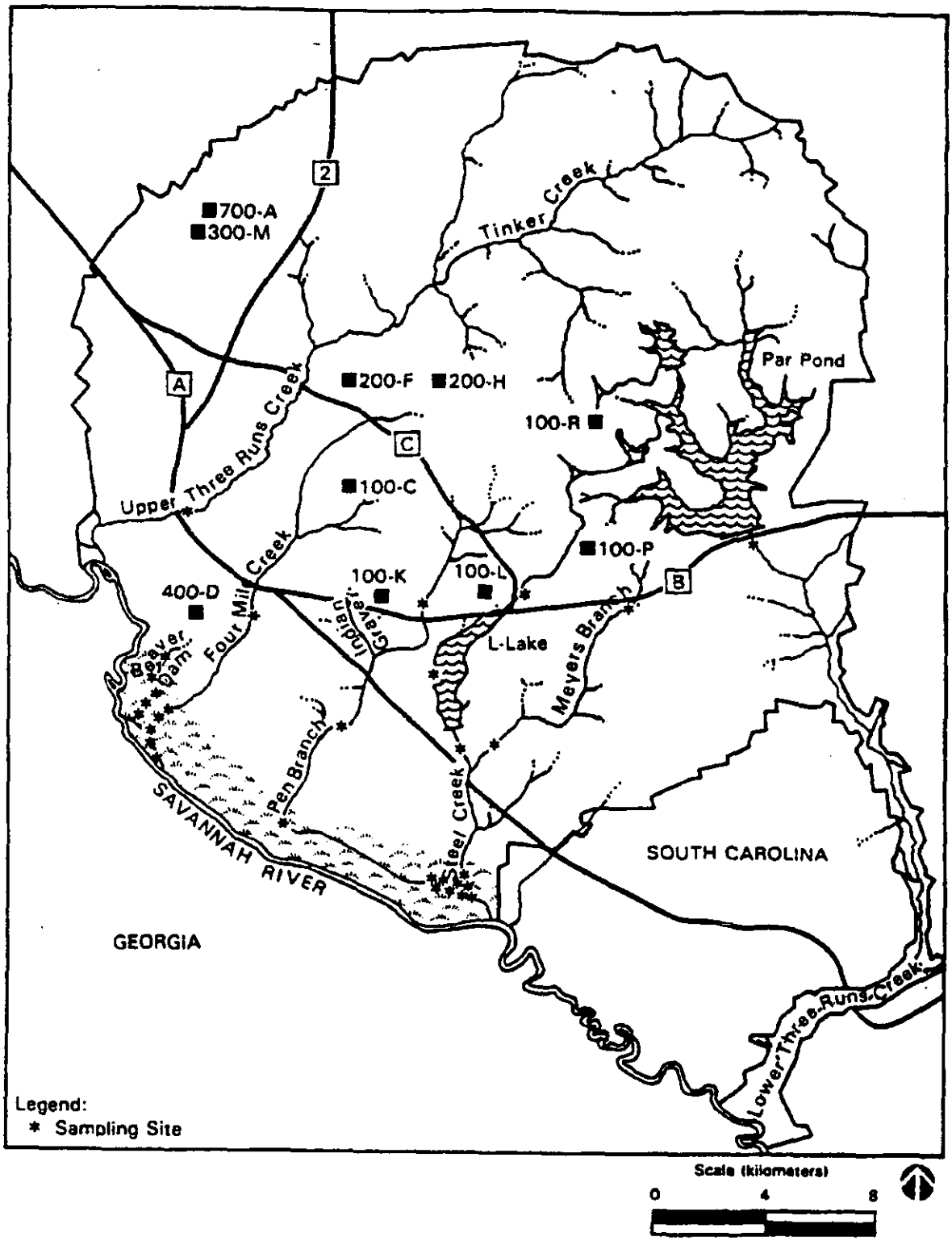

FIGURE 4-1. The Savannah River Site

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Upper Three Runs is the only major tributary of the SRS that has never received thermal discharges. Above its confluence with Tims Branch, Upper Three Runs is relatively unimpacted. Industrial effluents have been discharged into Tims Branch in the past, resulting in some heavy metal contamination. Since late 1985, the stream has been receiving effluents containing higher than background levels of nitrates from SRS operations in M Area (Specht, 1987). Beginning in late 1988, Upper Three Runs Creek also began receiving nitrate additions from the F/H Area Effluent Treatment Facility.

4.1.2 Beaver Dam Creek

Beaver Dam Creek, which is approximately 6 km long and drains an area of approximately 2.2 km^2, originates at the effluent outfall canal from D Area and flows south, parallel to Four Mile Creek, to the Savannah River. These two creeks are in close proximity and there is some mixing of their discharges in the Savannah River floodplain swamp. Beaver Dam Creek is deep, narrow, and channelized in its headwaters and near its mouth, and opens into a slough-like channel in its midreaches (Firth et al., 1986).

Before SRS operations, Beaver Dam Creek probably had only intermittent and/or very low flow. In 1952, Beaver Dam Creek began receiving heated effluent from a heavy water (D_2O) production facility and a coal-fired power plant in D Area. Since 1964 it has received effluent only from the power plant. Temperatures in Beaver Dam Creek typically average 1 to 8°C above ambient, and the average discharge is 4.7 m^3/sec at its mouth.

4.1.3 Pen Branch

Pen Branch drains an area of 91 km^2 and is approximately 16 km long. In its headwaters, Pen Branch is a largely unperturbed blackwater stream, similar to the headwater reaches of Four Mile Creek. Above the confluence with Indian Grave Branch discharge is approximately 0.1 m^3/sec. Thermal effluent from K Reactor joins Pen Branch via Indian Grave Branch and accounts for over 90% of the stream volume (approximately 11.4 m^3/sec total discharge). The reactor cooling water originates from the Savannah River and changes the water quality as well as the temperature and flow regimes in Pen Branch (Firth et al., 1986).

Pen Branch discharges into the Savannah River floodplain swamp rather than flowing directly into the Savannah River. Where it discharges into the swamp, it has formed a delta where temperatures typically range from 25 to 40°C above ambient. The flow from Pen Branch spreads over the delta and continues through the swamp as shallow sheet flow until entering the lower reaches of Steel Creek through which it discharges into the Savannah River. When the Savannah River inundates the floodplain swamp, Pen Branch flows along the northern border of the swamp and crosses the Steel Creek Delta. When the Savannah River is not flooding, the Pen Branch flow enters the Steel Creek channel downstream from the swamp. By the time Pen Branch discharges into Steel Creek, its temperature is near ambient, due to dilution and cooling in the swamp.

4.1.4 Steel Creek-Meyers Branch

The headwaters of Steel Creek originate near P Reactor, and the stream flows approximately 16 km before reaching its delta. Meyers Branch flows approximately 10 km before entering Steel Creek. Meyers Branch is a small blackwater stream that has remained relatively unperturbed by SRS operations. The confluence of Steel Creek and Meyers Branch is located downstream from the L-Lake dam and upstream from SRS Road A. The total area drained by the Steel Creek-Meyers Branch system is 91 km^2, and natural discharge 1.3 km upstream of SRS Road B (above L Lake and the confluence of Meyers Branch) is approximately 0.2 m^3/sec (water year 1987). This value is lower than the 0.6 m^3/sec recorded for water years 1984-1985 at the previous gauge station located at Road B. The gauge station was moved upstream when L Lake was filled in late 1985.

In 1954, Steel Creek began receiving thermal effluents from P and L reactors. By 1961, a total of 24 m^3/sec of thermal effluent was being released by both reactors into Steel Creek. Another 0.2 m^3/sec (mean value of water years 1985 through 1987) of nonthermal effluent enters the creek from P Area. In 1963, P-Reactor effluent was diverted to Par Pond, and in 1968, L Reactor was put on standby. From 1968 until early 1985, Steel Creek was recovering from the impacts of SRS operations. In 1985, L Lake was constructed on Steel Creek. This is an impoundment designed to receive and cool the heated effluent from L Reactor, which was brought back online in October 1985 (Firth et al., 1986).

During the period of 1954 to 1968, when Steel Creek was receiving thermal discharge and increased flow, an extensive delta developed where the creek entered the Savannah River floodplain swamp. The delta is drained by numerous braided channels that eventually coalesce and continue for approximately 1.6 km before entering the Savannah River. Prior to entering the river, the flow from Steel Creek is joined by the flow from Pen Branch and part of the flow from Four Mile Creek.

4.1.5 Four Mile Creek

Four Mile Creek is approximately 24 km long and drains an area of approximately 89 km^2. In its headwaters, Four Mile Creek is a small blackwater stream that is relatively unimpacted by SRS operations. Water chemistry in the headwater reaches of the creek is very similar to that of Upper Three Runs Creek, with the exception of nitrate concentrations, which are an order of magnitude higher than Upper Three Runs Creek. These elevated nitrate concentrations are probably the result of groundwater transport and outcropping from the F- and H-Area seepage basins (Newman et al., 1986). Prior to C-Reactor standby in 1985, heated Savannah River water (as hot as 70°C) was discharged into Four Mile Creek via Castor Creek, resulting in water temperatures in excess of 60°C in Four Mile Creek just downstream of its confluence with Castor Creek. In its lower reaches, Four Mile Creek broadens and flows through a delta that has been formed by the deposition of sediments. Although most of the flow through the delta is in one main channel, the delta has numerous standing dead

trees, logs, stumps, and cypress trees which provide structure and reduce water velocity in some areas. Downstream of the delta, the creek flows in one main channel and the majority of the flow discharges into the Savannah River at RM 152.1, while a small portion of the creek flows west and enters Beaver Dam Creek. When the Savannah River floods, water from Four Mile Creek flows along the northern boundary of the floodplain swamp and joins with Steel Creek and Pen Branch instead of flowing directly into the river.

4.1.6 Lower Three Runs Creek

Lower Three Runs Creek is a large blackwater creek (mean discharge 1.6 m^3/sec) draining 490 km^2, with a 1012 ha mainstream impoundment on its headwaters. The impoundment, Par Pond, is used as a source of cooling waters for P Reactor. Historically, SRS operations caused large discharge fluctuations just downstream from the dam at Par Pond, but groundwater and tributary inputs were sufficient to dampen these fluctuations farther downstream (Firth et al., 1986). Currently, P Reactor operates in a recirculating mode through Par Pond, and water lost by evaporation and seepage from the reservoir is replaced by Savannah River water.

Water is discharged from Par Pond to Lower Three Runs Creek over a fixed position weir. Wilde (1985) reported the long-term average flow to Lower Three Runs Creek from Par Pond as 0.9 m^3/sec. During the period from October 1984 to September 1985, the discharge below Par Pond at SRS Road B ranged from 0.04 to 1.39 m^3/sec, with a mean of 0.56 m^3/sec. Temperatures of water released from Par Pond into Lower Three Runs are near ambient. Water temperature below Par Pond at SRS Road B ranged from 8.5°C in February 1985 to 32.2°C in June 1985, and the mean temperature during the period from 1973 to 1982 was 20.3°C, approximately 2°C higher than the mean for other nonthermal streams (Gladden et al., 1985a).

4.1.7 Par Pond

Par Pond is a 1012-ha reactor cooling reservoir built to augment the cooling requirements for both P and R Reactors. (Figure 4-2). It was created in 1958 by the construction of an earthen dam (Cold Dam) on Lower Three Runs Creek and was formed along the course of Poplar Branch, Joyce Branch, and the upper reach of the Lower Three Runs Creek drainage system (Wilde and Tilly, 1985). From August 1958 to October 1961, Par Pond received thermal effluent from R Reactor only. During this time, R Reactor discharged thermal effluent to the Middle Arm via the precooler Pond C. Both reactors utilized Par Pond from November 1961 to June 1964. During this period, R Reactor discharged effluent to the North Arm via Pond B, while P Reactor discharged effluent into the middle arm of the pond via a series of canals and precooler ponds, including Pond C (Figure 4-2). In July 1964, R-Reactor operations were suspended and the reactor was placed on standby. Thereafter, Par Pond has received thermal effluent from P Reactor only, and Pond B has not received any effluent cooling water.

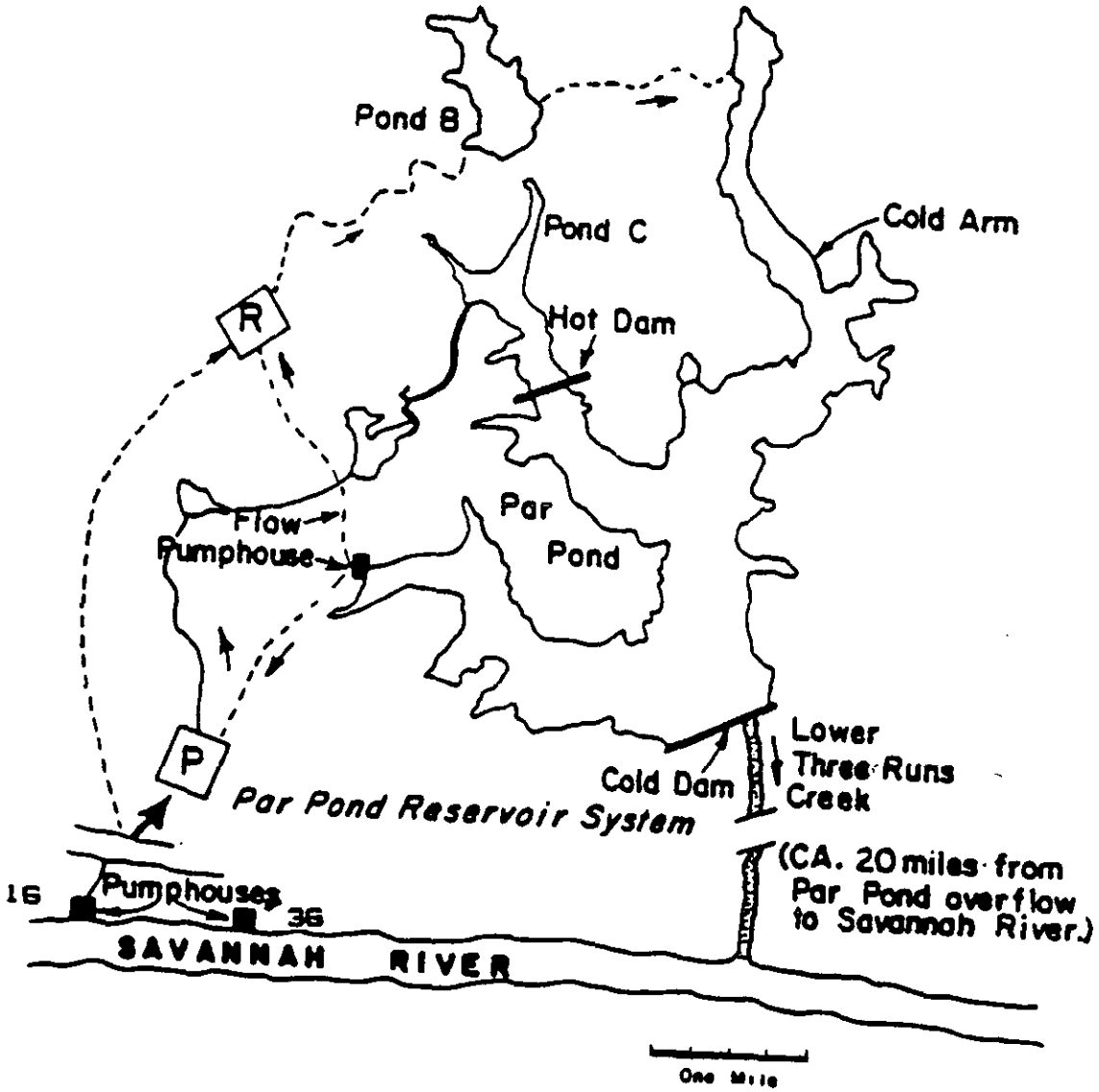

FIGURE 4-2. Par Pond Showing Flow Patterns
(source: Wilde and Tilly, 1985)

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A pumphouse located on the south arm (Intake Arm) of Par Pond allows water to be recirculated from Par Pond to P Area where it is discharged into the 186-P Basin and mixed with makeup water pumped from the Savannah River (Figure 4-2). Flow from the Par Pond pumphouse to P Reactor ranges from 5.9 m^3/sec to 11.6 m^3/sec (9.8 m^3/sec, average) when P Reactor is operating (Wilde, 1985). During reactor operations, recirculating water flows through the reactor heat exchangers, where it reaches temperatures of approximately 70°C, and is released through a series of precooler ponds and canals into Pond C (Wilde and Tilly, 1985). This precooling system accounts for approximately 86% of the total cooling in the Par Pond system (Wilde, 1985). Reactor cooling water effluent from Pond C passes through a concrete culvert below an earthen dam (Hot Dam) and is funneled under gravity head from the bottom of Pond C into Par Pond. The culvert terminates approximately 2 m below the surface of Par Pond, and the effluent flows upward, forming a thermal plume as it mixes with cooler water and spreads out at the surface of Par Pond (Wilde, 1985). Losses of water from the Par Pond system due to evaporation and seepage are compensated by pumping makeup water from the Savannah River (Wilde, 1985; Wilde and Tilly, 1985). Savannah River makeup water is pumped at a rate of 1.0 to 1.3 m^3/sec when the reactor is operating, and 0.6 to 0.8 m^3/sec when the reactor is not operating (Wilde, 1985). Between 1980 and 1985, the amount of makeup water pumped from the Savannah River averaged 1.1 m^3/sec (Wilde, 1985). Other than the addition of Savannah River makeup water, and the overflow and seepage to Lower Three Runs Creek via the Cold Dam, Par Pond is operated as a closed loop system.

Flow patterns for Par Pond are influenced by weather, drainage basin morphometry, and pumping rates associated with reactor operations (Wilde, 1985). Simple replacement time for the volume of water in Par Pond by rainfall and runoff from 1962 to 1977 averaged 704 days and ranged from 516 to 967 days (Tilly, 1981). However, actual replacement time was reduced by reactor operations to 68 days from 1962 to 1977 (Tilly, 1981) and to 108.8 days from January 1984 to June 1985 (Chimney et al., 1985). The shorter replacement time caused increased mixing in the lake and resulted in a more homogeneous distribution of plankton and nutrients than would have occurred in the absence of pumping activities (Tilly, 1981).

The major meteorological factors that affect the structure and function of the reservoir ecosystem are air temperature, solar insolation, relative humidity (and saturation deficit), wind speed and direction, and precipitation (Wilde and Tilly, 1985). The morphometry of Par Pond has been influenced by construction activities during the formation of the pond, which resulted in uniform contours leading to the pumphouse and noticeably steep slopes near the Hot Dam. In contrast, the North Arm is more riverine and shallow (Wilde and Tilly, 1985).

4.1.8 L Lake

L Lake was formed by impounding the headwaters of Steel Creek. L Lake extends about 7000 m along the Steel Creek Valley from the embankment above SC 125 (SRS Road A) to just above SRS Road B (Figure 4-1). The

lake width averages about 600 m, reaching a maximum of about 1,200 m (DOE, 1984). At a normal pool elevation of 58 m, the dam impounds about 31 million m^3 of water and covers about 4.185 km^2 (reported as 1034 acres, nominally 1000 acres) (U.S. Army Corps of Engineers, 1987).

L-Lake Dam is located approximately 7.2 km above the mouth of Steel Creek and about 0.8 km north of SC 125. The dam consists of a main embankment of rolled fill construction, with a lower embankment (saddledike) extending from the right abutment and a service bridge leading to an intake tower extending from the left abutment. The main embankment is about 670 m long with a 12-m crest width. The top of the embankment is at 27 m. The unpaved emergency spillway has a sill elevation of 60 m. A 60-cm-thick concrete cutoff wall is located on the upstream toe of the main dam to minimize seepage under the dam. The saddle dike is about 520 m long with a 12-m crest width. The maximum height of the saddle dike is 3.7 m (U.S. Army Corps of Engineers, 1987).

As originally constructed, L-Reactor cooling water effluent entered L Lake directly through an effluent canal situated north to south on the north shore of the lake. In 1986, the L-Reactor effluent diversion dike was built to divert the flow from L Reactor into the upper, northeastern portion of the lake to increase the lake's cooling efficiency. The dike and canal are oriented west to east on the north shore of L Lake, south of SRS Road B (Murdock, 1986). The canal formed by the dike is approximately 870 m long and 12 to 15 m wide. The water in the canal is nominally 1.2 m deep at the centerline, with a surface area of about 11,900 m^2 (DeWitt, 1986).

The outlet structures for the lake consist of a multigate intake tower, a prefabricated concrete conduit, and a stilling basin located in the valley of the left abutment (U.S. Army Corps of Engineers, 1987). Water passes through the intake tower and the conduit and is discharged into the stilling basin before being released to Steel Creek. The discharge intake structure is designed to pass the L-Reactor cooling water flow, the P-Area process water flow, and ambient Steel Creek flow and to serve as the principal means of flood control.

The system of eight gates in the dual wet well tower regulates the reservoir water level. Two gates near the bottom of the lake (lower gates or emergency gates) and two gates 3 m below the normal pool elevation (upper gates) can be opened to let water into the wet wells. These gates are either fully opened or closed. Under normal operating conditions, both lower gates are closed, and both upper gates are open. The lower gates can be opened to release water if the lake level gets too high. The volume of water released from the dam is controlled by the two service gates located at the base of the wet wells. Water flows through both upper gates into the two wet wells and through the service gates into the concrete conduit. Flow through service gates can vary from about 2 m^3/sec to 29 m^3/sec per gate. Service gates are not operated with an opening of less than about 15 cm to avoid cavitation. To release

flows less than 2 m^3/sec, such as the minimum flows required during reactor shutdown, two 46-cm-diameter knife gates can be opened. The knife gates can release flows ranging from about 0.3 m^3/sec to 2 m^3/sec to Steel Creek (Du Pont, 1985).

The reservoir level and the discharge water temperature and volume are electrically monitored by a control system. If the computerized operating system should fail, these data can be visually monitored and the gates manually operated at the dam site (Du Pont, 1985).

4.1.9 Savannah River

The Savannah River watershed includes western South Carolina, eastern Georgia and a small portion of southwestern North Carolina. It is formed by the confluence of the Tugaloo and Seneca Rivers in northeast Georgia and flows southeast through the Piedmont and Coastal Plain to the Atlantic Ocean. In its mid and lower reaches (including the SRS region), the river is broad with extensive floodplain swamps and numerous tributaries. The substrate consists of various combinations of silt, sand, and clay.

The U.S. Army Corps of Engineers regulates flow in the Savannah River by means of three large reservoirs (Thurmond, Hartwell, and Russell), as well as by locks and dams. Besides being affected by the reservoirs, the river is influenced by dredging, sewage discharge, and industrial activities. In general, the river water is well oxygenated, low in chemical and biochemical oxygen demand (Dukes, 1984) and slightly acidic.

The SRS has five nuclear reactors, two (C and R reactors) currently on standby, and a coal-fired power station. One reactor (K Reactor) is cooled by water pumped from the Savannah River and returned to the river through the Pen Branch Creek. Another reactor (P Reactor) utilizes a large, man-made cooling pond (Par Pond) and requires only pond makeup water from the Savannah River. The third reactor (L Reactor) discharges cooling water into L Lake to Steel Creek, which flows into the Savannah River near the southern boundary of the SRS. Cooling water pumped from the Savannah River for the power station returns to the river through Beaver Dam Creek.

The thermal plumes created in the Savannah River by SRS effluents vary in size and temperature as a function of changes in reactor operation, Savannah River water level, and season of the year. When flow in the Savannah River is low, the thermal creeks discharge directly into the river, producing plumes that follow the South Carolina shore. When the river flow is high enough to inundate the SRS floodplain swamp, there are no thermal plumes in the river. Under flood conditions, the creeks discharge into the flooded swamp and the water is channeled downstream along the upland bank of the swamp by the river overflow. Dilution and cooling occur in the floodplain swamp before the SRS effluent is discharged into the main channel (Shines and Tinney, 1983).

4.2 PEN BRANCH CREEK

4.2.1 Water Quality

The Indian Grave Branch/Pen Branch system has received cooling water discharges from operation of the K Reactor since 1954 and, since C Reactor has been placed on standby, is the only remaining stream system on the SRS receiving direct discharges from reactor operations. A synopsis of historical water quality monitoring of the Pen Branch system prior to the two-year water quality program instituted under the Comprehensive Cooling Water Study (CCWS) can be found in Gladden et al. (1985a). Tables 4-1 and 4-2 summarize the data from pre-CCWS, nonroutine surveys of temperature, dissolved oxygen, and stream flow in Pen Branch and Indian Grave. Routine monitoring of radioactive and nonradioactive parameters of the surface waters of the SRS is conducted by the Environmental Monitoring (EM) Section. Results of this monitoring program for all SRS surface waters for 1987 and 1988 can be found in Appendix A of this document.

The Comprehensive Cooling Water Study Final Report, Volume 2 (Lower, 1987) reports the results of a special study to determine levels of volatile, acid, and base/neutral organic compounds in Pen Branch. The study reported a lack of variability between thermal and nonthermal waters and no differences between periods of reactor operation and outage. Lower (1987) also reported the results of analyses for pesticides and PCB's in onsite streams and the Savannah River. The results for Pen Branch can be found in Table A-10 of Appendix A. Results of the 1983-1985 two-year water quality program instituted under the CCWS are also reported in Lower (1987). Sampling locations for this study are shown in Figure A-1 of Appendix A. The CCWS study monitored standard parameters and general water chemistry (Table 4-3), nutrients (Table 4-4), total and dissolved major cations (Tables 4-5 and 4-6), trace elements (Table 4-7), and organic carbon (Table 4-8).

Water quality impacts associated with continued operation of K Reactor would be expected to be similar to those seen during prior operational periods as described by Newman et al. (1986) in the following sections. Tabular data supporting the discussion from Newman et al. (1986) can be found in Tables A-19 through A-28 in Appendix A of this document.

During reactor operation median temperatures in thermal portions of the Pen Branch watershed (50.9 to 58.4°C) were nearly 40°C above those of the upstream non-thermal waters (15.6°C). The temperatures at the thermal sites fluctuated more widely than those of the nonthermal site. Median stream velocity at the nonthermal site (35 cm/sec) was considerably lower than those at the thermal sites (140 to 198 cm/sec). The pH values for the thermal sites (7.44 to 7.55) were higher than those of the non-thermal site (6.93). Median oxygen concentrations were 7.85 mg O_2/L (80% saturation) at the Pen Branch nonthermal site. The median oxygen concentrations in the thermal waters were 4.7 to 4.0 mg O_2/L or 87 to 90% saturation.

TABLE 4-1

Characteristics of Pen Branch and Indian Grave Branch

Location	Width, m	Average Depth, m	Average Velocity, m/s	Flow Rate, m^3/s	Temp., °C
Indian Grave Branch[a] Above K effluent	1.8	0.1	0.09	0.02	18.8
(K-Area effluent)[b]	-	-	-	-	(63.0)
Indian Grave Branch Road B crossing	-	-	-	-	60.9
Pen Branch[a] Road B crossing upstream of confluence w/Indian Grave Branch	2.1	0.1	0.2	0.08	20.2
Pen Branch Road A crossing	11.0	1.0	1.0	12.7	52.4
Pen Branch Road A-13.2	10.7	1.2	1.0	13.8	-
Pen Branch Road A-13	-	-	-	-	46.5

[a] Nonthermal site
[b] () denotes heated discharge to stream.

Source: Jacobsen et al. (1972); Gladden et al. (1985a)

TABLE 4-2

Dissolved Oxygen and Temperature: Pen Branch at SRS Road A, 1960 to 1968 (average value ±1 σ)

Temperature, °C		Dissolved Oxygen, mg/L	
Maximum	Mean	Minimum	Mean
57 ±4	42.5 ±4	4.2 ±0.4	6.2 ±0.5 (99% saturated)

Dissovled Oxygen and Temperature in Pen Branch (EPA, October 1970)

Location	Temperature, °C	Dissolved Oxygen, mg/L	Dissolved Oxygen, % Saturation
Pen Branch near headwaters	16	8.0	80
Pen Branch Road A	-	7.1	-

Source: Jacobsen et al. (1972); Gladden et al. (1985a)

TABLE 4-3

General Water Chemistry and Standard Parameters: Pen Branch Watershed

Station Number	Site	Temperature (°C)	pH	Total Alkalinity (mg/L as $CaCO_3$)	Dissolved Oxygen (mg O_2/L)	Dissolved Oxygen Saturation (%)	Specific Conductance (µmhos/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Chlorides (mg/L)	Sulfates (mg/L)
19	Pen Branch at SRS Road B	15.2 (46) 1.4 - 24.0	6.93 (46) 5.10 - 9.00	13.8 (45) 2.85 - 30.6	8.12 (46) 5.80 - 12.3	79.2 (46) 63.1 - 97.3	45.6 (38) 28.2 - 75.0	9.63 (45) 0.25 - 72.4	10.6 (43) 3.10 - 52.2	2.48 (45) 1.90 - 3.20	2.53 (28) 0.25 - 7.67
20	Indian Grave Branch downstream of K Reactor effluent	48.1 (46) 7.6 - 68.0	7.42 (46) 5.90 - 8.70	17.8 (44) 11.7 - 22.3	5.32 (45) 2.70 - 11.5	88.1 (45) 64.3 - 108.7	74.6 (36) 50.7 - 90.1	10.0 (45) 0.25 - 43.2	21.4 (43) 7.30 - 61.5	5.86 (46) 2.70 - 8.40	5.21 (28) 0.75 - 10.3
18	Pen Branch at SRS Road A-13	42.6 (45) 7.1 - 60.0	7.42 (44) 5.60 - 8.59	16.8 (44) 7.40 - 22.0	5.63 (45) 3.30 - 11.1	83.9 (45) 64.9 - 108.9	73.4 (37) 48.9 - 91.4	13.9 (43) 1.60 - 145.5	21.3 (42) 3.00 - 55.0	5.64 (45) 2.90 - 8.10	5.03 (26) 0.25 - 9.94
17	Pen Branch swamp near SRS Road A-17	33.5 (46) 7.90 - 46.3	8.11 (45) 5.70 - 9.25	16.0 (45) 7.71 - 21.0	7.53 (45) 5.50 - 12.3	100.3 (45) 56.4 - 127.1	71.9 (38) 47.7 - 98.3	4.63 (45) 0.25 - 36.7	14.6 (43) 3.80 - 57.4	6.02 (46) 2.90 - 8.20	4.97 (28) 1.96 - 8.02
9	Pen Branch swamp upstream of Steel Creek confluence	17.4 (42) 1.00 - 29.0	6.89 (45) 6.40 - 8.10	17.9 (42) 8.00 - 26.4	6.65 (43) 3.50 - 14.0	66.0 (42) 40.9 - 99.2	73.1 (35) 46.8 - 95.1	3.14 (42) 0.25 - 17.2	5.40 (40) 1.30 - 25.5	5.81 (43) 2.50 - 9.10	5.26 (25) 2.07 - 7.94

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

WB906070

W8906070

TABLE 4-4

Nutrient Concentrations: Pen Branch (as mg P/L or mg N/L)

Station Number	Site	Total Phosphorus	Total Orthophosphates	Dissolved Orthophosphates	Nitrates	Nitrites	Ammonia	Total Kjeldahl Nitrogen
19	Pen Branch at SRS Road B	0.042 (46) <0.010 - 0.147	0.017 (41) 0.003 - 0.059	0.007 (41) 0.002 - 0.022	0.050 (43) 0.011 - 0.184	0.002 (44) <0.001 - 0.005	0.039 (46) 0.005 - 0.700	0.236 (46) 0.045 - 0.900
20	Indian Grave Branch downstream of K Reactor effluent	0.114 (45) 0.028 - 0.275	0.080 (41) 0.037 - 0.146	0.066 (41) 0.015 - 0.128	0.288 (43) 0.038 - 0.685	0.019 (43) 0.005 - 0.041	0.109 (46) 0.013 - 0.210	0.298 (46) 0.075 - 0.770
18	Pen Branch at SRS Road A-13	0.093 (45) <0.010 - 0.286	0.071 (39) 0.013 - 0.133	0.059 (40) 0.005 - 0.124	0.310 (42) 0.094 - 0.510	0.021 (42) <0.001 - 0.048	0.075 (45) 0.016 - 0.230	0.239 (45) 0.080 - 0.855
17	Pen Branch swamp near SRS Road A-17	0.103 (46) <0.010 - 0.239	0.076 (42) 0.005 - 0.144	0.068 (41) 0.011 - 0.128	0.228 (43) 0.019 - 0.454	0.008 (44) 0.001 - 0.031	0.048 (46) 0.005 - 0.250	0.221 (46) 0.035 - 0.610
9	Pen Branch swamp upstream of Steel Creek confluence	0.065 (43) <0.010 - 0.188	0.045 (37) 0.004 - 0.113	0.019 (39) 0.003 - 0.054	0.091 (39) <0.001 - 0.378	0.003 (40) <0.001 - 0.010	0.027 (43) 0.005 - 0.220	0.224 (43) 0.032 - 0.640

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-5

Dissolved Major Cation Concentrations: Ca, Mg, Na, K (mg/L): Pen Branch Watershed

Station Number	Site	Calcium	Magnesium	Sodium	Potassium
19	Pen Branch at SRS Road B	5.69 (39) 2.55 - 10.6	0.512 (39) 0.430 - 0.733	1.88 (39) 1.14 - 2.82	0.432 (39) <0.368 - 1.33
20	Indian Grave Branch downstream of K Reactor effluent	3.28 (38) 2.66 - 3.88	1.29 (38) 1.15 - 1.57	8.27 (38) 4.99 - 11.8	1.41 (38) 0.629 - 2.76
18	Pen Branch at SRS Road A-13	3.68 (38) 2.93 - 13.4	1.23 (38) 0.764 - 1.54	7.65 (38) 2.37 - 11.4	1.35 (38) 0.444 - 3.79
17	Pen Branch swamp near SRS Road A-17	3.13 (39) 2.55 - 3.94	1.13 (39) 0.963 - 1.48	7.96 (39) 4.29 - 12.7	1.21 (39) <0.368 - 1.89
9	Pen Branch swamp upstream of Steel Creek confluence	3.50 (36) 2.62 - 4.31	1.29 (36) 0.992 - 1.58	7.79 (36) 3.60 - 14.0	1.34 (36) 0.502 - 2.34

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

M890607O

TABLE 4-6

Total and Dissolved Major Cation Concentrations: Al, Fe, Mn (mg/L): Pen Branch Watershed

Station Number	Site	Aluminum, Total	Aluminum, Dissolved	Iron, Total	Iron, Dissolved	Manganese, Total	Manganese, Dissolved
19	Pen Branch at SRS Road B	0.789 (39) <0.038 - 3.68	0.064 (39) <0.038 - 0.596	1.23 (39) <0.003 - 2.36	0.225 (39) 0.015 - 0.709	0.097 (15) <0.0004 - 0.231	0.059 (17) <0.0004 - 0.100
20	Indian Grave Branch downstream of K Reactor effluent	1.09 (39) 0.105 - 2.87	0.061 (38) <0.038 - 0.155	1.11 (39) 0.035 - 3.22	0.135 (38) 0.017 - 0.346	0.100 (16) <0.0004 - 0.291	0.052 (17) <0.0004 - 0.115
18	Pen Branch at SRS Road A-13	1.02 (38) 0.049 - 3.03	0.078 (38) <0.038 - 0.565	0.999 (38) 0.006 - 2.32	0.147 (38) <0.003 - 0.500	0.104 (15) <0.0004 - 0.322	0.062 (16) <0.0004 - 0.181
17	Pen Branch swamp near SRS Road A-17	0.823 (39) 0.182 - 2.30	0.112 (39) <0.038 - 0.765	0.871 (39) 0.424 - 2.35	0.176 (39) 0.028 - 0.573	0.089 (16) <0.0004 - 0.309	0.046 (17) <0.0004 - 0.139
9	Pen Branch swamp upstream of Steel Creek confluence	0.350 (36) 0.080 - 1.27	<0.038 (36) <0.038 - 0.178	0.972 (36) 0.019 - 1.79	0.212 (36) 0.025 - 0.739	0.071 (15) <0.0004 - 0.140	0.049 (15) <0.0004 - 0.120

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

WB906070

TABLE 4-7

Total Trace Elemental Concentrations (μg/L): Pen Branch Watershed

Station Number	Site	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
19	Pen Branch at SRS Road B	1.6 (15) <0.4 - 6.2	0.36 (15) <0.04 - 2.00	6.6 (15) <0.4 - 49.0	3.0 (15) <0.4 - 14.1	1.8 (15) <0.4 - 6.0	2.8 (15) <0.4 - 8.7	6.1 (15) <0.4 - 23.1
20	Indian Grave Branch downstream of K Reactor effluent	2.6 (16) <0.4 - 10.8	0.56 (16) <0.04 - 1.80	10.4 (16) <0.4 - 71.0	3.0 (16) <0.4 - 9.1	2.3 (16) <0.4 - 9.3	3.8 (16) <0.4 - 11.0	5.8 (16) <0.4 - 25.9
18	Pen Branch at SRS Road A-13	2.8 (15) <0.4 - 10.7	0.99 (15) <0.04 - 11.3	10.1 (15) <0.4 - 90.0	3.0 (15) <0.4 - 6.5	1.3 (15) <0.4 - 5.0	4.3 (15) <0.4 - 18.0	5.7 (15) <0.4 - 27.7
17	Pen Branch swamp near SRS Road A-1	2.3 (16) <0.4 - 8.2	0.37 (16) <0.04 - 1.60	7.1 (16) <0.4 - 57.0	3.2 (16) <0.4 - 7.1	2.4 (16) <0.4 - 18.7	3.2 (16) <0.4 - 13.0	6.2 (16) <0.4 - 21.6
9	Pen Branch swamp upstream of Steel Creek confluence	1.3 (15) <0.4 - 5.0	0.29 (15) <0.04 - 1.42	7.5 (15) <0.4 - 65.0	2.1 (15) <0.4 - 15.0	2.0 (15) <0.4 - 5.4	2.0 (15) <0.4 - 7.5	4.7 (15) <0.4 - 22.0

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

WB90607D

TABLE 4-8

Organic Carbon Concentrations (mg C/L): Pen Branch Watershed

Station Number	Site	Total Organic Carbon	Dissolved Organic Carbon	Particulate Organic Carbon
19	Pen Branch at SRS Road B	5.99 (25) 0.36 - 11.8	5.12 (9) 2.61 - 9.30	3.40 (10) 0.241 - 10.7
20	Indian Grave Branch downstream of K Reactor effluent	6.49 (25) 2.85 - 12.9	5.04 (9) 3.61 - 7.25	2.66 (10) 0.580 - 6.10
18	Pen Branch at SRS Road A-13	6.82 (23) 4.40 - 13.2	5.73 (10) 3.59 - 7.90	3.44 (9) 0.560 - 11.7
17	Pen Branch swamp near SRS Road A-17	6.42 (25) 1.84 - 10.5	5.75 (10) 3.73 - 8.80	2.43 (10) 0.450 - 6.12
9	Pen Branch swamp upstream of Steel Creek confluence	6.81 (22) 2.86 - 13.7	5.48 (11) 3.62 - 10.1	1.02 (11) 0.200 - 2.50

All values reported as means with number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

The total suspended solids concentrations at the nonthermal site (6.0 mg/L) were lower than those of the faster-moving, thermal stream sites (16.0 to 18.0 mg/L). Turbidity values displayed the same trend in Pen Branch Creek.

Median specific conductance increased from 46.5 µmhos/cm in the nonthermal sites to 76.1 µmhos/cm at the thermal sites. This change was linked to the specific conductance of Savannah River water. Ionic strength estimates for the nonthermal site were 0.000638 M (not including organic compounds) and 0.000652 M (including organic compounds). Ionic strengths were higher in the thermal waters (inorganic species only 0.000818 to 0.000841 M; organic species included 0.000829 to 0.000853 M).

At the nonthermal site, median concentrations of total alkalinity, chloride and sulfate were 13.8, 2.6, and 1.7 mg/L, respectively. Those of the thermal sites were 17.6 to 18.9, 5.4 to 5.7, and 5.19 to 5.23 mg/L, respectively. The higher total alkalinity, chloride, and sulfate concentrations at the thermal sites likely reflected the chemistry of the source water. Median total alkalinity concentration was lowest in winter (10.5 mg/L as $CaCO_3$) at the nonthermal site.

The dissolved fraction of metal cations includes nearly all of the calcium, magnesium, sodium, and potassium in Pen Branch Creek waters. Median concentrations of the divalent cations calcium and magnesium were slightly higher at the nonthermal site than those at the thermal sites. Sodium and potassium, however, were higher at the thermal sites than at the nonthermal sites. Concentrations of total and dissolved aluminum were higher in the waters of the thermal sites than those of the nonthermal site. Approximately 92% of the aluminum was associated with the solid phase at the nonthermal site and 92 to 93% was associated with the solid phase at the thermal sites. Total and dissolved iron concentrations were higher at the nonthermal site than those at the thermal sites. Approximately 83 to 86% of the iron was present in the solid phase. Median total manganese concentrations ranged from 0.060 to 0.081 mg/L. Roughly 20 to 28% of the manganese was present in the solid phase. At all sites, median total and dissolved iron and manganese concentrations were highest in the summer.

All measured forms of phosphorus were higher at the thermal portions of this system than those at the nonthermal site. Whereas, 13% of the phosphorus was present as dissolved ortho-phosphate at the nonthermal site, 49 to 59% was dissolved ortho-phosphate at the thermal site. Sixty-two percent of the phosphorus was not ortho-phosphate at the nonthermal site while 27 to 38% of the phosphorus at the thermal sites was not ortho-phosphate. The speciation and concentrations of phosphorus in the thermal sites reflected, at least partially, the phosphorus speciation and concentrations in the Savannah River. Although the median concentrations of organic nitrogen were not very different between the thermal and nonthermal waters of this stream, the percentage of nitrogen in the organic form was 73% at the nonthermal waters and only 23 to 26% at the thermal water. Median ammonia, nitrite, and nitrate concentrations were higher at the thermal sites than the nonthermal reflecting the nitrogen species and concentrations in the Savannah River.

Median total arsenic concentrations were slightly lower in the nonthermal waters of Pen Branch (0.6 μg/L) relative to the thermal waters (1.1 to 1.7 μg/L). Median dissolved arsenic concentrations were near or below the detection limit. Median total and dissolved cadmium concentrations were 0.20 to 0.31 and 0.15 to 0.27 μg/L, respectively. Although median total chromium concentrations were as high as 3.8 μg/L, median dissolved chromium concentrations were below the detection limit at all sites. Median total copper concentrations were approximately 2 to 3 μg/L while median dissolved copper concentrations were low at all sites (total 1.0 to 1.3 μg/L; dissolved <0.4 μg/L). The highest median concentration of total nickel was found in the Indian Grave waters (3.9 μg/L). Median total zinc concentrations were slightly higher than 3 μg/L and mercury and uranium and concentrations were below the detection limit in Pen Branch waters.

Total organic carbon concentrations were similar for thermal and nonthermal sites at Pen Branch. However, the nonthermal site had slightly more organic carbon in the dissolved phase (77%) relative to those of the thermal sites (68 to 69%). Except in the Indian Grave Branch (thermal effluent from K Reactor), the five-day BOD values for the Pen Branch sites were below 1.0 mg O_2/L. The 20-day BOD values for the thermal sites were slightly higher than those of the nonthermal site. The nitrogenous BOD did not display any significant trend among sites.

4.2.2 Phytoplankton

The K-Reactor cooling water effluent system, which includes Pen Branch and its principal tributary Indian Grave Branch, is a low potential impact area for phytoplankton because phytoplankton contribute insignificantly to the food chain base in this system. Both Indian Grave Branch and Pen Branch (in its upper and mid-reaches) are relatively shallow, turbulent streams offering little opportunity for phytoplankton growth. Further downstream, Pen Branch enters the Savannah River swamp where it forms an open delta before continuing into the Savannah River swamp forest. The food base throughout this system is detrital material (with some contribution by periphyton) rather than phytoplankton.

4.2.3 Periphyton

The periphyton community of Pen Branch was included in studies of the ecology of the thermal and nonthermal streams of the SRS that were conducted between 1983 and 1985 (Firth et al., 1986; Specht, 1987). Figure 4-3 and Table 4-9 describe the locations of sampling stations. The analyses of the periphyton communities in these studies was accomplished by taxonomic identifications, chlorophyll analyses, and measurement of ash-free dry weight (AFDW).

CORRESPONDING STATION NUMBERS

1983-1984	1984-1985
1	5
2	not sampled
3	14
4	21
5	22
6	23
7	26
8	28
9	33
10	35
11	39
12	40

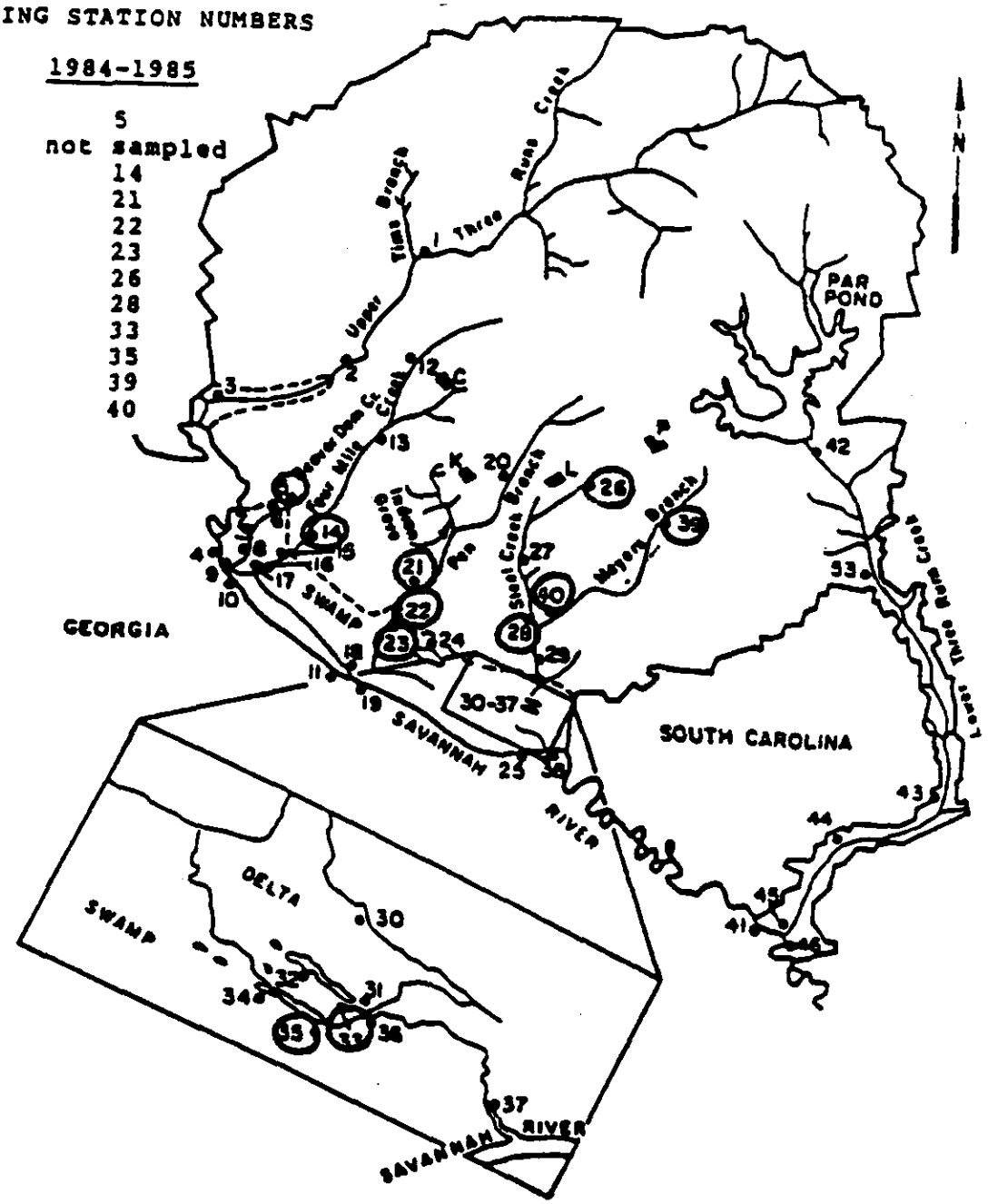


FIGURE 4-3. Map of Savannah River Site Showing Periphyton Sampling Locations (1983-1985)
(source: Paller et al., 1989b)

W8906070

TABLE 4-9

Periphyton Sampling Station Numbers, Location, and Thermal Regime

Station Number 1983-1984	Station Number 1984-1985	Location[a]	Thermal[a] Regime
	1	UTR	n
	2	UTR	n
Creek 157.2	3	UTR	n
RM 152.2	4	SR	n
1	5	BD	t
	6	BD	t
	7	BD	t
	8	BD	t
Creek 152.1	9	BD	t
RM 152.0	10	SR	n
RM 150.8	11	SR	n
	12	FM	n
	13	FM	t
2	-	FM	t
3	14	FMD	t
	15	FMD	t
	16	FMD	t
	17	FMD	t
Creek 150.6	18	FMD	t
RM 150.4	19	SR	n
	20	PB	n
4	21	PB	t
5	22	PBD	t
6	23	PBD	t
	24	PBS	n
RM 141.7	25	SR	n
7	26	SC	n
	26	SC	n
	27	SC	n
8	28	SC	n
	29	SC	n
	30	SCD	n
	31	SCD	n
	32	SCD	n
9	33	SCD	n
	34	SCS	n
10	35	SCS	n
	36	SC	n

TABLE 4-9, Contd

Station Number 1983-1984	Station Number 1984-1985	Location	Thermal Regime
Creek 141.6	37	SC	n
RM 141.5	38	SR	n
11	39	MB	n
12	40	MB	n
RM 129.1	41	SR	n
	42	LTR	n
	43	LTR	n
	44	LTR	n
Creek 129.0	45	LTR	n
	46	SR	n
	53	LTR	n
RM 157.3		SR	n
RM 137.7		SR	n
1G	1G	Intake Canal 1G	n
3G	3G	Intake Canal 3G	n

[a] n = Nonthermal
t = Thermal
SR = Savannah River
UTR = Upper Three Runs Creek
BD = Beaver Dam Creek
FM = Four Mile Creek
FMD = Four Mile Delta
PB = Pen Branch
PBD = Pen Branch Delta
PBS = Pen Branch Swamp
SC = Steel Creek
SCD = Steel Creek Swamp
MB = Meyers Branch Creek
LTR = Lower Three Runs Creek

Source: Paller et al. (1989)

4.2.3.1 Species Composition and Abundance

During 1983-1984, periphyton stream sampling was carried out in the winter and spring. Biomass (as determined by chlorophyll a analyses) and standing crop (as determined by ash-free dry measurements) results are presented in Tables 4-10 and 4-11, respectively.

Periphyton differed in type between thermal and nonthermal sites. Green algae and diatoms characterized the nonthermal sites, while thick mats of blue-green algae were unevenly distributed at the thermal sites (Specht, 1987). During winter, periphyton biomass values were highest at the thermal sites (1983-1984 Stations 2, 3, and 4, Table 4-10). Warm water temperatures during the winter months stimulated blue-green algal production in the thermal streams (Gladden et al., 1985). In the spring, mean periphyton biomass did not show a distinctive pattern relative to temperature. Organic standing crops tended to be highest at the thermal sites although values were highly variable (Table 4-11).

During 1984-1985, the range of mean periphyton biomass at thermal stream Stations 6, 8, and 21 was 0.10 to 0.18 g/m^2 (Table 4-12). Variations in periphyton biomass values were higher at the thermal stream sites than at the nonthermal sites. Periphyton biomass values in the nonthermal Steel Creek Delta sites (Stations 31, 32, and 33) fell within the same range as the thermal delta sites (Table 4-12). Mean periphyton biomass values did not differ significantly ($p > 0.05$) between the closed canopy Steel Creek swamp sites or between those swamp sites and the open canopy Steel Creek Delta sites (Table 4-12; Firth et al., 1986). Because the canopy at the Steel Creek swamp sites is not dense, light limitation was probably not an important factor constraining periphyton production (Firth et al., 1986). In comparison, the densely canopied Pen Branch swamp Station 24 had a significantly lower periphyton biomass than the Pen Branch Delta Station 22. Biomass at Pen Branch Station 24 did not appear to be affected by the status of K Reactor (Firth et al., 1986). There were no significant ($p > 0.05$) differences between thermally impacted Four Mile Creek Station 18 and the nonthermal creek mouth stations, despite the elevated temperatures at the mouth of Four Mile Creek (Firth et al., 1986).

Periphyton species composition was determined by microscopic examination and pigment analysis of samples collected quarterly during 1984-1985 (Bott et al., 1986). Differences between streams (thermal, nonthermal, or post-thermal) in total biomass, algal biomass, or diatom biomass were not statistically significant, although there were significant differences ($p < 0.05$) among streams within a thermal class (Firth et al., 1986). This was attributable to the wide ranges in thermal conditions for streams grouped in each thermal class. Blue-green algae were abundant only in the thermal streams. Significant seasonal differences ($p < 0.05$) occurred in both the nonthermal and post-thermal streams, with greater amounts of algal biomass and diatom biomass present in the spring than in autumn. However, in the thermal streams, seasonal effects were not apparent.

TABLE 4-10

Periphyton Biomass (g/m^2) at Each 1983-1984 Station During Winter and Spring Sampling[a]

Location	Station	Mean	(Range)	N[a]
		Winter		
BD-t	1[b]			
FM-t	2	9.18	(0.0-26.14)	37
FM-t	3	13.26	(0.25-32.70)	42
PB-t	4	11.61	(1.87-29.80)	29
SC-n	7	1.94	(0.31-13.45)	40
SC-n	8	1.35	(0.001-4.30)	43
MB-n	11	3.59	(0.56-10.11)	45
MB-n	12	7.29	(0.94-17.48)	44
		Spring		
BD-t	1	1.48	(0.0-8.16)	44
FM-t	2	14.42	(0.0-47.40)	45
FM-t	3	20.83	(0.53-38.18)	45
PB-t	4	3.81	(0.08-10.54)	45
SC-n	7	2.41	(0.05-17.51)	45
SC-n	8	0.56	(0.24-4.45)	43
MB-n	11	10.73	(0.13-40.42)	45
MB-n	12	9.22	(1.86-21.06)	45

Note: Abbreviations are listed in Table 4-9.

[a] N = number of samples
[b] Beaver Dam Creek was not sampled for biomass until spring.

Source: Specht (1987)

TABLE 4-11

Organic Standing Crop (g/m^2) at Each 1983-1984 Station (Winter and Spring 1984)[a]

Location	Station	Mean (Range)		N[a]
		Winter		
BD-t	1	1063.5	(529.1-1586-5)	6
FM-t	2	2346.7	(887.6-4976.6)	30
FM-t	3	653.0	(0.0-1771.3)	27
PB-t	4	1737.7	(765.6-3572.6)	30
SC-n	7	400.8	(0.0-3344.4)	28
SC-n	8	463.9	(0.0-2343.7)	30
MB-n	11	321.2	(17.0-1118.8)	16
MB-n	12	474.2	(0.0-1080.8)	28
		Spring		
BD-t	1	615.9	(0.0-1588.6)	30
FM-t	2	1508.8	(122.6-3667.1)	30
FM-t	3	1298.2	(224.7-2978.1)	30
PB-t	4	2254.4	(224.2-4684.4)	30
SC-n	7	198.4	(60.5-810.1)	30
SC-n	8	67.1	(21.0-288.7)	30
MB-n	11	382.1	(18.0-2411.7)	30
MB-n	12	920.5	(135.6-2475.3)	30

Note: Abbreviations are listed in Table 4-9.

[a] N = number of samples

Source: Specht (1987)

TABLE 4-12

Periphyton Biomass (g/m^2) Mean, N, Standard Error, Coefficient of Variation (CV) and Minimum and Maximum Values for Each 1984-1985 Station (October 1984 - September 1985)

Station	Location/ Thermal Regime	Mean	N	Standard Error	Minimum	Maximum
1	UTR-n	0.0848	72	0.0048	0.0314	0.2468
3	UTR-n	0.1010	71	0.0055	0.0353	0.2358
4	SR-n	0.2387	72	0.0373	0.0317	1.454
6	BD-t	0.1548	59	0.0393	0.0288	1.713
8	BD-t	0.1024	72	0.0101	0.0209	0.4330
9	BD-t	0.0586	72	0.0042	0.0145	0.2545
10	SR-n	0.2279	66	0.0438	0.0000	2.457
11	SR-n	0.2040	60	0.0259	0.0293	0.7491
14	FMD-t	0.2517	72	0.0347	0.0354	1.780
15	FMD-t	0.1030	48	0.0117	0.0104	0.4352
17	FMD-t	0.1191	54	0.0237	0.0334	1.222
18	FM-t	0.1368	71	0.0296	0.0121	1.713
19	SR-t	0.2797	72	0.0468	0.0380	1.597
20	PB-n	0.0683	70	0.0031	0.0220	0.1414
21	PB-t	0.1816	72	0.0315	0.0035	1.355
22	PBD-t	0.2338	72	0.0275	0.0055	1.223
24	PBS-n	0.0926	72	0.0067	0.0264	0.3096
25	SR-n	0.1980	72	0.0338	0.0251	1.388
26	SC-n	0.1509	72	0.0172	0.0429	0.8923
27	SC-n	0.1060	66	0.0085	0.0264	0.3812
28	SC-n	0.1390	66	0.0244	0.0087	1.487
29	SC-n	0.1304	72	0.0076	0.0372	0.4287
31	SCD-n	0.2360	72	0.0408	0.0220	2.911
32	SCD-n	0.1676	71	0.0135	0.0196	0.5013
33	SCD-n	0.2023	72	0.0160	0.0659	0.6390
34	SCS-n	0.1729	72	0.0175	0.0397	1.080
35	SCS-n	0.1904	72	0.0197	0.0342	0.8208
36	SC-n	0.1350	72	0.0122	0.0303	0.5068
37	SC-n	0.1000	71	0.0057	0.0381	0.2975
38	SR-n	0.1710	72	0.0294	0.0166	1.818
39	MB-n	0.0819	72	0.0035	0.0314	0.1564
40	MB-n	0.0761	66	0.0059	0.0259	0.3294
41	SR-n	0.1542	70	0.0161	0.0383	0.7761
42	LTR-n	0.1213	72	0.0076	0.0297	0.3305
53	LTR-n	0.0666	48	0.0068	0.0045	0.2809
43	LTR-n	0.1030	18	0.0088	0.0480	0.1695
44	LTR-n	0.0774	71	0.0041	0.0061	0.1504
45	LTR-n	0.1267	66	0.0269	0.0034	1.625

Note: Abbreviations are listed in Table 4-9.

Source: Firth et al. (1986)

4.2.3.2 Expected Impacts from Restarting the K Reactor

Based on the studies of periphyton conducted during prior SRS reactor operations, the restart of K Reactor is not expected to have any significant adverse impact on the periphyton community of the Pen Branch system. However, higher overall periphyton densities and a greater abundance of thermophilic blue-green algae in the upper portion of the creek system near the cooling water effluent discharge are expected because of the temperature elevation and nutrient enrichment associated with the discharge of heated Savannah River water into the Pen Branch drainage system.

4.2.4 Zooplankton

The use of zooplankton as a significant food source for larval fishes in the Savannah River and Steel Creek swamp was documented by Chimney and Dorchak (1987). It is assumed that zooplankton are also a food source for larval fishes in the other major tributaries on the SRS, including Pen Branch.

Chimney and Cody (1987) sampled zooplankton at 13 locations on the SRS from December 1984 through August 1985. Three locations were on the Savannah River (RM 157.0, RM 150.4, and RM 141.5) and 10 stations in the swamp/deltas of four major tributaries that drain the SRS (Beaver Dam Creek Stations 6 and 7; Four Mile Creek Station 17; Pen Branch Stations 22 and 24; and Steel Creek Stations 31, 32, 33, 34, and 35 were selected (Figure 4-4). Zooplankton samples were collected quarterly from December 1984 to August 1985, and on six additional dates during March to May 1985, a period which encompassed the peak spawning season for many species of fish in the system.

This discussion focuses primarily on the zooplankton community in the Pen Branch swamp and a comparison of zooplankton communities in Pen Branch with those in the other SRS creeks and the Savannah River.

4.2.4.1 Standing Crop Estimates

Densities of total zooplankton and each major taxonomic group thereof at Pen Branch Stations 22 and 24 on the 10 sampling dates are presented in Figure 4-5. Mean total densities ranged from a low of 67 organisms/m^3 in December at Station 24 to a high of 40,467 organisms/m^3 at Station 22 in late April (Figure 4-5). Station 24 had a single peak of much lower density than Station 22 in April.

Total mean densities of zooplankton at Station 22 were significantly higher than those at Station 24. The total mean densities in December at both stations were significantly lower ($p \leq 0.05$) than those found on the other dates.

Descriptive statistics for overall mean zooplankton densities from all sampling stations in the study by Chimney and Cody (1987) are presented in Table 4-13. Station 24 in Pen Branch had the lowest mean total density

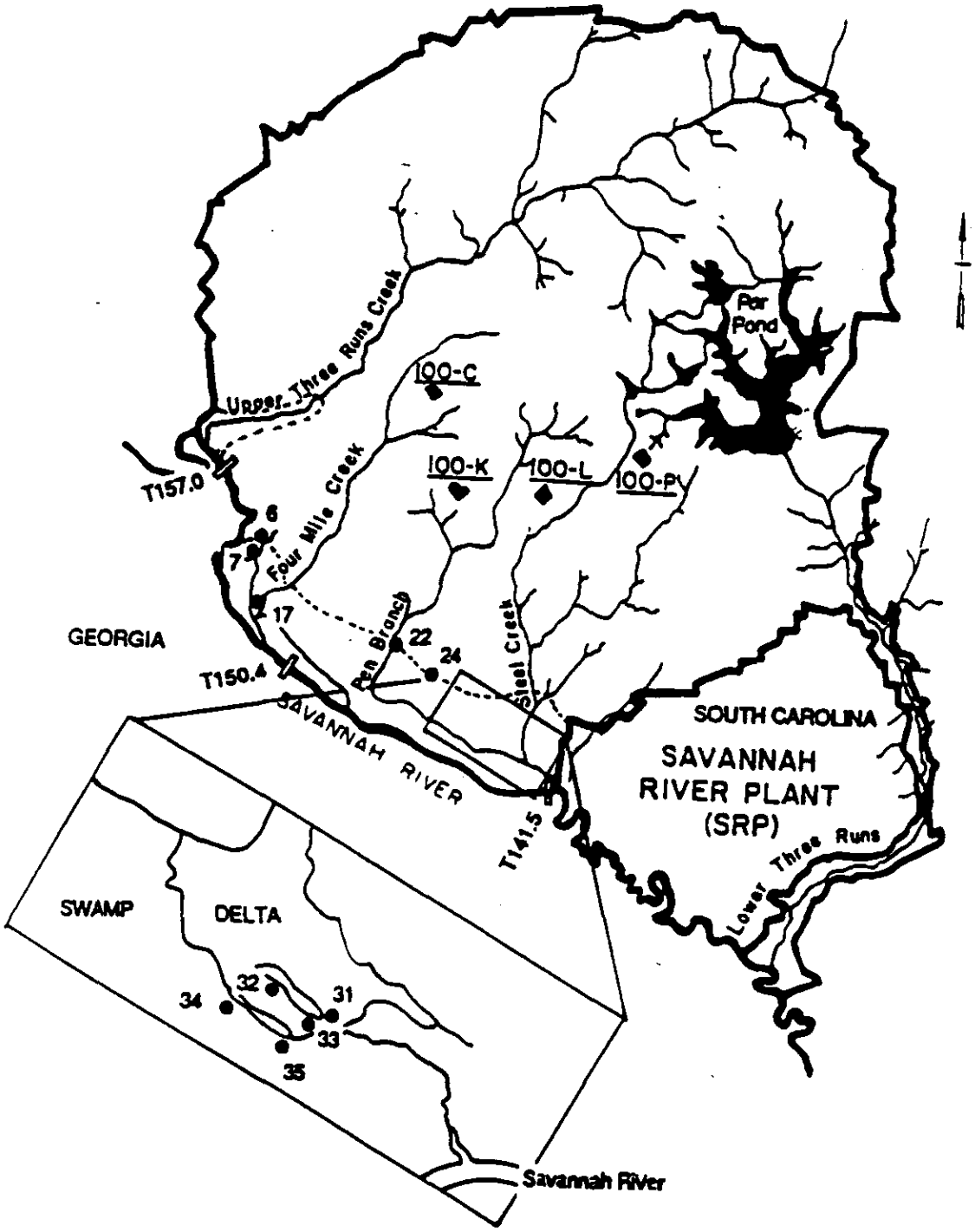
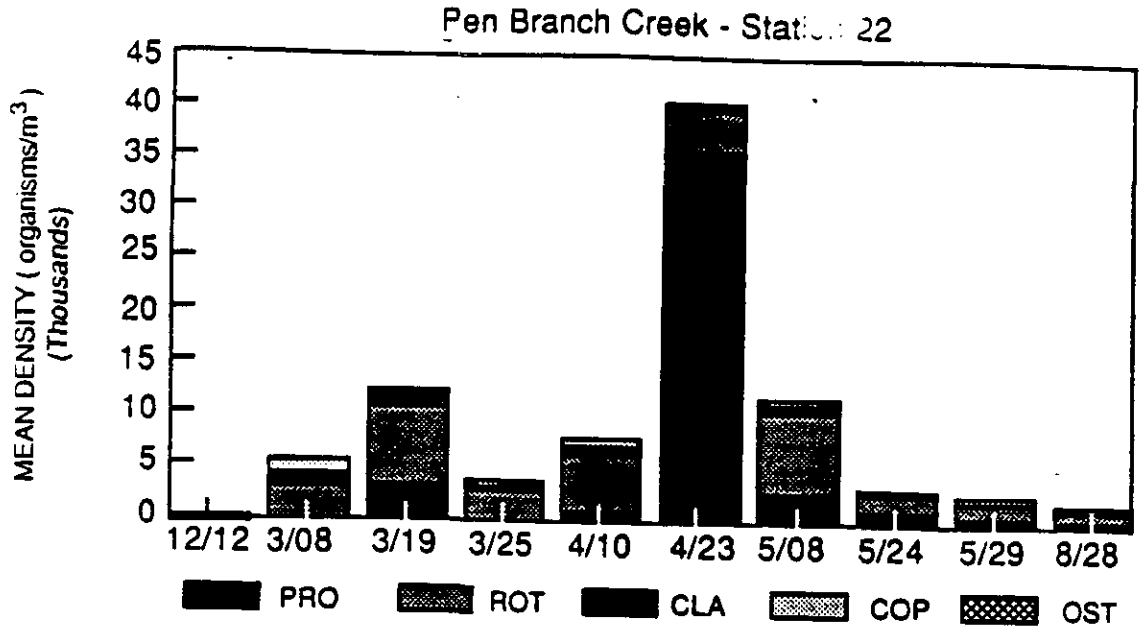


FIGURE 4-4. Map of the Savannah River Site Indicating the Location of Zooplankton Sampling Stations on the Savannah River (RM 141.5, RM 150.4, RM 157.0), Beaver Dam Creek (6,7), Four Mile Creek (17), Pen Branch (22,24), and Steel Creek (31,32,33,34,35). December 1984 - August 1985 (source: Chimney and Cody, 1987)



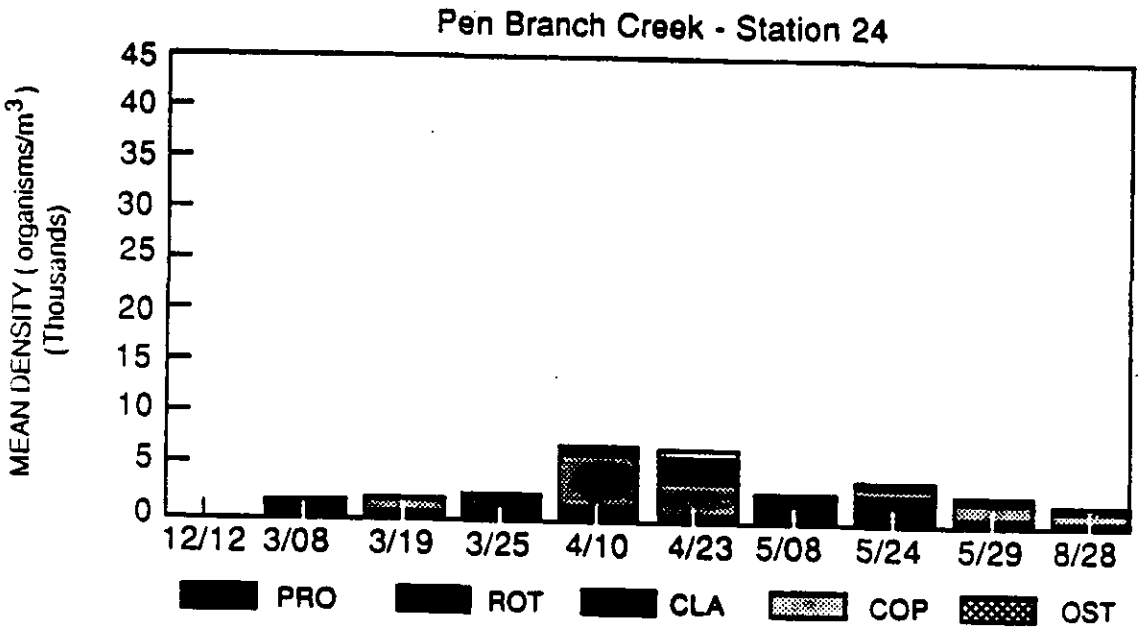


FIGURE 4-5. Mean Density of Zooplankton (organisms/m^3) at Pen Branch Sampling Stations. PRO = Protozoa; ROT = Rotifers; CLS = Cladocera; COP = Copepods; OST = Ostracoda, December 1984 - August 1985
(source: Chimney and Cody, 1987)

TABLE 4-13

Overall Mean, Median, N, Standard Error, Coefficient of Variation, Minimum and Maximum Values for Total Zooplankton Density (organisms/m^3) from all Savannah River and SRS Creek/Swamp Sampling Locations (December 1984 - August 1985)

Location	Mean	Median	N	Standard Error	Coefficient of Variation	Minimum	Maximum
SR 141.5	9,929	5,700	90	1,550	148.1	0	112,500
SR 150.4	19,199	11,900	90	2,524	124.7	0	163,000
SR 157.0	19,142	10,250	90	3,243	160.7	0	197,000
BD 6	8,233	3,250	30	1,981	131.8	400	43,800
BD 7	4,860	2,500	30	1,153	130.0	0	30,600
FM 17	20,803	9,200	30	5,575	146.8	600	138,000
PB 22	9,037	3,750	30	3,074	186.3	0	90,900
PB 24	3,130	2,750	30	447	78.2	0	10,000
SC 31	5,130	3,350	30	1,025	109.4	600	21,300
SC 32	5,497	5,700	30	633	63.0	200	13,100
SC 33	3,450	2,750	30	671	106.5	300	20,600
SC 34	22,237	5,100	30	6,184	152.3	0	117,500
SC 35	7,717	3,300	30	1,808	128.3	0	35,900

Note: SR = Savannah River; BD = Beaver Dam Creek; FM = Four Mile Creek; PB = Pen Branch; SC = Steel Creek

Source: Chimney and Cody (1987)

(3,130 organisms/m^3) of the 13 locations sampled. Statistical testing indicated that zooplankton densities were unrelated to the water temperature, dissolved oxygen, pH, and conductivity values that were measured at the time of collection (Chimney and Cody, 1987).

4.2.4.2 Community Structure

A total of 85 zooplankton taxa were collected during the study by Chimney and Cody (1987). Table 4-14 lists all individual taxa identified and indicates those that were numerically dominant (comprising at least 10% of the total zooplankton in at least one sample). Table 4-15 shows the number of taxa identified from each major taxonomic group in samples from the Savannah River, and the swamp/deltas of Pen Branch, Four Mile Creek, Beaver Dam Creek, and Steel Creek. A total of 39 zooplankton taxa (7 Protozoa, 21 Rotifera, 8 Cladocera, 2 Copepoda, and 1 Ostracoda) were identified from Pen Branch during the course of this study (Table 4-15). Descriptive statistics for mean taxa richness from Pen Branch Stations 22 and 24 are presented in Table 4-16. The number of taxa collected per individual sample ranged between 0 and 10. Mean taxa richness in Pen Branch was highest at Station 22 in March and at Station 24 in April (Figure 4-6). The lowest mean values occurred in December at both stations.

Descriptive statistics for overall mean taxa richness at all sampling stations in the study by Chimney and Cody (1987) are presented in Table 4-17. Although Four Mile Creek had the fewest total zooplankton taxa identified from it (38 taxa; Table 4-15), it had the highest overall mean taxa richness (6.0 taxa/sample; Table 4-17). Station 24 in the Pen Branch Delta/swamp had the lowest overall mean taxa richness (3.9 taxa/sample; Table 4-17). However, differences among stations in overall mean taxa richness were generally on the order of 1.0 or fewer taxa.

4.2.4.3 Seasonal Variations in Abundance and Distribution

Except for December at Station 24, the microzooplankton (Protozoa and Rotifera) numerically dominanted zooplankton at both Pen Branch stations and comprised as much as 99% of the community (Figure 4-7). Rotifera were numerically dominant on most dates at Station 22, while the Rotifera and Protozoa dominated with about about equal frequency at Station 24 (5 and 4 dates, respectively).

4.2.4.4 Expected Impacts from Restarting the K Reactor

The restarting of K Reactor is expected to have no significant impact on the zooplankton community in the Pen Branch System. Although water temperatures in Indian Grave Branch near the reactor cooling water discharge may be too high for zooplankton during reactor operation, zooplankton are not considered important components of this part of the creek system due to the shallowness, rapid current, and turbulence of the creek in this region. A resumption of K-Reactor operations is not expected to have any adverse effects on zooplankton in the Pen Branch Delta/swamp.

TABLE 4-14

Zooplankton Collected from the Savannah River and the Swamp/Deltas of Four Tributaries on the Savannah River Site (December 1984 - August 1985)

Taxa	Sampling Locations				
	BD	FM	PB	SC	SR
PHYLUM PROTOZOA					
Subphylum Ciliophora					
Class Ciliatea					
Subclass Peritrichia					
Order Peritrichida					
Family Vorticellidae					
Campanella sp.	x	x[a]	x[a]	x[a]	x[a]
Carchesium sp.	x[a]		x[a]	x[a]	x[a]
Epistylis sp.	x[a]	x[a]	x[a]	x[a]	x[a]
Opercularia sp.					x[a]
Vorticella sp.		x[a]	x[a]	x[a]	x[a]
Subclass Spirotrichia					
Order Heterotrichida					
Family Tintinnidae					
Codonella cratera				x	
Order Oligotrichida					
Family Strobilidiidae					
Strobilidium gyrans					x
Strobilidium sp.				x[a]	
Unident. oxytrich ciliate					x
Subphylum Sarcomastigophora					
Superclass Scarodina					
Class Rhizopodea					
Order Testacida					
Family Arcellidae					
Arcella sp.	x[a]	x[a]	x	x[a]	x[a]
Family Difflugiidae					
Centropyxis aculeata	x[a]	x[a]	x[a]	x[a]	x[a]
Difflugia sp.	x[a]	x	x[a]	x[a]	x[a]
Euglypha ciliata		x		x	
Family Trachelidae					
Trachelius sp.					x

TABLE 4-14, Contd

Taxa	Sampling Locations BD	FM	PB	SC	SR
PHYLUM ROTIFERA					
Class Monogonata					
Order Ploima					
Family Asplanchnidae					
Asplanchna priodonta		x			x
Asplanchna sp.					x
Brachionus bidentata					x[a]
B. calyciflorus	x				x
B. caudatus					x
B. havanaensis					x
B. rubens					x
Brachionus sp.					x
Colurella obtusa		x		x	x
Colurella sp.				x	
Euchlanis sp.	x[a]	x[a]	x[a]	x[a]	x[a]
Kellicottia bostoniensis					x
Keratella cochlearis	x			x	x
K. crassa			x	x	x
Lepadella patella	x		x[a]	x[a]	x
L. ovalis				x[a]	
Lepadella sp.		x	x[a]		
Macrochaetus subquadratus			x	x[a]	
Manfredium eudactylatum	x[a]	x	x		
Mytilina ventralis	x				
Notholca acuminata				x	
Platyias patulus					x
P. quadricornis	x			x	x
Trichotria tetractis	x[a]	x	x	x[a]	x
Family Dicranophoridae					
Dicranophorus sp.		x[a]			x
Wierzejskiella velvox		x	x		x
Family Lecanidae					
Lecane inermis		x	x	x	
L. leontina		x	x		
L. luna	x	x[a]	x[a]	x	x
L. mira				x	
L. ungulata		x[a]			
Lecane spp.	x[a]	x[a]	x	x[a]	x[a]
Monostyla bulla	x[a]	x[a]	x	x	x
M. lunaris	x[a]	x	x[a]	x	x
M. quadridentata	x	x	x[a]		x
Monostyla sp.	x	x	x	x	x

TABLE 4-14, Contd

Taxa	Sampling Locations BD	FM	PB	SC	SR
PHYLUM ROTIFERA, Contd					
Family Notommatidae					
Cephalodella sp.		x[a]	x	x	x
Notommata sp.		x			
Family Synchaetidae					
Polyarthra dolichoptera					x
Synchaeta sp.					x
Family Trichocercidae					
Trichocerca longiseta		x	x	x[a]	X
T. multicrinis			x	x	
Trichocerca sp.			x	x	x
Order Floscularlacea					
Family Testudinellidae					
Filinia longiseta					x
Monogonata spp.	x[a]	x[a]	x[a]	x	x[a]
Class Digononta					
Order Bdelloida					
Family Philodinidae					
Rotatoria sp.					x
Unid. spp.		x[a]		x[a]	x[a]
PHYLUM ARTHROPODA					
Class Crustacea					
Subclass Branchiopoda					
Order Cladocera					
Family Bosminidae					
Bosmina longirostris	x		x[a]	x	x
Family Chydoridae					
Alona sp.	x[a]	x	x	x[a]	x
Chydorus brevilabris	x[a]	x	x	x[a]	x
C. piger	x			x	
Chydorus sp.	x		x	x	x
Camptocercus cf. *rectirostris*	x	x		x	
Eurycercus sp.	x			x	x
Pleuroxus denticulatus					x
Pleuroxus sp.	x[a]		x	x	x[a]

TABLE 4-14, Contd

Taxa	Sampling Locations BD	FM	PB	SC	SR
PHYLUM ARTHROPODA, Contd					
Family Daphnidae					
Ceriodaphnia reticulata	x				x
Ceriodaphnia sp.	x				x
Daphnia parvula	x[a]	x	x		x
Scapholebris kingi	x			x[a]	
Simocephalus sp.	x		x	x[a]	
Family Macrothricidae					
Illyocryptus spinifer		x[a]		x	
Macrothrix laticornis		x	x		x
Family Sididae					
Diaphanosoma brachyurum	x				
Subclass Copepoda					
Order Eucopepoda					
Suborder Calanoida					
Family Diaptomidae					
Diaptomus sp.	x[a]				x
Suborder Cyclopoida					
Family Cyclopidae					
Cyclops varicans rubellus	x				
Cyclops sp.	x[a]	x	x[a]	x[a]	x
Macrocyclops sp.				x[a]	x
Paracyclops fimbriatus poppei	x[a]	x	x[a]	x[a]	x[a]
Suborder Harpacticoida					
Family Ameiridae					
Nitocra sp.				x[a]	
Subclass Ostracoda					
Unid. spp.	x[a]	x[a]	x[a]	x[a]	x

[a] Taxa comprised at least 10% of zooplankton in one or more samples.

Note: BD = Beaver Dam Creek; FM = Four Mile Creek; PB = Pen Branch; SC = Steel Creek; SR = Savannah River

Source: Chimney and Cody (1987)

TABLE 4-15

Total Number of Zooplankton Taxa Identified from the Savannah River and Tributaries of the Savannah River Site Which Drain the Savannah River (December 1984 - August 1985)

Taxa	Sampling Locations[a] SR	BD	FM	PB	SC	All Systems
Protozoa	11	6	7	7	10	14
Rotifera	34	15	22	21	24	47
Cladocera	11	14	6	8	11	17
Copepoda	4	4	2	2	4	6
Ostracoda	1	1	1	1	1	1
Total	61	40	38	39	50	85

[a] BD = Beaver Dam Creek; FM = Four Mile Creek; PB = Pen Branch; SC = Steel Creek; SR = Savannah River

Source: Chimney and Cody (1987)

TABLE 4-16

Mean, Median, N, Standard Error, Coefficient of Variation, Minimum and Maximum Values for Zooplankton Taxa Richness (taxa/sample) from Pen Branch Sampling Stations (December 1984 - August 1985)

Date	Mean	Median	N	Standard Error	Coefficient of Variation	Minimum	Maximum
				Station 22			
12/12/84	0.7	1	3	0.3	86.6	0	1
3/07/85	7.7	8	3	1.5	32.8	5	10
3/19/85	7.7	8	3	0.3	7.5	7	8
3/25/85	4.0	5	3	1.0	43.3	2	5
4/10/85	7.0	7	3	1.7	42.9	4	10
4/23/85	4.0	3	3	1.0	43.3	3	6
5/08/85	5.0	5	3	0.6	20.0	4	6
5/24/85	3.0	2	3	1.0	57.7	2	5
5/29/85	5.0	6	3	1.0	34.6	3	6
8/28/85	2.7	3	3	0.9	57.3	1	4
				Station 24			
12/12/84	0.3	0	3	0.3	173.2	0	1
3/08/85	5.0	5	3	1.2	40.0	3	7
3/19/85	3.0	3	3	0.6	33.3	2	4
3/25/85	4.3	4	3	0.9	35.3	3	6
4/10/85	6.3	7	3	1.2	32.9	4	8
4/23/85	6.3	7	3	1.8	48.2	3	9
5/08/85	3.3	3	3	0.3	17.3	3	4
5/24/85	3.7	4	3	0.9	41.7	2	5
5/29/85	4.0	4	3	0.6	25.0	3	5
8/28/85	3.0	3	3	0.0	0.0	3	3

Source: Chimney and Cody (1987)

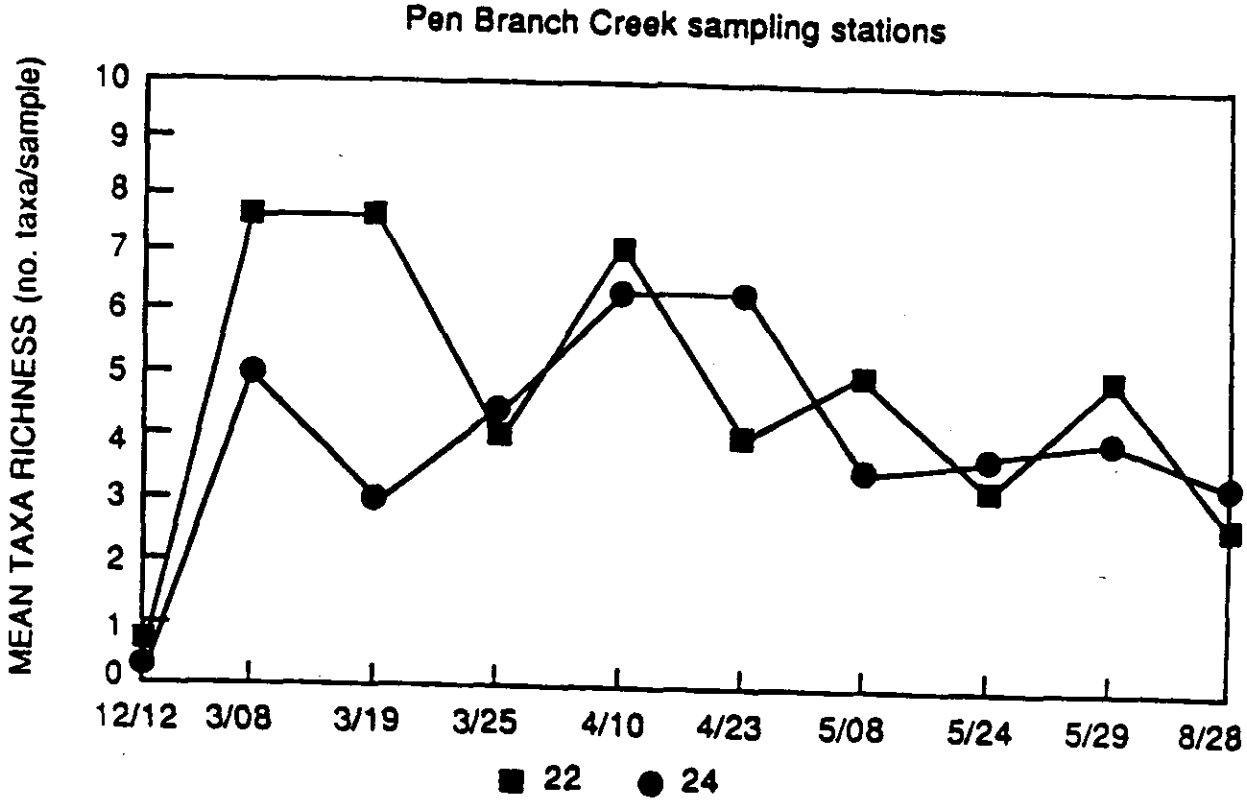


FIGURE 4-6. Mean Zooplankton Taxa Richness (no. taxa/sample) at Pen Branch Sampling Stations (December 1984 - August 1985) (source: Paller et al. (1989b)

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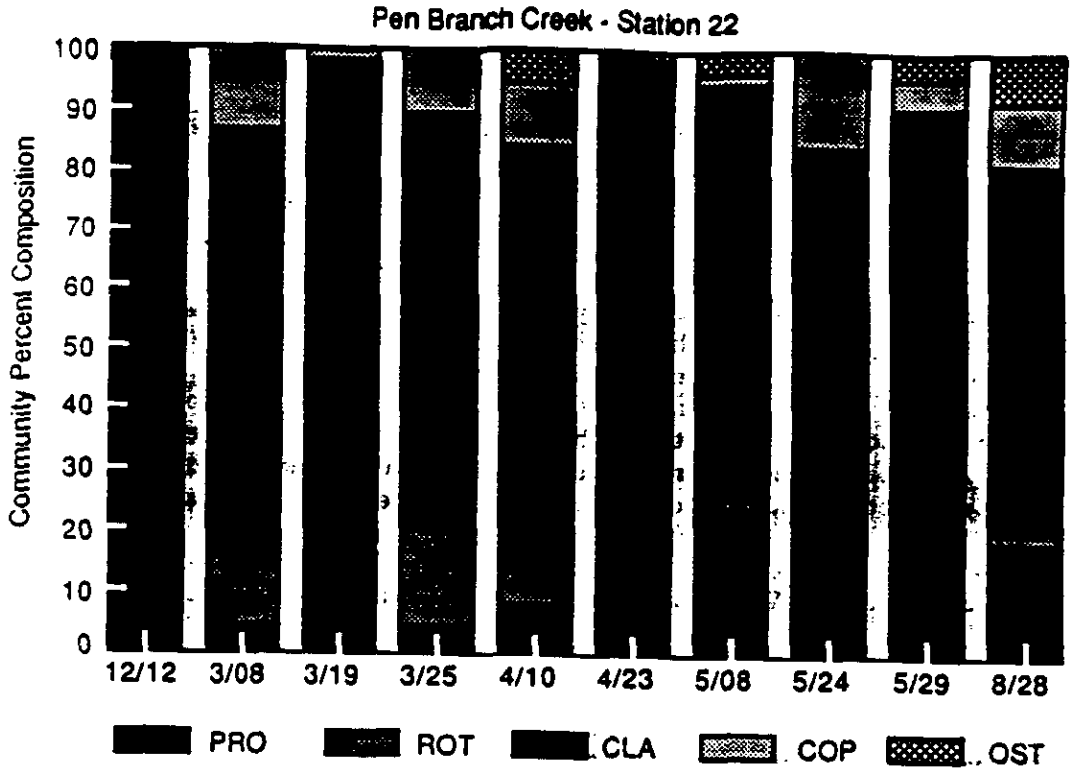
TABLE 4-17

Overall Mean, Median, N, Standard Error, Coefficient of Variation, Minimum and Maximum Values for Zooplankton Taxa Richness (taxa/sample) from All Savannah River and SRS Creek/Swamp Sampling Locations (December 1984 - August 1985)

Location	Mean	Median	N	Standard Error	Coefficient of Variation	Minimum	Maximum
SR 141.5	4.0	4	90	0.2	46.9	0	9
SR 150.4	4.7	5	90	0.2	45.7	0	9
SR 157.0	5.0	5	90	0.2	39.8	0	9
BD 6	4.2	4	30	0.4	59.2	0	9
BD 7	4.7	4	30	0.5	61.5	1	13
FM 17	6.0	6	30	0.5	47.3	2	12
PB 22	4.7	5	30	0.5	56.9	1	10
PB 24	3.9	4	30	0.4	54.6	0	9
SC 31	4.7	4	30	0.5	53.5	1	11
SC 32	5.3	5	30	0.5	48.1	1	10
SC 33	4.7	4	30	0.4	52.2	1	10
SC 34	5.2	5	30	0.5	48.5	0	10
SC 35	4.1	4	30	0.4	54.5	0	8

Note: SR = Savannah River; BD = Beaver Dam Creek; FM = Four Mile Creek; PB = Pen Branch; SC = Steel Creek

Source: Chimney and Cody (1987)



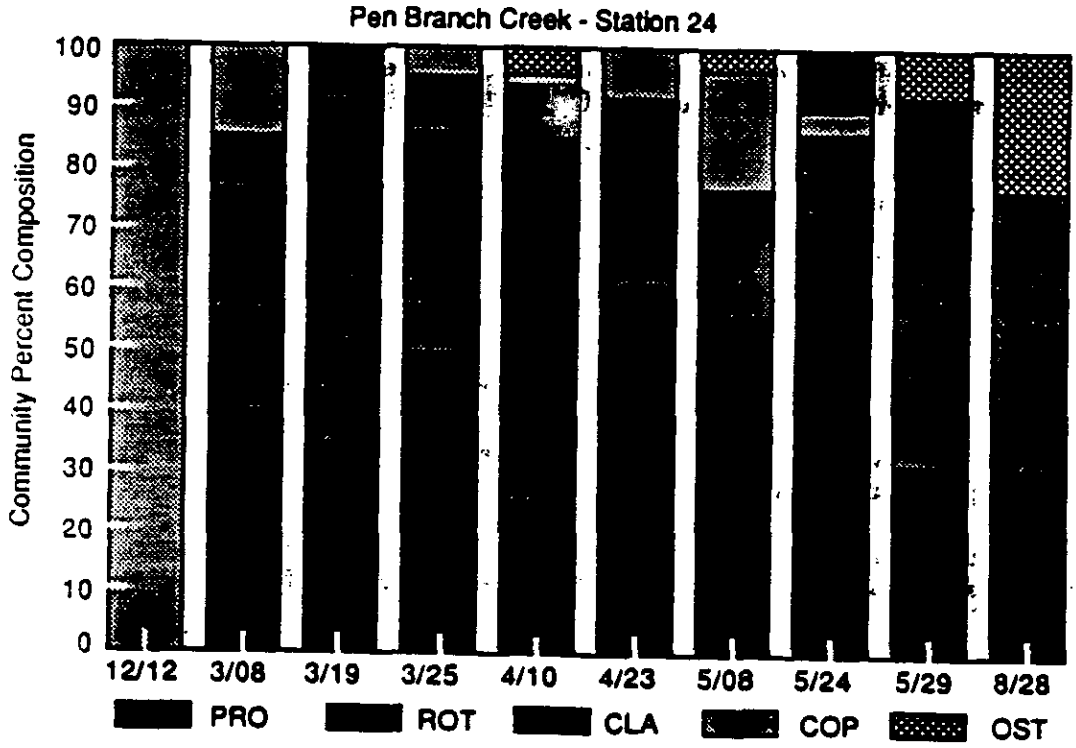


FIGURE 4-7. Zooplankton Community Percent Composition (relative abundance) at Pen Branch Sampling Stations. PRO = Protozoa; ROT = Rotifera; CLA = Cladocera; COP = Copepoda; OST = Ostracoda (December 1984 - August 1985) (source: Paller et al., 1989b)

4.2.5 Pen Branch Macroinvertebrates

Macroinvertebrates were sampled at five locat ns in Pen Branch/Indian Grave Branch from October 1984 through September 1985 (Stations 2, 4, 5, 6, and 23), and at seven locations in December 1988 and February and May 1989 (Stations 1-7, Figure 4-8). Data from 1984 and 1985 was collected as part of the Comprehensive Cooling Water Study (CCWS) when K Reactor was discharging thermal effluent to Pen Branch, and are representative of the conditions that exist when K Reactor is operating at full power. The data from 1988 and 1989 were collected after thermal discharges to the creek ended in April 1988 and are somewhat representative of the macroinvertebrate community that will be present in the creek at the time of reactor restart. In both studies, macroinvertebrate samples were collected monthly using Hester-Dendy multiplate samplers. Three replicates were collected at each station in 1984-1985 and five replicates were collected during 1988-1989. Details of sampling methods for the 1984-1985 and 1988-1989 sampling programs can be found in Firth et al. (1986) and Enwright (1989a, 1989b, and 1989c), respectively.

4.2.5.1 Description of Sampling Stations

Several distinct types of aquatic habitat are present in Pen Branch/Indian Grave Branch. These habitat types include: the unperturbed headwater reaches of Pen Branch, which are located upstream from its confluence with Indian Grave Branch; Indian Grave Branch/Pen Branch downstream of K-Reactor outfall; Pen Branch Delta; and Pen Branch/Savannah River swamp. Because these areas differ with respect to water velocity, substrate composition, aquatic vegetation, and canopy cover, they support distinctly different macroinvertebrate communities. Stations 1 and 2 (CCWS Station 20) are located in the headwaters of Pen Branch. The stream at these locations is small (1 to 1.5 m wide at Station 1; 1.5 to 2.5 m wide at Station 2), heavily canopied, and has not been subject to thermal perturbation. Stations 3 and 4 (CCWS Station 21) are located in Pen Branch approximately 4 and 7 km, respectively, downstream from the K-Reactor outfall on Indian Grave Branch. Station 5 (CCWS Station 22) and CCWS Station 23 are located in the braided Pen Branch Delta, where the stream spreads out into numerous small channels and water velocities are reduced. Station 6 (CCWS Station 24) is located in a heavily canopied area of the Pen Branch/Steel Creek swamp. During reactor operations, temperatures at this site are sometimes elevated by 3 to 5°C (Firth et al., 1986), but this portion of the swamp has not been subject to severe thermal perturbation. Station 7 is located in Indian Grave Branch, just downstream from the K-Reactor outfall. During reactor operation, Station 7 is subject to the most severe thermal regime, with temperatures as high as 70°C. Temperatures at Stations 3 through 5 are also elevated by reactor discharges, generally averaging 20 to 30°C above ambient (Firth et al., 1986).

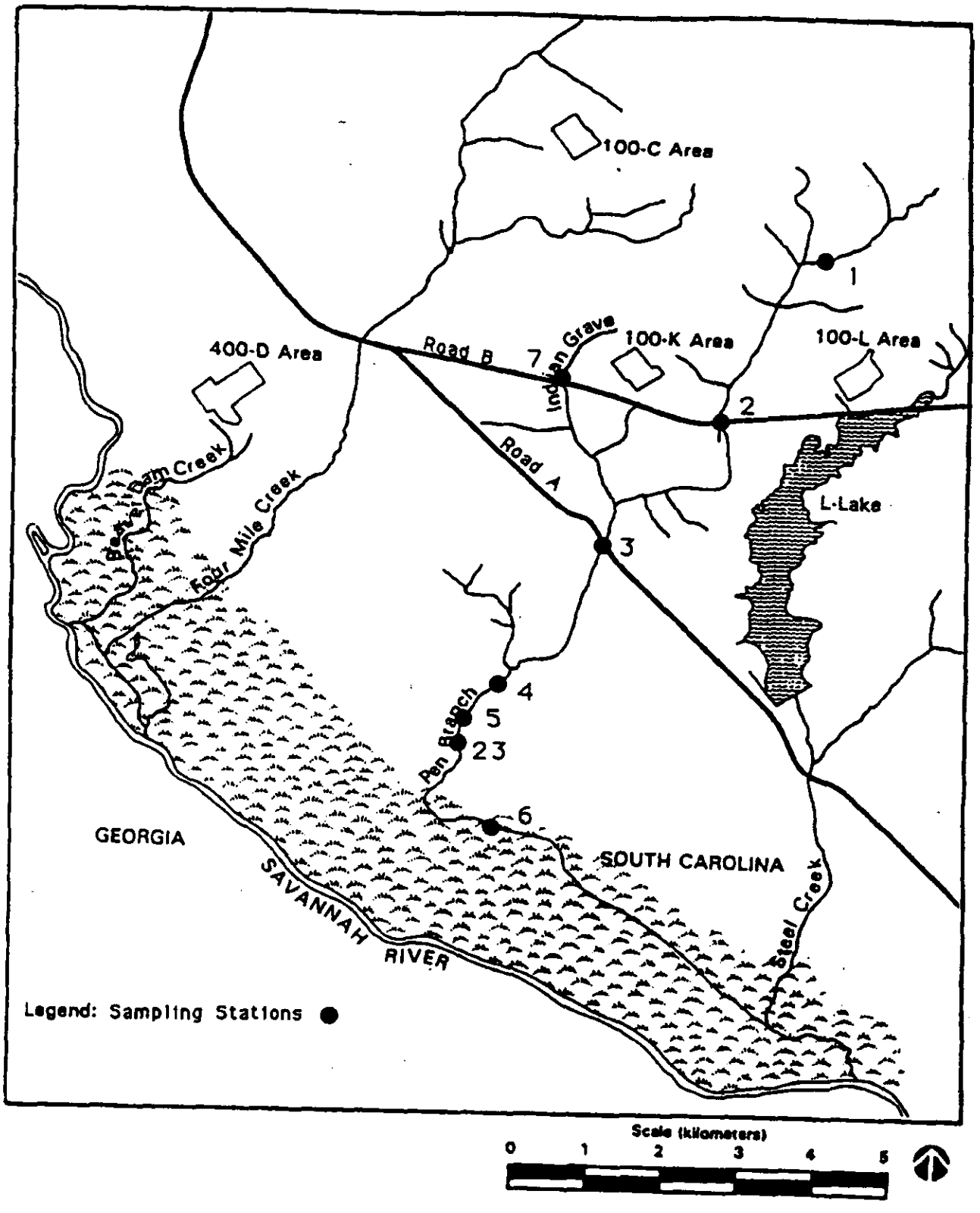


FIGURE 4-8. Macroinvertebrate Sampling Stations in Pen Branch and Indian Grave Branch

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4.2.5.2 Pen Branch Macroinvertebrate Community During Reactor Operation

During 1984-1985 when R Reactor was operating, a total of 92 taxa were collected from Pen Branch (Table 4-18); of these, 41 were collected exclusively at the nonthermal stations (Stations 2 and 6). Taxa richness was highest at Station 2 above the reactor cooling water outfall, where a total of 70 macroinvertebrate taxa were collected (Table 4-18). Taxonomic richness below the reactor outfall was lowest at Station 4 (28 taxa), and gradually increased in a downstream direction, to 33 taxa at Station 5 and 38 taxa at Station 23 (Table 4-18), as temperatures became less severe. At Station 6, where temperatures were at or near ambient, a total of 55 taxa were collected (Table 4-18). The mean number of taxa collected per sampler showed a similar trend, with 15.2 taxa/sampler collected at Station 2, while below the reactor outfall, values ranged from 3.2 taxa/sampler at Station 4 to 14.4 taxa/sampler at Station 6 (Table 4-18).

Table 4-19 presents the relative abundance of major taxonomic groups of macroinvertebrates at each sampling station, while Table 4-20 contains a complete taxonomic listing for each station. At all of the stations except Station 23, Diptera was by far the most common taxon collected, ranging from 43.3 to 77.7% of the organisms collected (Table 4-19). Although most of the dipterans were chironomid larvae, distinct differences in the relative abundance of chironomid subfamilies and tribes were observed among the stations. The Orthocladiinae and Tanytarsini were the most abundant taxa at unimpacted Station 2 (17.9 and 13.5%, respectively), while Chironomini and Tanytarsini predominated at the thermally impacted stations (Table 4-19).

Nematode worms were the most abundant taxon at Station 23 (71.5%) and were also abundant at the other thermally impacted stations (Table 4-19). Nematodes are often an important component of the fauna at thermally stressed sites because of their tolerance for heated water (Kontratieff and Kondratieff, 1984). Oligochaete worms were also commonly collected at all stations, with abundances ranging from 1.6 to 7.7% (Table 4-19).

Ephemeroptera (mayflies), Coleoptera (beetles; primarily Macronychus glabratus and Ancyronyx variegatus) and Trichoptera (caddisflies; primarily Cheumatopsyche spp. and Lype diversa) were all relatively abundant at the nonthermal station (Station 2), comprising 14.1, 13.4, and 10.9%, respectively, of the macroinvertebrate fauna collected from the multiplate samplers (Table 4-19). Mayflies were also abundant in the swamp at Station 6, accounting for 22.5% of the macroinvertebrates collected. Stenonema modestum was the most common species of mayfly collected at both Stations 2 and 6, while Caenis and Stenocron interpunctatum were also abundant at Station 6 (Table 4-20).

Gastropods (primarily Physella heterostropha, Helisoma trivolvis, and Gyraulus parvus were relatively abundant at Stations 23 and 6, accounting for 5.5 and 5.1%, respectively, of the organisms collected. The remaining taxa listed in Table 4-19 (Turbellaria, Arachnida, Odonata, and Plecoptera) each generally accounted for less than 3% of the organisms collected.

TABLE 4-18

Mean Number of Taxa, Density, and Biomass of Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Pen Branch (October 1984 - September 1985)

Parameter	Station 2	4	5	23	6
Mean number of taxa/sampler	15.2	3.2	6.0	7.1	14.4
Mean density (number/m^2)	695.2	55.6	841.6	2144.9	1620.1
Mean biomass (g AFDW/m^2)	0.187	0.003	0.078	0.070	0.320
Total number taxa collected	70	28	33	38	55
Total number taxa collected all stations combined					92

Source: Firth et al. (1986)

TABLE 4-19

Percent Abundance of Major Groups of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Pen Branch During Reactor Operation (October 1984 - September 1985)

Taxa	Station 2	4	5	23	6
Turbellaria	0.03	0.00	0.00	0.00	0.85
Nematoda	0.42	5.54	24.75	71.47	18.84
Oligochaeta	2.76	7.68	5.99	1.63	4.77
Gastropoda	0.90	2.32	1.33	5.53	5.12
Arachnida	0.17	0.36	0.02	0.01	1.89
Ephemeroptera	14.09	1.96	0.31	4.10	22.49
Odonata	0.46	0.71	0.08	0.07	0.07
Plecoptera	3.06	0.00	0.02	0.00	0.02
Coleoptera	13.35	1.61	0.07	0.03	0.88
Trichoptera	10.87	1.43	0.29	0.11	1.25
Diptera[a]	53.12	77.68	67.11	17.04	43.34
Chironomini	(11.66)	(43.21)	(20.63)	(7.17)	(6.14)
Tanytarsini	(13.89)	(17.68)	(31.29)	(3.46)	(23.30)
Orthocladiinae	(17.88)	(11.96)	(3.76)	(0.76)	(5.01)
Tanypodinae	(2.47)	(0.89)	(3.37)	(3.65)	(3.59)
Other	0.77	0.71	0.03	0.01	0.48
Total	100.00	100.00	100.00	100.00	100.00

[a] Includes subtaxa in parentheses.

Source: Modified from Firth et al. (1986)

TABLE 4-20

Mean Invertebrate Density/number/m^2 at Each Station on Pen Branch for Each Taxon Collected on Hester-Dendy Multiplate Samplers (October 1984 - September 1985)

Taxa	Station 2	4	5	23	6
Turbellaria	0.2				13.8
Nematoda	2.9	3.1	208.4	1533.4	305.4
Oligochaeta	19.2	4.3	50.4	34.9	77.3
Hirudinea	0.2			0.2	1.1
Gastropoda	1.7		0.5	0.3	9.0
Family Ancylidae	3.1			0.2	1.7
Ferrissia rivularis	1.1		0.3	0.2	11.3
Laevapex fuscus					0.3
Family Hydrobiidae					
Amnicola					0.9
Somatogyrus sp.		0.2	0.2		1.6
Family Physidae					
Physella heterostropha	0.2	1.1	10.2	117.9	25.5
Family Planorbidae					0.8
Gyraulus parvus					12.1
Helisoma					0.9
Helisoma trivolvis	0.2				18.3
Family Viviparidae					
Campeloma decisum					0.5
Pelecypoda					
Family Corbiculidae					
Corbicula fluminea	0.8				4.5
Family Sphaeriidae	0.2				
Crustacea					
Isopoda					
Asellus			0.2		1.4
Amphipoda		0.2			
Family Talitridae					
Hyalella azteca	0.2	0.2			0.5
Decapoda					
Family Astacidae					
Procambarus	0.3				
Arachnida					
Hydracarina	1.2	0.2	0.2	0.3	30.7
Insecta					
Ephemeroptera					
Family Baetidae					
Baetis	6.1		0.3	0.2	8.7
Pseudocloeon parvulum				0.2	

TABLE 4-20, Contd

Taxa	Station 2	4	5	23	6
Insecta, Contd					
Ephemeroptera, Contd					
Family Caenidae					
Caenis	0.5	0.3	1.7	75.3	37.7
Family Ephemerellidae					
Dannella simplex	1.7				
Ephemerella invaria	2.8			11.5	
Eurylophella temporalis	1.6			0.2	0.8
Family Heptageniidae					1.4
Stenacron interpunctatum	0.3	0.2		0.3	36.2
Stenonema modestum	74.5	0.6	0.6	0.3	279.5
Family Neoephemeridae					
Neoephemera youngi	0.2				
Family Oligoneuriidae					
Isonychia	0.9				
Family Tricorythidae					
Tricorythodes	9.5				0.2
Odonata					
Anisoptera	0.2	0.2	0.2		
Family Aeshnidae					
Boyeria vinosa	0.5				
Nasiaeschna pentacantha	0.5				
Family Libellulidae					
Erythemis simplicicollis				0.3	
Pachydiplax longipennis				0.2	
Zygoptera					
Family Calopterygidae					
Hetaerina	0.2				
Family Coenagrionidae					
Argia	1.2	0.2	0.2		0.5
Enallagma	0.2			0.9	0.5
Ischnura	0.2		0.3		
Plecoptera	0.3		0.2		
Family Perlidae	0.2				
Acroneuria abnormis	0.2				0.2
Paragnetina fumosa	0.5				
Perlesta placida	17.7				0.2
Family Perlodidae					
Helopicus bogaloosa	0.5				
Isoperla	0.8				
Family Pteronarcyidae					
Pteronarcys dorsata	0.3				
Family Taeniopterygidae					
Taeniopteryx longicera	0.6				
Taeniopteryx robinae	0.2				

TABLE 4-20, Contd

Taxa	Station 2	4	5	23	6
Hemiptera					
Family Belostomatidae					
Belostoma				0.2	
Coleoptera					
Family Dryopidae					
Helichus	0.3				
Family Elmidae	2.0				
Ancyronyx variegatus	20.3		0.2		0.5
Macronychus glabratus	68.4	0.5	0.2	0.2	10.9
Microcylloepus pusillus	0.3	0.2			
Stenelmis	0.6				0.6
Family Eubriidae					
Ectopria nervosa	0.6				0.2
Family Gyrinidae					
Dineutes	0.3				1.4
Gyrinus					0.2
Family Hydrophilidae					
Berosus				0.2	0.2
Enochrus spp.		0.2			
Hydrobius			0.2		
Tropisternus				0.3	
Megaloptera					
Family Corydalidae					
Corydalus cornutus	2.3				0.3
Nigronia	0.2				
Family Sialidae					
Sialis	1.2				
Trichoptera					
Family Brachycentridae					
Brachycentrus	0.9				0.2
Family Hydropsychidae	0.6			0.2	
Cheumatopsyche spp.	29.2	0.3	1.1	1.1	2.8
Hydropsyche	0.5		0.5	0.2	0.5
Macrostemum carolina	0.2				
Family Hydroptilidae					
Orthotrichia			0.2		
Oxyethira	0.2		0.2	0.3	5.1
Family Leptoceridae					
Ceraclea	0.3				
Nectopsyche candida	0.2				
Oecetis	2.3				

TABLE 4-20, Contd

Taxa	Station 2	4	5	23	6
Trichoptera, Contd					
Family Limnephilidae					
Pycnopsyche					0.2
Family Philopotamidae					
Chimarra	0.8	0.3			
Family Polycentropodidae					
Cernotina					1.6
Neureclipsis				0.2	
Phylocentropus					1.1
Polycentropus	0.3		0.2		0.9
Family Psychomyiidae					
Lype diversa	40.2	0.2	0.2	0.3	0.3
Diptera					
Family Ceratopogonidae	4.2	0.2	46.6	5.6	38.5
Ceratopogonidae pupae			0.9		
Subfamily Forcipomyiinae	0.2		0.3	0.3	0.2
Family Chaoboridae					
Chaoborus punctipennis		0.2			2.0
Family Chironomidae					
Chironomidae pupae	22.0	1.2	18.2	35.5	44.5
Subfamily Chironominae					
Tribe Chironomini	81.2	24.2	173.7	153.9	99.5
Tribe Tanytarsini	96.7	9.9	263.5	74.2	377.6
Subfamily Diamesinae					
Potthastia	0.2		0.3	0.2	0.2
Subfamily Orthocladiinae	124.5	6.7	31.7	16.3	81.2
Subfamily Tanypodinae	17.2	0.5	28.4	78.4	58.2
Family Empididae	20.5	0.3			
Family Ephydridae			0.5		
Family Simulidae	0.8				
Simulium	2.0	0.3	0.2	0.6	0.5
Family Stratiomyliidae			0.3	0.3	
Odontomyia sp.				0.2	
Family Tipulidae	0.2				
Hexatoma			0.5		
Tipula	0.2				

Source: Firth et al. (1986)

Mean densities of macroinvertebrates on the multiplate samplers ranged from 55.6/m^2 at the most thermally impacted station in Pen Branch (Station 4) to 2144.9/m^2 in the delta (Station 23; Table 4-18). The high density at Station 23 was due primarily to large numbers of nematodes (Table 4-20). Densities at the two stations that were not thermally impacted (Stations 2 and 6) were 695.2 and 1620.6/m^2, respectively.

Macroinvertebrate biomass (ash-free dry weight) was very low at the thermally impacted stations (0.003 to 0.078 g/m^2) and much higher at the unimpacted stations (0.187 to 0.320 g/m^2; Table 4-18). At Station 2, large numbers of mayflies (primarily Stenonema modestum) and fewer numbers of large predatory stoneflies (Perlesta) and dobsonflies (Corydalus) made up the majority of the biomass, while at Station 6, mayflies (mainly S. modestum and Stenonema interpunctatum) and gastropods accounted for most of the biomass (Firth et al., 1986). Although Station 23 had by far the greatest mean density of organisms (2144.9/m^2; Table 4-18), biomass was relatively low at this station (0.033 g/m^2), due to a preponderance of small nematodes (Table 4-20).

4.2.5.3 Post-Thermal Recovery of Pen Branch Macroinvertebrate Community

The macroinvertebrate data collected in the 1988-1989 program subsequent to the shutdown of K Reactor differ in several ways from the data collected during reactor operation, because data were collected for three months in the 1988-1989 program, as compared to 12 months in the 1984-1985 study. Second, five replicates were collected in the 1988-1989 program, as compared to three replicates in 1984-1985. Lastly, the level of taxonomic resolution was better in the 1988-1989 study. Any comparisons of species richness or taxonomic composition must take these important differences into consideration.

During the sampling conducted during 1988 and 1989, 132 taxa of macroinvertebrates were collected in Pen Branch and Indian Grave Branch (Table 4-21). Of these taxa, 86 were collected from the portions of the creeks that had been thermally impacted (Table 4-21). It is likely that more taxa would have been collected if sampling had been conducted over the course of an entire year, since some species occur seasonally and some rare species are collected infrequently. The total number of taxa collected was highest at Station 1 (58 taxa; Table 4-22). Fewer taxa were collected at the other five stations in Pen Branch, ranging from 48 at Station 5 to 53 at Stations 2 and 6 (Table 4-22). In Indian Grave Branch, only 35 taxa were collected (Table 4-22).

The mean number of taxa collected per multiplate sampler ranged from 8.9 at Station 7 to 19.6 at Station 2 (Table 4-22). In general, fewer taxa were collected from the portions of the creek that have been thermally perturbed (Stations 7, 3, 4, and 5, in order of increasing distance from the reactor outfall) than from unperturbed areas of the creek (Stations 1, 2, and 6; Table 4-22). However, in the Pen Branch Delta (Station 5) the number of taxa collected per sampler was relatively high (16.1), probably due to the greater habitat diversity that has resulted from

recolonization of the stream by aquatic macrophytes. These data indicate that although the macroinvertebrate community of the thermally impacted areas of Pen Branch has undergone some recovery subsequent to the reactor shutdown in April 1988, taxonomic richness is still somewhat depressed as compared to unimpacted areas. It is likely that the macroinvertebrate community is still undergoing recovery.

For all stations combined, chironomid dipterans were by far the most abundant group of macroinvertebrates on the multiplate samplers, comprising 68.4 to 91.8% of the organisms collected (Table 4-23). Orthoclad midges were the most abundant chironomids (36.5 to 71.2%) at all but Station 5, where tanytarsine midges were dominant (46.9%; Table 4-23). Nonchironomid dipterans (mostly blackflies or dance flies) were abundant at some stations, comprising 0.4 to 26.6% of the collections. Trichoptera (caddisflies) and Ephemeroptera (mayflies) were also abundant at most stations, accounting for 0.4 to 11.2% and 0 to 8.4%, respectively, of the organisms collected on the multiplate samplers. Plecoptera (stoneflies) and Coleoptera (beetles) were locally abundant at Station 2 (7.8 and 9.3%, respectively), but comprised less than 1% of the macroinvertebrates collected at each of the other stations.

Dominant taxa (based on mean densities) included several species of orthoclad midges (Corynoneura nr. taris, Cricotopus spp., Orthocladius spp., and Tvetenia discoloripes gr.), chironomini midges (Microtendipes pedellus, and Polypedilum spp.) tanytarsine midges (Rheotanytarsus distinctissimus and Tanytarsus spp.), and blackflies (Simulium tuberosum and S. vittatum; Table 4-21). Other taxa that were abundant at one or more stations included the mayflies, Caenis sp. and Stenonema modestum/smithae; the stonefly, Perlesta placida; the caddisflies, Cheumatopsyche spp. and Hydropsyche spp., the beetle, Macronychus glabratus, and danceflies (Empidae; Table 4-21).

Station 7, which is located in Indian Grave Branch just downstream from the reactor outfall, differed from the other stations in that the community was comprised almost exclusively of dipterans (99.57%; Table 4-23). Dominant dipterans at this station included the chironomids, Cricotopus and Orthocladius as well as blackflies and empidid dance flies (Table 4-21). These differences are probably due, at least in part, to differences in substrate composition. Station 7 contains rock rip-rap, which provides stable substrate for attachment by blackflies and other species which prefer rock substrates. However, the conspicuous absence of clinging mayflies, such as Stenonema, and the overall low taxonomic richness suggest that Station 7 has undergone less recovery than the Pen Branch stations.

Macroinvertebrate densities on the multiplate samplers ranged from 534.7 individuals/m^2 at Station 2 to 988.3/m^2 at Station 5 (Table 4-22). Densities were variable from month to month (Enwright, 1989a, 1989b, 1989c), and no relationship between density and thermal history was apparent.

TABLE 4-21

Mean Density (number/m^2) of Macroinvertebrates on Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch During Ambient Thermal Conditions (December 1988 - May 1989)

Taxon	Station 1	2	3	4	5	6	7	Total
ANNELIDA (worms and leeches)								
Batrachobdella phalera	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Glossiphoniidae	0.00	0.00	0.00	0.00	1.48	0.00	0.00	1.48
Nais communis	0.00	0.00	1.11	0.40	0.00	0.37	0.00	1.88
Placobdella parasitica	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.74
Stylaria lacustris	0.00	0.00	0.00	0.00	0.00	1.48	0.00	1.48
MOLLUSCA (snails, clams)								
Ferrissia hendersoni	3.33	0.00	0.00	0.00	0.37	0.00	0.00	3.70
Micromenetus dilatatus	0.37	0.00	0.00	0.00	0.00	2.59	0.00	2.96
Physella heterostropha	1.11	0.00	0.37	0.00	0.37	4.07	0.00	5.92
Pseudosuccinea columella	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74
CRUSTACEA								
Crangonyx obliquus	0.37	0.00	0.00	0.00	0.00	3.70	0.00	4.07
Hyallela azteca	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.37
EPHEMEROPTERA (mayflies)								
Acerpenna pygmaeus	1.85	0.00	0.00	0.00	0.00	0.00	0.00	1.85
Baetis intercalaris	0.00	1.85	0.74	0.40	6.67	0.00	0.00	9.66
Baetis propinquus	0.00	1.11	0.00	0.00	0.00	0.00	0.00	1.11
Caenis sp.	0.00	0.00	2.96	0.40	47.78	2.22	0.00	53.36
Dannella simplex	0.00	1.48	0.00	0.00	0.00	0.00	0.00	1.48
Ephemerella dorothea	0.37	5.19	1.85	0.00	0.00	0.00	0.00	7.41
Ephemerella inconstans	0.00	5.93	0.00	0.00	0.00	0.00	0.00	5.93
Ephemerella rotunda/invaria	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Ephemerellidae	0.00	0.37	0.00	0.40	0.00	0.00	0.00	0.77
Eurylophella doris	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Eurylophella nr. *temporalis*	1.11	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Eurylophella prudentalis	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Heptagenia flavescens	0.37	0.00	0.00	0.40	0.00	0.00	0.00	0.77
Heptageniidae[a]	0.37	0.00	0.00	0.40	0.00	0.37	0.00	1.14
Leptophlebia sp.	2.59	0.00	0.00	0.00	0.00	0.00	0.00	2.59
Paraleptophlebia sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Stenacron interpunctatum	25.93	0.00	0.00	0.00	1.48	0.00	0.00	27.41
Stenonema integrum	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Stenonema modestum/smithae	13.70	23.70	7.41	3.57	2.96	3.33	0.00	54.67
Tricorythodes sp.	0.00	3.33	0.00	0.00	0.00	0.00	0.00	3.33
ODONATA								
Argia tibialis	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Boyeria vinosa	0.00	0.37	0.00	0.00	0.00	0.74	0.00	1.11
Argia translata	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Enallagma sp.	0.00	0.00	0.00	0.00	4.44	0.00	0.00	4.44

TABLE 4-21, Contd

Taxon	Station 1	2	3	4	5	6	7	Total
PLECOPTERA (stoneflies)								
Amphinemura delosa	0.00	1.48	0.00	0.00	0.00	0.00	0.00	1.48
Isoperla bilineata	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Isoperla clio	0.37	1.48	0.00	0.00	0.00	0.00	0.00	1.85
Isoperla nr. nana	1.11	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Perlesta placida	3.33	28.89	0.00	0.40	0.00	0.00	0.00	32.62
Perlidae[a]	0.00	7.41	0.00	0.00	0.00	0.00	0.00	7.41
Perlodidae	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
TRICHOPTERA (caddisflies)								
Cernotina spicata	0.00	0.00	0.37	0.00	0.00	0.37	0.00	0.74
Cheumatopsyche spp.	0.37	3.70	5.19	30.56	96.67	3.70	0.79	140.98
Chimarra sp.	0.00	0.00	0.00	14.68	0.37	0.00	0.00	15.05
Hydropsyche elissoma/rossi	0.00	0.00	8.89	28.17	0.00	1.11	1.19	39.36
Hydropsyche nr. incommoda	0.00	0.00	0.74	3.17	0.37	0.00	0.00	4.28
Hydropsyche rossi	0.00	0.00	5.19	18.65	0.74	0.00	0.40	24.98
Hydroptila sp.	0.00	0.00	1.11	0.40	0.00	0.00	0.00	1.51
Lype diversa	4.07	5.93	0.00	0.00	0.00	0.00	0.00	10.00
Macrostemum carolina	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Neureclipsis sp.	0.00	0.00	11.85	2.38	0.00	0.00	0.79	15.02
Oecetis sp.	0.00	0.00	1.11	1.98	0.00	0.37	0.00	3.46
Oxyethira sp.	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Triaenodes nr. marginata	0.00	0.00	0.37	0.40	0.37	0.00	0.00	1.14
LEPIDOPTERA (moths)								
Parapoynx obscuralis	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Pyralidae	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
MEGALOPTERA (hellgrammites)								
Chauliodes pectinicornis	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Nigronia serricornis	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Sialis sp.	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.74
COLEOPTERA (beetles)								
Ancyronyx variegatus	0.37	1.48	0.37	0.00	0.37	0.00	0.00	2.59
Dineutus sp.	0.00	0.37	0.00	0.40	0.00	0.00	0.00	0.77
Gyrinus sp.	0.00	0.00	0.00	0.00	0.00	2.22	0.00	2.22
Hydroporus sp.	2.22	0.00	0.00	0.00	0.00	0.00	0.00	2.22
Macronychus glabratus	0.37	47.41	1.11	0.00	0.00	2.22	0.00	51.11
Sperchopsis tessellatus	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Stenelmis sp.	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Tropisternus sp.	0.00	0.00	0.00	0.40	0.37	0.00	0.00	0.77
DIPTERA - Chironomidae (midges)								
Tanypodinae								
Ablabesmyia janta	0.00	0.00	0.00	0.00	0.74	1.48	0.00	2.22
Ablabesmyia mallochi	4.44	1.11	0.37	0.00	10.00	27.78	0.00	43.70
Ablabesmyia sp.[a]	2.22	0.37	0.00	0.00	0.74	0.00	0.00	3.33

TABLE 4-21, Contd

Taxon	Station 1	2	3	4	5	6	7	Total
DIPTERA, Contd								
Conchapelopia sp.	2.96	7.78	5.19	1.59	12.22	6.67	0.00	36.41
Labrundinia becki	0.37	0.00	0.00	0.00	1.11	0.00	0.00	1.48
Labrundinia nr. neopilosella	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.37
Labrundinia pilosella	0.37	0.00	0.00	0.00	0.00	18.52	0.00	18.89
Nilotanypus fimbriatus	1.48	0.00	0.00	0.00	0.00	0.00	0.40	1.88
Paramerina sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Procladius sp.	0.00	0.00	0.00	0.00	0.00	1.48	0.00	1.48
Zavrelimyia sp.	4.07	0.00	0.00	0.79	0.00	0.00	0.00	4.86
Orthocladiinae								
Brillia flavifrons	0.00	9.63	1.48	1.98	0.00	0.00	2.38	15.47
Cardiocladius sp.	0.00	0.00	4.07	0.40	0.00	0.00	13.89	18.36
Corynoneura nr. taris	176.30	17.78	1.48	14.68	57.78	117.04	2.78	387.84
Corynoneura sp.	0.00	3.33	2.22	0.00	0.00	0.37	0.00	5.92
Corynoneura sp. 4	5.19	5.56	0.00	0.00	3.70	0.37	0.00	14.82
Cricotopus bicinctus	0.00	0.37	0.74	0.40	11.85	111.48	0.00	124.84
Cricotopus sp.	0.74	2.59	5.93	2.38	1.11	0.37	200.79	213.91
Cricotopus tremulus gp.	0.00	0.00	0.74	1.19	0.00	0.00	0.00	1.93
Eukiefferiella claripennis gp.	0.00	0.74	18.89	24.60	0.00	0.00	5.16	49.39
Eukiefferiella devonica gp.	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Nanocladius distinctus	0.37	0.00	0.00	0.00	0.00	6.67	0.00	7.04
Nanocladius sp.	0.74	0.00	0.74	0.00	2.22	4.81	0.00	8.51
Orthocladius (Eudactylocladius)	0.00	0.00	4.44	1.59	0.00	0.00	5.95	11.98
Orthocladius curtiseta	0.00	0.00	2.22	0.00	1.85	0.37	38.89	43.33
Orthocladius nigritus	11.11	11.85	76.30	14.29	0.00	0.00	5.16	118.71
Orthocladius nr. oliveri	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Orthocladius obumbratus	0.00	7.04	0.00	0.40	0.00	0.00	0.00	7.44
Orthocladius sp.	0.37	11.11	110.37	191.27	1.11	0.74	97.22	412.19
Orthocladius sp.[a]	0.00	0.00	0.00	0.00	1.48	0.00	0.00	1.48
Parakiefferiella sp.	2.22	2.22	8.15	4.37	6.67	31.11	3.97	58.71
Parakiefferiella sp. B	2.96	2.59	5.93	3.97	11.11	9.26	1.19	37.01
Parametriocnemus lundbecki	3.33	44.44	0.74	0.40	0.00	1.85	0.00	50.76
Parametriocnemus sp. C	1.11	2.22	0.00	0.00	0.00	0.00	0.00	3.33
Psectrocladius (Meso.) sp.	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Rheocricotopus robacki	0.37	23.70	11.85	5.16	9.63	12.96	3.57	67.24
Rheocricotopus tuberculatus	0.37	1.85	0.00	0.00	0.00	0.00	0.00	2.22
Symposiocladius lignicola	2.22	1.48	3.33	0.79	0.37	0.00	4.37	12.56
Synorthocladius semivirens	0.00	0.00	0.00	0.00	0.00	0.00	4.76	4.76
Thienemanniella fusca gp.	4.44	42.59	0.00	0.40	5.93	7.41	7.54	68.31
Thienemanniella xena gp.	1.85	22.22	8.15	29.76	40.74	31.48	25.79	159.99
Tvetenia discoloripes gp.	0.00	10.74	224.44	260.32	25.19	0.74	72.22	593.65
Tvetenia paucunca/vitracies	0.00	34.44	0.37	0.00	1.85	0.37	0.79	37.82
Unniella multivirga	18.15	0.00	0.00	0.00	0.00	0.00	0.00	18.15

TABLE 4-21, Contd

Taxon	Station 1	2	3	4	5	6	7	Total
DIPTERA, Contd								
Diamesinae								
Potthastia longimana	0.00	8.15	0.00	0.00	0.74	2.96	0.40	12.25
Chironomini								
Chironomus sp.	1.11	0.37	0.00	0.00	1.11	0.37	0.00	2.96
Cryptochironomus parafulvus	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
Dicrotendipes modestus	0.00	0.00	0.00	0.00	12.22	0.37	0.40	12.99
Microtendipes pedellus	198.52	2.22	0.00	0.00	0.00	0.37	0.00	201.11
Phaenopsectra flavipes	1.85	0.00	1.11	0.00	0.00	0.74	0.00	3.70
Phaenopsectra/Tribelos sp.	6.67	4.44	0.00	0.00	0.00	10.37	0.00	21.48
Polypedilum convictum	0.37	42.22	3.33	32.94	38.15	6.30	1.59	124.90
Polypedilum fallax	2.59	17.04	0.00	2.78	0.00	0.37	1.19	23.97
Polypedilum halterale	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Polypedilum illinoense	0.00	0.37	0.00	0.40	9.26	6.30	2.38	18.71
Polypedilum sp.	0.74	0.00	0.37	0.00	0.00	0.00	0.00	1.11
Polypedilum sp.[a]	3.70	0.00	0.37	19.44	0.00	1.11	0.00	24.62
Stenochironomus sp.	0.00	0.00	0.00	0.40	0.00	0.00	1.19	1.59
Tanytarsini								
Microsectra sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Paratanytarsus sp.	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Rheotanytarsus distinctissimus	1.11	11.11	42.22	48.02	32.96	110.37	26.19	271.98
Tanytarsus glabrescens gp.	0.00	2.59	2.59	0.40	0.37	0.00	0.00	5.95
Tanytarsus sp.	56.67	7.04	6.67	4.76	85.93	19.26	0.40	180.73
Tanytarsus sp. XVI Rutter	34.81	0.00	0.00	0.00	0.00	0.00	0.00	34.81
Tanytarsus sp. XVII Rutter	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.74
Tanytarsus sp.[a]	8.52	0.00	0.37	0.00	335.93	7.78	0.00	352.60
DIPTERA - Misc. (true flies)								
Atrichopogon sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Bezzia sp.	0.00	0.00	0.00	0.00	0.37	0.74	0.00	1.11
Bezzia sp. 2	0.00	0.00	0.00	0.40	8.89	13.70	0.00	22.99
Empididae	2.22	7.41	10.74	3.57	0.00	0.00	36.90	60.84
Palpomyia sp. 4	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Sciomyzidae	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Simulium dixiense/jonesi	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Simulium jonesi	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Simulium tuberosum	0.00	14.44	42.96	109.92	37.04	0.37	3.97	208.70
Simulium venustum/verecundum	0.00	0.00	0.00	0.00	16.67	1.11	0.00	17.78
Simulium venustum/vittatum	0.00	0.00	1.48	0.00	14.07	0.00	0.00	15.55
Simulium vittatum	0.00	0.37	28.15	7.54	1.85	0.00	152.38	190.29
Tipula sp. 1	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40

[a] Immature or damaged organisms; probably the same as another taxon.

Source: Data from Enwright (1989a, 1989b, 1989c)

TABLE 4-22

Mean Number of Taxa, Density, and Biomass of Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch During Ambient Thermal Conditions (December 1988 - May 1989)

Parameter	Station 1	2	3	4	5	6	7
Mean number of taxa/sampler	14.0	19.6	12.9	13.9	16.1	14.3	8.9
Mean density/ (number/m^2)	635.7	534.7	692.7	864.0	988.3	610.7	681.7
Mean biomass (g AFDW/m^2)	0.040	0.039	0.044	0.089	0.082	0.030	0.029
Total number of taxa collected	58	53	50	50	48	53	35

Source: Enwright (1989a, 1989b, 1989c)

TABLE 4-23

Percent Abundance of Major Groups of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch During Ambient Thermal Conditions (December 1988 - May 1989)

Taxon	Station 1	2	3	4	5	6	7	Mean
Annelida	0.00	0.00	0.16	0.04	0.19	0.42	0.00	0.12
Crustacea	0.06	0.00	0.00	0.00	0.00	0.67	0.00	0.09
Mollusca	0.76	0.00	0.05	0.00	0.15	1.09	0.00	0.27
Ephemeroptera	7.36	8.45	1.98	0.62	6.07	1.33	0.00	3.58
Odonata	0.12	0.07	0.00	0.00	0.46	0.12	0.00	0.13
Plecoptera	0.76	7.76	0.05	0.04	0.00	0.00	0.00	0.95
Trichoptera	0.70	1.80	5.03	11.20	10.16	1.09	0.44	5.06
Lepidoptera	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.01
Megaloptera	0.18	0.00	0.00	0.00	0.04	0.00	0.00	0.03
Coleoptera	0.53	9.28	0.21	0.09	0.08	0.73	0.00	1.22
Diptera - Misc.	0.35	4.22	12.14	13.54	8.14	2.79	26.65	10.07
Diptera - Chironomidae	89.20	68.42	80.32	74.47	74.68	91.75	72.92	78.47
Tanypodinae	2.57	1.73	0.80	0.26	2.56	9.22	0.05	2.31
Orthocladiinae	36.54	48.75	71.23	62.08	18.83	55.25	68.17	50.20
Diamesinae	0.00	1.52	0.00	0.00	0.08	0.49	0.05	0.25
Chironomini	33.98	12.47	0.80	6.22	6.26	4.31	0.98	8.74
Tanytarsini	16.11	3.95	7.49	5.91	46.94	22.50	3.65	16.97
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Enwright (1989a, 1989b, 1989c)

Macroinvertebrate biomass was exceptionally low at all stations, ranging from 0.0291 g/m^2 at Station 7 to 0.0890 g/m^2 at Station 4 (Table 4-22). The low biomass was due primarily to the predominance of small chironomids and a scarcity of large predators on the multiplate samplers.

4.2.5.4 Impact Evaluation

During reactor operation at full power levels, temperatures in Indian Grave Branch and most of Pen Branch downstream from its confluence with Indian Grave Branch are too high to support most species of macroinvertebrates. Macroinvertebrate habitat during reactor operation is minimal, and is limited primarily to deep muds, which may be cool enough to support oligochaetes and nematodes, and to the peripheral edges of the stream channels in the delta. During reactor outages, the stream is rapidly colonized by chironomids, some of which may complete their life cycles in as little as two weeks (Merritt and Cummins, 1984).

Subsequent to the shutdown of K Reactor in April 1988, Pen Branch was recolonized by numerous macroinvertebrate taxa. During the limited sampling program which began eight months after thermal discharges to the creek had ceased, 86 taxa were collected from the portions of the creek that had been previously subject to thermal perturbation. Although these data indicated that the macroinvertebrate community of Pen Branch exhibited substantial recovery, taxonomic richness and biomass were still depressed downstream from the reactor outfall, which indicates that recovery is not complete. The Indian Grave Branch station, which is closer to the reactor outfall and therefore was subjected to a more severe thermal regime than Pen Branch, appeared to be recovering more slowly than Pen Branch.

Macroinvertebrate studies conducted in Four Mile Creek subsequent to the shutdown of C Reactor in June 1985 (Lauritsen, 1989) may be useful in predicting long-term recovery of Pen Branch. Lauritsen (1989) reported rapid recolonization of Four Mile Creek by macroinvertebrates, with the highest mean densities occurring just 16 days after reactor shutdown. Most of the early colonizers were chironomids (mostly Tanytarsini and Tanypodinae), but substantial populations of caddisflies and mayflies were established within six weeks. Within one month of reactor shutdown, taxonomic richness had increased almost eight-fold. Data collected through September 1987 indicated that although the initial macroinvertebrate recolonization of the stream was rapid, taxa richness continued to increase for almost two years before stabilizing.

Reactivation of K Reactor to full power levels will disrupt most of the macroinvertebrate species that have become established in the stream during the extended reactor outage, and the community will revert to one similar to that described in Section 4.2.5.2. If K Reactor is operated at less than full power and the temperatures of the cooling water discharges are lower, more species would be expected to survive in the stream, particularly in the delta where temperature perturbations are less intense and the braided channels provide cooler habitats along the edges of the channels. After construction of a cooling tower, it is anticipated that

initial rapid recolonization of the macroinvertebrate community will occur, but that several years will be required for the community to approach stability. The community may continue to undergo long-term succession, as regrowth of vegetation in the delta occurs, providing greater habitat diversity.

4.2.6 Pen Branch Fish

The Pen Branch drainage and its relationship to K Reactor are shown in Figure 4-9. The headwaters of Pen Branch above the confluence with Indian Grave Branch are largely unperturbed. Downstream from K Area, thermal effluent from K Reactor joins Pen Branch via Indian Grave Branch. When K Reactor is operating, discharged cooling water from K Area (heated to temperatures as high as 70°C) comprises 98% of the stream volume in the upper reaches of Pen Branch (Paller et al., 1989). Pen Branch discharges into the Savannah River floodplain swamp where it has formed a delta characterized by stands of dead bald cypress (Taxodium distichium) and water tupelo (Nyssa aquatica) and extensive beds of emergent vegetation. Temperatures in the delta may be as much as 20 to 25°C above ambient (Paller et al., 1989). Pen Branch flow spreads over the delta and continues through the swamp in a series of braided channels until joining the lower reaches of Steel Creek. Steel Creek discharges into the Savannah River. By the time Pen Branch flow reaches Steel Creek, it is at or near ambient temperature. Habitat and community structure in the Pen Branch system (i.e., Pen Branch and Indian Grave Branch) have been strongly influenced by K-Reactor discharges. However, K Reactor has not been operating since April 1988, resulting in considerable recovery of the Pen Branch/Indian Grave Branch ecosystem (Paller et al., 1989).

To facilitate the assessment of fish community structure, the Pen Branch system was divided into four reaches based on stream gradient and proximity to the K-Reactor outfall (Figure 4-9). Upper Pen Branch consists of the headwaters located above the confluence of Pen Branch and Indian Grave Branch (Stations 1, 2, and 3). Reach 1 consists of the relatively high gradient reach extending from the K-Reactor outfall to Highway 125. It includes portions of both Indian Grave Branch and Pen Branch (Stations 8 and 4). Reach 2 extends from Highway 125 to the mouth of the delta (Station 5), and Reach 3 extends from the delta through the Savannah River swamp to the Savannah River (Stations 6 and 7).

The fish communities of Pen Branch have been studied by a number of researchers including Bennett and McFarlane (1983), Aho et al. (1986a), Paller and Saul (1986), Meffe and Sheldon (1989a, 1989b), Mealing and Paller (1988), and Mealing and Heuer (1988a, 1989a, 1989b, and 1989c). Fisheries data collected from the Pen Branch system are summarized in Paller et al. (1989).

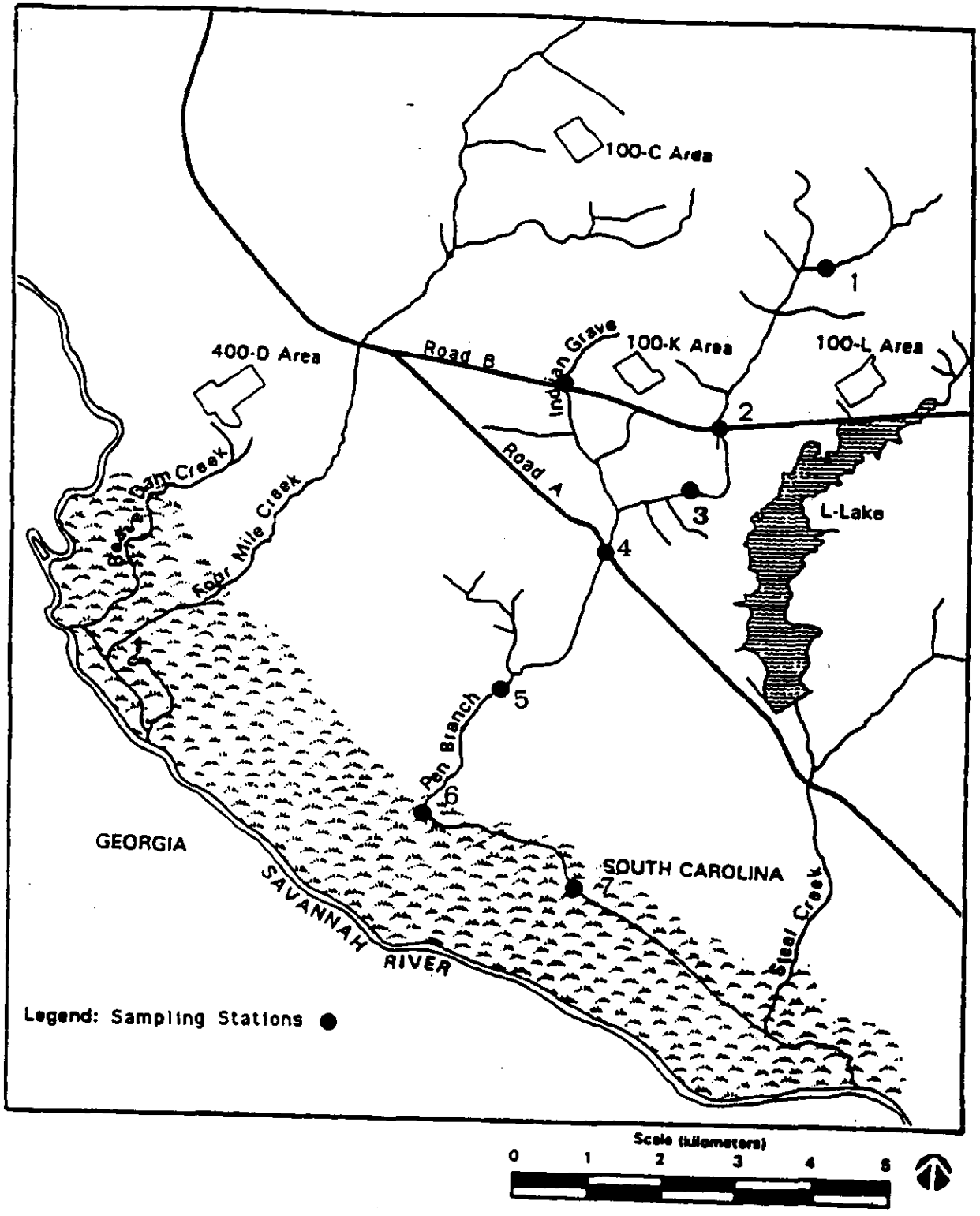

FIGURE 4-9. Fish Sampling Stations in Pen Branch and Indian Grave Branch

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Upper Pen Branch

Aho et al. (1986a) used multiple-pass electrofishing during 1984 and 1985 to sample the fish assemblages in 100 m sample sites located in the headwaters of Pen Branch, Steel Creek, and Meyers Branch. They found that community structure was generally comparable among streams with the exception of one relatively depauperate sample site in Pen Branch (PB1 in Tables 4-24 and 4-25). The relatively low number of species collected at this site may have been due to low habitat complexity (approximately 50% of the site was one large pool). In 1985, Meffe and Sheldon (1989a) sampled the fish community and measured habitat variables at sample sites in the headwaters of Pen Branch and three other streams on the SRS. They used multivariate statistical methods to examine fish-habitat relationships and associations of fish species (Figure 4-10). These analyses demonstrated that current velocity and stream size were important determinants of fish community structure in SRS streams. They also showed that most species prefer deeper, slower water, which is the predominant habitat type in low gradient coastal plain streams.

The most recent electrofishing surveys in Pen Branch were conducted in November-December 1988 and January-March 1989 (Mealing and Paller, 1988; Mealing and Heuer, 1988, 1989a, 1989b, and 1989c) at seven sample stations located throughout the Pen Branch system (all but Station 1 in Figure 4-9). The dominant species in upper Pen Branch (Stations 2 and 3) were pirate perch, yellowfin shiner, bluehead chub, redfin pickerel, and spotted sunfish (Table 4-26). These data, together with those of Aho et al. (1986a) and Meffe and Sheldon (1989a) indicate the presence of a diverse fish assemblage in the upper reaches of Pen Branch.

Reach 1

While not verified by sampling, it can be assumed that fish were absent from Reach 1 when K Reactor was operating since water temperatures often exceeded 50°C. During the current extended outage of K Reactor, however, fish have recolonized Reach 1 (Mealing and Paller, 1988; Mealing and Heuer, 1988, 1989a, 1989b, and 1989c). Sixteen species were collected from Pen Branch (Station 4) and 11 species were collected from Indian Grave Branch (Station 8) between November 1988 and January 1989 (Table 4-26). The dominant species at the Pen Branch station were largemouth bass, lake chubsucker, chain pickerel, and redbreast sunfish. The dominant species at the Indian Grave Branch sample station were spotted sucker, coastal shiner, lake chubsucker, and redbreast sunfish. Catch per unit effort (CPUE expressed as number collected per 100 m) was much lower at the sample stations in Reach 1 than at the sample stations in upper Pen Branch (Figure 4-11), possibly reflecting habitat degradation as a result of high flows and high temperatures during previous periods of reactor operation.

Most of the fish that recolonized Reach 1 apparently left this area in January when cold-testing of the K-Reactor pumping system began and stream flows began to fluctuate widely (Figure 3-35). Reductions in

TABLE 4-24

Distribution and Percent Composition of the Fish Assemblages Collected from the Mid and Upper Reaches of Streams on the Savannah River Site

Species	Stream Sites[a]								
	PB1	PB2	PB3	SC1	SC2	SC3	MB1	MB2	MB3
Yellowfin shiner	–	51.7	50.9	53.8	41.1	9.6	59.4	54.7	43.9
Bluehead chub	–	9.7	3.0	13.6	13.2	0.2	8.9	8.0	2.0
Northern hogsucker	–	–	–	11.3	1.7	0.4	0.6	1.0	1.6
Brown bullhead	11.7	1.6	0.3	<0.1	0.1	0.2	0.1	0.1	0.5
Lake and creek chubsucker	13.0	1.6	1.1	0.9	1.5	0.5	1.6	3.2	1.9
Yellow bullhead	3.2	0.7	0.3	0.1	0.6	0.5	–	0.1	0.8
Flat bullhead	–	1.5	0.8	2.0	1.2	0.3	0.1	0.5	0.3
Margined madtom	–	1.1	4.2	0.6	0.4	0.2	1.0	2.2	0.1
Speckled madtom	–	–	4.8	2.6	3.2	2.3	1.7	1.8	3.1
Tadpole madtom	–	0.7	0.7	0.2	1.4	0.4	0.9	0.1	0.3
Dollar sunfish	19.4	0.7	0.1	0.2	1.5	0.5	1.4	0.5	0.1
Redbreast sunfish	0.9	1.5	5.4	7.2	2.7	3.8	2.2	4.0	1.9
Spotted sunfish	1.9	4.4	4.4	0.4	5.9	14.6	1.5	2.4	4.9
Largemouth bass	–	0.1	0.5	0.4	0.8	2.5	–	0.2	0.1
American eel	0.7	1.3	0.4	1.2	1.2	3.8	0.4	0.9	10.9
Pirate perch	7.8	11.5	8.8	0.2	6.4	11.2	10.6	8.9	9.3
Mosquitofish	–	–	–	0.8	5.0	1.9	–	0.1	0.2
Chain pickerel	–	0.3	0.5	–	–	0.4	–	0.2	0.1
Redfin pickerel	12.3	5.9	0.6	0.2	17	0.9	1.4	0.6	1.4
Mud sunfish	27.2	1.5	–	–	–	<0.1	–	0.2	0.1
Ironcolor shiner	–	0.1	–	<0.1	–	0.7	–	<0.1	0.1
Savannah Darter	–	3.4	3.5	0.3	0.4	0.3	2.7	1.8	1.1
Blackbanded darter	–	–	4.4	2.3	2.3	1.9	0.3	0.7	1.3
Lined topminnow	–	–	0.1	–	–	<0.1	–	0.1	–
Tesselated darter	–	–	4.6	0.2	4.3	8.6	1.4	4.8	8.8
Dusky shiner	1.9	0.5	0.4	0.1	1.2	23.8	3.5	1.9	4.4
Bowfin	–	–	0.1	–	–	–	–	–	–
Creekchub	–	–	–	0.1	0.3	–	0.2	–	–
Coastal shiner	–	–	–	–	1.9	7.2	–	–	–
Warmouth	–	–	0.1	<0.1	–	0.2	0.1	0.1	–

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TABLE 4-24, Contd

Species	Stream Sites[a] PB1	PB2	PB3	SC1	SC2	SC3	MB1	MB2	MB3
Bluespotted sunfish	–	–	–	0.1	–	0.1	–	0.1	–
Banded pygmy sunfish	–	–	0.1	–	–	<0.1	–	–	–
Sawcreek darter	–	–	–	–	–	0.2	–	–	–
Pugnose minnow	–	–	–	–	–	0.2	–	–	–
Yellow perch	–	–	–	0.2	–	<0.1	–	0.1	0.1
Golden shiner	–	–	–	0.2	–	–	–	–	–
Flier	–	–	–	–	–	<0.1	–	<0.1	0.1
Swampfish	–	–	–	–	–	0.9	–	–	0.1
Snail bullhead	–	0.1	–	–	–	–	–	<0.1	–
Eastern mudminnow	–	–	0.1	–	0.1	0.1	–	<0.1	0.1
Spotted sucker	–	–	–	0.8	–	0.8	–	–	–
Swamp darter	–	–	0.1	–	–	0.3	–	–	0.1
Rosyface chub	–	–	–	–	–	<0.1	–	–	–
Bannerfin shiner	–	–	–	–	–	<0.1	–	–	–
Brook silverside	–	–	–	–	–	0.2	–	–	–
Blackbanded sunfish	–	–	–	–	–	<0.1	–	<0.1	–
Bluegill	–	0.1	–	–	–	<0.1	–	–	–
Gold topminnow	–	–	–	–	–	–	–	–	0.2
Number of collections	5	8	8	7	7	7	4	4	4
Total number of individuals	309	1519	1809	2531	1174	3415	1579	2823	1501
Mean relative abundance (no./100 m^2)	41.2	87.5	51.7	80.3	47.9	62.3	104.5	70.6	44.2
Number of species	11	22	27	29	25	43	21	33	31

[a] Station locations shown in Figure 6.2.5-1.

Source: Aho et al. (1986a)

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TABLE 4-25

Species Diversity (H'), Number of Species Collected, and Mean Relative Abundance (Individuals per 100 m^2) of Fish from Nine Stream Sites on the Savannah River Site from March 1984 Through December 1985

	Stream Sites								
	Pen Branch			Steel Creek			Meyers Branch		
	PB1	PB2	PB3	SC1	SC2	SC3	MB1	MB2	MB3
Diversity	1.85(4.0)[a]	1.77(14.6)	1.73(13.2)	1.64(14.8)	2.03(20.2)	2.16(18.3)	1.53(10.9)	1.80(12.9)	1.95(11.7)
Spring 1984	2.85	2.18	2.13	1.74	2.09	1.86	-	1.67	-
Summer	1.88	1.94	2.11	2.07	2.49	2.08	-	1.99	-
Fall	1.94	1.64	2.15	1.45	2.31	2.14	-	2.07	-
Winter	1.74	1.34	1.91	1.79	1.30	1.49	-	1.44	-
Spring 1985	1.83	1.68	2.19	1.59	2.22	2.41	1.42	1.55	1.90
Summer	-[b]	1.97	1.58	1.43	2.15	2.59	1.36	1.77	2.26
Fall	-	1.79	1.76	1.41	1.67	2.54	1.61	1.91	1.93
Winter	-	1.63	1.59	-	-	-	1.72	2.01	1.71
Species Richness	8.4(19.9)	15.1(16.0)	17.3(11.9)	15.9(19.8)	17.9(14.6)	25.0(1.03)	17.3(12.4)	18.8(2.17)	19.5(6.6)
Spring 1984	10	18	16	15	18	24	-	16	-
Summer	8	12	18	19	22	26	-	17	-
Fall	8	13	17	12	17	23	-	15	-
Winter	6	16	17	16	14	21	-	25	-
Spring 1985	10	13	16	12	20	26	20	14	18
Summer	-	18	21	17	16	29	16	20	19
Fall	-	17	18	20	18	26	18	24	20
Winter	-	14	14	-	-	-	15	19	21
Relative Abundance	41.2(24.1)	87.5(33.9)	51.7(46.9)	80.3(87.3)	47.9*23.1)	55.4(42.8)	104.5(17.0)	70.6(47.8)	44.2(37.1)
Spring 1984	50.7	45.0	32.9	69.1	42.3	34.2	-	78.4	-
Summer	26.0	50.5	29.3	40.2	55.1	55.5	-	43.4	-
Fall	45.0	100.9	25.0	26.4	53.4	25.5	-	25.8	-
Winter	36.7	121.8	66.6	50.0	33.1	57.0	-	127.0	-
Spring 1985	47.3	68.2	38.2	32.7	44.6	67.5	101.8	48.6	38.4
Summer	-	91.8	91.6	122.7	40.6	98.5	97.9	85.6	28.4
Fall	-	119.1	74.8	221.3	66.3	49.9	129.7	102.0	67.0
Winter	-	102.5	55.2	-	-	-	88.4	53.6	42.8

[a] Mean (coefficient of variation) for all seasons.

[b] Indicates no data available. Pen Branch 1 had dried up due to extended drought conditions. Steel Creek sites were either in, or immediately downstream of, a newly constructed reservoir after October 1985. Meyers Branch 1 and 3 were not sampled until after the study had been underway for a year.

Source: Aho et al. (1986a)

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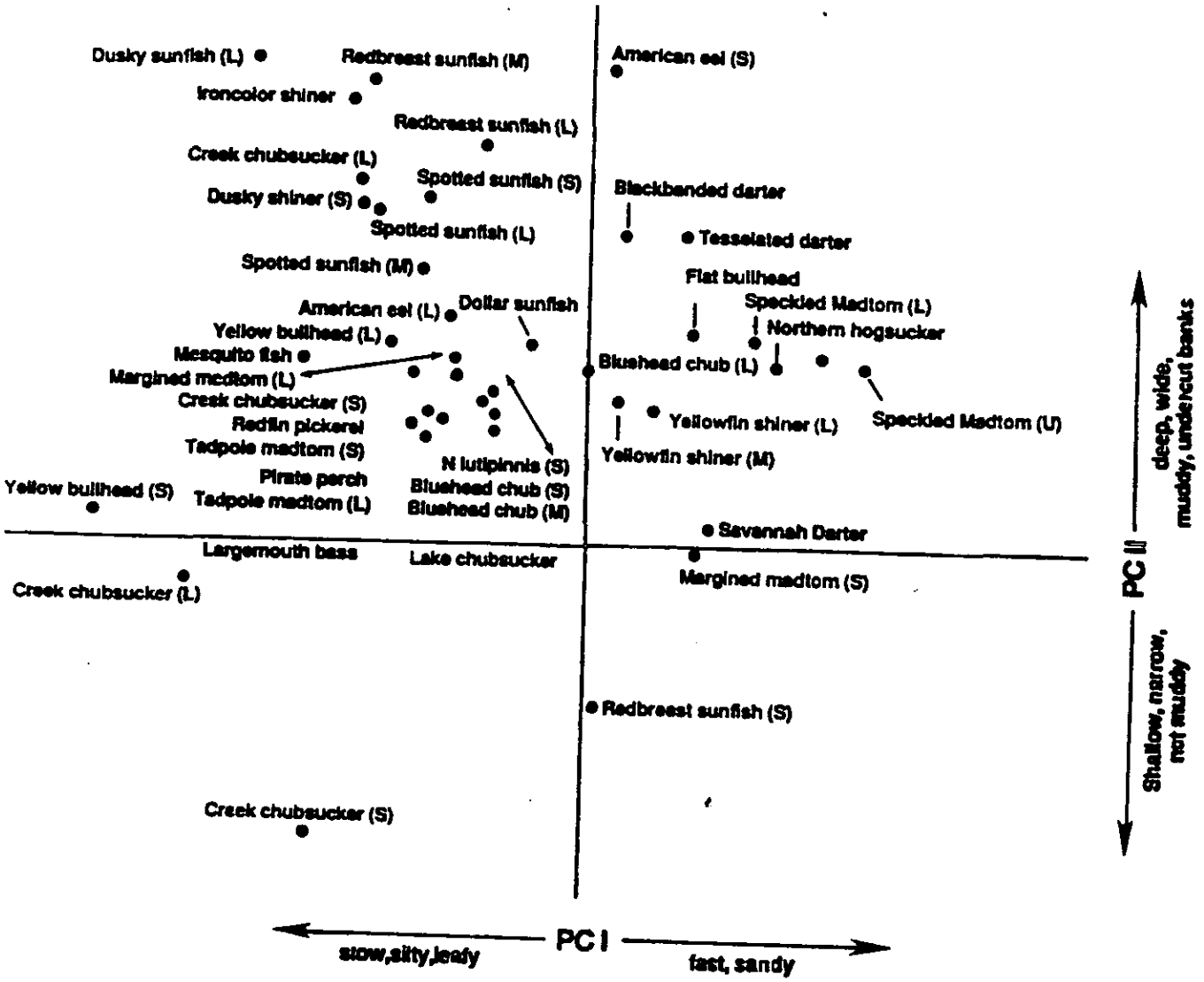

FIGURE 4-10. Plot of Centroids of Species Densities in Principal Components Space. S, M, and L are, respectively, small, medium, and large size classes. Because of space limitations on the figure, arrows in the lower corner of the upper left quadrant indicate 11 centroids whose species names are listed as a group directly below. (source: Meffe and Sheldon, 1989a)

TABLE 4-26

Percent Composition of Electrofishing Collections from Pen Branch During an Extended Outage of K Reactor. Samples were Collected Monthly from November 1988 - March 1989.

Species	Sample Station Numbers and Locations: Above K Reactor 2	Above K Reactor 3	Reach 1 4	Reach 2 5	Reach 3 6	Reach 3 7	Indian Grave 8
Longnose gar				3.3		8.9	
Bowfin				1.6	0.1		
American eel	0.7	0.2	2.6	0.8		2.3	3.7
Eastern mudminnow	4.2	0.1					
Redfin pickerel	10.9	0.3			0.1	0.3	
Chain pickerel			12.8	2.4		2.6	
Bluehead chub	11.9	5.6					
Golden shiner			1.3			0.7	3.7
Spottail shiner			1.3			2.3	
Yellowfin shiner	17.9	73.6					
Taillight shiner						0.7	
Coastal shiner				11.4	15.8	18.4	18.5
Creek chub		1.1					
Creek chubsucker	4.2	0.5	2.6	0.8	0.1	1.6	
Lake chubsucker	1.8	0.4	14.1	11.4	19.1	7.2	14.8
Spotted sucker			6.4			0.3	22.2
Silver redhorse			1.3				
Yellow bullhead	4.2			0.8	4.3		3.7
Flat bullhead		0.3	1.3				
Channel catfish				0.8			
Tadpole madtom	2.8	1.2					
Margined madtom		0.3					
Speckled madtom		1.2					
Pirate perch	24.2	5			0.3	0.7	3.7
Mosquitofish		0.1			10.9		
Lined topminnow	2.1	0.1					
Brook silversides			3.8	1.6	0.3	41.8	
Everglades pygmy sunfish						0.3	
Bluespotted sunfish					0.1		
Mud sunfish	1.1						
Redbreast sunfish	2.5	0.5	11.5	6.5	1	1.3	14.8
Warmouth			1.3	0.8			
Bluegill				0.8		1	
Dollar sunfish	1.4			2.4	14.5	0.3	
Redear sunfish			3.8	16.3		1.3	
Spotted sunfish	9.8	0.5	1.3	3.3	33.1	1.3	3.7
Largemouth bass	0.4	0.2	33.3	35		6.6	
Savannah darter		1.8					3.7
Christmas darter		0.7					
Tesselated darter		4.3	1.3		0.1		
Sawcheck darter		0.1					
Blackbanded darter		1.7					7.4
Total	100.0	100	100	100	100	100	100

Source: Mealing and Paller, 1988; Mealing and Heuer, 1988, 1989a, 1989b, and 1989c)

fish abundance in Reach 1 are indicated by a sharp decline in electrofishing catch per unit effort (CPUE; Figure 4-11)) after December 1988, when pump testing began. High stream flows can result in the downstream displacement of fishes, and marked reductions in the abundance of species that lack the physical and behavioral adaptations necessary to orient in fast waters (Minckley and Meffe, 1987; Bain et al., 1988).

Reach 2

Aho et al. (1986a) studied the fish assemblages in Reach 2 of Pen Branch and a similar section of Four Mile Creek during 1983-1985 in relation to the operating cycles of K and C reactors, respectively. They placed fyke nets in the stream channels during and following outage periods so that the upstream and downstream movements of fish could be monitored. Very few fish were collected from Reach 2 when heated effluents were being released. When water temperatures returned to ambient levels during outages, however, fish moved upstream into the creek from the Savannah River swamp. Reinvasion of the stream channels, which involved both juveniles and adults, was rapid, with some individuals captured within 12 hours of the cessation of reactor operations. In total, 29 species were collected from Reach 2 of Pen Branch during reactor outages; the most abundant species were spotted sunfish and lake chubsucker (Figure 4-12).

Paller and Saul (1986) sampled Reach 2 during 1984 and 1985. Their sampling was restricted to side channels and pools connected to the main channel, because the main channel was too hot to safely electrofish during periods of reactor operation. They found only mosquitofish in these relatively cool refugia when the reactor was operating (Table 4-27). During outages, dollar sunfish and unidentified juvenile sunfish were also collected, suggesting recolonization.

As was the case for Reach 1, Reach 2 of Pen Branch was recolonized during the current extended K-Reactor outage. Seventeen species were collected from Reach 2 (sample Station 4) during the extended outage; largemouth bass, redear sunfish, lake chubsucker, and coastal shiner were the dominant species (Table 4-26). As in Reach 1, catch rates decreased markedly following the initiation of reactor pump testing in January 1989 (Figure 4-12).

Reach 3

Reach 3 of the Pen Branch system includes both disturbed, open canopy areas (such as the Pen Branch Delta) where water temperatures are high and the fish fauna is depauperate, and comparatively undisturbed closed canopy areas deeper in the swamp where water temperatures have cooled to near ambient levels and the fish fauna is relatively rich.

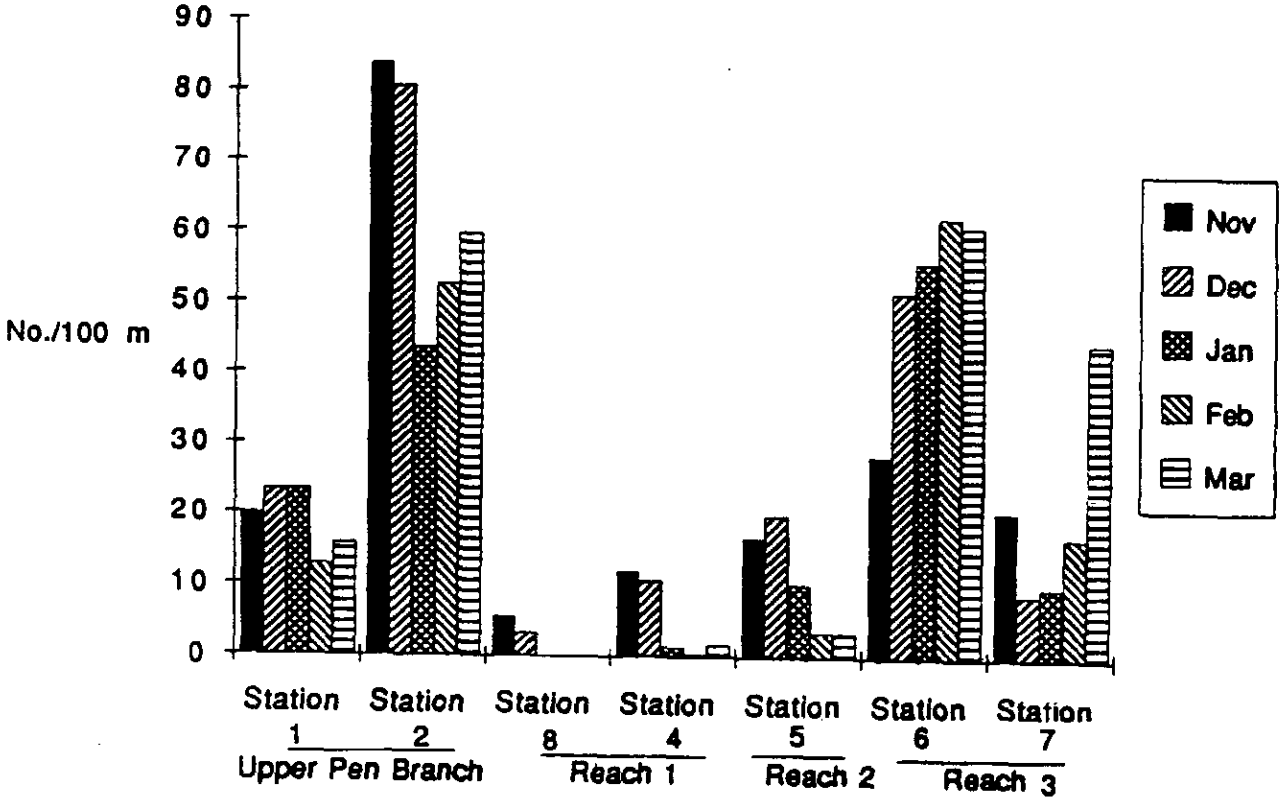

FIGURE 4-11. Number of Fish Collected by Electrofishing at Sampling Stations in the Pen Branch System. Each Value is the Mean of Three 100 m Transects (source: Mealing and Paller, 1988; Mealing and Heuer, 1988, 1989a, 1989b, and 1989c)

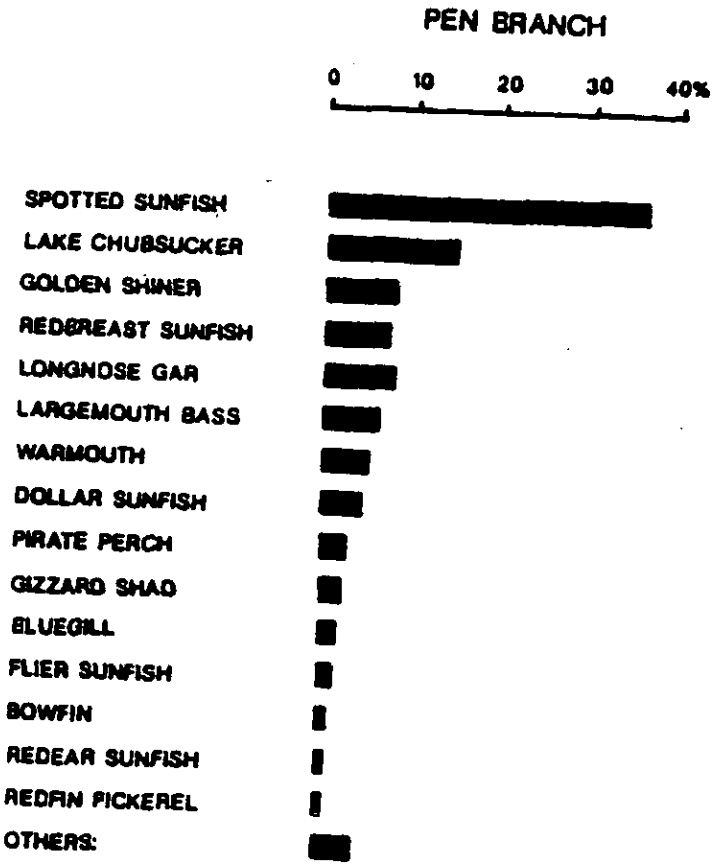

FIGURE 4-12. Overall Percentage Composition of the Fish Assemblage Caught in the Fyke Nets in Pen Branch (source: Aho et al., 1986a)

TABLE 4-27

Fish Collected from Pen Branch near Road A-13.2 (Reach 2)

Date	K-Reactor Status	Temp. (°C)	Taxa	Number Collected
12/31/84	Up	32.6	Mosquitofish	4
5/6/85	Down	18.0	Mosquitofish	12
			Dollar sunfish	1
			Sunfish spp.	25
8/7/85	Down	24.8	Dollar sunfish	2

Source: Paller and Saul (1986)

Aho et al. (1986a) collected fish by electrofishing at 12 sites in the Savannah River floodplain swamp including three (S11, S12, and S13) in the comparatively undisturbed area near Stave Island in Reach 3 (Station 7, Figure 4-9. Thirty-eight species were collected from the Stave Island area (Table 4-28). With the exception of two migratory species (hickory shad, Alosa mediocris, and striped mullet, Mugil cephalus), all were year round residents. Sunfishes and minnows were the dominant taxa in the swamp. Based on multivariate analyses of habitat are fish community structure, Aho et al. (1986a) hypothesised that fish community structure in the Savannah River swamp was influenced by two major habitat gradients. The first corresponded to the degree of habitat disturbance caused by elevated water temperatures and the second corresponded to the amount of shading by the cypress/tupelo overstory.

Paller and Saul (1986) used backpack electrofishing to sample fish during 1984 and 1985 in the highly disturbed open canopy delta of Pen Branch. Mosquitofish dominated the community at this location (Table 4-29) and were observed in high densities. Small numbers of spotted sunfish and dollar sunfish were also collected.

As described for Reaches 1 and 2 of Pen Branch, the Pen Branch Delta was recolonized during the extended outage of K Reactor. Mealing and Paller (1988) and Mealing and Heuer (1988, 1989a, 1989b, and 1989c) collected 14 species from the delta (i.e., Station 6) during the outage; dominant species included spotted sunfish, lake chubsucker, coastal shiner, dollar sunfish, and mosquitofish (Table 4-26). The relatively shallow water in the delta was probably responsible for the predominance of small species in this habitat. Mealing and Paller (1988) and Mealing and Heuer (1988, 1989a, 1989b, and 1989c) also electrofished three transects further downstream near Stave Island in the closed canopy swamp (sample Station 6). They collected 17 species; large fish such as longnose gar and largemouth bass were well represented in deeper channels (Table 4-26). Other relatively abundant species included brook silversides and coastal shiners. These species were also present near Stave Island before the extended K-Reactor outage. In contrast to Reaches 1 and 2, CPUE did not decline in the delta and swamp following pump testing in 1989 (Figure 4-11), probably because changes in current velocity were not as great as in Reaches 1 and 2 where the flow was usually confined to a narrow channel.

While not sampled as extensively as the adult fish, larval fish assemblages in Pen Branch have been studied by Paller (1985); Paller et al. (1986a), and Aho et al. (1986a). No attempts have been made to collect ichthyoplankton from the Pen Branch system during the current K-Reactor outage.

Larval fish were collected from three sampling stations on Pen Branch during 1984 and 1985. One station was located near Road B in the undisturbed headwaters at Pen Branch (i.e., Upper Pen Branch). The second was located approximately 7.0 km downstream from K Reactor (Reach 2) where water temperatures were well above ambient. The third sampling station was located among the braided channels, dead cypress and tupelo, and emergent vegetation in the Pen Branch Delta (Reach 3); this station was

TABLE 4-28

Fish Species Present in the Pen Branch Swamp Near Stave Island

Coastal shiner
Ironcolor shiner
Dusky shiner
Pugnose minnow
Taillight shiner
Golden shiner
Spottail shiner
Carp
Lake chubsucker
Spotted sucker
Mosquitofish
Brook silversides
Pirate perch
Largemouth bass
Spotted sunfish
Redbreast sunfish
Dollar sunfish
Bluegill
Bluespotted sunfish
Warmouth
Black crappie
Redear sunfish
Banded pygmy sunfish
Blackbanded darter
Tesselated darter
Yellow perch
Swamp darter
American eel
Longnose gar
Florida gar
Swampfish
Bowfin
Channel catfish
White catfish
Tadpole madtom
Flat bullhead
Chain pickerel
Gizzard shad

Source: Aho et al. (1986a)

TABLE 4-29

Fish Collected from the Pen Branch Delta (Reach 3)

Date	K-Reactor Status	Temp. (°C)	Taxa	Number Collected
11/28/84	Down	17.1	Mosquitofish	982
			Redbreast sunfish	1
			Dollar sunfish	6
			Spotted sunfish	1
			Pirate perch	1
5/6/85	Down	25.2	Mosquitofish	172
			Dollar sunfish	14
			Spotted sunfish	3
8/7/85	Down	27.1	Mosquitofish	25
			Dollar sunfish	9
			Spotted sunfish	1

Source: Paller and Saul (1986)

also highly thermal. A total of 53 fish larvae and eggs were collected from these Pen Branch stations between March and July 1984 (Table 4-30), while 22 eggs and larvae were collected during the 1985 effort (Table 4-31).

Except during April 1984, most were collected in Upper Pen Branch upstream from the reactor outfall (Figure 4-13). However, juvenile mosquitofish and sunfish larvae were collected from the delta during April 1984 and a small number of unidentified eggs were collected from the sampling station near Road A-13.2. The latter probably drifted into the sampling area from relatively cool pools and side channels rather than being produced in the main channel (where temperatures often exceeded 40°C). A similar pattern was observed during 1985 (Paller et al., 1986a) except that ichthyoplankton were only collected from the sample station above the reactor outfall.

Ichthyoplankton were collected from two sample stations in the relatively undisturbed Stave Island area of Pen Branch (Reach 3) by Aho et al. (1986a). At least 10 taxa were collected from the Stave Island sample stations (Table 4-32); dominant taxa were darters, sunfishes, minnows, and brook silversides. Aho et al. (1986a) found that spawning occurred earlier than usual (as early as January) at thermal sample sites, and that spawning was advanced even near Stave Island where temperatures were only one to two degrees warmer than ambient (Figure 4-14).

In summary, fish assemblage structure varies throughout the Pen Branch system, as a result of both the influence of K-Reactor discharge and natural changes in habitat and gradient that accompany the transition of Pen Branch from a small headwater stream to a part of the Savannah River swamp. During periods of reactor operation, water temperature exerts a controlling influence on community structure in Reaches 1 and 2 and part of Reach 3. Most fish taxa are eliminated from Indian Grave Branch and Reaches 1 and 2 of Pen Branch. A few species, however, are able to maintain residual populations in relatively cool refugia off the main channel. Sufficient cooling occurs by the time the effluent reaches the delta (Reach 3) to permit a few species to become established. As water temperatures continue to cool, additional species become established, and community structure is essentially normal by the time the effluent reaches Stave Island (also Reach 3), which is deep within the Savannah River swamp. As studies during the extended outage demonstrate, some taxa are quick to recolonize formerly thermal areas after temperatures decline to ambient levels, although abundance may remain relatively low in areas that have suffered habitat degradation. In the absence of elevated temperatures, habitat becomes the primary determinant of fish community structure with small stream species such as yellowfin shinner and bluehead chub inhabiting the upper reaches; sunfishes, chubsuckers, and largemouth bass predominating in the mid reaches; and a typical southeastern swamp community including longnose gar, brook silverside, largemouth bass, coastal shiner, and chain pickerel inhabiting the deep swamp reaches.

TABLE 4-30

Number and Percent Composition of Ichthyoplankton Collected from Pen Branch (March 14 - July 31, 1984) (Reaches 2, 3, and Upper Pen Branch)

Taxa	Number	Percent
Suckers	4	7.5
Sunfish and/or bass	2	3.8
Darters	16	30.2
Swampfish	1	1.9
Minnows	19	35.8
Mosquitofish	3	5.7
Topminnow	1	1.9
Catfish and/or bullhead	1	1.9
Unid. ichthyoplankton	6	11.3
Total	53	100.0

Source: Paller (1985)

TABLE 4-31

Number and Percent Composition of Ichthyoplankton Collected from Pen Branch (February - July 1985) (Reaches 2, 3, and Upper Pen Branch)

Taxa	Number	Percent
Minnows	10	45.5
Sunfish and/or bass	1	4.5
Darters	8	36.4
Yellow perch	1	4.5
Unid. ichthyoplankton	2	9.1
Total	22	100.0

Source: Paller et al. (1986a)

TABLE 4-32

Number of Ichthyoplankton Collected Near Stave Island (Reach 3). Fish were Identified to the Lowest Taxonomic Level Possible.

Taxa	Sampling Area 1	Sampling Area 2
Minnow	32	6
Golden shiner	1	0
Ironcolor shiner	4	1
Swampfish	0	1
Pirate perch	1	4
Brook silverside	14	11
Banded pygmy sunfish	5	4
Sunfish (*Lepomis* sp.)	13	19
Redbreast sunfish	3	2
Spotted sunfish	13	5
Largemouth bass	10	2
Darters	33	205
Tesselated darter	0	1
Egg	11	12
Unidentifiable larvae	2	2

Source: Aho et al. (1986a)

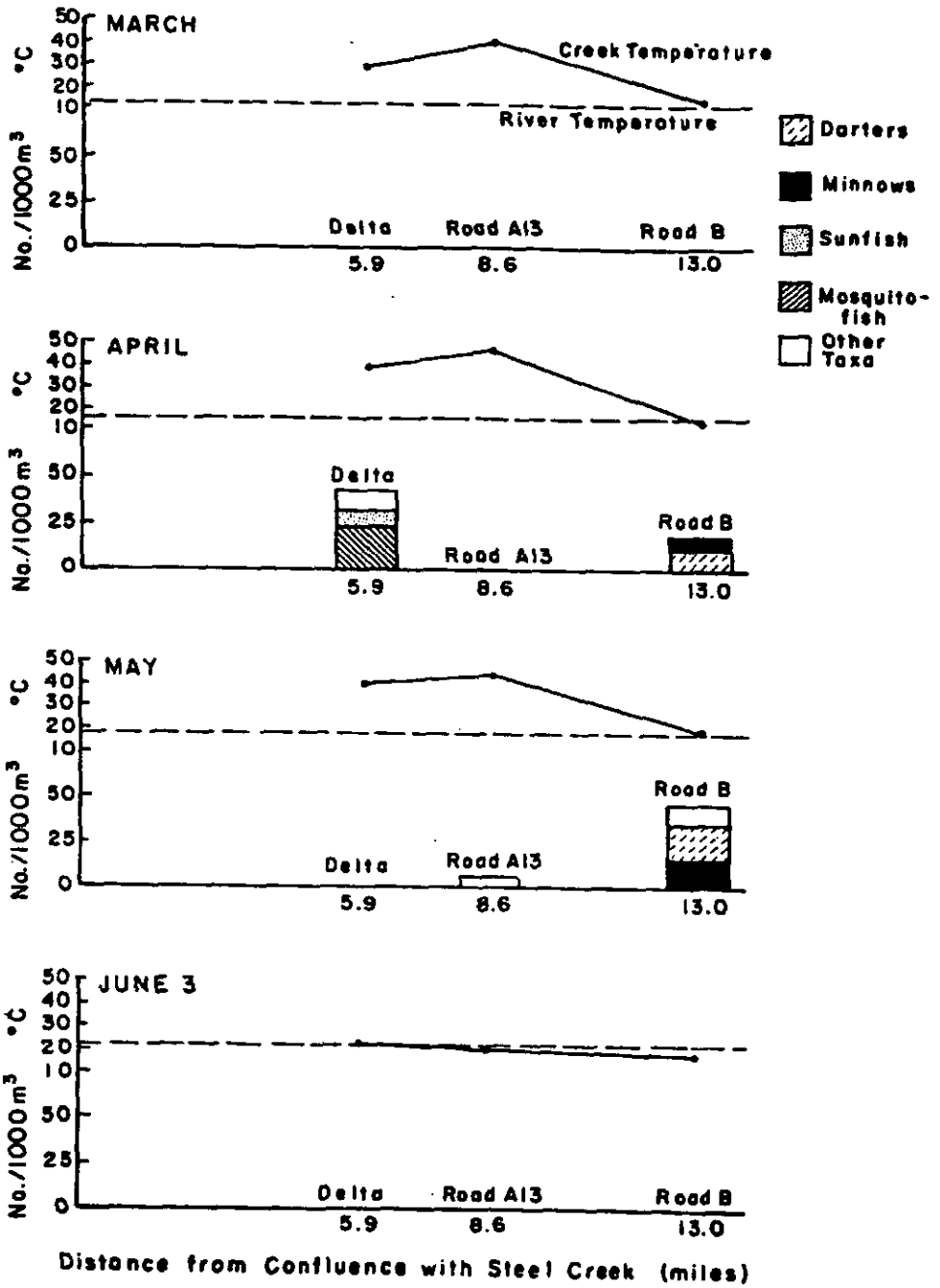

FIGURE 4-13. Average Ichthyoplankton Density and Water Temperature at Three Sampling Stations Along Pen Branch (March - July 1984) (source: Paller, 1985)

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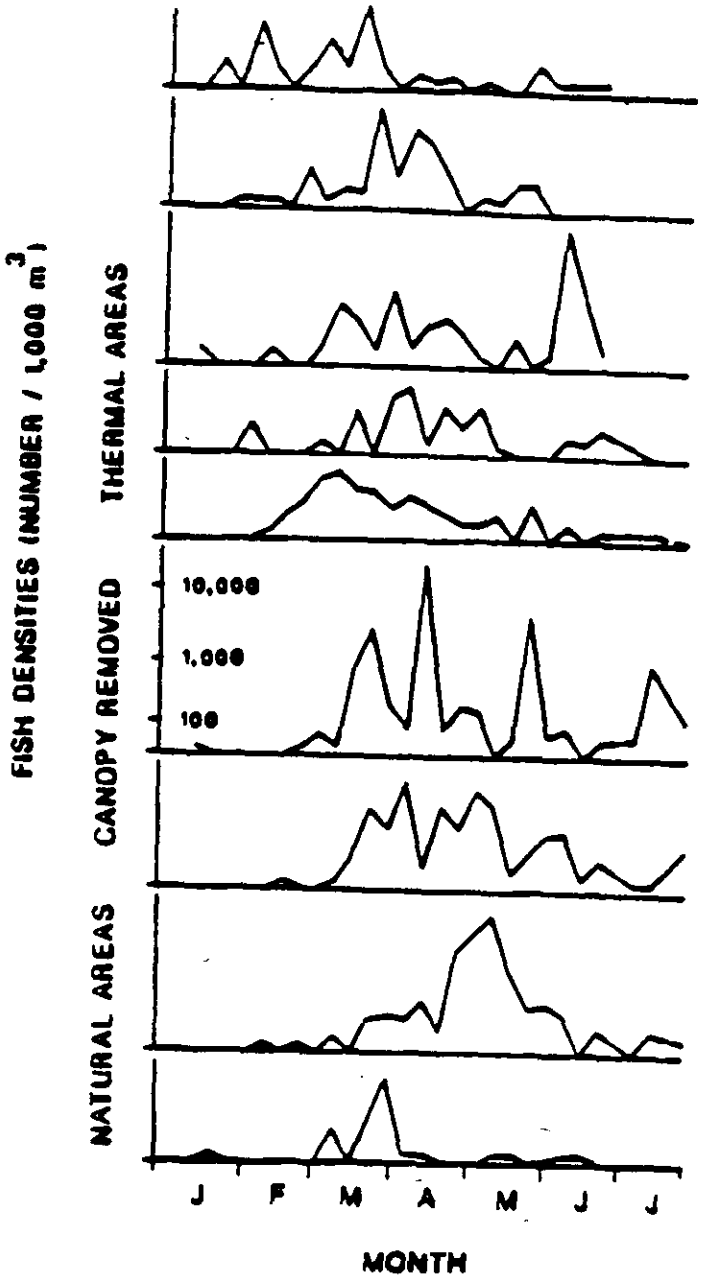

FIGURE 4-14. Seasonal Changes of Total Ichthyoplanton Density at Each Station. Geometric Mean Densities were Computed from the Total Number of Fish (plus one) per Sample and Plotted on a Log Scale. Broken lines show the intervals when samples were not taken each week. (source: Aho et al., 1986a)

4.3 L LAKE

4.3.1 Water Quality

L Lake, the once-through cooling reservoir for L Reactor, was formed by damming Steel Creek in 1985 and the reservoir was filled by October of that year. Water quality monitoring has been conducted on a regular basis in regions 4-8 (Figure 4-15) since the filling of L Lake (Gladden et al., 1988). Ranges of values for 34 water quality parameters collected from November 1985 to December 1987 can be found in Table 4-33. NPDES monitoring data for the L Lake outfall to Steel Creek for 1987 and 1988 can be found in Appendix A of this document.

A summary of the status of L-Lake water quality (Gladden et al., 1988) is presented below. Even though the summary was developed from data collected during periods of reactor operation, it may not be representative of conditions at a later successional stage of L Lake (see Section 4.2 of Gladden et al., 1988 for a discussion of successional development of lakes).

Thermal discharges from L Reactor could induce thermal stratification in L Lake, but during spring and summer local climate also stratifies the reservoir. During the summer and early fall of 1987, withdrawal of water from the bottom of the reservoir at the dam influenced this stratification.

Oxygen was depleted during stratified periods and this condition affected water quality. The oxidation-reduction potential became negative at the sediment-water interface, while pH was lowered in the hypolimnion. Nitrate-N and sulfate-S also decreased. Conductance, total dissolved solids, total inorganic carbon, alkalinity, orthophosphate-P, ammonia-N, Fe, Mn, and hydrogen sulfide concentrations all increased below the thermocline. These increases were less during 1987 than in 1986 for all parameters except total dissolved solids and hydrogen sulfide. Concentrations of Al, Ca, Mg, K, and Na were apparently not related to patterns of reactor operation or seasonal changes in the lake.

Phosphorus, Fe, sulfate-S, Mn, ammonia-N, Si, and TSS concentrations were spatially distributed in regular patterns in the hypolimnion during periods of stratification. These patterns were more a reflection of redox potentials in the lake than of L-Reactor operations. Discharge water from L Lake had high mean concentrations of total TP (averaging 130 to 121 μg/L in 1986 and 1987, respectively) indicating that P loading into L Lake from the Savannah River was very high, and probably contributed to greater rates of primary productivity in the lake.

The high rates of algal productivity caused oxygen to be supersaturated and pH values to increase to levels above 9.0 in the mixed layer. These changes were concurrent during periods of L-Reactor operation and shutdown periods in late June and early July. During fall and winter, dissolved oxygen and pH trends were not related to L-Reactor operations. Therefore, the effect of reactor operations was often confounded by normal seasonal changes in water quality in L Lake.

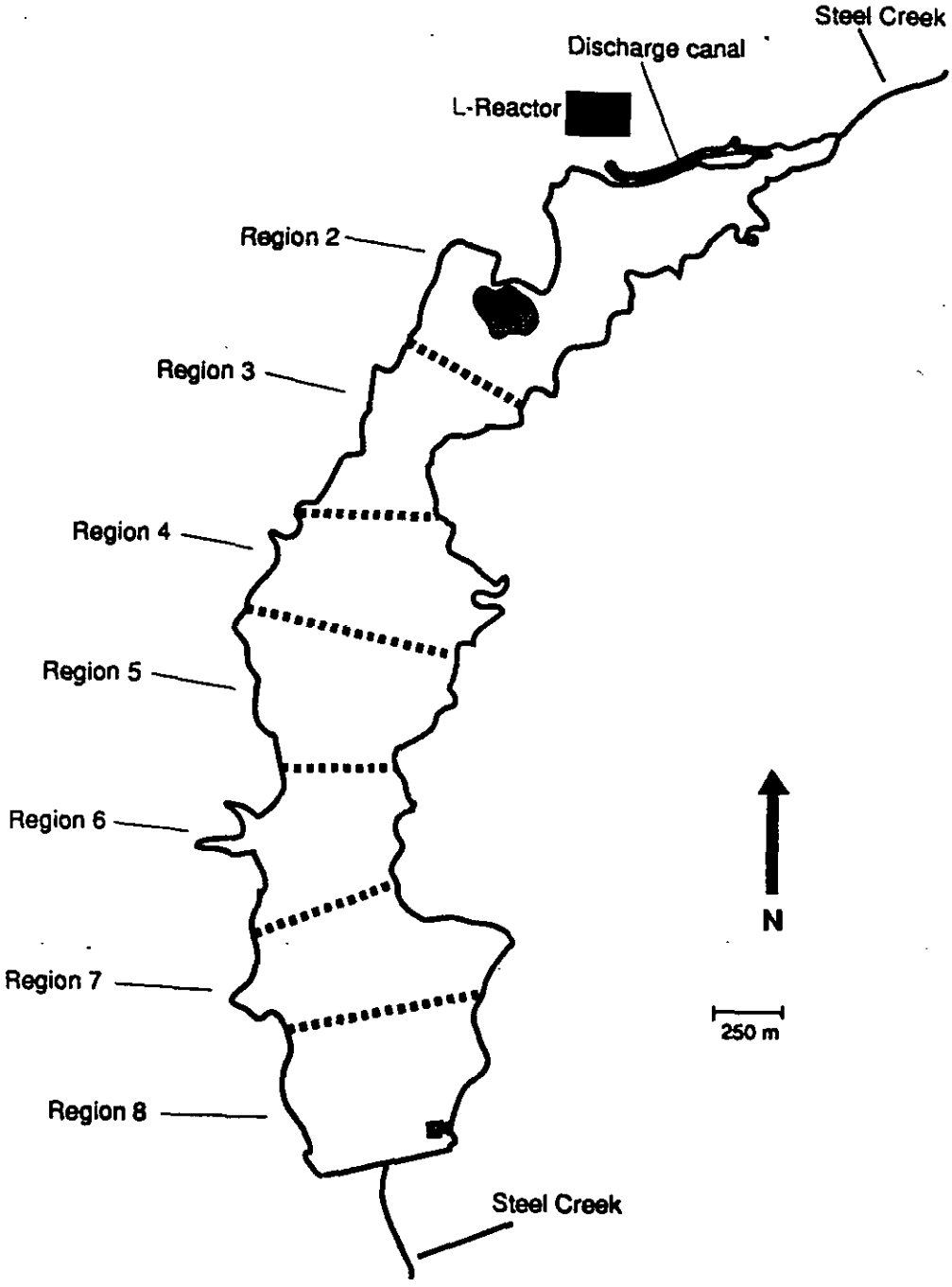

FIGURE 4-15. L-Lake Regions 4-8

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TABLE 4-33

Water-Quality Data (range of values) from L Lake

Parameter	Temp (°C)	DO (mg/L)	pH	Cond/ (µS/cm)	TDS (mg/L)	TSS (mg/L)	TOC (mg/L)
1985-86							
Region 4	10.8 - 33.6	0.1 - 10.1	5.6 - 9.5	64 - 133	25 - 91	1 - 41	1 - 13
Region 5	10.9 - 30.2	0.1 - 11.0	5.9 - 9.6	64 - 112	32 - 91	1 - 13	3 - 11
Region 6	10.9 - 31.1	0.1 - 11.8	5.6 - 9.6	61 - 117	40 - 76	1 - 17	3 - 11
Region 7	10.9 - 32.3	<0.1 - 11.9	5.2 - 9.6	61 - 120	27 - 88	1 - 39	3 - 10
Region 8	10.7 - 29.8	0.1 - 11.0	5.5 - 9.7	61 - 111	25 - 82	<1 - 13	3 - 12
1987							
Region 4	7.6 - 32.6	<0.1 - 10.0	5.1 - 9.9	53 - 98	38 - 97	1 - 11	2 - 11
Region 5	9.3 - 33.0	<0.1 - 10.2	5.4 - 9.9	67 - 93	29 - 75	1 - 11	<1 - 11
Region 6	9.5 - 31.4	0.1 - 10.7	6.0 - 10.0	67 - 103	30 - 74	1 - 11	1 - 9
Region 7	8.9 - 37.1	0.1 - 12.2	5.3 - 10.1	56 - 143	39 - 74	1 - 11	2 - 12
Region 8	10.2 - 30.8	0.1 - 0.7	5.8 - 10.1	61 - 102	34 - 73	1 - 11	<1 - 12

Parameter	DOC (mg/L)	TIC (mg/L)	ALK (mg $CaCO_3$/L)	OP (mg/L)	TP (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)
1985-86							
Region 4	1 - 11	1 - 21	14.5 - 39.5	<0.005 - 0.654	0.018 - 0.698	<0.001 - 0.036	<0.01 - 0.660
Region 5	2 - 9	1 - 15	12.7 - 50.9	<0.005 - 0.561	0.024 - 0.557	<0.001 - 0.020	<0.01 - 0.276
Region 6	3 - 9	1 - 13	11.0 - 34.0	<0.005 - 0.489	0.018 - 0.484	<0.001 - 0.022	<0.01 - 0.269
Region 7	3 - 8	1 - 17	14.8 - 34.8	<0.005 - 0.573	0.014 - 0.584	<0.001 - 0.025	<0.01 - 0.758
Region 8	2 - 8	1 - 12	15.0 - 32.7	<0.005 - 0.413	0.020 - 0.423	<0.001 - 0.022	<0.01 - 0.304
1987							
Region 4	1 - 10	2 - 9	13 - 23	<0.005 - 0.164	0.028 - 0.271	<0.001 - 0.045	<0.01 - 0.307
Region 5	1 - 9	2 - 7	13 - 21	<0.005 - 0.083	0.026 - 0.117	<0.001 - 0.018	<0.01 - 0.260
Region 6	1 - 10	2 - 7	14 - 22	<0.005 - 0.103	0.026 - 0.123	<0.001 - 0.019	<0.01 - 0.253
Region 7	<1 - 8	1 - 12	14 - 28	<0.005 - 0.220	0.024 - 0.225	<0.001 - 0.076	<0.01 - 0.369
Region 8	2 - 10	2 - 10	13 - 29	<0.005 - 0.242	0.027 - 0.245	<0.001 - 0.017	<0.01 - 0.409

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TABLE 4-33, Contd

Parameter	NH_4-N (mg/L)	TIN (mg/L)	SiO_2 (mg/L)	Total Al (mg/L)	Diss. Al (mg/L)	Total Ca (mg/L)	Diss. Ca (mg/L)
1985-86							
Region 4	<0.01 - 2.72	<0.01 - 2.73	1.8 - 10.5	<0.1 - 0.42	<0.1 - 0.18	2.12 - 5.09	2.08 - 4.94
Region 5	<0.01 - 2.27	<0.01 - 2.28	1.5 - 10.5	<0.1 - 0.37	<0.1 - 0.17	2.53 - 5.15	2.53 - 4.81
Region 6	<0.01 - 1.86	0.01 - 1.87	1.0 - 10.4	<0.1 - 0.57	<0.1 - 0.25	2.09 - 5.13	2.08 - 4.78
Region 7	<0.01 - 2.21	0.01 - 2.22	0.6 - 10.4	<0.1 - 0.79	<0.1 - 0.27	1.87 - 5.25	1.76 - 4.79
Region 8	<0.01 - 1.67	<0.01 - 1.72	0.4 - 10.2	<0.1 - 1.03	<0.1 - 0.94	2.39 - 4.91	2.68 - 4.76
1987							
Region 4	<0.01 - 1.05	0.02 - 1.06	3.0 - 9.7	<0.1 - 0.93	<0.1 - 0.17	3.00 - 4.68	2.51 - 4.26
Region 5	<0.01 - 0.54	0.01 - 0.55	2.9 - 9.5	<0.1 - 0.64	<0.1 - 0.20	3.10 - 4.44	2.55 - 4.17
Region 6	<0.01 - 0.78	0.02 - 0.80	2.8 - 9.4	<0.1 - 0.54	<0.1 - 0.20	2.78 - 4.26	2.59 - 4.18
Region 7	<0.01 - 1.70	0.01 - 1.72	2.9 - 9.7	<0.1 - 0.69	<0.1 - 0.17	3.17 - 4.71	3.06 - 4.10
Region 8	<0.01 - 1.89	0.32 - 1.91	2.7 - 10.0	<0.1 - 0.75	<0.1 - 0.20	2.55 - 4.76	2.46 - 4.16

Parameter	Total Fe (mg/L)	Diss. Fe (mg/L)	Total Mg (mg/L)	Diss. Mg (mg/L)	Total Mn (mg/L)	Diss. Mn (mg/L)	Total K (mg/L)
1985-86							
Region 4	0.052 - 11.60	<0.020 - 11.60	1.04 - 1.69	1.01 - 1.76	<0.02 - 2.60	<0.02 - 2.50	1.10 - 2.06
Region 5	0.101 - 8.94	<0.020 - 8.66	1.20 - 2.00	1.12 - 1.95	<0.02 - 1.88	<0.02 - 1.93	1.17 - 1.96
Region 6	0.078 - 7.78	<0.020 - 7.30	0.97 - 1.54	1.02 - 1.53	<0.02 - 8.46	<0.02 - 7.80	0.86 - 4.59
Region 7	0.070 - 5.30	<0.020 - 5.51	1.08 - 1.68	1.12 - 1.67	<0.02 - 1.57	<0.02 - 1.53	0.95 - 2.27
Region 8	0.087 - 6.90	<0.020 - 5.44	1.19 - 1.57	1.18 - 1.58	<0.02 - 1.83	<0.02 - 1.90	1.00 - 4.20
1987							
Region 4	0.063 - 1.58	<0.020 - 1.42	1.03 - 1.49	1.05 - 1.47	<0.02 - 0.98	<0.02 - 0.60	0.49 - 2.43
Region 5	0.040 - 1.89	<0.020 - 0.76	1.08 - 1.62	1.09 - 1.48	<0.02 - 0.35	<0.02 - 0.34	0.99 - 2.12
Region 6	0.037 - 1.14	<0.020 - 0.86	1.06 - 1.50	1.05 - 1.49	<0.02 - 0.23	<0.02 - 0.24	0.72 - 2.08
Region 7	0.027 - 2.00	<0.020 - 1.59	1.05 - 1.50	1.07 - 1.46	<0.02 - 0.77	<0.02 - 0.76	0.86 - 1.95
Region 8	<0.020 - 1.83	<0.020 - 1.97	0.93 - 1.44	0.88 - 1.43	<0.20 - 0.32	<0.02 - 0.24	0.78 - 1.88

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TABLE 4-33, Contd

Parameter	Diss. K (mg/L)	Total Na (mg/L)	Diss. Na (mg/L)	Cl (mg/L)	H_2S (mg/L)	SO_4 (mg/L)
1985-86						
Region 4	1.10 - 1.94	5.92 - 11.19	5.44 - 11.19	6 - 9	<0.1 - 0.3	2 - 6
Region 5	0.97 - 1.94	7.21 - 13.00	7.19 - 13.30	6 - 13	<0.1 - 0.4	2 - 6
Region 6	0.82 - 2.89	6.89 - 12.40	6.81 - 13.40	6 - 9	<0.1 - 0.4	2 - 6
Region 7	1.05 - 2.15	7.06 - 11.30	6.76 - 11.20	6 - 10	<0.1 - 0.6	2 - 6
Region 8	0.94 - 4.55	6.18 - 10.84	6.96 - 11.03	6 - 11	<0.1 - 0.6	2 - 7

Parameter	Diss. K (mg/L)	Total Na (mg/L)	Diss. Na (mg/L)	Cl (mg/L)	H_2S (mg/L)	SO_4 (mg/L)
1987						
Region 4	0.86 - 1.71	6.96 - 11.80	7.28 - 11.20	5.3 - 11.6	<0.1 - <0.1	4 - 9
Region 5	0.61 - 1.73	6.78 - 11.80	7.38 - 11.30	5.2 - 9.0	<0.1 - 0.2	3 - 9
Region 6	0.63 - 1.60	6.90 - 11.40	7.37 - 12.30	5.2 - 9.3	<0.1 - 0.3	3 - 9
Region 7	0.69 - 1.65	6.87 - 10.80	7.39 - 11.70	5.1 - 9.1	<0.1 - 0.5	2 - 8
Region 8	0.83 - 1.48	6.67 - 11.20	7.21 - 11.70	5.1 - 8.3	<0.1 - 0.7	1 - 9

Temp = temperature
DO = dissolved oxygen
Cond. = specific conductance
TDS = total dissolved solids
TSS = total suspended carbon
TOC = total organic carbon
NH_4-N = ammonia-nitrogen
SO_4 = sulfate
TIN = total inorganic nitrogen

SiO_2 = silica
Al = aluminum
Ca = calcium
Cl = chloride
Fe = iron
Mg = magnesium
Mn = manganese
K = potassium
Na = sodium

DOC = dissolved organic carbon
TIC = total inorganic carbon
ALK = alkalinity
OP = ortho-phosphorus
TP = total phosphorus
NO_2-N = nitrite-nitrogen
NO_3-N = nitrate-nitrogen
H_2S = hydrogen sulfate

Source: Gladden et al. (1988)

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During periods of thermal stratification, nitrate-N concentrations declined and organic carbon levels increased in the hypolimnion. Silica concentrations inversely related to diatom densities. These changes were probably a result of increased primary productivity.

Regional differences in water quality were not found in the mixed layer due to mixing from the wind. In the hypolimnion, TIC, orthophosphate, ammonia-N, nitrate-N, silica, iron, and manganese were greater in Region 4 than in Region 8. The most likely cause of these chemical gradients is the morphometry of the lake. Being shallower in Region 4, these elements and compounds have less water for dilution there than in than at Region 8, which is much deeper and has a larger volume of water.

L-Lake water quality was within the range of other reservoirs in the southeastern United States for DO, conductivity, TSS, TOC, alkalinity, nitrate-N, Na, Cl, hydrogen sulfide, and sulfate-S. Temperature maxima in L Lake were relatively higher than at other lakes in the region. During 1986, pH, as well as concentrations of phosphorus, ammonia-N, Fe, and Mn were greater than in other local reservoirs. In 1987, pH maxima were even higher, while phosphorus, ammonia-N, Fe, and Mn concentrations decreased to levels that were comparable to other lakes in the region. Most of the concentrations of, and trends in, water-quality parameters in L Lake can be attributed to reservoir succession.

4.3.2 *Phytoplankton*

This section summarizes results of the L-Lake phytoplankton studies conducted from January 1986 through December 1987. Topics discussed include: community characteristics, comparisons with other reservoirs of the region, status during the study period, and expected impacts associated with a restart of L Reactor. The historical information summarized in this section was primarily taken from a report by Starkel et al. (1988a).

4.3.2.1 Phytoplankton Community Characteristics

Parameters measured to evaluate the phytoplankton community of L Lake were species composition, density, biovolume, seston dry weight (DW), seston ash-free dry weight (AFDW), chlorophyll a concentration, and primary productivity. These parameters were measured monthly from January 1986 through December 1987 in Regions 4 through 8 of the lake (Figure 4-15).

A total of 220 phytoplankton taxa were identified from the pelagic zone of L Lake during the 1986-1987 studies (Starkel et al. (1988a). A comprehensive species list (Table 4-34) included 86 taxa of green algae (Chlorophyta; 39.1% of total taxa), 53 taxa of diatoms (Bacillariophyta; 24.1%), 41 taxa of blue-green algae (Cyanophyta; 18.6%), 23 taxa of golden-brown algae (Chrysophyta; 10.5%), five taxa of cryptomonads (Cryptophyta; 2.3%), 8 taxa of euglenoids (Euglenophyta; 3.6%), and four taxa of dinoflagellates (Pyrrhophyta; 1.8%).

TABLE 4-34

Phytoplankton Taxa Identified from Monthly Sampling in 1986 and 1987 from Pelagic Zone Sampling Stations

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Bacillariophyta					
Achnanthes exigua	-	-	-	X	-
Achnanthes lanceolata var. *apiculata*	-	X	-	-	-
Achnanthes minutissima	X	X	X	X	X
Asterionella formosa	-	-	-	X	X
Atthea zachariasi	X	X	X	X	X
Capartogramma crucicula	X	-	-	-	-
Cyclotella atomus	X	X	X	X	X
Cyclotella meneghiniana	X	X	X	X	X
Cyclotella pseudostelligera	X	X	X	X	X
Cyclotella stelligera	X	X	X	X	X
Cymbella minuta	-	-	-	-	X
Eunotia pectinalis	-	X	-	-	-
Eunotia zazumensis	-	X	-	-	-
Fragilaria crotonensis	-	X	X	X	X
Gomphonema parvulum	X	X	-	X	X
Gyrosigma acuminata	-	-	-	X	-
Gyrosigma spencerii	X	X	X	X	X
Melosira ambigua	X	X	X	X	X
Melosira distans	X	X	X	X	X
Melosira granulata	X	X	X	X	X
Melosira granulata var. *angustissima*	X	X	X	X	X
Melosira varians	X	X	X	X	X
Navicula capitata	-	X	-	-	-
Navicula confervacea	X	X	X	X	X
Navicula cryptocephala	X	X	X	X	X
Navicula cuspidata	X	-	-	-	-
Navicula decussis	X	X	-	-	X
Navicula luzonensis	-	-	X	-	-
Navicula minima	X	X	-	-	-
Navicula rhynchocephala var. *germainii*	-	X	-	-	-
Navicula spp.	X	X	X	-	X
Nitzschia acicularis	X	X	X	X	X
Nitzschia agnita	X	X	X	X	X
Nitzschia amphibia	X	-	X	X	X
Nitzschia capitellata	X	-	-	-	-
Nitzschia fonticola	X	X	X	-	-
Nitzschia gracilis	X	X	X	X	X
Nitzschia holsetica	X	X	X	X	X
Nitzschia palea	X	X	X	X	X
Nitzschia paleacea	X	X	X	X	X
Nitzschia spp.	-	X	X	-	-

TABLE 4-34, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Bacillariophyta, Contd					
Pinnularia spp.	-	-	-	X	-
Rhizosolenia eriensis	X	-	-	-	-
Rhizosolenia longiseta	X	X	X	X	X
Skeltonema potamos	X	X	X	X	X
Stephanodiscus sp. 1	-	-	X	-	X
Surirella robusta	X	X	-	X	X
Synedra delicatissima	X	-	X	X	X
Synedra parasitica	-	X	-	-	-
Synedra rumpens	X	X	X	X	X
Synedra tenera	X	X	X	X	X
Synedra ulna	X	X	X	X	X
Synedra ulna var *oxyrhynchus*	X	-	-	-	-
Division Chlorophyta					
Actinastrum hantzschii	X	X	X	X	X
Ankistrodesmus falcatus	X	X	X	X	X
Ankistrodesmus spiralis	X	X	X	X	X
Chaetophora elegans	-	-	-	-	X
Characium spp.	X	X	X	X	X
Chlamydomonas spp. (<5 µm)	X	X	X	X	X
Chlamydomonas spp. (5-9.9 µm)	X	X	X	X	X
Chlamydomonas spp. (10-15 µm)	X	X	X	X	X
Chlamydomonas spp. (>15 µm)	X	X	X	X	X
chlorobacteria spp. (<2 µm)	-	X	-	-	-
chloroflagellate spp. (<5 µm)	X	X	X	-	-
chloroflagellate spp. (5-9 µm)	-	X	X	X	X
Closteriopsis longissima	X	-	-	-	X
Closterium aciculare	X	X	X	-	X
Closterium acutum	X	X	X	X	X
Closterium cornu	X	-	X	-	-
Closterium gracile	X	X	X	X	X
Closterium moniliferum	X	-	-	-	-
Closterium parvulum	X	-	-	-	-
coccoid Chlorophyta spp. (<5 µm)	X	X	X	X	X
coccoid Chlorophyta spp. (5-9.9 µm)	X	X	X	X	X
coccoid Chlorophyta spp. (10-15 µm)	-	-	-	-	X
Coelastrum microporum	X	X	X	-	X
Coelastrum reticulatum	X	X	X	X	X
Coelastrum spaericum	X	X	-	X	X
Coronastrum aestivale	X	X	X	X	X
Cosmarium botrytis	-	-	X	-	-
Cosmarium depressum	X	X	X	X	X

TABLE 4-34, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Chlorophyta, Contd					
Cosmarium reniforme	-	-	-	-	X
Crucigenia crucifera	X	X	X	X	X
Crucigenia guadrata	X	X	X	X	X
Crecigenia tetrapedia	-	X	X	X	X
Desmidium swartzii	-	-	X	-	-
Dictyosphaerium ehrenbergianum	-	X	-	-	-
Dictyosphaerium pulchellum	X	X	X	X	X
Didymocystis fina	X	X	X	X	X
Elakatothrix viridis	X	X	X	X	X
Euastrum binale	X	X	X	X	X
Franceia ovalis	-	X	-	-	-
Gleocystis planctonica	X	X	X	X	X
Golenkenia radiata	-	-	X	X	X
Kirchneriella lunaris	X	X	X	X	X
Kirchneriella obesa	-	X	-	-	X
Lagerheimia genevensis	-	-	X	-	-
Leptosira medicinana	-	-	X	-	-
Miractinium pusillum	X	X	X	X	X
Mougeotia spp.	-	X	X	-	X
Oedogonium spp. lg	X	X	X	X	X
Oocystis parva	X	X	X	X	X
Oocystis pusilla	X	X	X	X	X
Pandorina morum	X	X	X	X	X
Pediastrum duplex	X	X	X	X	X
Pediastrum tetras	X	X	X	X	X
Pleurotaenium ehrenbergii	-	X	-	-	-
Scenedesmus acuminatus	X	X	X	X	X
Scenedesmus acutus	X	X	X	X	X
Scenedesmus brasiliensis	X	X	X	X	X
Scenedesmus brevispina	X	-	-	-	-
Scenedesmus denticulatus	X	X	X	X	X
Scenedesmus dimorphus	X	X	X	X	X
Scenedesmus ecornis	X	X	X	X	-
Scenedesmus producto capitatus	X	X	X	X	X
Scenedesmus quadricauda	X	X	X	X	X
Scenedesmus sp.	-	-	-	X	-
Scenedesmus spinosus	X	X	X	X	X
Schroderia setigera	X	X	X	X	X
Selenastrum minutum	X	X	X	X	X
Selenastrum westii	X	X	X	X	X
Spermatozoopsis exultans	X	X	X	X	-
Sphaerocystis schroeteri	X	X	X	X	X
Staurastrum alternans	-	X	-	-	-

TABLE 4-34, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Chlorophyta, Contd					
Staurastrum chaetoceros	X	X	X	X	X
Staurastrum cingulum	X	X	X	X	X
Staurastrum excavatum	X	X	X	X	X
Staurastrum gracile	X	X	X	X	-
Staurastrum hexacerum	-	-	-	-	X
Staurastrum leptocladium	X	X	X	X	X
Staurastrum punctulatum	X	X	X	-	-
Tetraedron caudatum	-	X	-	-	-
Tetraedron gracile	X	X	X	X	X
Tetraedron minimum	X	X	X	X	X
Tetraedron trigonum	X	X	X	X	X
Tetrastrum staurogeniaeforme	-	X	-	-	-
Treubaria setigerum	X	X	X	X	X
Treubaria triappendiculata	-	X	X	X	X
Ulothrix tenerrima	X	X	X	-	-
Division Chrysophyta					
Chromulina spp. (<5 µm)	X	X	X	X	X
Chromulina spp. (5-9.9 µm)	X	X	X	X	X
Chrysoflagellate spp. (<5 µm)	X	X	X	X	X
Chrysoflagellate spp. (5-9.9 µm)	X	X	X	X	X
Chrysophyte sp. 2	X	X	X	X	X
Chrysosphaerella longispina	X	X	-	-	-
coccoid Chrysophyta spp. (<5 µm)	X	X	X	X	X
coccoid Chrysophyta spp. (5-9.9 µm)	X	X	X	X	X
coccoid Chrysophyta spp. (10-15 µm)	X	X	X	X	-
Dinobryon divergens	-	X	-	X	X
Dinobryon sp. 1	X	X	X	X	-
Kephiron sp.	-	X	-	-	-
Mallomonas caudata	X	X	-	X	X
Mallomonas pseudocoronata	X	X	-	X	-
Mallomonas sp. 3	X	-	X	X	-
Mallomonas tonsurata	X	X	X	X	X
Microglena cordiformis	X	X	X	X	X
Ochromonas spp. (<5 µm)	X	-	X	-	-
Ochromonas spp. (5-9.9 µm)	-	-	-	-	X
Ophiocytium capitatum	-	X	-	-	-
Ophiocytium cochleare	-	X	X	X	-
Paraphysomonas spp.	-	-	X	X	X
Synura uvella	X	X	X	X	X

TABLE 4-34, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Cryptophyta					
Cryptomonas erosa	X	X	X	X	X
Cryptomonas marsonii	X	X	X	X	X
Cryptomonas rostratiformis	X	X	X	X	X
Rhodomonas minuta	X	X	X	X	X
Rhodomonas minuta var. *nannoplanktonica*	X	X	X	X	X
Division Cyanophyta					
Anabaena planctonica	X	X	X	X	X
Anabaena spiroides	X	X	X	X	X
Anabaena spp.	-	X	X	X	-
Anabaena subcylindrica	X	X	X	X	X
Anabaena wisconsinense	X	-	X	-	-
Aphanizomenon flos-aquae	X	X	X	X	X
Aphanocapsa elachista	-	-	X	X	X
Aphanothece nidulans	-	-	X	X	X
Aphanothece saxicola	-	X	X	-	X
Chroococcus lacustris	-	X	X	X	X
Chroococcus minutus	X	-	X	-	X
Chroococcus sp. 1	-	X	-	-	-
coccoid Cyanophyta spp. (<5 µm)	X	X	X	X	X
coccoid Cyanophyta spp. (5-9.9 µm)	X	X	X	X	X
Coelosphaerium naegelianum	X	X	X	X	X
Coelosphaerium pallidum	X	X	X	X	X
Lyngbya limnetica	X	X	X	X	X
Lyngbya sp. 1	X	X	X	-	-
Lyngbya spp.	-	X	-	X	-
Merismopedia minima	X	X	X	X	X
Merismopedia tenuissima	X	X	X	X	X
Microcystis aeruginosa	X	X	X	X	X
Microcystis incerta	X	X	X	X	X
Oscillatoria acutissima	X	X	X	X	X
Oscillatoria amphibia	X	-	X	X	X
Oscillatoria anguina	-	X	-	-	-
Oscillatoria angustissima	X	X	X	X	X
Oscillatoria geminata	X	X	X	X	X
Oscillatoria limosa	X	-	-	-	-
Oscillatoria ornata	X	X	X	X	-
Oscillatoria sp. 1	X	-	X	X	-
Oscillatoria spp.	-	X	X	-	-
Oscillatoria subtilissima	-	X	X	X	X
Oscillatoria tenuis	X	X	X	-	X
Phormidium molle	X	-	-	-	-

TABLE 4-34, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Cyanophyta, Contd					
Phormidium sp. 1	X	X	X	X	X
Phormidium spp.	X	X	X	X	X
Rhabdoderma sp. 1	-	X	X	X	X
Rhabdoderma sp. 2	X	X	X	X	X
Schizothrix sp. 1	X	X	X	X	X
Schizothrix spp.	X	X	X	X	X
Division Euglenophyta					
Euglena acus	-	X	X	X	-
Euglena minuta	X	X	X	X	X
Euglena spp.	X	X	X	X	X
Phacus monilatus	X	X	X	X	X
Phacus spp.	-	-	X	-	-
Trachelomonas hispida	X	X	X	X	X
Trachelomonas stokesiana	X	X	X	-	-
Trachelomonas volvocina	X	X	X	X	X
Division Pyrrhophyta					
Ceratium hirundinella	X	X	X	X	X
Gymnodinium ordinatum	X	X	X	X	X
Gymnodinium sp. 1	X	X	X	X	X
Peridinium inconspicuum	X	X	X	X	X

Source: Gladden et al. (1988)

There was substantial seasonal variation in taxa richness (Figure 4-16). Within each year, the highest numbers of taxa occurred in March 1986 (38 to 46 taxa) and in October 1987 (47 to 61 taxa). Monthly values declined after March in both years to low values of 14 to 19 taxa in July 1986 and 18 to 21 taxa in July and August 1987. No differences among regions were apparent in the monthly taxa richness data. Richness values tended to be lowest in late spring and early summer. Late summer increases in taxa richness for both years occurred within one to two months after reactor shutdown, but no corresponding decreases in taxa richness was apparent in the fall following reactor startup.

Most total densities of phytoplankton in L Lake were less than 20,000 organisms/mL between October and March of both years and ranged from 20,000 to 210,000 organisms/mL in the spring and summer (Figure 4-17). From April through September of both years, nearly all of the phytoplankton abundance was associated with blue-green algae, especially Microcystis aeruginosa (Figures 4-18 and 4-19). There were no consistent regional differences in the densities of total phytoplankton or blue-green algae. Annual mean densities of total phytoplankton abundances and blue-green algae were higher in 1987 than in 1986 (except for Region 4), but the relatively large standard deviations and ranges of values in both years (Table 4-35) indicate that these differences may have been of little importance. The percentage composition by blue-green algae was slightly lower in all regions in 1987 than in 1986 (89.9 to 93.6% in 1986 vs. 87.7 to 89.7% in 1987).

Densities of the major taxonomic groups of phytoplankton, other than blue-green algae, were usually less than 10,000 organisms/mL. The diatoms, golden-brown algae, and cryptomonads typically had highest densities in fall and winter months of both years. Densities of green algae were highest in summer and fall of both years. Green algae had higher mean densities in 1987 (1,598 to 1,988 organisms/mL) than in 1986 (808 to 1,357 organisms/mL) due largely to high densities (>1,000 organisms/mL) in all sampling regions from August through December 1987. In contrast, the abundance of green algae never exceeded 1,000 organisms/mL in any region over 2 consecutive months in 1986. The golden-brown algae were also more abundant in 1987 (regional means from 2,346 to 2,948 organisms/mL) than in 1986 (regional means from 889 to 1,385 organisms/mL) due to sustained high densities (approximately 3,000 to 12,000 organisms/mL) from September through December 1987.

Numerically, blue-green algae constituted over 85% of the phytoplankton community from April through September in Regions 4-8 during both years (Figure 4-19). The relative abundance of blue-greens was less than 50% only rarely, including the first 3 months of the study. Diatoms were numerically important components of the phytoplankton community in the winter, when their relative abundance ranged from 15% to 65%. Golden-brown algae were important in the winter of 1986 (relative abundance often over 50% in February and March 1986) and in the fall and winter of 1987 (nearly 50% of the total community in December 1987).

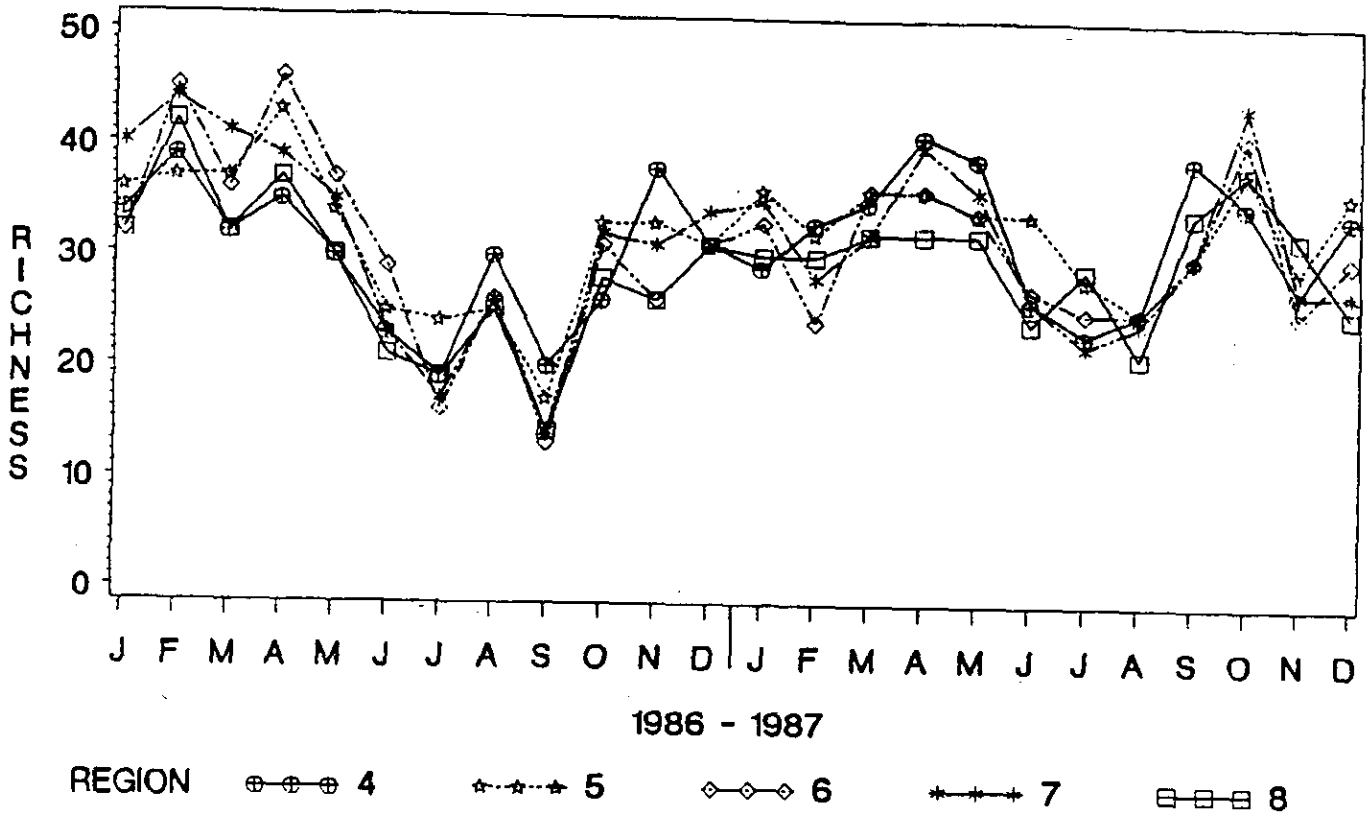

FIGURE 4-16. Phytoplankton Taxa Richness in the Pelagic Mixed Zone of L Lake, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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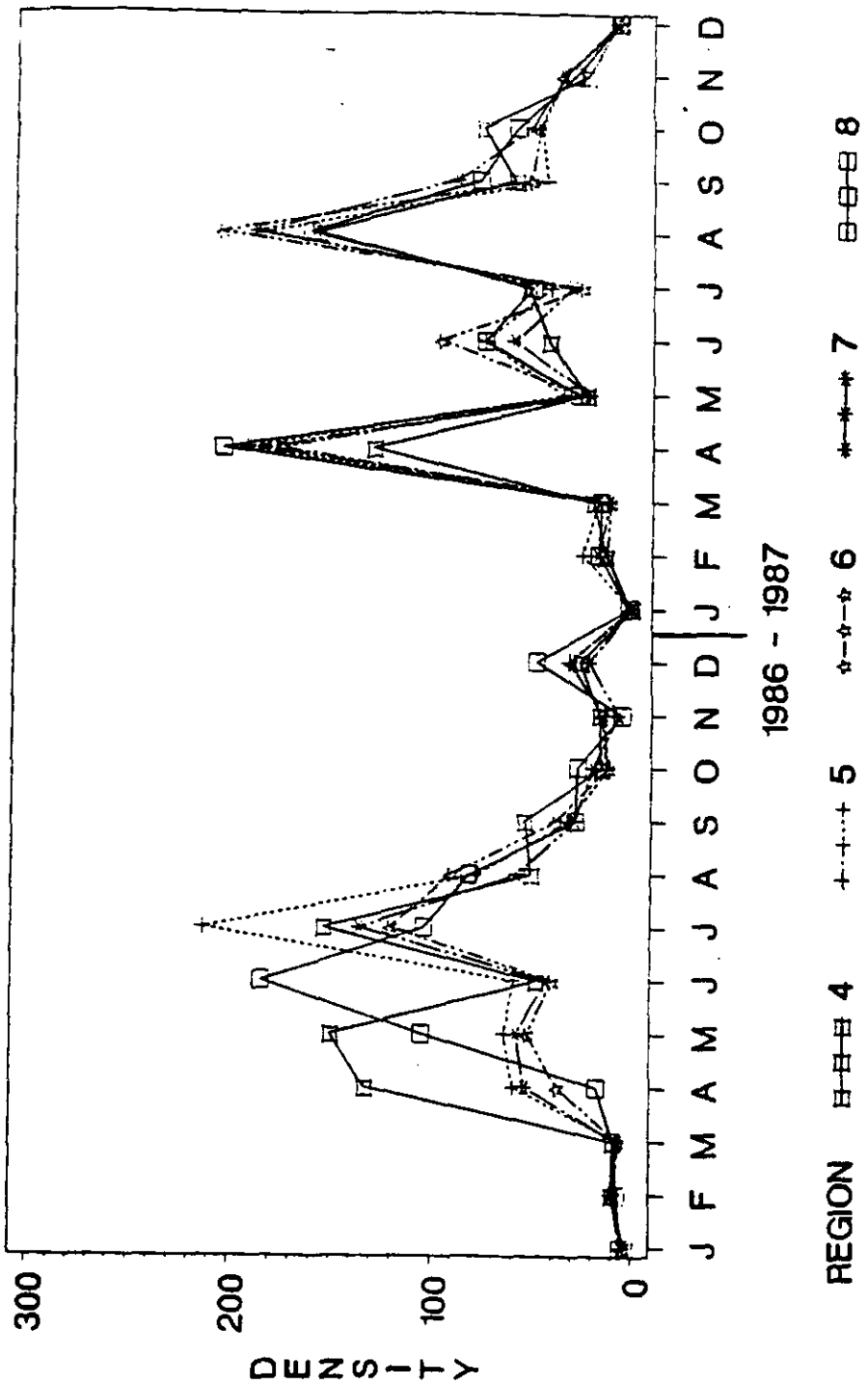

FIGURE 4-17. Mean Total Phytoplankton Densities in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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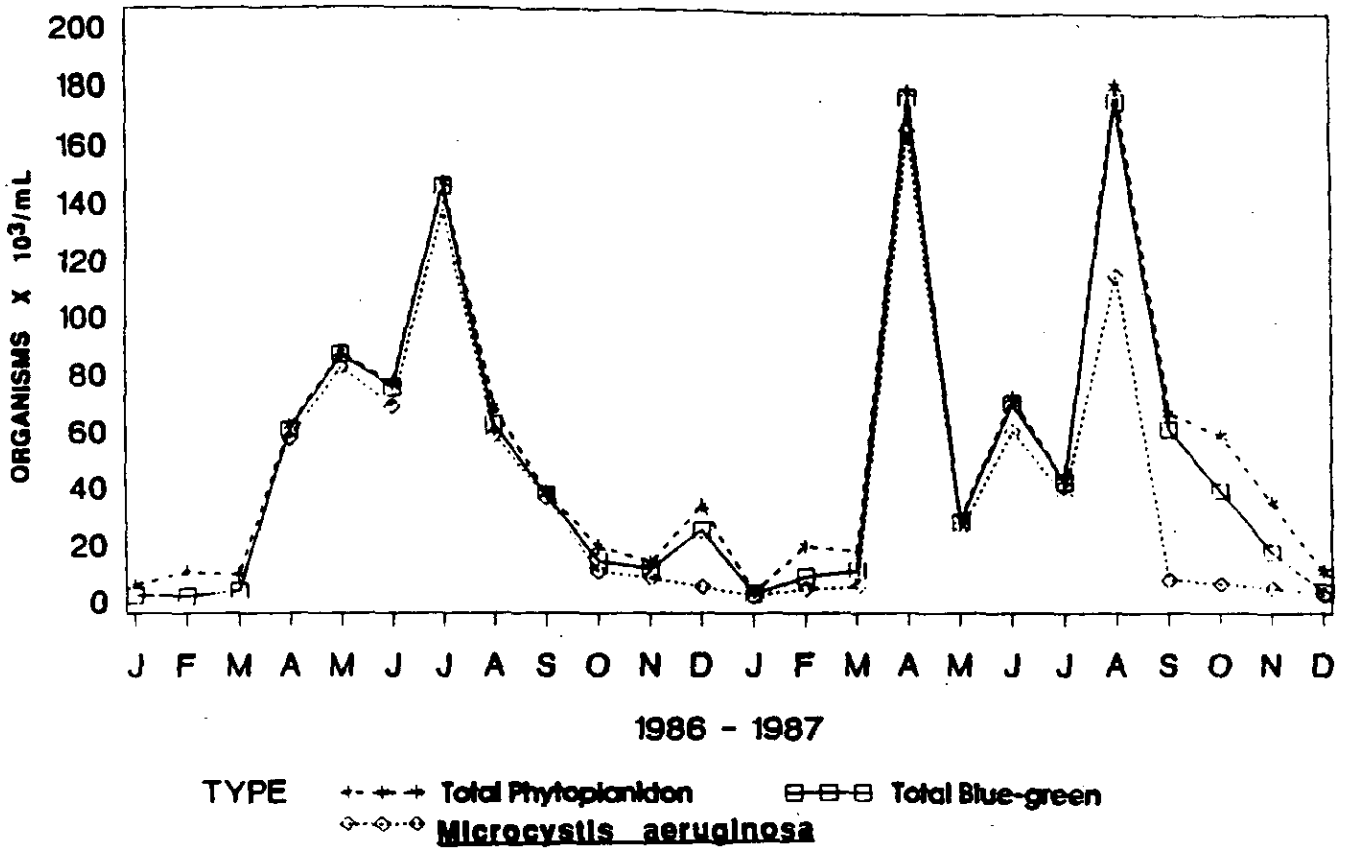

FIGURE 4-18. Mean Densities of Phytoplankton in the Pelagic Zone of Regions 4-8 in L Lake (January 1986 - December 1987) (source: Gladden et al., 1988)

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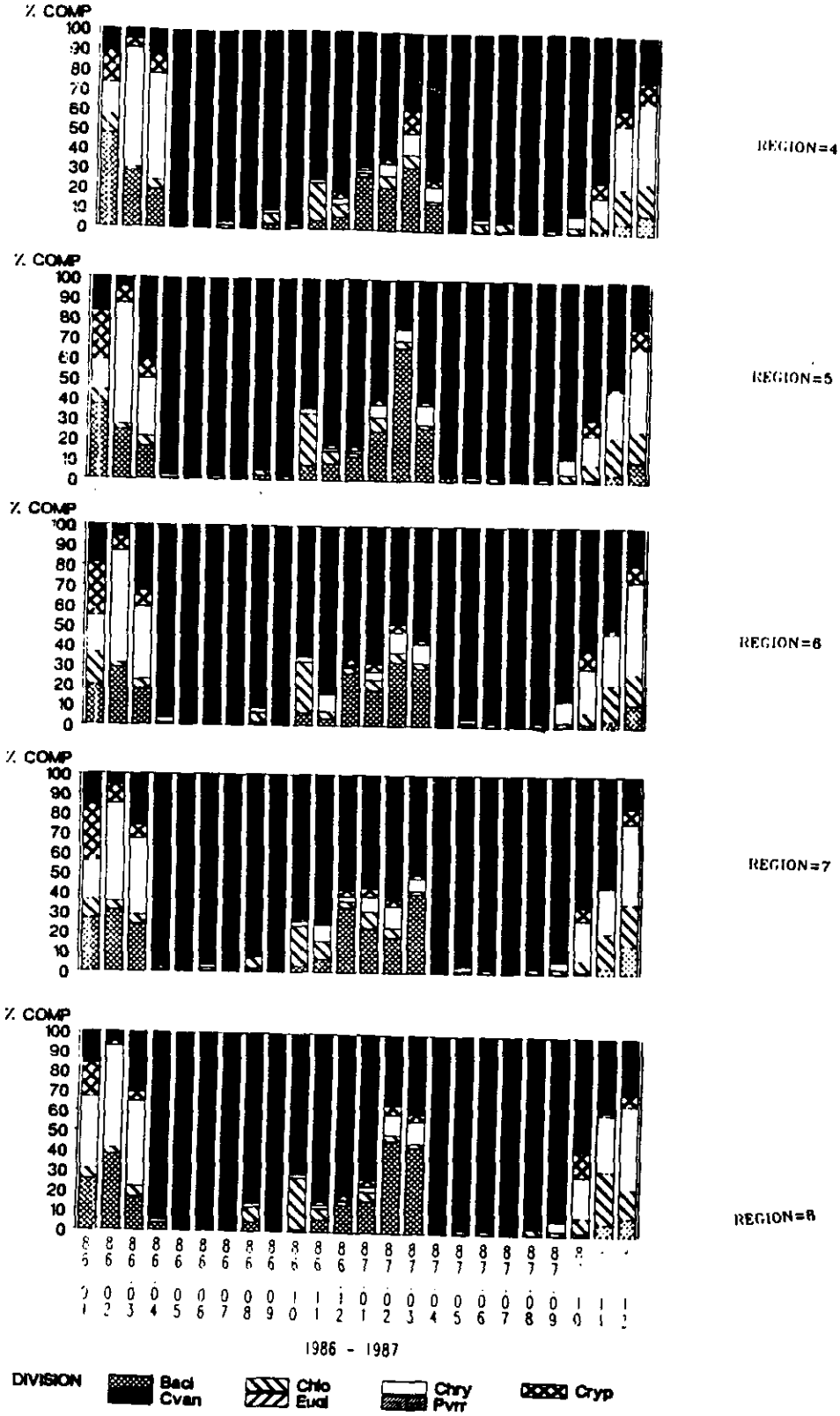

FIGURE 4-19. Relative Abundance (% composition) of Phytoplankton Major Taxonomic Groups in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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TABLE 4-35

Yearly Descriptive Statistics for Total Phytoplankton (TP) and Blue-Green Algae (BG) Densities (organisms/mL) from the Mixed Zone of L-Lake Pelagic Sampling Stations (January 1986 - December 1987)

Region	Mean	Median	N	Percentage Comp.	Std	CV	Minimum	Maximum
				1986				
4	TP 56,128	32,693	24	-	69,081	123.1	2,553	255,704
	BG 52,151	27,805	24	92.9	70,551	135.3	194	255,116
5	TP 48,865	31,393	24	-	58,872	120.5	2,807	256,541
	BG 45,753	30,662	24	93.6	59,789	130.7	386	255,271
6	TP 38,399	30,771	24	-	35,178	91.6	4,022	126,086
	BG 34,656	28,209	24	90.3	36,007	103.9	334	125,382
7	TP 37,666	24,758	24	-	37,305	99.0	4,253	140,202
	BG 33,872	20,748	24	89.9	38,822	114.6	374	139,103
8	TP 50,158	26,238	24	-	71,608	142.8	4,504	340,655
	BG 46,027	25,156	24	91.8	72,577	157.7	320	339,676
				1987				
4	TP 51,606	26,582	24	-	49,560	96.0	757	171,578
	BG 45,438	22,766	24	88.1	50,335	110.8	310	167,847
5	TP 59,641	40,985	24	-	65,513	109.8	1,403	254,498
	BG 52,606	31,981	24	88.2	66,685	126.8	784	247,271
6	TP 58,986	36,194	24	-	66,479	112.7	1,694	236,807
	BG 52,789	24,525	24	89.5	67,563	128.0	1,007	232,070
7	TP 59,107	31,746	24	-	65,737	111.2	1,214	211,534
	BG 53,041	22,983	24	89.7	66,351	125.1	715	210,056
8	TP 61,582	40,895	24	-	62,530	101.5	1,782	232,240
	BG 53,983	28,665	24	87.7	64,249	119.0	1,042	230,926

Source: Gladden et al. (1988)

Temporal variations in phytoplankton relative abundance were similar in the five sampling regions of L Lake, and differences among regions on any given date were regarded as minor. The most noteworthy distinction between years was the reduced relative abundance of blue-green algae in all regions during November and December 1987 compared to the same period in 1986. There was a corresponding increase in the relative abundance of golden-brown algae in November and December 1987 relative to 1986 (Figure 4-19).

The numerically dominant taxon most frequently encountered was the blue-green alga Microcystis aeruginosa. This taxon constituted >5% of the total phytoplankton in 45 of 60 samples in 1986 and 56 of 60 samples in 1987 (Table 4-36). The list of numerically dominant taxa contained more taxa of blue-green algae than taxa from any other major taxonomic group (5 taxa in 1986 and 4 taxa in 1987). The list of numerically dominant taxa was somewhat longer and more diverse in 1986 (11 taxa; 6 major taxonomic groups) than in 1987 (8 taxa; 3 major groups). There were no substantial differences in the phytoplankton community structure in the various regions of L Lake, with respect to numerically dominant taxa, in either year.

Phytoplankton biovolume estimates provided additional information on the absolute and relative abundance of phytoplankton that complemented the phytoplankton density data. Temporal and spatial variation in total phytoplankton biovolumes from the mixed zone are presented in Figure 4-20. Yearly descriptive statistics for total phytoplankton and blue-green algae mixed-zone biovolumes are given in Table 4-37. The dominance by blue-green algae in general, and M. aeruginosa in particular, was much less pronounced in terms of biovolume than in terms of density (Figure 4-21); however, the dominance was still substantial in spring, summer, and fall.

The relative abundance of phytoplankton by biovolume in Regions 4-8 is shown for the major taxonomic groups in Figure 4-22. The most striking contrast between the relative abundance data for density (Figure 4-19) and the relative abundance data for biovolume (Figure 4-22) was the increased importance of diatoms when measured by biovolume. Diatoms accounted for 45% or more of the phytoplankton biovolume in all regions in January and February 1986 and from December 1986 through March 1987. Correspondingly, the importance of blue-green algal biovolume was diminished during these periods in comparison to the relative abundance in terms of the density. Another important difference was the increased importance of cryptomonads from September through December 1987, when their relative biovolume ranged from 5% to 55%. The volumetric importance of both blue-green and golden-brown algae declined relative to their numerical abundances during this interval. However, the relative biovolume of blue-green algae was very high (50-100%) from April through August of both years.

Differences in relative biovolume were noted between years (Figure 4-22). For example, diatoms (Bacillariophyta) had much higher relative biovolumes in March 1987 (75-85%) than in March 1986 (5-10%). Blue-green algae had lower relative biovolumes from September through November 1987 (5-55%)

TABLE 4-36

Numerically Dominant Phytoplankton Taxa (constituting >5% of the total density) from the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Year	Division	Taxon	No. Samples as a Dominant
1986	Cyan	*Microcystis aeruginosa*	45
	Baci	*Melosira granulata*	19
	Cyan	*Anabaena Spiroides*	12
	Chry	Chrysoflagellate spp. (<5 µm)	10
	Cyan	Coccoid Cyanophyta spp. (<5 µm)	9
	Cyan	*Anabaena planctonica*	6
	Baci	*Skeletonema potamos*	6
	Chry	Chrysophyte sp. 2	5
	Chlo	*Gloeocystis planctonica*	5
	Cyan	*Microcystis incerta*	5
	Cryp	*Rhodomonas minuta* var. *nannoplanktonica*	5
1987	Cyan	*Microcystis aeruginosa*	56
	Cyan	*Microcystis incerta*	41
	Cyan	Coccoid Cyanophyta spp. (<5 µm)	20
	Chry	Coccoid Chrysophyta spp. (<5 µm)	19
	Baci	*Melosira granulata*	15
	Cyan	*Oscillatoria angustissima*	15
	Chry	Chrysoflagellate spp. (<5 µm)	13
	Chry	Coccoid Chrysophyta spp. (5-9.9 µm)	11

Note: Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophyta; Chry = Chrysophyta; Cryp = Cryptophyta.

Source: Gladden et al. (1988)

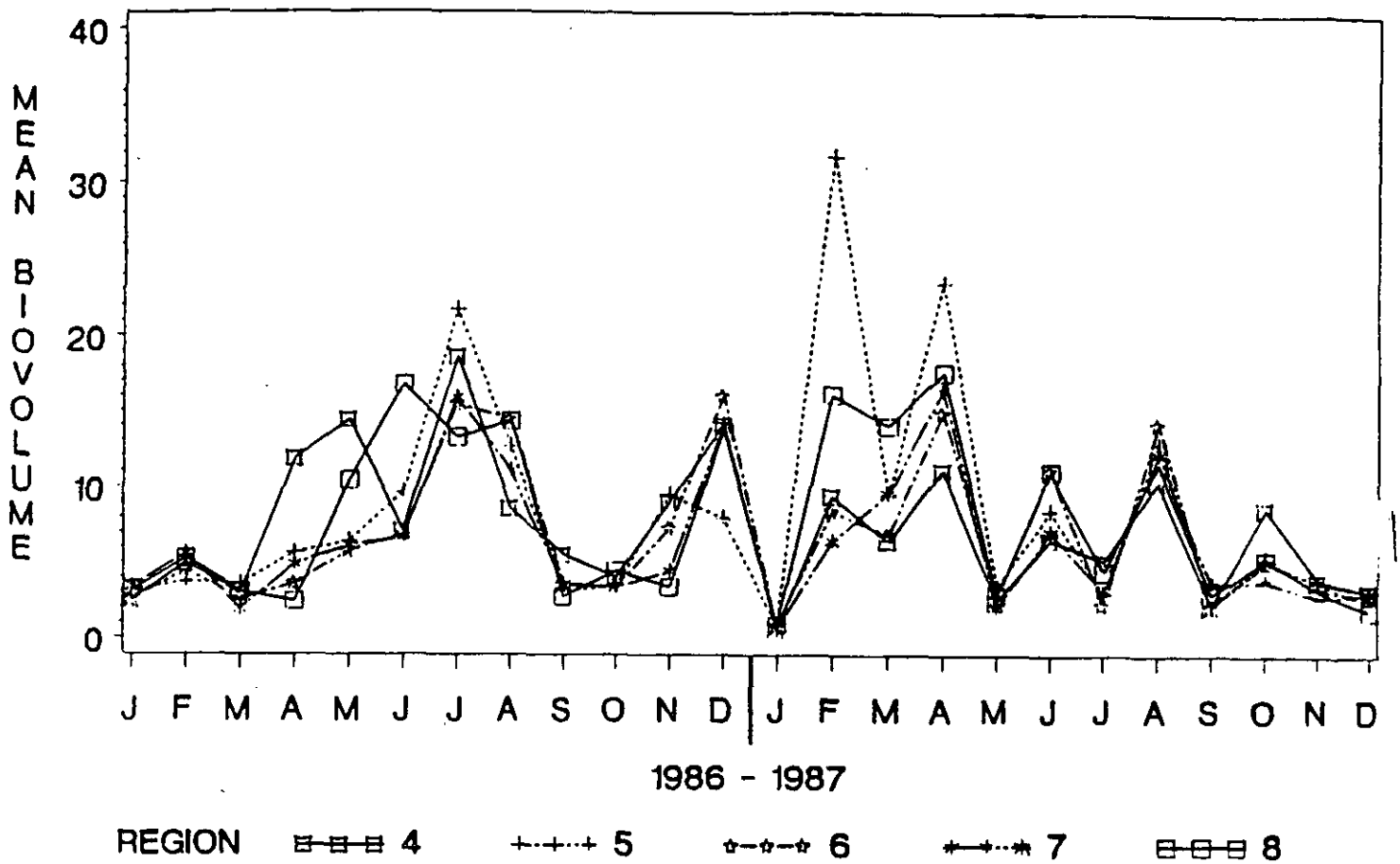

FIGURE 4-20. Mean Total Phytoplankton Biovolume in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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TABLE 4-37

Yearly Descriptive Statistics for Total Phytoplankton (TP) and Blue-Green Algae (BG) Biovolume ($\mu m^3/mL$) from the Mixed Zone of L-Lake Pelagic Sampling Stations (January 1986 - December 1987)

Region	Mean	Median	N	Percentage Comp.	STD	CV	Minimum	Maximum
				1986				
4	TP 8,630,728	7,268,787	24	-	6,382,030	73.9	2,204,721	29,160,455
	BG 5,587,039	4,122,945	24	64.7	6,980,173	124.9	32,068	28,753,382
5	TP 7,530,953	4,736,475	24	-	5,862,372	77.8	2,249,406	26,272,943
	BG 5,142,515	3,177,100	24	68.3	6,080,158	118.2	38,492	26,196,183
6	TP 7,143,412	5,362,548	24	-	5,188,373	72.6	1,666,692	19,157,833
	BG 4,305,687	3,044,312	24	60.3	4,394,346	02.1	91,176	15,222,578
7	TP 6,719,063	5,280,455	24	-	4,929,843	73.4	1,895,534	17,852,741
	BG 3,876,779	2,543,250	24	57.7	4,320,265	111.4	164,587	15,658,011
8	TP 7,480,928	5,263,535	24	-	6,189,366	82.7	912,710	28,029,697
	BG 4,548,775	2,257,573	24	60.8	6,421,083	141.2	126,006	27,912,358
				1987				
4	TP 5,828,151	6,094,152	24	-	3,659,391	62.8	572,250	12,026141
	BG 3,026,242	1,048,548	24	51.9	3,798,301	125.5	23,688	11,112981
5	TP 8,918,442	4,621,826	24	-	9,798,969	109.9	783,894	35,740,945
	BG 3,770,361	822,267	24	42.3	5,361,166	142.2	31,718	20,017,048
6	TP 6,218,883	3,950,773	24	-	4,863,448	78.2	665,043	15,877,233
	BG 3,802,301	652,281	24	61.1	5,501,263	144.7	31,304	15,240,284
7	TP 5,883,533	3,485,510	24	-	5,023,817	85.4	488,870	17,302,289
	BG 3,519,212	955,144	24	59.8	5,192,278	147.5	30,010	16,849,338
8	TP 7,639,798	4,627,111	24	-	6,150,220	80.5	688,046	20,535,153
	BG 3,955,807	8,757,761	24	51.8	5,456,630	137.9	4,020	19,186,998

Source: Gladden et al. (1988)

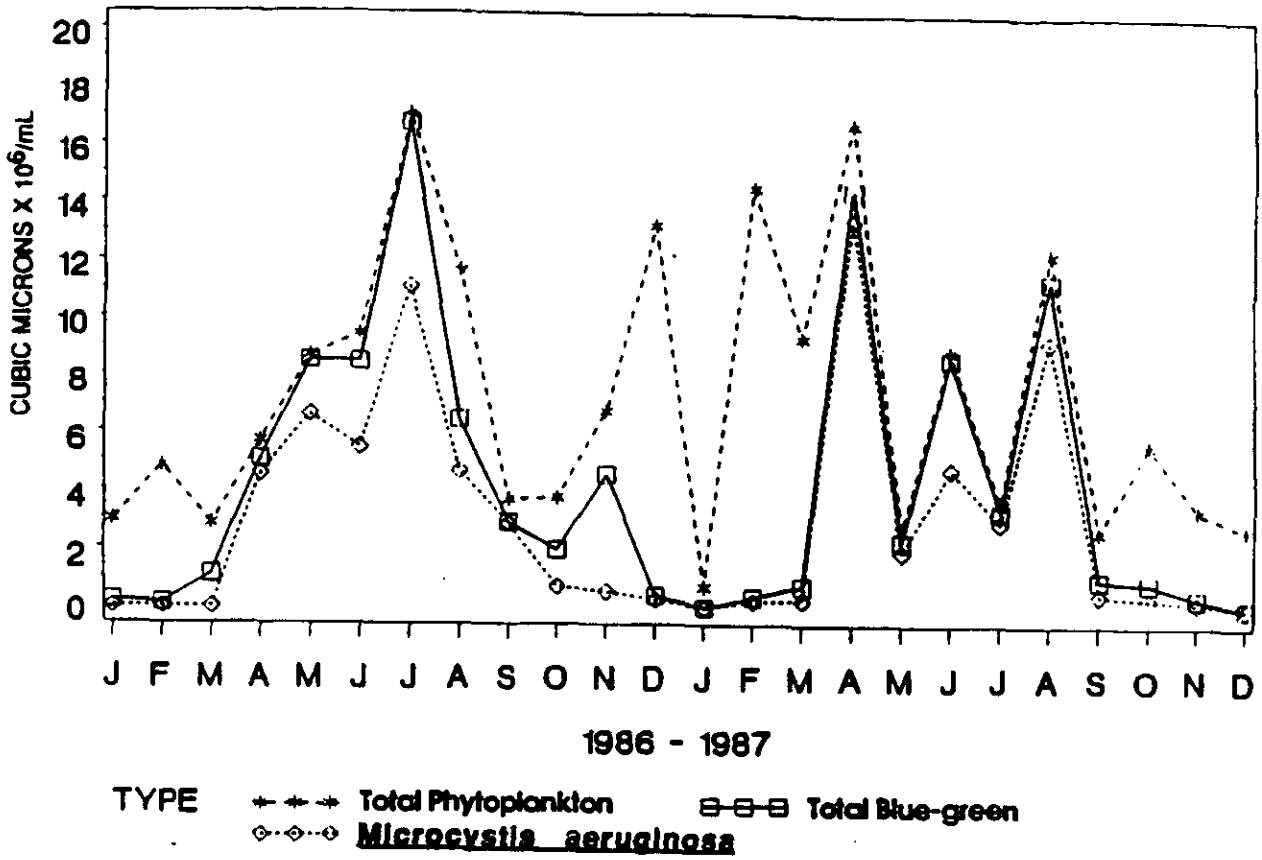

FIGURE 4-21. Mean Phytoplankton Biovolume in the Pelagic Zone of Regions 4-8 in L Lake (January 1986 - December 1987) (source: Gladden et al., 1988)

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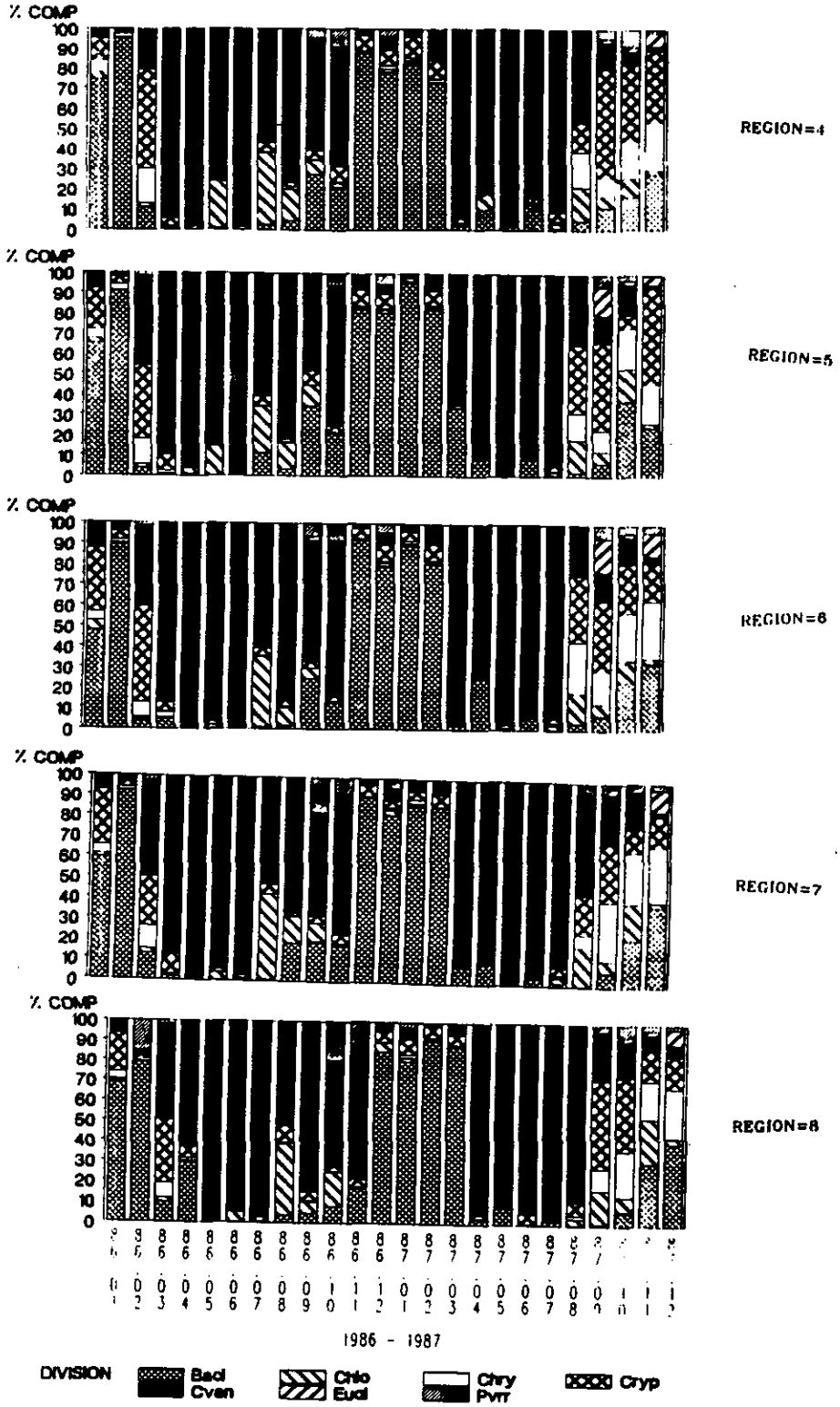

FIGURE 4-22. Relative Biovolume (% composition) of Phytoplankton Major Taxonomic Groups in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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than during the same period in 1986 (45-85%). Although there were some regional differences in total phytoplankton biovolumes (Figure 4-20) and the relative biovolumes of major groups (Figure 4-22), no discrete spatial pattern was observed. Annual precentages of blue-green algal biovolume tended to be lower in 1987 than 1986 (Table 4-37).

The L-Lake taxon that was volumetrically dominant most often was Microcystis aeruginosa (41 of 60 samples in 1986 and 40 of 60 samples in 1987). Also, more blue-green taxa were volumetrically dominant than any other major taxonomic group (Table 4-38). The list of biovolume dominants in 1987 had one more taxon and one more major taxonomic group represented than in 1986. As noted previously for phytoplankton density, there were no substantial differences between the phytoplankton community structure in the various regions of L Lake with respect to biovolume in either year.

The phytoplankton community of L Lake, dominated by the blue-green taxa Microcystis and Anabaena and the diatom Melosira granulata, represents a eutrophic association according to criteria described by Wetzel (1983). Nine of the 17 phytoplankton taxa identified to species that were numerically or volumetrically dominant in L Lake (Tables 4-36 and 4-38) are listed as nuisance algae by the EPA (Taylor et al., 1980). If taxa listed solely by genus on the EPA list are included, the number of dominant taxa in L Lake that are considered nuisance algae increases to 11. L-Lake nuisance species and their associated problem conditions are listed in Table 4-39. Most of the L-Lake nuisance species are associated with eutrophic conditions, but nearly all are associated with other conditions as well. Microcystis aeruginosa, the overall dominant taxon in L Lake, is associated with most of the EPA problem conditions: toxicity, eutrophic condition, pollution tolerance, taste and odor problems, and aesthetic problems. The genus Anabaena is listed as occurring in eutrophic conditions, but the most abundant Anabaena species in L Lake were not specifically listed by Taylor et al. (1980). Microcystis aeruginosa and several species of Anabaena were the principal blue-green taxa in L Lake during midsummer in both years, when blue-green algae accounted for >90% of the relative abundance in all regions (Figures 4-19 and 4-22). Melosira granulata, the second most frequently encountered dominant taxon in L Lake, is associated with organic pollution and eutrophication, as well as filter clogging (Taylor et al., 1980).

Seston

Variation in mean seston dry weight (DW) in L Lake did not follow a discernible seasonal cycle (Figure 4-23). Concentrations in all regions generally ranged between 10 to 20 g/m^2 throughout this study. There were no consistent differences between sampling regions and no apparent relationship to the shutdowns of L Reactor. Yearly mean DW values in each region were similar in 1986 (16.3 to 17.8 g/m^2) and 1987 (15.1 to 17.6 g/m^2). Field observations of variations in the amount of visible suspended materials in L Lake, including algal scums, suggested that the distribution of seston in L Lake was often patchy and highly influenced by changes in wind patterns (Starkel et al., 1988a).

TABLE 4-38

Volumetrically Dominant Phytoplankton Taxa (constituting >5% of the total biovolume) from the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Year	Division	Taxon	No. Samples as a Dominant
1986	Cyan	*Microcystis aeruginosa*	41
	Baci	*Melosira granulata*	30
	Cyan	*Anabaena spiroides*	28
	Cryp	*Cryptomonas erosa*	16
	Cyan	*Anabaena planctonica*	11
	Chlo	*Selenastrum westii*	11
	Pyrr	*Ceratium hirundinella*	10
	Cyan	*Anabaena subcylindrica*	8
1987	Cyan	*Microcystis aeruginosa*	40
	Baci	*Melosira granulata*	35
	Cryp	*Cryptomonas erosa*	30
	Cyan	*Anabaena spiroides*	16
	Chry	Coccoid Chrysophyta spp. (5-9.9 µm)	16
	Cyan	Coccoid Cyanophyta spp. (<5 µm)	11
	Eugl	*Phacus monilatus*	6
	Chlo	*Pandorina morum*	5
	Chry	*Synura uvella*	5

Note: Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophyta; Chry = Chrysophyta; Cryp = Cryptophyta; Eugl = Euglenophyta; Pyrr = Pyrrhophyta.

Source: Gladden et al. (1988)

TABLE 4-39

Nuisance Algae Among Dominant L-Lake Phytoplankton Taxa Identified to Species and Associated with Problem Conditions Listed in Taylor et al. (1980) (January 1986 - December 1987)

Taxon	Eutrophic Conditions	Pollution Tolerant	Taste/Odor Problems	Filter Clogging	Toxic to Animals	Aesthetically Displeasing
Bacillariophyta						
Melosira granulata	X	X	-	X	-	-
Skeletonema potamos	X	-	-	-	-	-
Chrysophyta						
Synura uvella	-	-	X	-	-	-
Cyanophyta						
Microcystis aeruginosa	X	X	X	-	X	X
Anabaena planctonica	X[a]	-	X	-	-	-
Chlorophyta						
Gleocystis planctonica	-	-	X	-	-	-
Pandorina morum	X	X	X	-	-	-
Pyrrhophyta						
Ceratium hirundinella	X	-	X	X	-	-
Cryptophyta						
Cryptomonas erosa	-	-	X	-	-	-

[a] The genus Anabaena is listed by Taylor et al. (1980) as occurring in eutrophic conditions.

Source: Gladden et al. (1988)

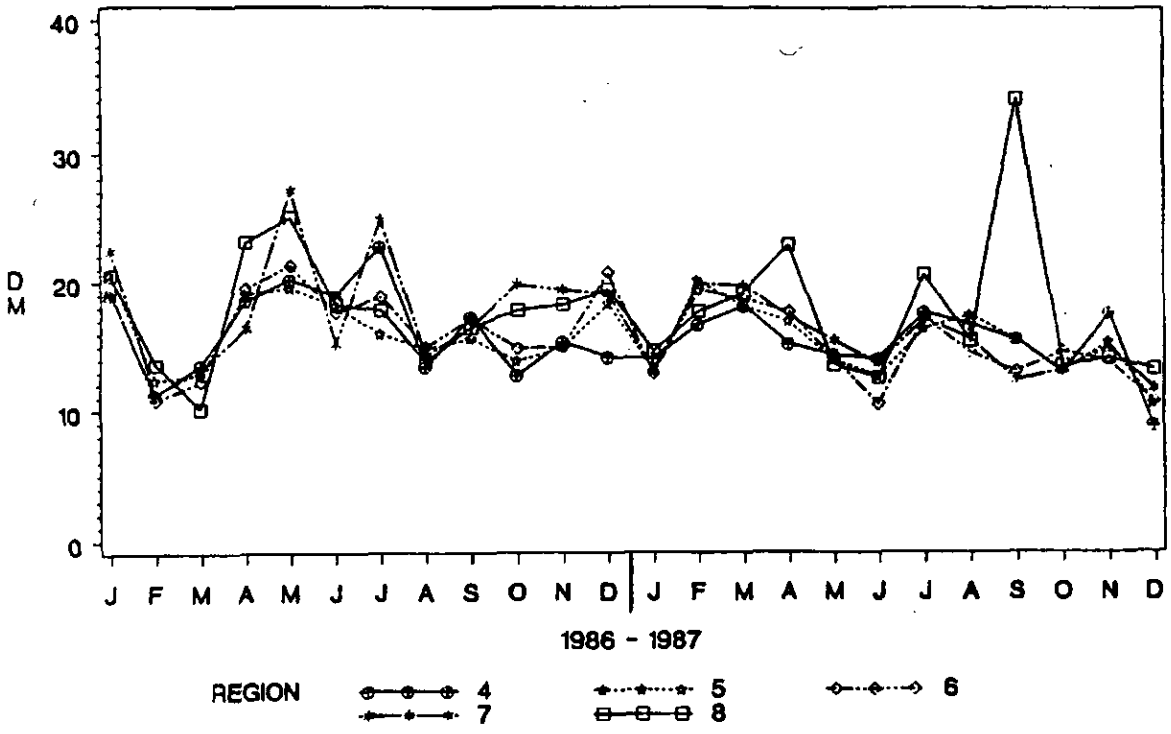

FIGURE 4-23. Dry Weight and Ash-Free Dry Weight of Seston from L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986-December 1987) (source: Gladden et al., 1988)

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Mean ash-free dry weight (AFDW) of seston exhibited pronounced seasonal cycling. Concentrations ranged from approximately 4.5 g/m^2 to 23 g/m^2 (Figure 4-23). The lowest AFDW levels occurred from December to February in both years; AFDW increased markedly in spring and summer and was highest from May to July 1986 and from July to September 1987. There were no consistent regional differences detected and no obvious impacts of the L-Reactor summer shutdowns. Yearly mean AFDW in each region was higher in 1986 (11.8 to 13.1 g/m^2) than in 1987 (9.5 to 10.8 g/m^2).

Chlorophyll a

Mean chlorophyll a concentrations fluctuated markedly during this study, and there were no discernible seasonal patterns (Figure 4-24). The highest values occurred in January and March 1986 (approximately 143 to 195 mg/m^2), and smaller pulses were observed in June-July 1986, November 1986, February-March 1987, May-June 1987, and October-November 1987.

A decline in chlorophyll a concentrations in August of both years followed the summer shutdown of L Reactor. There were no consistent differences between sampling regions. Yearly mean chlorophyll a in each region was higher in 1986 (70.5 to 73.3 mg/m^2) than in 1987 (47.1 to 54.4 mg/m^2) and corresponded with lower AFDW concentrations in 1987.

Primary Productivity

Mean phytoplankton productivity varied considerably during the study (Figure 4-25). Values were extremely high from January to March 1986 (approximately 300 to 1,050 mg $C/m^2/hr$). Two smaller peaks occurred in spring and summer 1987 and were probably more indicative of a normal seasonal cycle. Yearly means in all regions were markedly higher in 1986 (294.6 to 368.7 mg $C/m^2/hr$) than in 1987 (168.1 to 192.7 mg $C/m^2/hr$), due in large measure to the high productivities observed in early 1986. There were no consistent differences detected among regions and no obvious relationship between phytoplankton productivity and the summer shutdown of the reactor.

The extremely high productivity in L Lake from January to March 1986 may be attributed to the initial effects of inundation of the L-Lake basin. An initial burst of productivity is a well-recognized characteristic of new reservoirs (Neel, 1963; Baxter, 1985).

Phytoplankton productivity (Figure 4-25), seston chlorophyll a (Figure 4-24), and seston AFDW (Figure 4-23) did not appear to be closely related. Relatively high values for each of these measures coincided only in July 1986 and in May and June 1987. Relatively low values coincided only in January and December 1987.

Primary productivity in L Lake did not appear to respond directly to the reactor operating cycle, but the input of nutrients to the system from the reactor discharge undoubtedly influenced both productivity and phytoplankton biomass. The rate at which phosphorus enters a lake affects

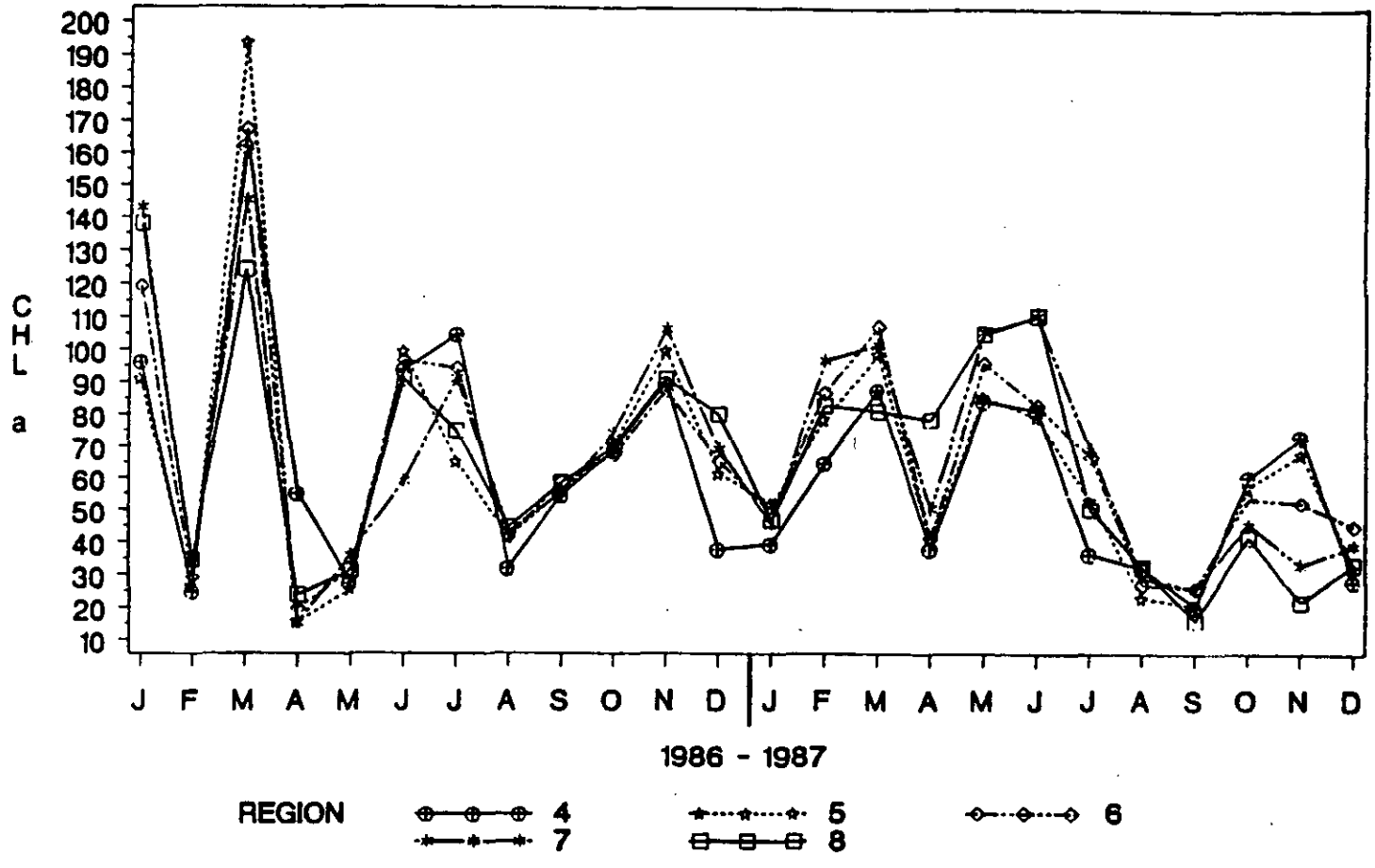

FIGURE 4-24. Mean Chlorophyll a Concentrations from L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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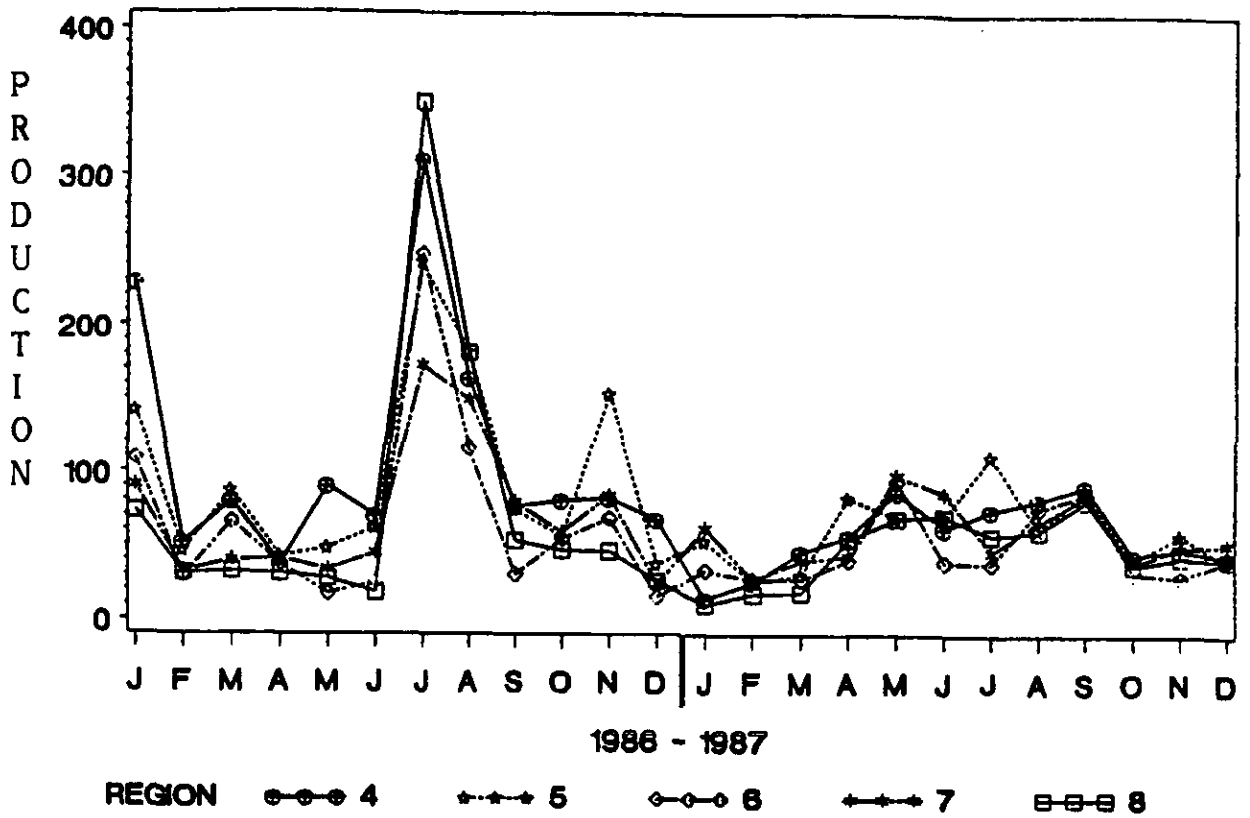

FIGURE 4-25. Mean Phytoplankton Primary Productivity at L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

phytoplankton productivity because phosphorus is generally the major limiting nutrient (Wetzel, 1983). Rough calculations of phosphorus loading through the L-Reactor discharge were made by multiplying measured concentrations times flow. The mean total phosphorus concentrations in the reactor effluent were 130 ±29 and 121 ±41 mg/m^3 for 1986 and 1987, respectively (Starkel et al., 1988b), so 125 mg/m^3 was considered a reasonable approximation for the two years. The average L-Reactor discharge, from the restart in 1985 through December 1987, was 7.34 m^3/s (Gladden et al., 1988). Multiplying concentrations times flow, yields a loading rate of 2.9×10^7 g phosphorus/yr to L Lake. Considering the nominal area of L Lake to be 1,000 acres and converting the phosphorus input to an areal basis (4047 m^2/acre), the estimated annual loading rate was 7.15 $g/m^2/yr$. For a lake with the characteristics of L Lake (mean depth 8 m), the "dangerous" loading level for eutrophication is 0.20 g phosphorus/m^2/yr (Wetzel, 1983). Thus, loading rates of total phosphorus to L Lake were over 35 times higher than the "dangerous" level.

4.3.2.2 Comparison to Regional Reservoirs

General characteristics of the L-Lake phytoplankton community are compared to values reported for other southeastern reservoirs in Table 4-40. These comparisons must be made cautiously because there is often considerable variability in methodology and data presentation among studies.

Phytoplankton appear to be substantially more abundant in L Lake than in the other reservoirs of the region in terms of phytoplankton density and chlorophyll a values. The rate of primary production by the phytoplankton in L Lake is also well above the values typically reported for other reservoirs of the region.

Although domination of the phytoplankton by blue-green algae in late summer and early fall is a common phenomenon in regional lakes and reservoirs including Par Pond and Pond B at the SRS (Wetzel, 1983; Wilde, 1983), the dominance of blue-green algae in L Lake, particularly by *Microcystis aeruginosa*, was much more pronounced than has been reported for other southeastern reservoirs.

4.3.2.3 Status of L-Lake Phytoplankton Community

The phytoplankton community of L Lake was characterized by unusually high productivity and domination by nuisance species. The five sampling regions were generally similar to one another in terms of the structural and functional characteristics. Comparisons of phytoplankton data from 1986 with data from 1987 revealed some possible trends that may represent improving biological balance in L Lake. Phytoplankton taxa richness was higher in 1987, while seston ash-free dry weight, phytoplankton chlorophyll a, and productivity were lower. However, it was beyond the scope of the study to separate and identify the extent to which natural variability, reservoir aging, reduced reactor power levels in 1987 compared to 1986, and other factors contributed to these apparent

TABLE 4-40

Comparison of Phytoplankton Data from L Lake with Literature Values from Other Southeastern Lakes and Reservoirs

Reservoir/Lake	Mean Total Density (no./mL)	Maximum Total Density (no./mL)	Mean Species Richness (Taxa)	Total Number Taxa	Mean Chl. a (µg/L)	Maximum Chl. a (µg/L)	Mean Primary Prod. (mg C/m^2/day)	Maximum Primary Prod. (mg C/m^2/day)
L Lake[a]	52,214	340,655	34	220	25.2	87.3	2,253	10,021
Par Pond, SC[b]	4,488	32,968	72	337	5.1	25.0	444	1,579
Pond B, SC[b]	3,058	11,815	58	203	2.9	8.2	186	627
Southeastern Lakes/Reservoirs								
Clarks Hill, SC[c]	3,674	11,369	-	206	5.2	12.7	-	-
Clarks Hill, SC[d]	-	-	-	-	6.3	6.3	239	426
Lake Robinson, SC[d]	4,723	11,305	-	-	-	-	240	342
Lake Robinson, SC[e]	-	-	-	-	11.9	36.0	385	3,111
Clear Pond, SC[d]	-	-	-	-	5.3	6.2	285	651
Big Snooks, SC[d]	-	-	-	-	1.2	1.3	101	255
Lake Hartwell, SC[f]	8,384	35,100	14	194	7.8	24.9	-	-
Parr Reservoir, SC[g]	7,274	115,481	15	-	-	-	-	-
Monticello Reservoir, SC[g]	11,434	159,833	13	-	-	-	-	
Lake Keowee, SC[h]	978	~1,250	-	-	2.71	-	-	-
13 SC lakes[i,j]	4,305	-	35	-	7.2	21.4	-	-
15 NC lakes[j,k]	3,804	-	30	-	6.0	23.4	-	-
14 GA lakes[j,l]	6,220	-	31	-	6.3	21.2	-	-
Lake Norman, NC[m]	1,550	8,367	34	200	-	-	792	1,176

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TABLE 4-40, Contd

Reservoir/Lake	Mean Total Density (no./mL)	Maximum Total Density (no./mL)	Mean Species Richness (Taxa)	Total Number Taxa	Mean Chl. a (µg/L)	Maximum Chl. a (µg/L)	Mean Primary Prod. (mg C/m^2/day)	Maximum Primary Prod. (mg C/m^2/day)
Mt. Island, NC[m]	1,137	4,263	32	236	-	-	828	1,752
Lake Wylie, SC[m]	1,590	17,782	43	319	-	-	962	1,727
Fishing Creek, SC[m]	1,679	5,087	47	171	-	-	-	-
Lake Wateree, SC[m]	6,900	26,664	48	216	-	-	2,578	5,291

Sources: [a] Starkel et al. (1988a); [b] Chimney et al. (1985); [c] Applied Biology (1982); [d] Mallin (1984); [e] Carolina Power and Light (1976); [f] Carr (1982); [g] Dames and Moore (1985); [h] Duke Power Co. (1977); [i] Hern et al. (1977); [j] Taylor et al. (1978); [k] Morris et al. (1978a); [l] Morris et al. (1978b); and [m] Weiss et al. (1975).

Taken from Gladden et al. (1988)

trends. Although temporal improvement of the L Lake algal communities is possible, substantial amelioration of the eutrophic conditions appears unlikely unless the nutrient loading is abated.

Primarily because of the dominance of blue-green algae in general, and *Microcystis aeruginosa* in particular, the phytoplankton community of L Lake was dominated by pollution-tolerant species in 1986 and 1987. Phytoplankton diversity in L Lake was low and productivity was high relative to other southeastern reservoirs.

4.3.2.4 Expected Impacts from Restarting L Reactor

Restarting L Reactor is expected to result in a phytoplankton community in L Lake that is similar to or more ecologically desirable than the community characterized by the 1986/1987 studies conducted when the reactor was previously operating.

4.3.3 Periphyton

The periphyton community in L Lake was sampled in the littoral zones of Regions 4-8 using natural substrates (sediment cores) and artificial substrates (glass slides) (Starkel et al., 1988a). The parameters measured included species composition, density, biovolume, dry weight (DW), ash-free dry weight (AFDW), chlorophyll a, and primary productivity (sediment core samples only).

4.3.3.1 Species Composition and Abundance

A total of 323 periphyton taxa were identified from the L-Lake periphyton samples (Table 4-41). Most of these taxa were diatoms, green algae, or blue-green algae, although euglenoids, golden-brown algae, dinoflagellates, and cryptomonads were reported.

L-Lake sediment core taxa richness generally fluctuated between 30 and 50 taxa with no distinctive seasonal pattern (Figure 4-26). Taxa richness ranged from 22 taxa at Region 8 in April 1986 to 63 taxa in January 1986 at Region 6. During the first four months of the study (January through April 1986), Region 8 consistently had the lowest taxa richness and Region 6 had the highest. Otherwise, there were no discernible regional differences in taxa richness. There were no meaningful differences in taxa richness in 1986 compared to 1987.

Taxa richness on periphytometer slides in L Lake generally varied between approximately 20 and 40 taxa; richness values tended to be high in the winter and late summer of both years (Figure 4-26). There were no consistent regional differences in numbers of taxa. Fluctuations in periphytometer taxa richness did not seem to be correlated with the summer shutdowns of L Reactor, and there were no meaningful differences in taxa richness between 1986 and 1987.

TABLE 4-41

Periphyton Taxa Collected in Sediment Cores and on Periphytometer Slides from L-Lake Littoral Zone Sampling Stations (January 1986 - December 1987)

Taxon	Cores	Slides
Bacillariophyta		
Achnanthes exigua	XBD[a]	XBD
Achnanthes hungarica	-	X
Achnanthes lanceolata	XBD	XD
Achnanthes lanceolata var. apiculata	XBD	XB
Achnanthes linearis	-	X
Achnanthes minutissima	XD	XBD
Amphora ovalis	X	X
Amphora perpusilla	X	-
Amphora spp.	-	X
Amphora veneta	X	X
Caloneis bacillum	X	X
Caloneis ventricosa	X	-
Caloneis ventricosa var. minula	X	X
Capartogramma crucicula	XB	X
Cocconeis placentula	X	X
Cyclotella atomus	-	X
Cyclotella meneghiniana	X	X
Cyclotella pseudostelligera	X	X
Cyclotella sp.	X	-
Cyclotella stelligera	X	X
Cymbella affinis	-	X
Cymbella minuta	XD	XD
Cymbella minuta var. silesiaca	X	-
Cymbella tumida	XB	XBD
Diploneis subovalis	X	-
Epithemia adnata	XB	XB
Eunotia incisa	X	-
Eunotia pectinalis	X	-
Eunotia sp.	X	-
Fragilaria capucina	X	-
Fragilaria construens	XBD	X
Fragilaria crotonensis	XBD	X
Fragilaria spp.	X	X
Fragilaria vaucheriae	X	X
Frustulia vulgaris	X	X
Gomphonema augur	X	-
Gomphonema clevei	X	XB
Gomphonema gracile	X	XBD
Gomphonema olivaceum	X	-
Gomphonema parvulum	XBD	XBD
Gomphonema rhombicum	X	XBD

TABLE 4-41, Contd

Taxon	Cores	Slides
Bacillariophyta, Contd		
Gomphonema spp.	X	-
Gomphonema subclavatum	X	XBD
Gomphonema truncatum	X	XB
Gomphonema turris	-	XB
Gyrosigma scalproides	X	-
Gyrosigma spencerii	XB	-
Melosira ambigua	X	X
Melosira distans	X	-
Melosira granulata	XBD	XB
Melosira granulata var. angustissima	X	-
Melosira sp. 1	XB	-
Melosira varians	XBD	XBD
Melosira viridulall	X	-
Meridion circulare	-	X
Navicula agnita	X	-
Navicula aikenensis	X	X
Navicula arvensis	X	X
Navicula atomus	X	X
Navicula biconica	X	X
Navicula capitata	XBD	X
Navicula confervacea	XBD	XB
Navicula cryptocephala	XBD	XBD
Navicula cryptocephala var. veneta	XD	X
Navicula cuspidata	X	-
Navicula decussis	XBD	XBD
Navicula elginensis var. neglecta	XBD	X
Navicula gastrum	X	X
Navicula gibbosa	XD	X
Navicula gregaria	XD	X
Navicula gysingensis	X	X
Navicula halophiloides	X	X
Navicula hamburgi	X	-
Navicula lateropunctata	XBD	XD
Navicula luzonensis	X	X
Navicula menisculus	X	-
Navicula mensuilus upsaliensis	X	-
Navicula minima	X	XD
Navicula mutica	X	-
Navicula muticopsis	X	-
Navicula paucivisitata	X	X
Navicula pupula	X	X
Navicula radiosa	X	-
Navicula rhynchocephala	X	-
Navicula rhynchocephala germainii	XB	X

TABLE 4-41, Contd

Taxon	Cores	Slides
Bacillariophyta, Contd		
Navicula schroeteri var. escambii	X	XD
Navicula seminulum	X	X
Navicula solinarum var. intermedia	X	-
Navicula spp.	X	X
Navicula symmetrica	X	-
Navicula viridula	XB	X
Neidium affine	X	-
Neidium gracile var. f. aequale	X	-
Neidium spp.	X	-
Nitzschia acicularis	X	X
Nitzschia agnita	X	X
Nitzschia amphibia	XBD	XBD
Nitzschia apiculata	X	-
Nitzschia biacrula	XBD	X
Nitzschia capitellata	X	-
Nitzschia capitellata var. sibirica	X	X
Nitzschia clausii	X	X
Nitzschia dissipata	X	-
Nitzschia filiformis	X	-
Nitzschia fonticola	X	X
Nitzschia frustulum	X	-
Nitzschia gracilis	XBD	XB
Nitzschia ignorata	X	-
Nitzschia intermedia	X	-
Nitzschia linearis	XB	-
Nitzschia lorenziana	X	-
Nitzschia microcephala	-	X
Nitzschia palea	XB	X
Nitzschia paleacea	XBD	XBD
Nitzchia paradoxa	-	X
Nitzschia sigma	X	-
Nitzschia spp.	X	X
Nitzschia tryblionella	X	-
Nitzschia tryblionella var. levidensis	X	-
Nitzschia tryblionella var. victoriae	X	-
Nitzschia vermicularis	X	-
Pinnularia abaujensis	XB	-
Pinnularia acrosphaeria	XB	X
Pinnularia biceps	X	-
Pinnularia borealis	X	-
Pinnularia braunii	X	X
Pinnularia major	XB	-
Pinnularia spp.	X	X

TABLE 4-41, Contd

Taxon	Cores	Slides
Bacillariophyta, Contd		
Pinnularia subcapitata	X	-
Pinnularia viridis	X	-
Skeletonema potamos	X	X
Stephanodiscus sp. 1	-	X
Surirella angusta	X	X
Surirella delicatissima	X	-
Surirella linearis	X	-
Surirella ovata	X	-
Surirella quatimalensis	X	-
Surirella robusta	X	-
Surirella spp.	X	-
Surirella tenera	XB	XB
Synedra delicatissima	X	X
Synedra parasitica	X	X
Synedra pulchella	X	X
Synedra rumpens	XBD	XBD
Synedra tenera	X	XBD
Synedra ulna	XB	XB
Chlorophyta		
Actinastrum hantzschii	X	X
Ankistrodesmus falcatus	X	X
Ankistrodesmus spiralis	XD	XD
Ankistrodesmus spiroides	X	-
Chaetophora elegans	X	XBD
Characium spp.	X	XD
Chlamydomonas spp.	X	X
Chlamydomonas spp. (<5 µm)	-	X
Chlamydomonas spp. (10-15 µm)	X	X
Chlamydomonas spp. (5-9.9 µm)	X	XBD
Chloroflagellate spp. (<5 µm)	-	X
Chloroflagellate spp. (5-9.9 µm)	-	X
Closterium acerosum	X	-
Closterium acutum	-	X
Closterium parvulum	-	X
Closterium venus	X	X
Coccoid chlorophyta spp.	X	XB
Coccoid chlorophyta spp. (<5 µm)	X	XD
Coccoid chlorophyta spp. (>15 µm)	X	-
Coccoid chlorophyta spp. (10-15 µm)	-	XB
Coccoid chlorophyta spp. (5-9.9 µm)	XD	XBD
Coelastrum microporum	X	-
Coelastrum reticulatum	XD	X
Coelastrum spaericum	XD	X

TABLE 4-41, Contd

Taxon	Cores	Slides
Chlorophyta, Contd		
Cosmarium abbreviatum	-	X
Cosmarium angulosum	X	X
Cosmarium botrytis	XB	-
Cosmarium contractum	X	X
Cosmarium depressum	X	-
Cosmarium exiguum	X	X
Cosmarium granatum	XB	X
Cosmarium laeve	-	X
Cosmarium portianum	X	-
Cosmarium regnelli	X	X
Cosmarium reniforme	X	-
Cosmarium spp.	X	X
Cosmarium subcrenatum	-	X
Cosmarium tenue	-	X
Cosmarium undulatum	X	-
Crucigenia crucifera	XD	X
Crucigenia quadrata	-	X
Crucigenia tetrapedia	X	X
Dictyosphaerium pulchellum	X	X
Didymocystis fina	X	X
Elakatothrix gelatinosa	XD	-
Elakatothrix viridis	X	X
Euastrum bidens	X	-
Euastrum binale	X	X
Franceia ovalis	X	-
Gleocystis planctonica	X	X
Gonatozygon aculeatum	X	-
Gonatozygon pilosum	-	X
Kirchneriella lunaris	-	X
Kirchneriella obesa	X	-
Lagerheimia subsalsa	-	X
Leptosira medicinana	-	X
Miractinium pusillum	-	X
Mougeotia spp.	XB	XB
Oedogonium spp. lg	XB	XBD
Oedogonium spp. sm	X	XBD
Oocystis pusilla	-	X
Pandorina morum	X	X
Pediastrum duplex	X	X
Pediastrum tetras	X	X
Penium margaritaceum	X	-
Scenedesmus acuminatus	-	X
Scenedesmus acutus	X	X
Scenedesmus bicaudatus	X	-

TABLE 4-41, Contd

Taxon	Cores	Slides
Chlorophyta, Contd		
Scenedesmus bijuga	-	X
Scenedesmus brasiliensis	X	X
Scenedesmus brevispina	X	X
Scenedesmus denticulatus	XBD	XBD
Scenedesmus dimorphus	XD	XD
Scenedesmus ecornis	X	X
Scenedesmus opoliensis	X	X
Scenedesmus quadricauda	XD	X
Scenedesmus sp.	X	-
Scenedesmus spinosus	X	X
Schroderia setigera	-	X
Selenastrum minutum	X	X
Selenastrum westii	-	X
Sphaerocystis schroeteri	X	X
Spirogyra spp.	-	X
Spirogyra spp. lg	-	XB
Spirogyra spp. sm	-	XB
Staurastrum alternans	-	X
Staurastrum chaetoceros	-	X
Staurastrum cingulum	X	X
Staurastrum excavatum	X	X
Staurastrum gracile	-	X
Staurastrum hexacerum	X	-
Staurastrum margaritaceum	X	-
Staurastrum natator	X	-
Staurastrum polymorphum	-	X
Staurastrum punctulatum	X	X
Staurastrum sp.	X	-
Tetraedron caudatum	-	X
Tetraedron minimum	X	X
Tetraedron regulare	X	-
Tetraedron triangulare	X	-
Tetraedron trigonum	-	X
Tetrastrum staurogeniaeforme	-	X
Treubaria triappendiculata	X	-
Ulothrix aequalis	-	XB
Ulothrix subtilisma	-	X
Ulothrix zonata	-	XB
Chrysophyta		
Chrysoflagellate (<5 µm)	X	XD
Chrysoflagellate (5-9.9 µm)	X	X
Coccoid chrysophyta spp. (<5 µm)	-	X
Coccoid chrysophyta spp. (5-9 µm)	X	X

TABLE 4-41, Contd

Taxon	Cores	Slides
Chrysophyta, Contd		
Microglena cordiformis	X	-
Ophiocytium capitatum	-	X
Cryptophyta		
Cryptomonas erosa	X	X
Rhodomonas minuta	X	X
Cyanophyta		
Anabaena planctonica	X	-
Anabaena sp. 1	X	X
Anabaena spiroides	XB	X
Anabaena spp.	XBD	X
Anabaena subcylindrica	XBD	X
Anabaena subsolitaria	X	-
Aphanocapsa elachista	XD	-
Aphanothece saxicola	-	XD
Calothrix fusca	-	X
Calothrix sp. 1	X	XD
Calothrix spp.	X	X
Chamaesiphon incrustans	-	X
Chamaesiphon minimus	X	XD
Chroococcus dispersus	XD	X
Chroococcus minor	X	-
Chroococcus minutus	X	X
Coccoid cyanophyta spp.	X	XD
Coccoid cyanophyta spp. (<5 μm)	XBD	XBD
Coccoid cyanophyta spp. (5-9.9 μm)	X	XBD
Coccoid cyanophyta (10-15 μm)	X	X
Coelosphaerium naegelianum	XD	XD
Coelosphaerium pallidum	-	X
Lyngbya epiphytica	-	X
Lyngbya limnetica	-	X
Lyngbya sp. 1	XD	X
Lyngbya spp.	X	X
Lyngbya subtilis	XD	XBD
Merismopedia glauca	XD	-
Merismopedia minima	X	-
Merismopedia tenuissima	XD	X
Microcystis aeruginosa	XBD	XD
Microcystis incerta	XD	XD
Oscillatoria acutissima	XBD	XBD
Oscillatoria amphibia	X	-
Oscillatoria anguina	X	-
Oscillatoria chalybea	-	X

TABLE 4-41, Contd

Taxon	Cores	Slides
Cyanophyta, Contd		
Oscillatoria geminata	XD	X
Oscillatoria limosa	X	XB
Oscillatoria nigra	XB	X
Oscillatoria ornata	X	-
Oscillatoria sancta	X	-
Oscillatoria sp. 1	X	-
Oscillatoria spp.	XBD	X
Oscillatoria subtilissima	X	XD
Oscillatoria tenuis	XBD	X
Phormidium molle	-	X
Phormidium retzii	X	X
Phormidium sp. 1	X	XD
Phormidium spp.	X	XD
Phormidium uncinatum	X	-
Rhabdoderma sigmoidea	-	XBD
Rhabdoderma sp. 2	-	XD
Schizothrix calcicola	-	X
Euglenophyta		
Euglena acus	X	-
Euglena minuta	X	-
Euglena spirogyra	X	-
Euglena spp.	X	X
Trachelomonas hispida	X	-
Trachelomonas verrucosa	X	X
Trachelomonas volvocina	X	X
Pyrrhophyta		
Gymnodinium ordinatum	X	-
Peridinium inconspicuum	X	-
Peridinium sp.	X	-

[a] X = Observed
B = Comprising >5% of the total periphyton biovolume in at least one sample set.
D = Comprising >5% of the total periphyton density in at least one sample set.

Source: Gladden et al. (1988)

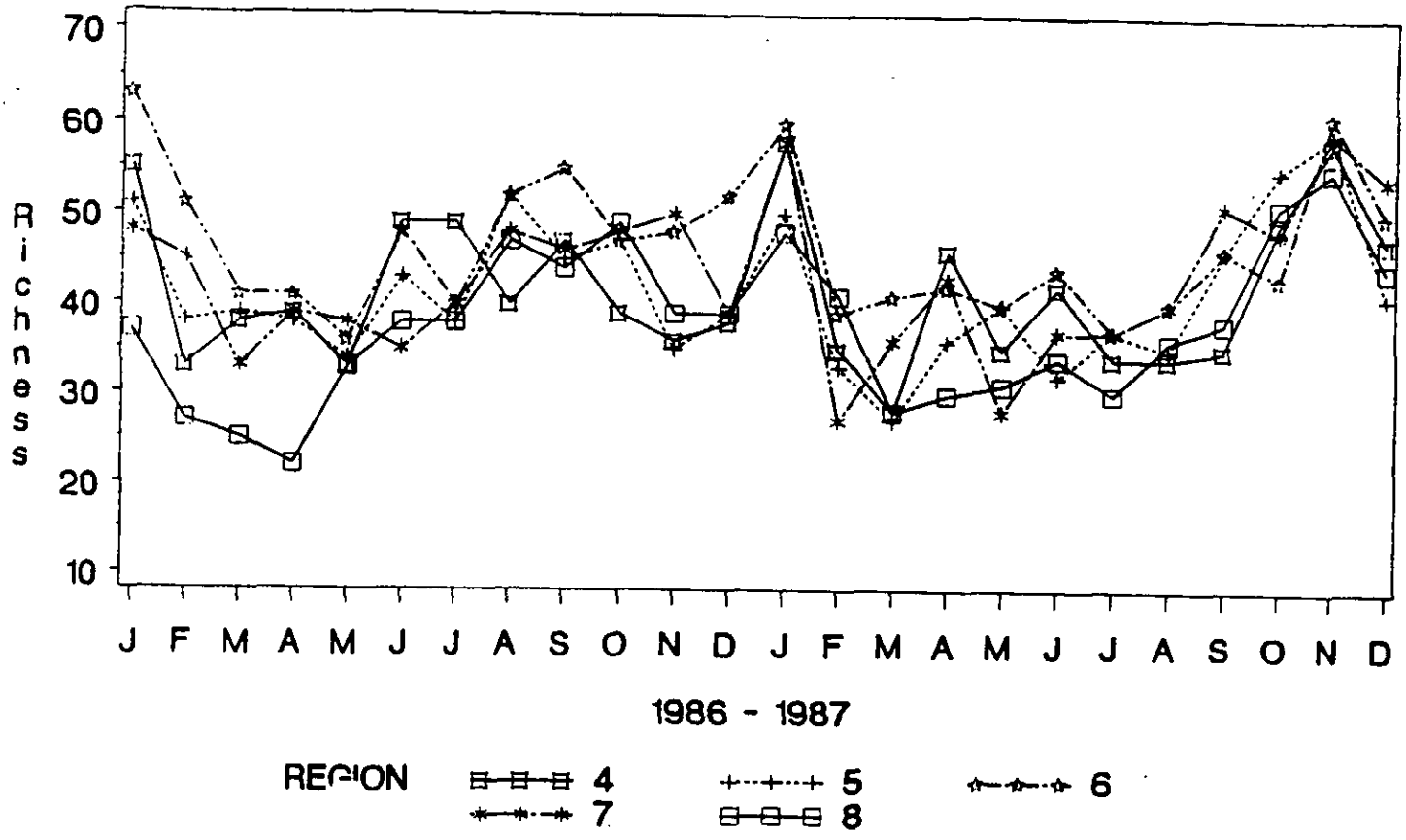

FIGURE 4-26. Periphyton Taxa Richness in Sediment Cores and on Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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Sediment core periphyton samples were analyzed microscopically to determine relative abundances of taxa. Diatoms, green algae, and blue-green algae each constituted an important fraction. The periphyton community in all regions was dominated by diatoms (≥50% relative abundance) during the winter of both years and the fall of 1986 (Figure 4-27). Blue-green algae were the most dominant group during some spring and summer months of both years. Green algae were dominant in May 1986 in Regions 4 and 5 and in the fall of 1987 in Regions 6-8. No other regional differences in community composition were observed. Numerically dominant taxa in sediment cores included several diatoms, the planktonic blue-green alga Microcystis aeruginosa, and a few species of green algae (Table 4-42).

Most total periphyton densities on slides ranged between approximately 5,000 and 15,000 organisms/mm^2 in all regions during this study (Figure 4-28). Major peaks in abundance (approximately 25,000 to about 35,000 organisms/mm^2) occurred in February 1986 and January 1987. Lesser peaks (approximately 20,000 organisms/mm^2) occurred in October of both years. There was no indication of consistent differences in total densities between sampling regions or between 1986 and 1987.

Diatoms, green algae, and blue-green algae were the numerically dominant groups on the periphytometer slides. Diatoms were overall the most abundant group (approximately 1,000 to 22,000 organisms/mm^2) and exhibited peak densities (>10,000 organisms/mm^2) in the winter and fall of both years. Most densities of green algae ranged between approximately 500 and 3,000 organisms/mm^2; however, population peaks (approximately 8,000 to 12,000 organisms/mm^2) occurred in the winter of both years. Annual mean densities of green algae were higher in 1987 than in 1986 in all regions, but no meaningful differences between annual densities in the other groups were apparent. Blue-green algae reached peak densities (approximately 9,000 to 11,000 organisms/mm^2) that were comparable to those of green algae. Maximum blue-green algal abundances occurred in May and June of both years and in January 1987. There were no consistent regional differences in densities of any major taxonomic group and no obvious relationship between variations in density and the summer shutdowns of the reactor.

Diatoms generally dominated the periphyton on slides (relative abundance >50%) in the winter of 1986 and in the fall of both years (Figure 4-29). Blue-green algae were most abundant in the spring and summer months. The abundance of green algae did not display a clear temporal pattern. However, the relative abundance of green algae was substantially greater during the winter of 1987 compared to the winter of 1986; the relative abundance of blue-green algae was substantially less in the spring and summer of 1987 than during the same period in 1986. Taxa that were numerically most dominant on periphytometer slides included seven diatom taxa, six green algal taxa, and seven blue-green algal taxa (Table 4-42). The diatom Achnanthes minutissima was the most frequently occurring dominant taxon in the periphytometer samples during both 1986 and 1987.

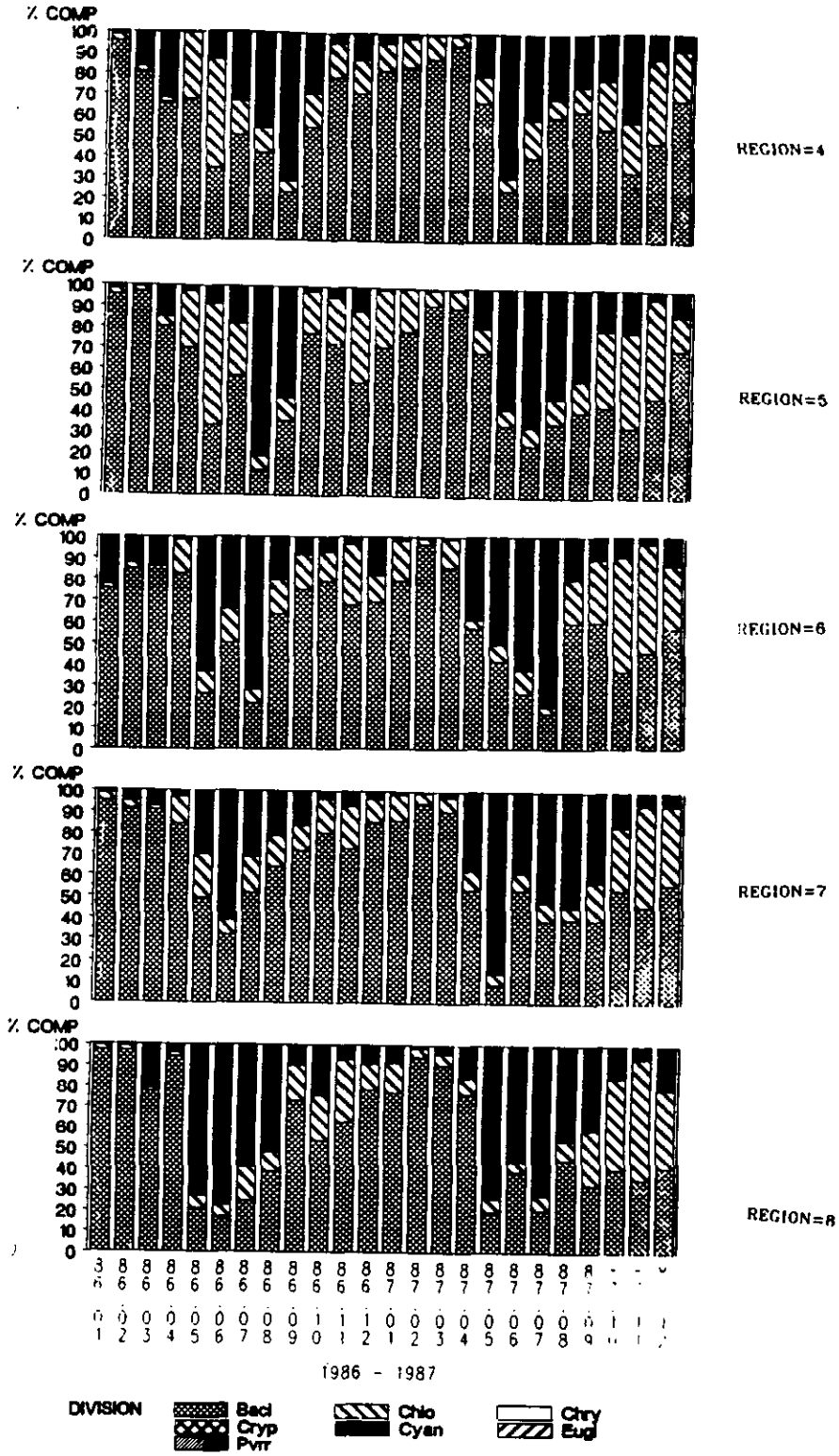

FIGURE 4-27. Relative Abundance (% composition) of Periphyton Major Taxonomic Groups in Sediment Cores from L-Lake Littoral Sampling Stations, Regions 4-8, January 1986-December 1987 (source: Gladden et al., 1988)

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TABLE 4-42

Numerically Dominant Periphyton Taxa (constituting >5% of the total periphyton density) at L-Lake Littoral Zone Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Taxon	Number of Samples Where Dominant			
	Sediment Cores		Periphytometer Slides	
	1986	1987	1986	1987
Bacillariophyta				
Navicula decussis	44	53	5	16
Melosira granulata	36	36	<5	<5
Navicula cryptocephala	32	19	<5	<5
Navicula lateropunctata	13	<5	<5	<5
Synedra rumpens	12	<5	24	<5
Nitzschia amphibia	10	<5	<5	<5
Achnanthes minutissima	8	<5	37	51
Achnanthes exiqua	6	<5	<5	<5
Nitzschia paleacea	5	<5	<5	<5
Achnanthes lanceolata	<5	7	<5	<5
Gomphonema parvulum	<5	<5	18	5
Melosira varians	<5	<5	7	<5
Gomphonema gracile	<5	<5	<5	6
Cyanophyta				
Microcystis aeruginosa	27	36	<5	<5
Coccoid cyanophyte spp. (<5 µm)	<5	<5	18	8
Lyngbya subtilis	<5	5	7	33
Microcystis incerta	<5	5	<5	<5
Chamaesiphon minimus	<5	<5	10	<5
Phormidium sp. 1	<5	<5	6	<5
Phormidium spp.	<5	<5	6	<5
Rhabdoderma sigmoidea	<5	<5	5	<5
coccoid cyanophyte spp. (>5 µm)	<5	<5	<5	22
Chlorophyta				
Scenedesmus denticulatus	17	32	<5	5
Scenedesmus dimorphus	15	6	<5	<5
Ankistrodesmus spiralis	8	17	<5	<5
coccoid chlorophyte spp. (<10 µm)	<5	5	8	9
Chaetophora elegans	<5	<5	28	16
Characium spp.	<5	<5	11	5
Chlamydomonas spp.	<5	<5	6	5
Oedogonium spp. (small)	<5	<5	<5	8

Source: Gladden et al. (1988)

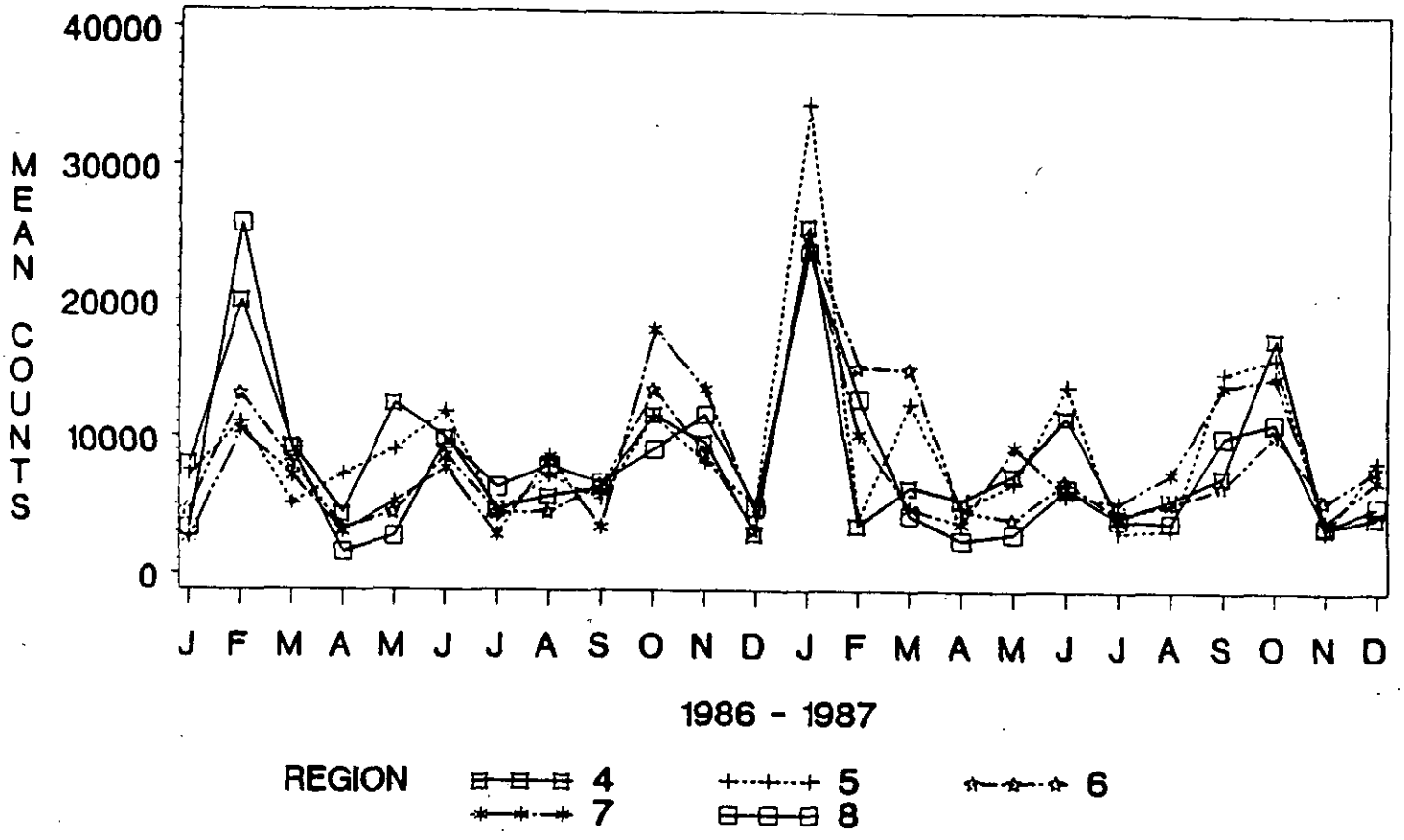

FIGURE 4-28. Mean Total Periphyton Densities on Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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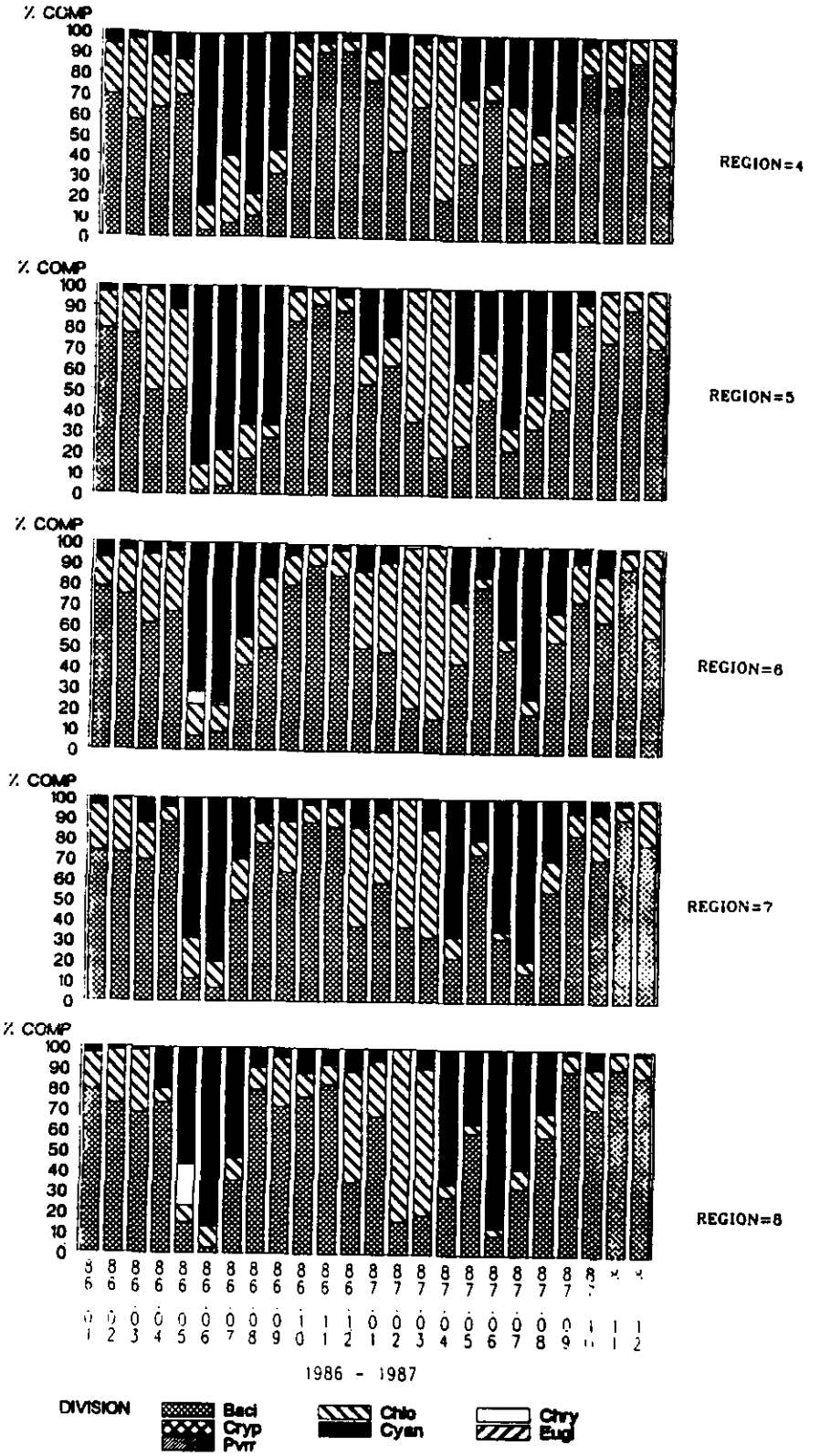

FIGURE 4-29. Relative Abundance (% composition) of Periphyton Major Taxonomic Groups in Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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Biovolume Abundance

Relative periphyton biovolume in L-Lake sediment cores was generally dominated by diatoms throughout 1986 and 1987 (Figure 4-30). Diatoms accounted for at least 90% of the community biovolume in the winter of both years. The green and blue-green algae were the only other major taxonomic groups found to be volumetrically important in sediment cores. In general, blue-green algae were most abundant in the spring and summer, while the green algae contributed most to the total periphyton biovolume in the fall and winter. However, blue-green and green algae together rarely made up more than 50% of the total biovolume in any given region or month, and they were less important as measured by biovolume than by numerical abundance. No important regional differences were noted, nor was there an obvious relationship between sediment core biovolume and the summer outages of L Reactor.

Taxa that were the most volumetrically dominant in samples from the sediment cores included 11 diatoms, two green algae, and one blue-green alga (Table 4-43). Seven of these taxa were dominant in both years. The diatoms Melosira granulata and Navicula decussis were the most volumetrically dominant taxa in both years. Species composition on periphytometer slides differed substantially from that of the core samples. Taxa that were the most volumetrically dominant on periphytometer slides included 15 diatoms, seven green algae, and three blue-green algae (Table 4-43). Ten taxa were dominant in both years. The most common dominant in 1986 (the diatom Achnanthes minutissima) was ranked second in 1987. The most common dominant in 1987 (the diatom Cymbella tumida) was never dominant in 1986 (Starkel et al., 1988a).

The highest total periphyton biovolumes on the periphytometers occurred in the winter (January and February) of both years (Figure 4-31). However, winter pulse was substantially higher in 1986 than in 1987. Annual mean biovolumes were lower in 1987 than in 1986 in all regions, but this was primarily due to an unusually high peak that occurred in February 1986 (Figure 4-31).

Diatoms often dominated the periphyton biovolume on slides in winter and fall of both years (Figure 4-32). Green algae were generally important in the spring and summer months and occasionally in the fall. There was considerable variability among regions and between years in the biovolumes of the major taxonomic groups. Blue-green algae constituted a noteworthy portion (up to 80% in Regions 7 and 8) of the periphyton biovolume in late spring and early summer of both years.

Dry Weight and Ash-Free Dry Weight

Sediment core AFDW exhibited no consistent temporal or spatial pattern during the study (Figure 4-33). Most mean values ranged between approximately 100 and 400 g/m^2 in all regions, although peaks up to 2,000 g/m^2 were reported.

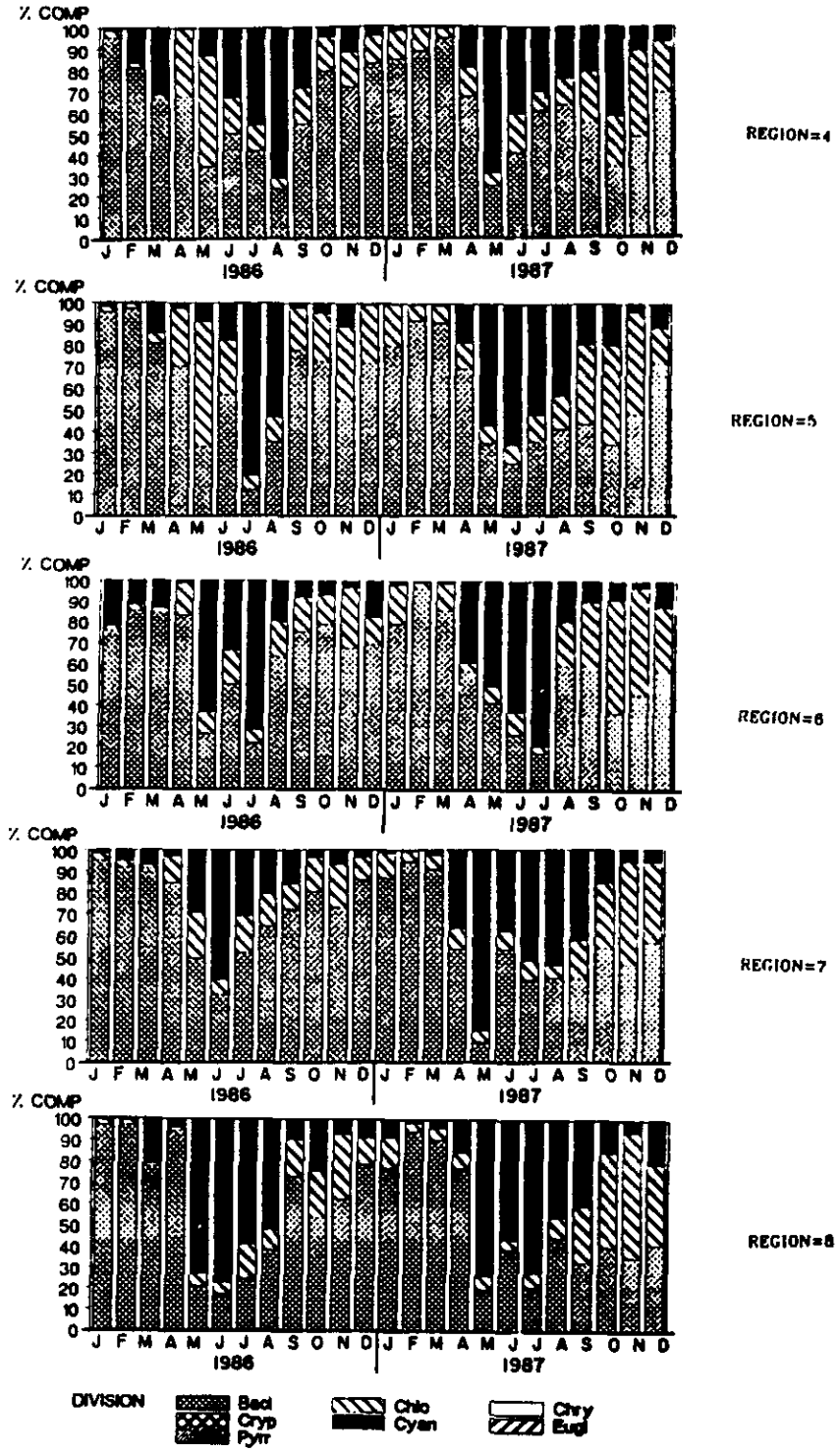

FIGURE 4-30. Relative Biovolume (% composition) of Periphyton Major Taxonomic Groups in Sediment Cores from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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TABLE 4-43

Volumetrically Dominant Periphyton Taxa (constituting >5% of the total periphyton biovolume) at L-Lake Littoral Zone Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Taxon	Number of Samples Where Dominant			
	Sediment Cores		Periphytometer Slides	
	1986	1987	1986	1987
Bacillariophyta				
Melosira granulata	50	55	10	6
Navicula decussis	43	53	<5	16
Melosira varians	27	18	17	17
Navicula cryptocephala	25	14	7	5
Navicula lateropunctata	14	<5	<5	<5
Nitzschia amphibia	10	5	<5	<5
Navicula capitata	7	<5	<5	<5
Navicula viridula	7	12	<5	<5
Pinnularia acrosphaeria	5	<5	<5	<5
Achnanthes lanceolata	<5	28	<5	<5
Nitzschia gracilis	<5	5	<5	<5
Achnanthes minutissima	<5	<5	34	31
Gomphonema parvulum	<5	<5	28	5
Synedra rumpens	<5	<5	23	7
Synedra ulna	<5	<5	18	8
Gomphonema gracile	<5	<5	12	22
Gomphonema subclavatum	<5	<5	8	14
Gomphonema rhombicum	<5	<5	5	<5
Cymbella tumida	<5	<5	<5	37
Epithemia adnata	<5	<5	<5	9
Synedra tenera	<5	<5	<5	<5
Gomphonema truncatum	<5	<5	<5	6
Cyanophyta				
Microcystis aeruginosa	15	14	<5	<5
Coccoid cyanaphyte spp. (<5 µm)	<5	<5	6	<5
Coccoid cyanophyte spp. (>5 µm)	<5	<5	<5	17
Lyngbya subtilis	<5	<5	<5	5
Chlorophyta				
Oedogonium spp. (large)	6	<5	22	<5
Scenedesmus denticulatus	<5	11	<5	<5
Chaetophora elegans	<5	<5	29	14
Coccoid chlorophyte spp. (<10 µm)	<5	<5	16	10
Spirogyra spp. (small)	<5	<5	<5	12
Oedogonium spp. (small)	<5	<5	<5	6
Spirogyra spp. (large)	<5	<5	<5	6
Chlamydomonas spp.	<5	<5	<5	5

Source: Gladden et al. (1988)

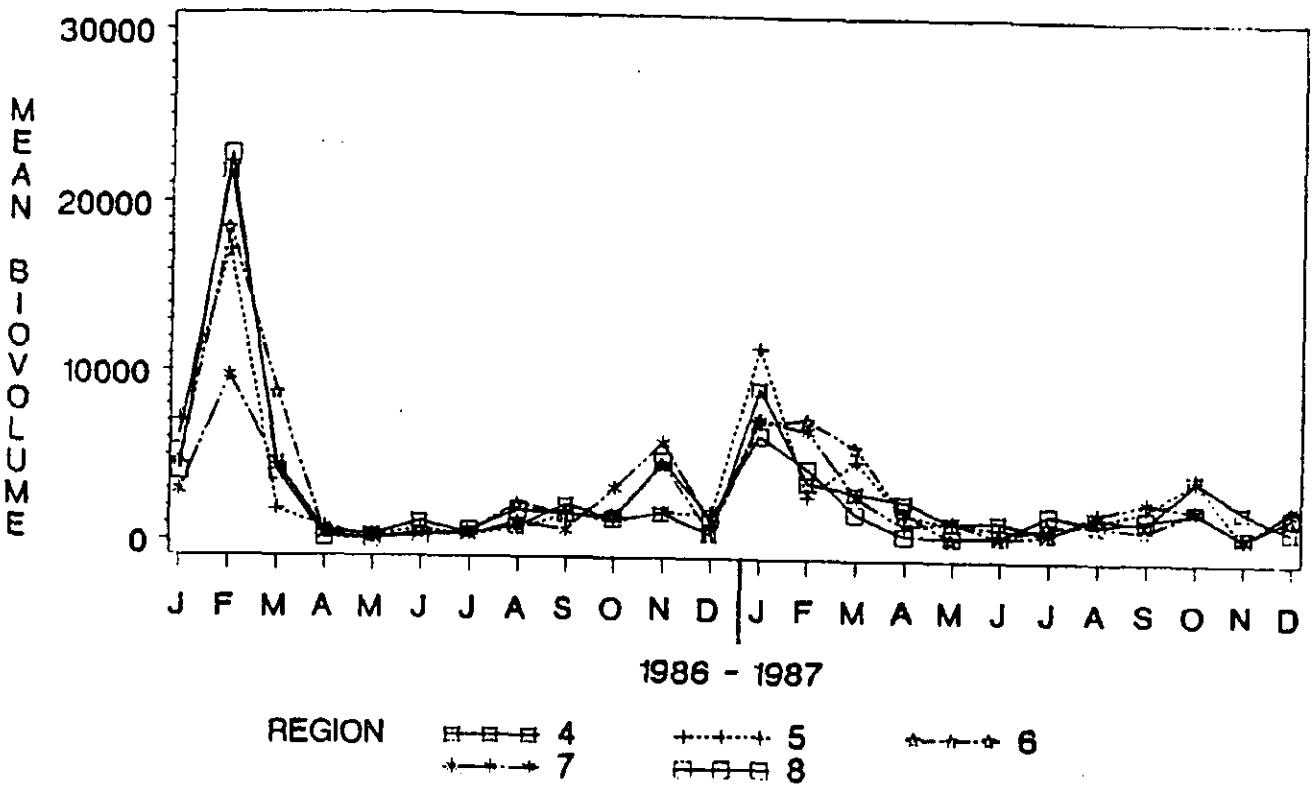

FIGURE 4-31. Mean Total Periphyton Biovolumes on Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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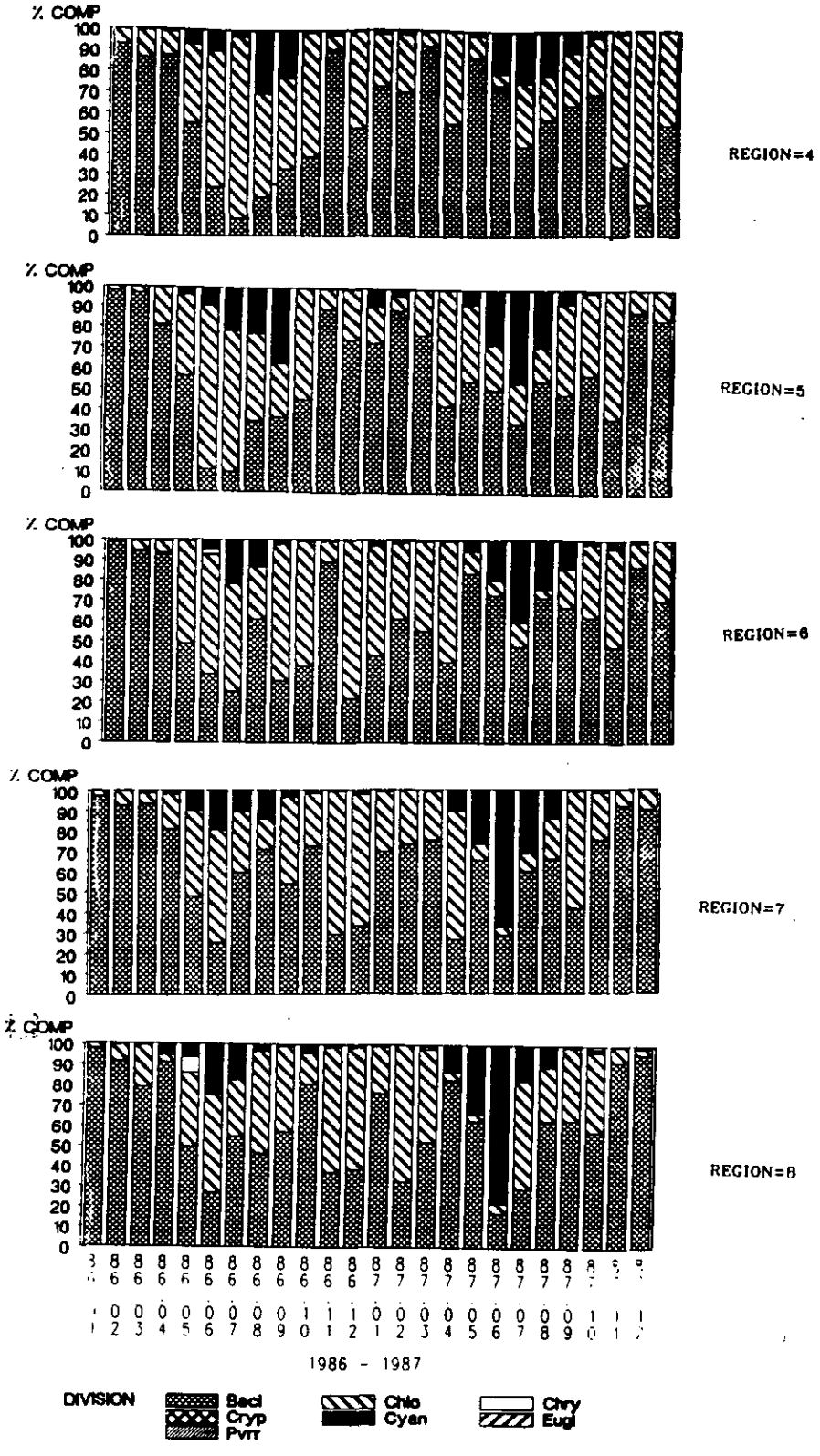

FIGURE 4-32. Relative Biovolume (% composition) of Periphyton Major Taxonomic Groups on Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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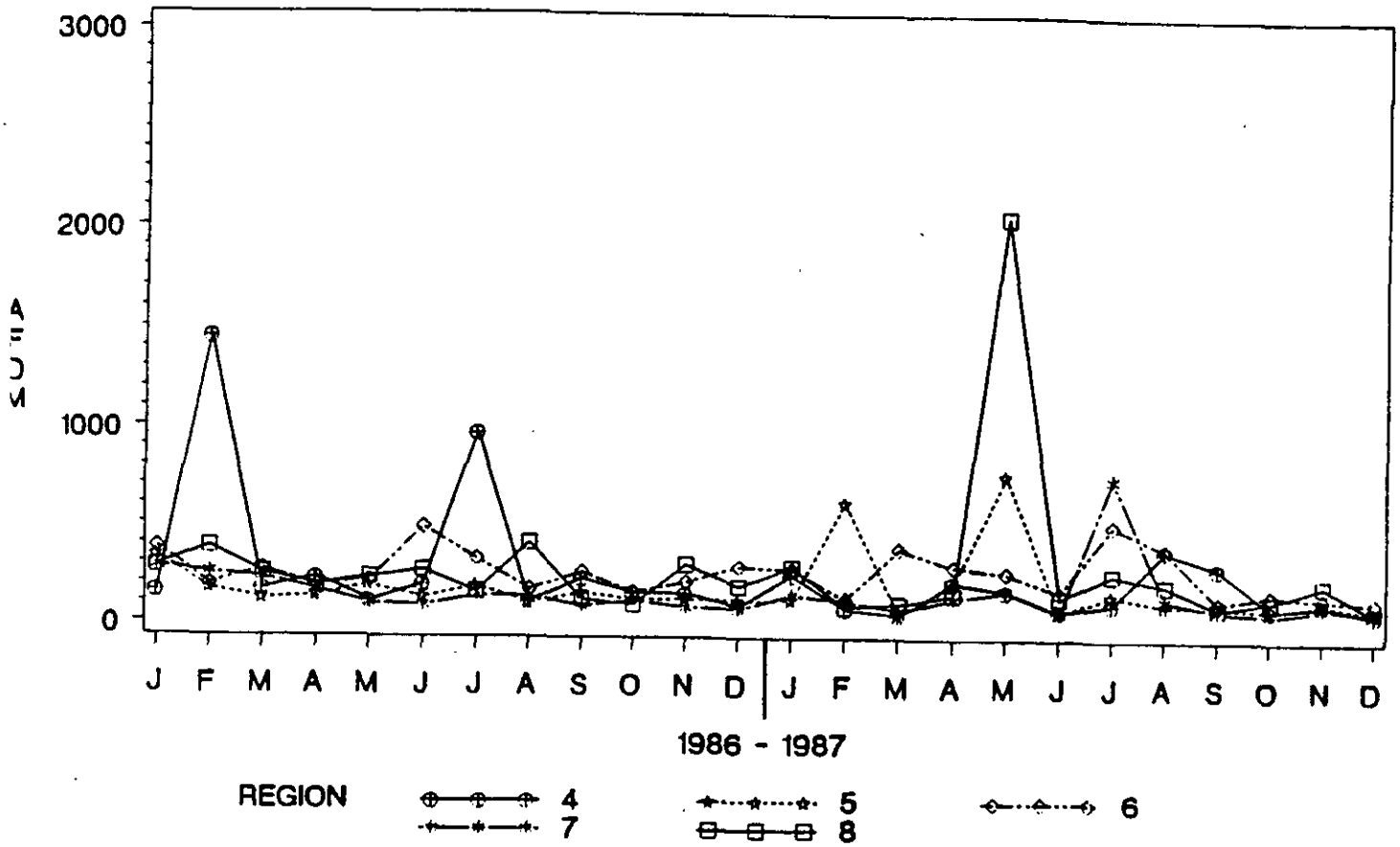

FIGURE 4-33. Mean Ash-Free Dry Weight (g/m^2) in Sediment Cores from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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Most mean DW values on periphytometer slides ranged between approximately 1 and 11 g/m^2 (Figure 4-34). There was no consistent seasonality or regional differences in DW . Annual mean DW in all regions was markedly higher in 1987 (6.6 to 8.3 g/m^2) than in 1986 (4.1 to 5.3 g/m^2). AFDW values for periphytometer slides ranged from approximately 0.5 to 18.0 g/m^2 (Figure 4-34). Temporal variation in AFDW on slides generally paralleled those for DW.

Chlorophyll a and Primary Productivity

Most mean chlorophyll a values from sediment cores ranged from approximately 30 to 130 mg/m^2 in all regions (Figure 4-35). There were no consistent regional differences, and temporal variations in chlorophyll a did not seem to follow a consistent seasonal pattern, change in response to the summer shutdown of the reactor, or differ substantially between 1986 and 1987. Most mean chlorophyll a values on periphytometer slides ranged from approximately 2 to 16 mg/m^2 (Figure 4-35) and these values also displayed no obvious trends.

Yearly regional means for periphyton productivity ranged from 64.9 to 108.5 mg $C/m^2/hr$ in 1986 and from 46.6 to 59.8 mg $C/m^2/hr$ in 1987 (Figure 4-36; Starkel et al., 1988a). Most monthly productivity values were between 20 and 100 mg $C/m^2/hr$ in all regions (Figure 4-36), but a large pulse in productivity occurred (up to 350 mg $C/m^2/hr$) in July and August 1986. Otherwise, there were no consistent temporal or spatial differences.

4.3.3.2 Comparison to Regional Reservoirs

A comprehensive literature search revealed no periphyton abundance data (expressed as density or biovolume) or productivity data (using sediment cores) from other southeastern reservoirs that could be compared to the L-Lake study results (Gladden et al., 1988).

Periphyton species richness on the periphytometers in L Lake (16-45 taxa per station per month) was comparable to the range (8-53 taxa per station per month) of taxa richness reported for periphytometer sampling results from other southeastern reservoirs (Carr & Assoc., 1982; Applied Biology, 1982).

Based on the taxa lists from periphytometer sampling, the L-Lake periphyton community differed from the Par Pond periphyton community (Wilde, 1985) by having higher proportions of diatoms (39.8 vs. 25.5%) and blue-green algae (18.6 vs. 12.3%) and lower proportions of green algae (37.1 vs. 57.5%).

The only available chlorophyll a data for periphytometer sampling in southeastern reservoirs was from Par Pond. Annual mean chlorophyll a concentrations from periphyton slides in Par Pond ranged from 0.5 at a near-ambient temperature station to 14.2 mg/m^2 at a location near the Hot

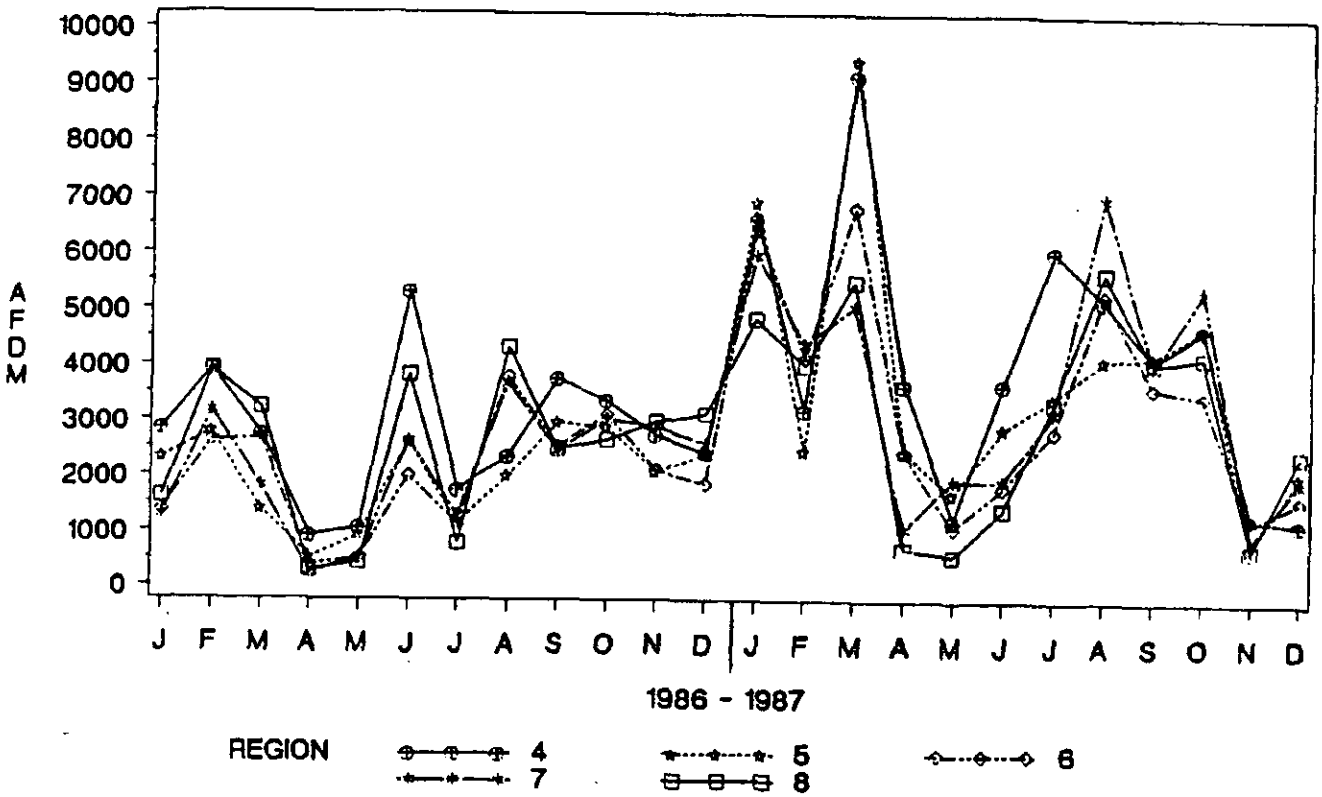

FIGURE 4-34. Dry Weight and Ash-Free Dry Weight (g/m^2) on Periphytometer Slides from L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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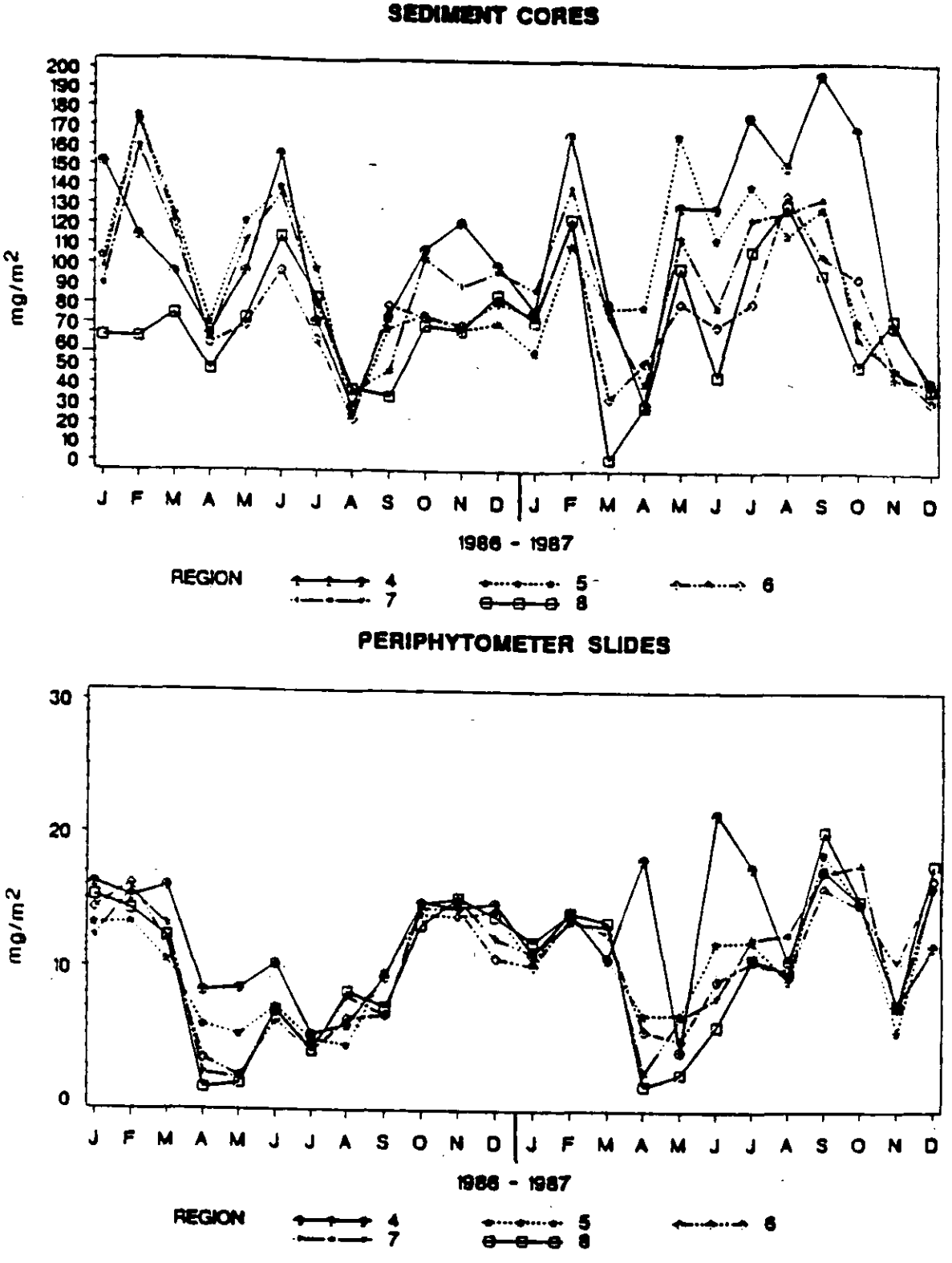

FIGURE 4-35. Mean Periphyton Chlorophyll a Values from Sediment Cores and Periphytometer Slides at L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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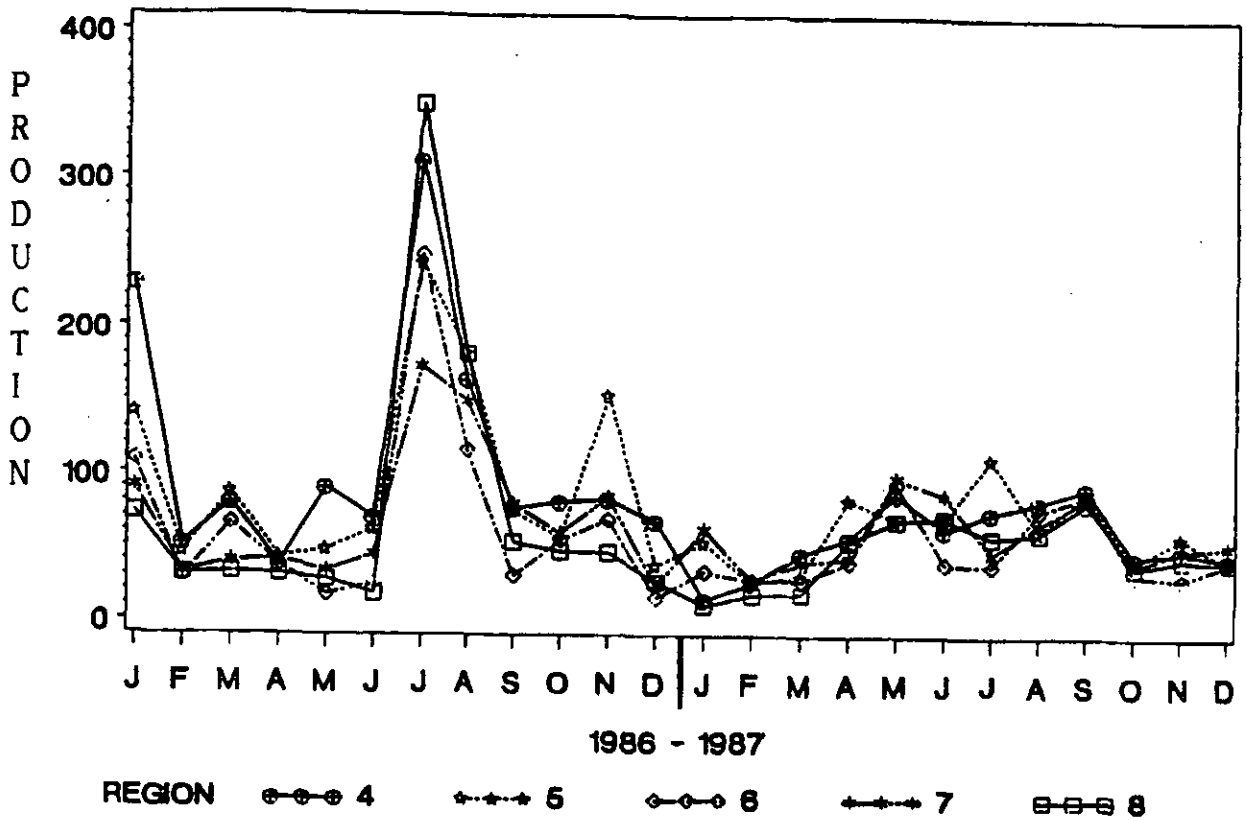

FIGURE 4-36. Mean Periphyton Primary Productivity (mg C/m^2/hr) from Periphytometer Slides at L-Lake Littoral Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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Dam where thermal effluent enters the pond (Tilly, 1975). In contrast, annual mean chlorophyll a values from periphytometer sampling locations in L Lake ranged from 8.4 to 13.3 mg/m^2 in Regions 4-8.

The periphyton weight values (both DW and AFDW) in L Lake from periphytometers were higher than values reported for other aquatic systems in the southeast. The highest value of periphyton AFDW in a southeastern system was 13 g/m^2 for a stream in Tennessee (Ehrlick and Slack, 1969). The highest annual mean DW value reported for Par Pond was 4.1 g/m^2 (Tilly, 1975). The L-Lake maximum AFDW measurement from periphytometer samples was 21.9 g/m^2, and the highest L-Lake annual DW mean on periphytometers was 8.3 g/m^2.

4.3.3.3 Status of L-Lake Periphyton Community

The periphyton of L Lake was characterized by species indicative of eutrophic condition and high productivity (Gladden et al., 1988). The five sampling regions were generally similar to one another in terms of periphyton structural and functional characteristics. Comparisons of periphyton data from 1986 with data from 1987 reveal some possible trends that may represent improving biological balance in L Lake. However, it was not possible to separate and identify the extent to which natural variability, reservoir aging, reduced reactor power levels in 1987 compared to 1986, and other factors contributed to these apparent trends. Although temporal improvement of the L Lake periphyton community is possible, substantial amelioration of the eutrophic conditions appears unlikely unless nutrient loading is reduced.

4.3.3.4 Expected Impacts from Operating L Reactor

The continued operation of L Reactor should result in a periphyton community in L Lake that is similar to the community described in the 1986/1987 studies. The community may be less dominated by blue-green algae because of the stabilization of the reservoir resulting from aging.

4.3.4 Zooplankton

4.3.4.1 Community Characteristics

Monthly zooplankton samples were collected in duplicate from January 1986 through December 1987 at five sampling stations located in the central portions of Regions 4-8 (Chimney, 1988). When the lake was isothermal, samples were integrated over the entire water column from surface to bottom. During periods of thermal stratification and a hypolimnion greater than 3 m thick, two types of samples were collected, one representing the epilimnion and thermocline strata and a second representing the hypolimnion. Microzooplankton (protozoans and rotifera) were collected with a pump system. Macrozooplankton (cladocerans and copepods)

were collected with vertical tows using a 12.5-cm-diameter plankton net having 80-µm aperture netting and tow speed at 0.5 to 1.0 m/s. A Birge closing-net was used to collect the hypolimnetic samples (Chimney, 1988).

A total of 125 species were collected from the mixed (epilimnion and thermocline) zone in 1986 and 105 species during 1987 (Table 4-44). The number of species collected showed no consistent trend with regard to region of the lake or between the years 1986 and 1987. The number of total species in the mixed layer was low during the summer months (June through August) of both years (Figure 4-37). The most frequently collected species in L Lake were ciliate protozoans (Table 4-45) a trend which is common for communities of eutrophic lakes. In general, the species richness of microzooplankton always exceeds the taxa richness of the crustacean macrozooplankton in temporate limnetic waters. A complete species listing for the regions of L Lake is given in Table 4-46.

Total zooplankton density in L Lake exhibited the familiar pattern of abrupt increases and declines, reflecting changes in the physical and biotic features of pelagic habitat (e.g., temperatures, food resource abundance, and predation pressure from invertebrates, and fish) (Figure 4-38). This cyclical pattern was observed in all regions of the lake and was not correlated to the seasons. Months of maximum density in 1986 were February, April, July, November, and December. In 1987, abundance maxima occurred during February, March, June, and October. The differences among regions on any given date appeared to represent the characteristic patchiness of plankton populations which is typically coupled to the turbulent nature of current patterns in a lake (Hutchinson, 1967).

The Protozoa numerically dominated the zooplankton community of L Lake at all times. Figure 4-39 indicates protozoan monthly concentrations from January 1986 to December 1987. Densities varied between approximately 3,000 to nearly 40,000 organisms/L, with four-fold changes in abundance occurring from one month to the next. There were regional differences in protozoan densities each month, but these trends were not consistent throughout the 2-year period. These differences can be attributed to patchiness and sampling variability. No down-lake gradients were detected, nor did reactor operation (especially summer shutdowns) appear to affect densities.

Monthly mean Rotifer densities during 1986 ranged from a maximum of 1,924 individuals/L in Region 5 during February to a minimum of 0 individuals/L at Regions 6, 7, and 8 during several months (Figure 4-40). During 1987, the density range encompassed a maximum of 5,478 rotifers/L in Region 8 during September to 0 rotifers/L on several occasions. Temporal variations did not exhibit any discernible seasonal trends and were not correlated to reactor operation patterns. Several abundance peaks were caused by the species Keratella cochlearis, Trichocerca rousseleti, T. pusilla, and Polyarthra vulgaris. Spatial patterns were absent during the 2-year period with no evident trends among regional sampling locations.

TABLE 4-44

Total Number of Zooplankton Taxa Identified from the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Taxon	Region 4	5	6	7	8	All Regions
			1986			
Protozoa	42	47	46	43	43	59
Rotifera	31	28	27	30	28	44
Cladocera	9	10	9	8	11	12
Copepoda	8	9	8	7	8	9
Ostracoda	1	1	1	1	1	1
All taxa	91	95	91	89	91	125
			1987			
Protozoa	44	40	39	42	40	53
Rotifera	27	26	24	27	21	35
Cladocera	9	8	8	7	8	9
Copepoda	7	7	6	7	6	7
Ostracoda	1	1	1	1	1	1
All taxa	88	82	78	84	76	105

Source: Gladden et al. (1988)

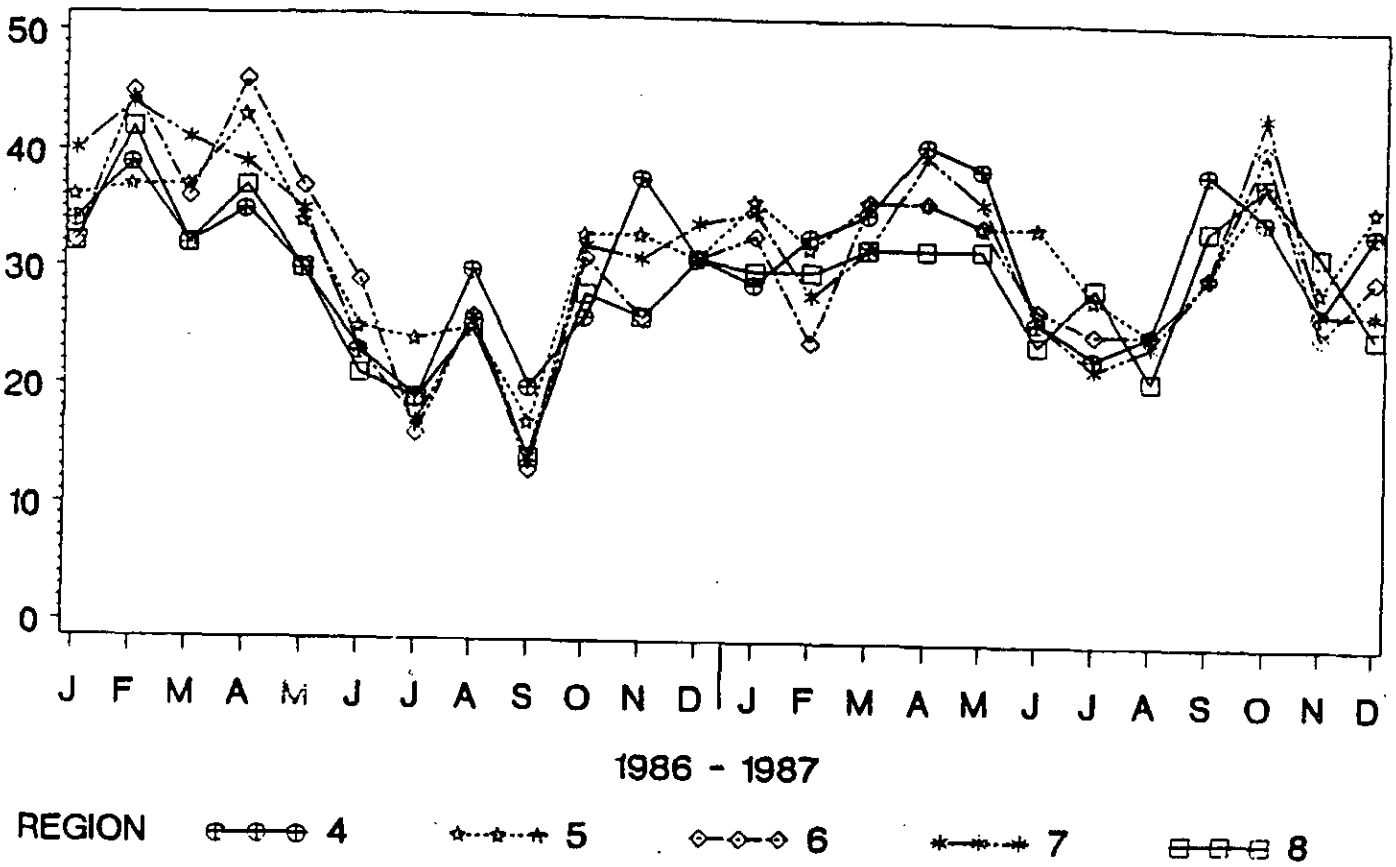

FIGURE 4-37. Zooplankton Taxa Richness (no. taxa) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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TABLE 4-45

Comparison of Numerically Dominant Zooplankton Taxa Identified from the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987)

Year	Taxon	No. Samples as a Dominant
1986	Ciliate sp. 4	38
	Holophyrid ciliate	33
	Uronema sp. 1	31
	Urotrichia farcta	29
	Strombidium spp.	25
	Vorticella sp. 3	23
	Strombidium delicatissium	19
	Cyclidium sp. 1	17
	Ciliate sp. 5	16
	Mesodinium acarus	12
	Tintinnopsis sp. 1	10
	Coleps striatus	9
	Halteria sp. 2	8
	Urotrichia armata	5
1987	Ciliate sp. 4	59
	Uronema sp. 1	58
	Strombidium spp.	36
	Urotrichia farcta	32
	Holophyrid ciliate	30
	Vorticella sp. 3	26
	Mesodinium acarus	22
	Halteria sp. 2	17
	Tintinopsis sp. 1	15
	Ciliate sp. 5	12
	Anureopsis fissa	5

Source: Gladden et al. (1988)

TABLE 4-46

Zooplankton Taxa Collected from L-Lake Pelagic Zone Sampling Stations (January 1986 - December 1987)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Phylum Protozoa					
Acanthocystis spp.	-	-	-	X	-
Actinophrys spp.	X	X	X	X	-
Amphileptidae	X	X	X	X	X
Askenasia sp. 1	X	X	X	X	X
Askenasia sp. 2	X	X	X	X	X
Askenasia spp.	X	X	X	X	X
Astramoeba spp.	-	X	-	-	X
Bursaridium spp.	X	X	-	X	X
Campanella umbellaria	X	X	X	X	X
Centropyxis aculeata	X	-	-	X	X
Ciliate - unidentified spp.	X	X	X	-	X
Ciliate - unidentified spp. (<50 µm)	X	X	X	X	X
Ciliate - unidentified spp. (50-99 µm)	X	X	X	X	X
Ciliate - unidentified spp. (100-200 µm)	X	X	X	X	X
Ciliate - unidentified spp. (>200 µm)	X	X	-	-	-
Ciliate sp. 01	X	X	X	X	X
Ciliate sp. 02	-	-	-	-	X
Ciliate sp. 04	X	X	X	X	X
Ciliate sp. 05	X	X	X	X	X
Ciliate sp. 08	-	X	X	X	-
Ciliate sp. 12	X	X	X	X	X
Ciliate sp. 15	X	X	X	X	X
Ciliate sp. 21	X	-	X	-	-
Ciliate sp. 26	X	X	X	-	-
Ciliate sp. 27	X	X	X	X	X
Codonella cratera	X	X	X	X	X
Coleps hirtus	-	X	X	X	X
Coleps sp. 1	X	X	X	X	X
Coleps spp.	X	X	X	X	X
Coleps striatus	X	X	X	X	X
Colpoda spp.	X	-	-	-	-
Cyclidium sp.1	X	X	X	X	X
Cyclotrichium sp. 1	X	-	X	X	X
Cyrtolophosis spp.	X	X	X	X	X
Didinium balbanii var. *nanum*	X	X	X	X	X
Didinium nastum	X	-	X	-	X
Difflugia limnetica	X	X	X	X	X
Difflugia sp. 1	-	X	-	-	-
Dileptus bivacuolatus	-	X	X	X	X
Epistylus spp.	X	X	X	X	X

TABLE 4-46, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	REG 8
Phylum Protozoa, Contd					
Euglypha ciliata	X	X	X	X	-
Euglypha sp. 1	X	X	X	X	-
Euglypha sp. 2	X	X	-	-	-
Halteria sp. 1	-	-	X	X	X
Halteria sp. 2	X	X	X	X	X
Hemiophyrs sp.1	X	X	X	X	X
Holophyrid ciliate	X	X	X	X	X
Holophyrid ciliate (50-100 µm)	X	X	X	X	X
Holophyrid ciliate (>100 µm)	-	-	X	-	X
Keronidae	X	-	-	X	-
Mesodinium acarus	X	X	X	X	X
Metacyctis spp.	-	-	-	X	-
Microthorax elegans	-	X	-	-	-
Nuclearia simplex	-	X	-	-	X
Oxytrich ciliate	-	X	-	-	-
Paraeuglypha reticulata	X	X	X	-	X
Paramecium spp.	-	-	-	-	X
Podophrya sp.	X	X	-	-	-
Rhabdostyla spp.	-	X	-	-	-
Spathidoides sulcata	X	X	X	X	X
Spirostomidae	-	X	X	X	X
Staurophyra elegans	X	-	X	X	X
Strobilidium gyrans	X	X	X	X	X
Strobilidium sp.	X	-	-	X	-
Strombidium delicatissium	X	X	X	X	X
Strombidium spp.	X	X	X	X	X
Suctorian ciliate	X	X	X	X	X
Tintinnopsis cylindrica	X	X	X	X	X
Tintinnopsis sp. 1	X	X	X	X	X
Trachelius spp.	X	X	-	-	X
Urocentrum turbo	-	X	-	-	X
Uronema sp. 1	X	X	X	X	X
Uronema spp.	X	-	-	-	-
Urotrichia armata	X	X	X	X	X
Urotrichia farcta	X	X	X	X	X
Urotrichia sp. 3	X	X	X	X	X
Vorticella sp. 1	X	X	X	X	X
Vorticella sp. 2	X	X	X	X	X
Vorticella sp. 3	X	X	X	X	X
Phylum Rotifera					
Anureopsis fissa	X	X	X	X	X
Ascopmorha saltans	X	-	-	-	-
Asplanchna priodonta	X	X	-	-	-

TABLE 4-46, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Phylum Rotifera, Contd					
Asplanchna sp.	X	X	X	X	X
Brachionus angularis	-	X	X	-	-
Brachionus havanaensis	X	X	X	X	X
Cephalodella sp. 1	X	X	X	X	X
Cephalodella sp. 2	X	X	X	X	X
Cephalodella spp.	-	-	-	-	X
Collothea mutabulis	X	X	X	X	X
Colurella obtusa	-	X	-	-	-
Colurella uncinata	-	-	-	-	X
Conochiloides dossuarius	X	X	X	X	X
Conochilus unicornis	X	X	X	X	X
Filinia longiseta	X	X	X	X	X
Floscularia sp. 1	X	-	-	-	X
Hexarthra mira	X	X	X	X	X
Kellicottia bostoniensis	X	X	X	X	X
Kellicottia longispina	X	-	-	-	-
Keratella cochlearis	X	X	X	X	X
Keratella cochlearis var. *hispida*	-	X	-	-	-
Keratella cochlearis var. *tecta*	X	X	X	X	X
Keratella crassa	X	-	X	X	-
Lecane sp. 1	X	-	-	-	-
Lecane stichaea	-	-	-	X	X
Lepadella patella	-	-	-	X	-
Lepadella sp. 1	X	-	-	X	-
Lepadella triptera	-	X	-	-	-
Monommata actices	X	X	-	-	-
Monostyla bulla	X	-	-	X	-
Monostyla closterocerca	X	X	-	-	X
Monostyla lunaris	X	-	-	X	-
Notommata sp.	X	X	X	X	X
Ploesoma sp. 1	X	X	X	X	-
Polyarthra euryptera	-	-	X	X	X
Polyarthra remata	X	X	X	X	X
Polyarthra sp. 1	X	X	X	X	-
Polyarthra vulgaris	X	X	X	X	X
Rotifer-unidentified spp. (<50 µm)	X	X	X	X	-
Rotifer-unidentified spp. (100-200 µm)	X	X	X	X	X
Rotifer-unidentified spp. (50-99 µm)	X	X	X	X	X
Rotifer sp. 1	-	X	-	-	X
Synchaeta oblonga	X	X	X	X	X
Synchaeta spp.	X	X	X	X	X
Synchaeta stylata	-	-	-	X	X
Trichocerca cylindrica	X	X	X	X	X

TABLE 4-46, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Phylum Rotifera, Contd					
Trichocerca multicrinis	-	X	X	-	-
Trichocerca pusilla	X	X	X	X	X
Trichocerca rousseleti	X	X	X	X	X
Trichocerca similis	X	X	X	X	X
Trichocerca sp. 1	-	X	X	X	X
Trichocerca spp.	X	X	-	-	-
Phylum Arthropoda					
Class Crustacea					
Subclass Brachiopoda					
Order Cladocerca					
Alona sp.	X	X	X	X	X
Bosmina longirostris	X	X	X	X	X
Ceriodaphnia spp.	X	X	X	X	X
Chydorus brevilabris	X	X	X	X	X
Daphnia ambigua	X	X	X	-	X
Daphnia parvula	X	X	X	X	X
Daphnia retrocurva	X	X	X	X	X
Diaphanosoma brachyurum	X	X	X	X	X
Eubosmina spp.	-	X	X	X	X
Eurycercus spp.	-	X	-	-	-
Leptodora kindti	X	X	X	-	X
Moina micrura	X	X	X	X	X
Sida crystallina	X	X	X	X	X
Simocephalus sp.	-	-	-	-	X
Subclass Copepoda					
Order Eucopepoda					
Cyclops sp.	X	X	X	X	X
Diaptomus sp.	X	X	X	X	X
Macrocyclops sp.	X	X	X	X	X
Mesocyclops edax	X	X	X	X	X
Nauplius larvae	X	X	X	X	X
Paracyclops fimbriatus poppei	X	X	X	X	X
Tropocyclops prasinus	X	X	X	X	X
Harpacticoida	-	X	X	-	X
Nitocra sp.	X	X	-	-	-
Subclass Ostracoda					
Unidentified spp.	X	X	X	X	X

Source: Chimney (1988)

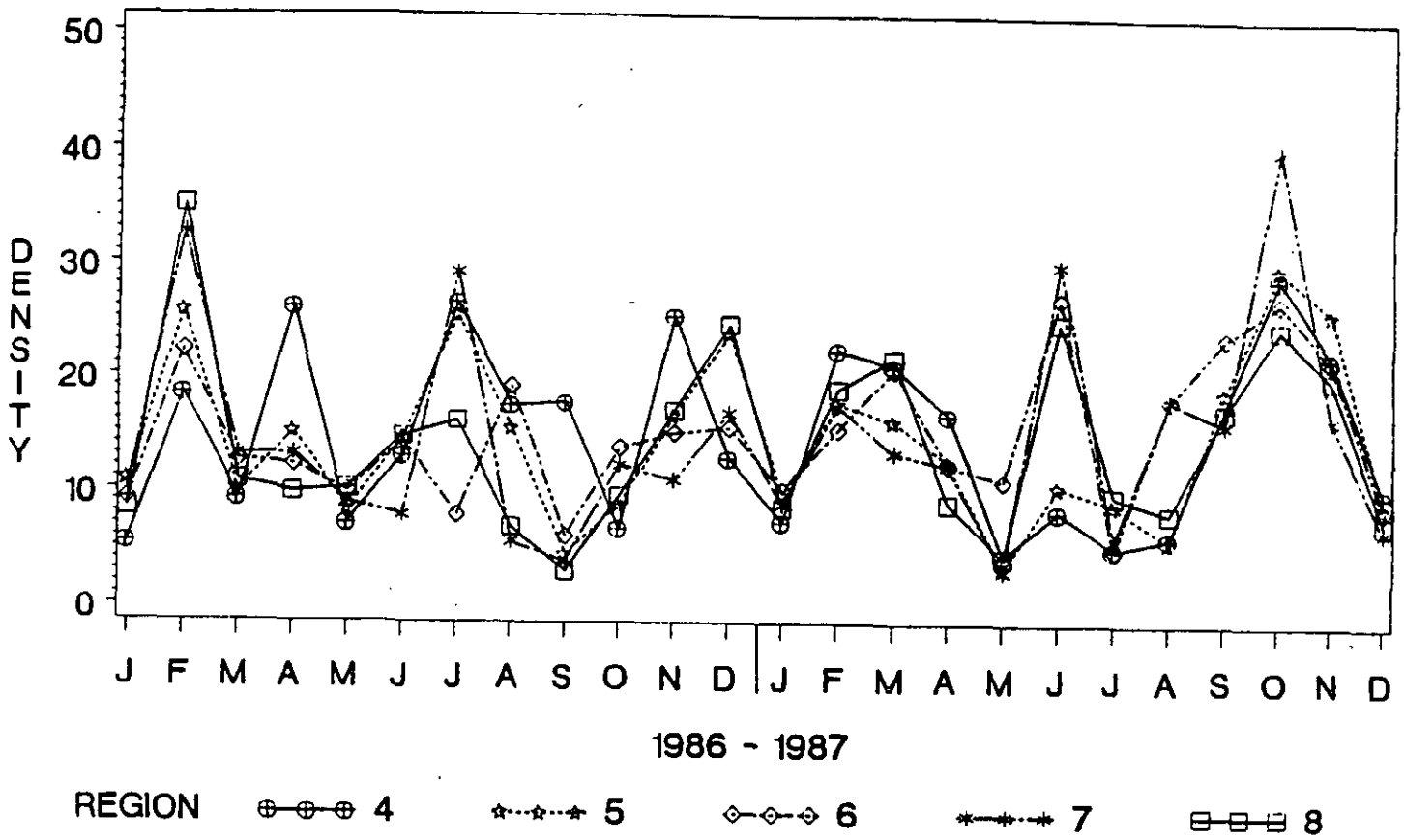

FIGURE 4-38. Mean Total Zooplankton Density (organisms/L x 1,000) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987)
(source: Gladden et al., 1988)

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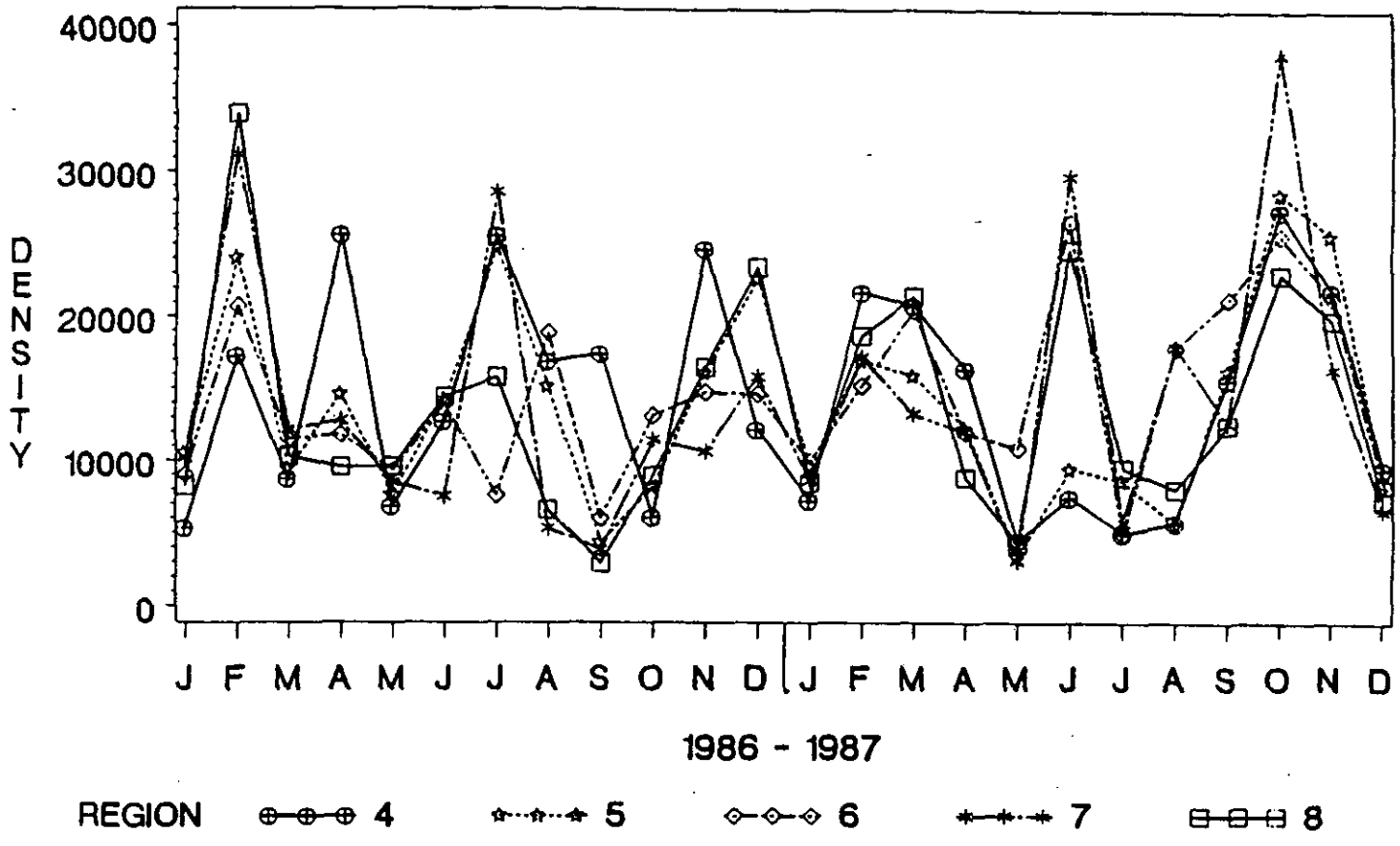

FIGURE 4-39. Mean Density of Protozoa (organisms/L) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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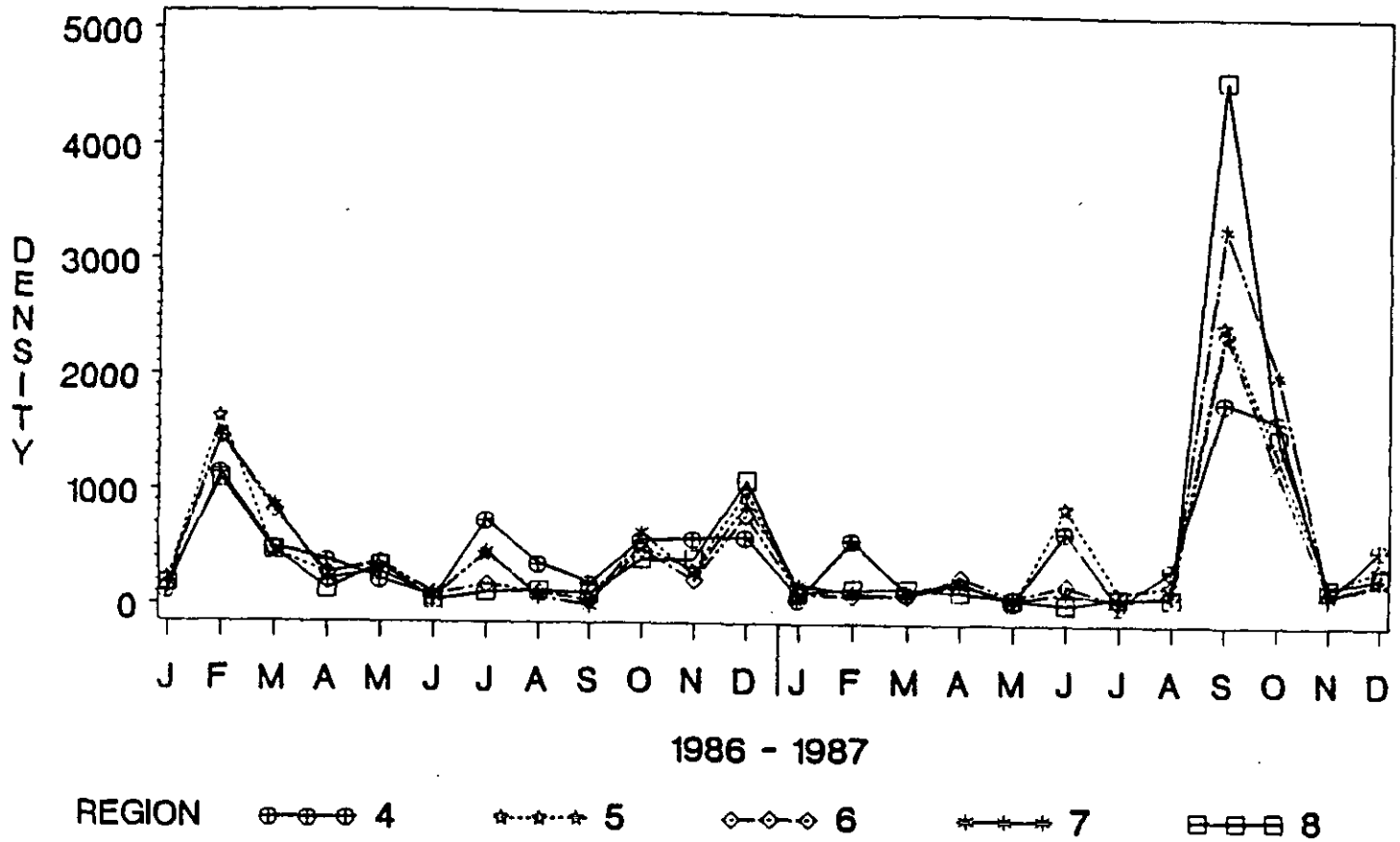

FIGURE 4-40. Mean Density of Rotifera (organisms/L) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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Cladoceran densities in L Lake varied between 5 organisms/L and 145 organisms/L during the years 1986 and 1987 (Figure 4-41). Cladocerans exhibited several population pulses in the epilimnion. In 1986, densities were highest from May to June when the group was numerically dominated by Daphnia parvula and Diaphanosoma brachyurum. Two smaller pulses occurred in August (Region 7 only) and October (all regions), both of which were dominated by D. brachyurum. A single abundance peak occurred during 1987 in June and July, again composed chiefly of D. brachyurum. Annual means indicated no substantial yearly differences in cladoceran abundance. Spatial differences in densities between the sampling regions of L Lake were not detectable, with the exception of greater densities in Regions 4-6 when compared to Regions 7 and 8 during the summer abundance peak in 1987. No consistent downlake gradients were observed during the study regardless of reactor operating status. Densities for both years in all regions of L Lake were comparable to estimates in Par Pond (Chimney et al., 1985).

Figure 4-42 illustrates the monthly temporal pattern of cyclopoid plus calanoid copepods for the 2-year study period. There were several distinct abundance peaks, with densities ranging from near 0 to approximately 190 organisms/L. The copepods showed three peaks, April to August 1986, October 1986, and June to August 1987. During both years there was a seasonal shift in dominant species. Cyclopoids, which were numerically important early in the year, were replaced by calanoids during late summer. In 1986, the copepod community was dominated by nauplii instars from January to March, by the cyclopoid Mesocyclops edax and nauplii in April to June, by nauplii and lower numbers of both M. edax the Diaptomus genera in July, and by nauplii and Diaptomus from August to October . During 1987, a similar sequence was observed with the transition from Mesocyclops to Diaptomus dominance occurring in May.

The densities reported from L Lake are similar to earlier estimates from the surface waters of Par Pond (Chimney et al., 1985). Spatial differences among regions in L Lake reflect only the patchiness that typically characterizes the horizontal distribution of zooplankton in pelagic waters. Different sampling sites experienced peaks in abundance in an inconsistent manner. Furthermore, there was not a consistent downlake gradient detected in the distribution of copepods in the mixed layer. Reactor operations also did not appear to affect copepod distributions in the lake.

4.3.4.2 Comparison to Regional Lakes

Table 4-47 compares the L-Lake zooplankton community to other SRS impoundments and other southeastern U.S. lakes with respect to density and number of species. Densities of rotifers, cladocerans, and copepods were within the ranges reported for Par Pond, Pond B, and several other reservoirs in the region. L-Lake taxa richness values were also similar to or higher than those of other regional lakes.

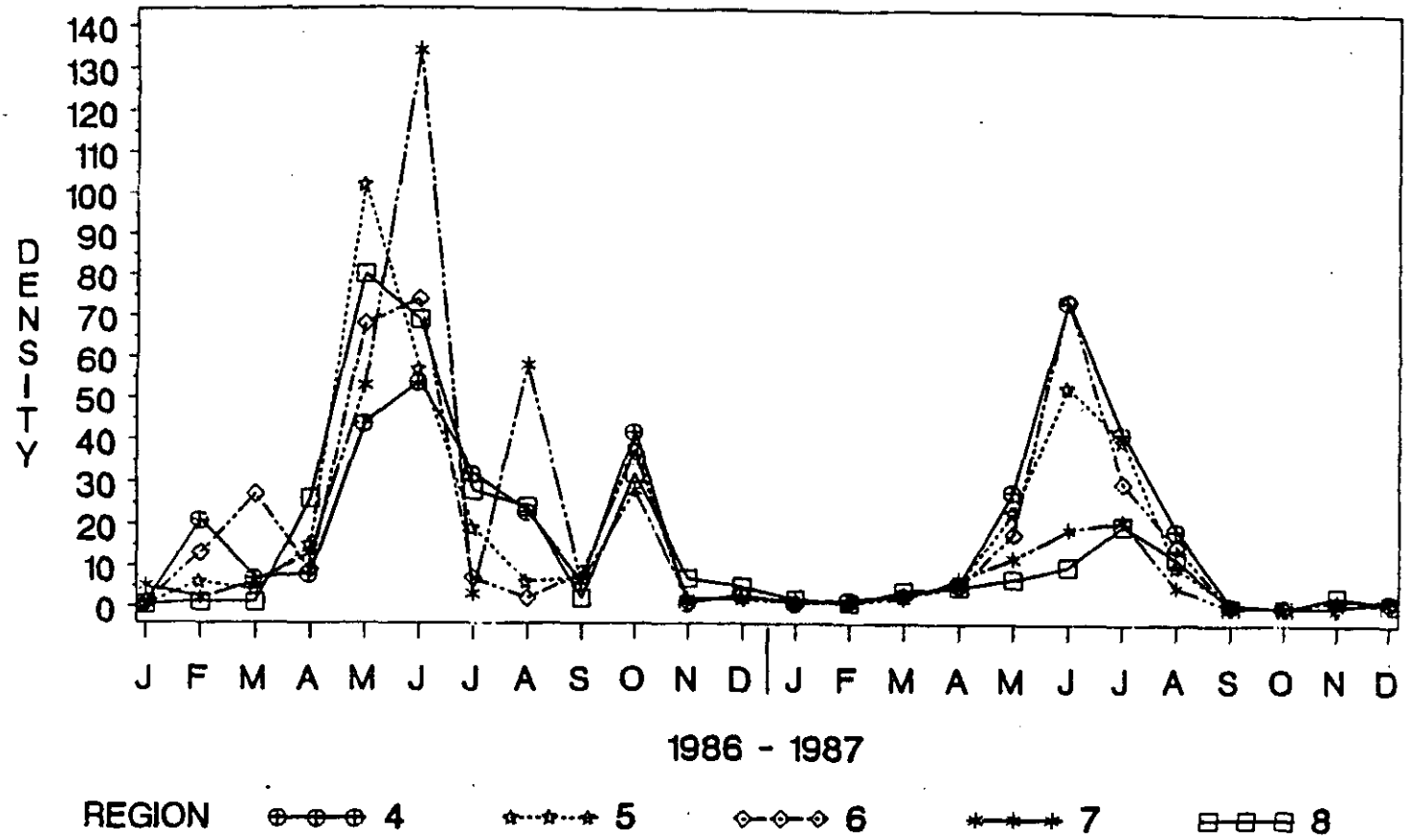

FIGURE 4-41. Mean Density of Cladocera (organisms/L) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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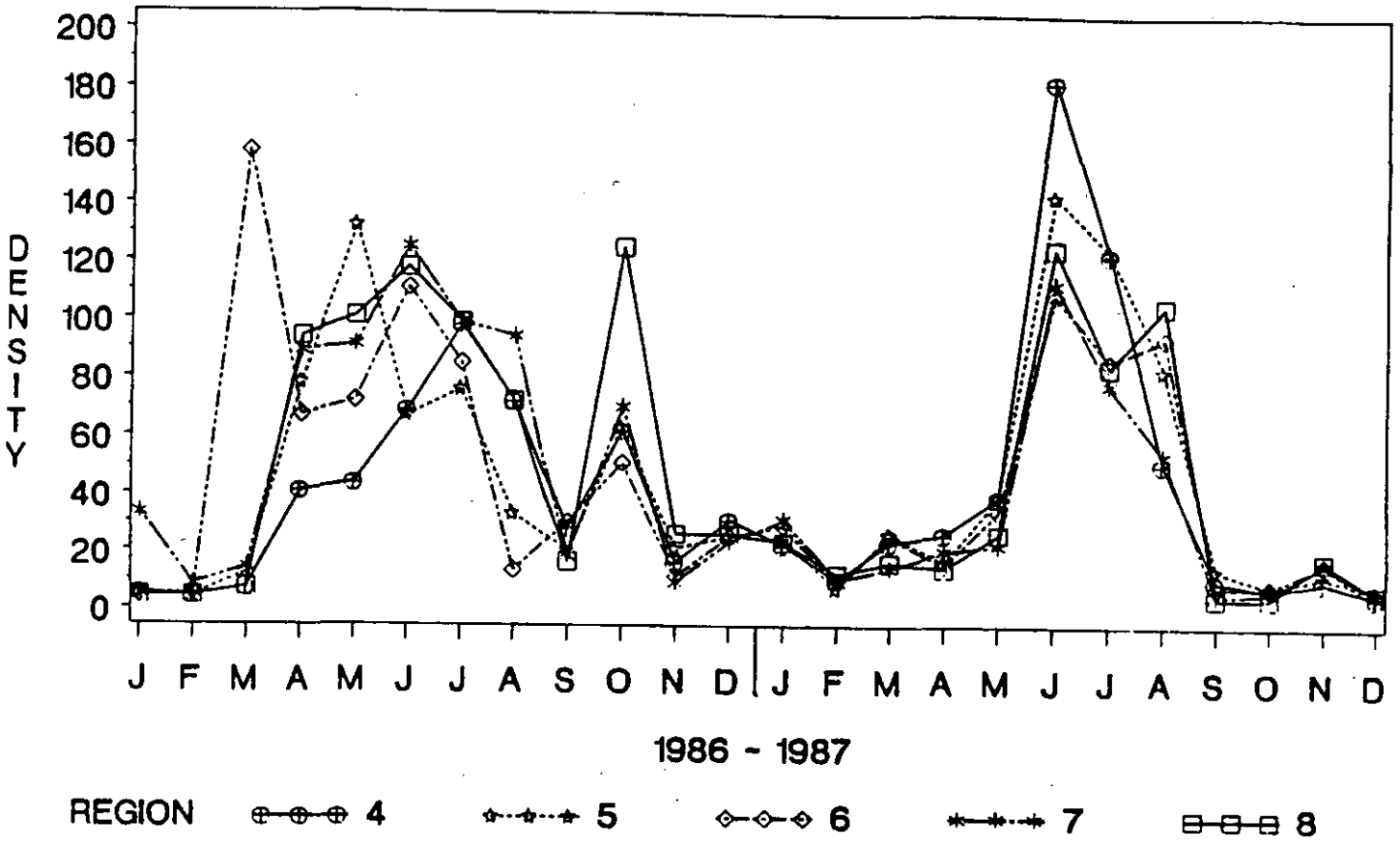

FIGURE 4-42. Mean Density of Copepoda (organisms/L) in the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8 (January 1986 - December 1987) (source: Gladden et al., 1988)

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This comparison of the zooplankton community in L Lake to zooplankton communities in other lakes of the region could not be accurately or precisely performed because of variations in sampling procedures. Sampling gear varies from trap devices to nets or closing-nets. Mesh size or aperture of the netting is crucial in capturing smaller microzooplankton. For example, in Table 4-47 many of the referenced studies used mesh sizes too coarse to collect Protozoa and smaller aloricate rotifers.

Protozoan densities were higher in L Lake than those in Par Pond and Pond B. One hypothesis to explain the differences is based upon the productivity of L Lake. Much of the primary production in the lake was associated with large densities of Microcystis, which is inedible to most herbivorous zooplankters. As such, Microcystis would then die off and sink in the water column where it would become particulate organic detritus and a nutritious substrate for bacteria. Both detritus and pelagic bacteria are important food resources for ciliated protozoans which could then exploit this large food source. Comparisons of these trends to other regional reservoirs are not possible because microzooplankton are inadequately sampled in most cases.

4.3.4.3 Status of Zooplankton Community

The zooplankton community of L Lake is numerically dominated by microzooplankton. The microzooplankton accounted for 103 species (59 protozoans and 44 rotifers) in 1986 and 88 species in 1987 (53 protozoans and 35 rotifers) out of the total of 125 species of zooplankton identified from L Lake samples in 1986-1987.

Numerically, the Protozoa dominated the zooplankton community in all regions and generally constituted at least 90% of all collected animals (Chimney, 1988). All dominant species in 1986 were ciliate protozoans (14 species). Ten of the 11 dominant species collected during 1987 were also ciliates. The rotifers ranked second in relative abundance, approximately 26%.

Zooplankton densities were always greater in the mixed layer than in the hypolimnion, which was anoxic for extended periods. Total densities of Rotifera, Cladocera, and Copepoda were comparable to previously observed densities in Par Pond. However, densities of Protozoa in L Lake were an order of magnitude greater than those in Par Pond and may have been supported by high densities of phytoplankton and pelagic bacteria.

Spatial and temporal variations of zooplankton in L Lake were typical of zooplankton in lakes and reservoirs in the southeastern United States, and may have resulted from the absence of a strong down-lake thermal gradient in Regions 4-8 during periods when L Reactor was operating. There were no apparent down-lake gradients in the epilimnion for taxa richness, total zooplankton density, or densities of Protozoa, Rotifera, Copepoda, or Cladocera. Changes in the numerical abundance of zooplankton did not

TABLE 4-47

Comparison of Zooplankton Density and Taxa Richness Data from the Mixed Zone of L-Lake Pelagic Sampling Stations, Regions 4-8, with Values from Other Savannah River Site Impoundments, Southeastern Lakes/Reservoirs, and Other Cooling Impoundments

	Maximum Total Density (no./L)	Minimum Total Density (no./L)	Number Protozoa Taxa	Number Rotifera Taxa	Number Cladocera Taxa	Number Copepoda Taxa	Number Total Taxa
This Study 1986							
L-Lake Region 4	35,350	3,288	42	31	9	8	91
L-Lake Region 5	29,330	3,004	47	28	10	9	95
L-Lake Region 6	24,389	95	46	27	9	8	91
L-Lake Region 7	37,009	3,593	43	30	8	7	89
L-Lake Region 8	41,673	2,238	43	28	11	8	91
All L-Lake regions	-[a]	-	59	44	12	9	125
This Study 1987							
L-Lake Region 4	29,851	2,983	44	27	9	7	88
L-Lake Region 5	32,065	3,101	40	26	8	7	82
L-Lake Region 6	32,756	4,033	39	24	8	6	78
L-Lake Region 7	40,400	2,441	42	27	7	7	84
L-Lake Region 8	30,444	4,016	40	21	8	6	76
All L-Lake regions	-	-	53	35	9	7	105
SRS Impoundments							
Par Pond[b]	4,054	205	79	68	11	6	164
Pond B[b]	3,102	169	58	44	4	9	115
Southeastern Lakes/Reservoirs							
Warrior Lake, AL[c]	600	10	11	38	15	4	68
Seminole Lake, FL[d]	1,275	<1	6	25	15	8	54
Lake Norman, NC[e]	190	<1	-	-	-	-	-
Lake Norman, NC[f]	267	15	-	45	28	11	84
Lake Robinson, SC[gh]	409	-	4	33	13	8	58
Clarks Hill Lake, SC[i]	311	6	2	31	19	7	59
Hartwell Lake, SC[j]	545	10	-	13	10	6	29
Lake Keowee, SC[k]	95	-	-	53	22	10	85
Lake Wylie, SC[e]	186	<1	-	33	34	12	79
Fishing Creek Res., SC[e]	49	<1	-	-	-	-	-
Wateree Lake, SC[e]	420	<1	-	-	-	-	-
Parr Reservoir, SC[l]	231	-	-	-	-	-	-
Monticello Reservoir, SC[l]	384	-	-	-	-	-	-
Lake Anna, VA[m]	-	-	-	42	17	12	71

TABLE 4-47, Contd

	Maximum Total Density (no./L)	Minimum Total Density (no./L)	Number Protozoa Taxa	Number Rotifera Taxa	Number Cladocera Taxa	Number Copepoda Taxa	Number Total Taxa
Other Cooling Impoundments							
Sunderland Reservoir, NE[n]	1,416	-	-	28	20	12	60
Dresden Cooling Lake, IL[o,p]	520	-	-	29	14	12	55
Lake Sangchris, IL[q]	-	-	-	29	28	10	67

[a] Data not available.
[b] Chimney et al. (1985).
[c] Harmon Engineering and Testing Co., Inc. (1983).
[d] Water and Air Research, Inc. (1982).
[e] Weiss et al. (1975).
[f] Duke Power Co. (1985c).
[g] Carolina Power and Light (1976).
[h] Mallin (1984).
[i] Applied Biology (1982).
[j] Carr and Assoc. (1982).
[k] Duke Power Co. (1977).
[l] Dames and Moore (1985).
[m] Saunders (1975).
[n] Nalco Environmental Science (1976).
[o] Ecological Analysts (1982).
[p] Lewis (1984).
[q] Waite (1981).

Source: Gladden et al. (1988)

correspond to changes in L-Reactor operations, including summer shutdowns. The principal effect of L Reactor on L-Lake zooplankton may have been to stimulate high phytoplankton production and bacterial densities that support high Protozoa densities.

Zooplankton community structure was typical of regional lakes with all trophic levels, primary consumers, primary carnivores, and omnivores present. Most of the species in L Lake are ubiquitous to the region and can tolerate a wide range of physiocochemical conditions, including thermal stress. Because juvenile instars of the macrozooplankton species and microzooplankton species having very short generation times were collected throughout the study period, successful reproduction of L-Lake zooplankton is quite evident.

4.3.4.4 Expected Impacts from Continued Operation of L Reactor

Since L-Reactor operations in 1986 and 1987 did not result in a measureable significant adverse impact to the zooplankton community of L Lake, the continued operation of L Reactor is not expected to adversely influence the existing zooplankton community of the lake.

4.3.5 L-Lake Macroinvertebrates

Macroinvertebrates were collected in five regions of L Lake (Figure 4-43) from January 1986 through December 1987 (O'Hop and Lauritsen, 1988). Triplicate benthic macroinvertebrates were collected monthly at 2 and 4 meter depths using a petite ponar grab sampler, and nighttime meroplankton samples were collected monthly with plankton nets. Adult insects were collected monthly using emergence traps. In addition, profundal benthic samples, daytime and nighttime meroplankton samples, and dip net samples were collected quarterly in each of the five lake regions. Detailed sampling methods for the L-Lake macroinvertebrate program can be found in O'Hop and Lauritsen (1988); macroinvertebrate data are summarized in Gladden et al. (1988).

4.3.5.1 Ponar Dredge Sampling Program

In 1986 and 1987, a total of 130 macroinvertebrate taxa were collected in L Lake from all sampling methods combined (Table 4-48). The most abundant taxa collected from the benthos include three chironomid taxa: Tribes Chironomini (60.3 to 77.4%) and Tanytarsini (7.5 to 14.9%), and Subfamily Tanypodinae (1.6 to 4.1%; Table 4-49). Also abundant were oligochaete worms (3.7 to 13.4%) and the phantom midge Chaoborus punctipennis (<1 to 2.9%). The amphipod, Hyalella azteca, was abundant in 1986 (4.0 to 11.8%) but declined to <0.1% of the organisms collected in 1987. This species is often associated with aquatic vegetation (Pennak, 1978), and densities may remain low until aquatic macrophytes become well established in the lake. Most of the other taxa collected in the ponar samples each accounted for less than 1% of the organisms collected.

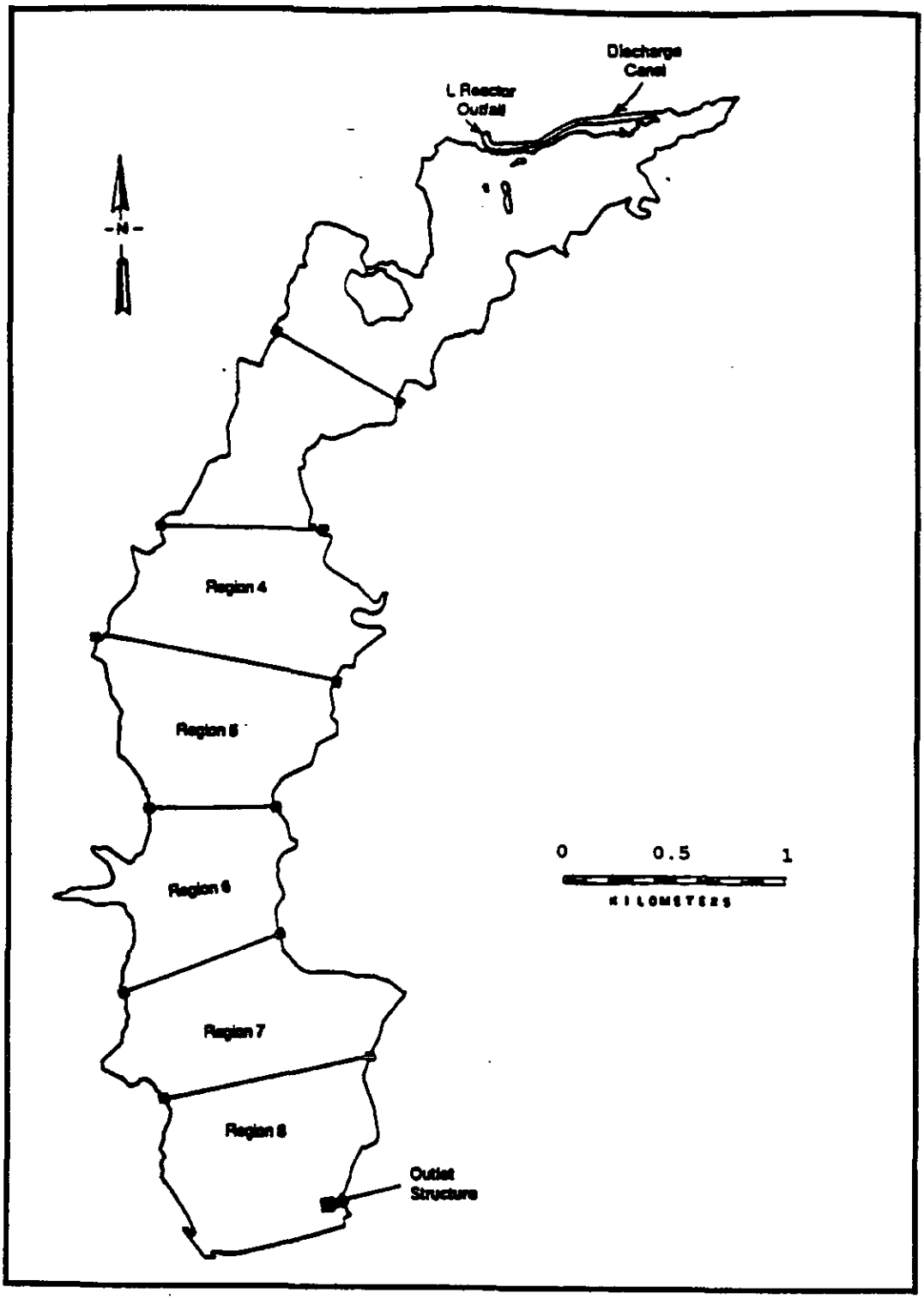

FIGURE 4-43. Macroinvertebrate Sampling Locations in L Lake (January 1986 - December 1987) (source: Gladden et al., 1988)

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TABLE 4-48

Macroinvertebrate Taxa Found in Regions 4-8 of L Lake (January 1986 - December 1987)

Taxon	Common Name	Functional Group	1986[d]	1987[d]
Coelenterata	Hydra			
Hydra		P	P	
Turbellaria	Flat worms	P	D P	P
Nematoda	Round worms	CG	D P	M D P
Hirudinea	Leeches	P	D P	D P
Oligochaeta (unid.)	Segmented worms	CG	M D P	M D P
Naididae (unid.)		CG	M	
Stylaria lacustris		CG	M	M D
Hydracarina	Water mites	P	M D P	M D P
Amphipoda	Scuds	CG		P
Gammaridae				
Gammarus fasciatus		CG	D P	
Talitridae				
Hyalella azteca		CG	M D P	M D P
Isopoda	Isopods			
Asellidae				
Asellus		CG	D	P
Decapoda	Crayfish			
Palaemonetes paludosus		Sh	D P	D
Gastropoda (unid.)	Snails	Sc	D P	D P
Ancylidae (unid.)		Sc	D P	P
Ferrissia rivularis		Sc	P	
Pseudosuccinea columella		Sc	D P	D
Planorbidae (unid.)		Sc	D P	P
Helisoma sp.		Sc	D P	
H. trivolvis		Sc	D P	D P
Menetus dilatatus		Sc	D P	D P
Physidae				
Physella heterostropha		Sc	D	D
Bivalvia	Clams			
Sphaeriidae		CF		P
Corbiculidae				
Corbicula fluminea		CF	P	
Ephemeroptera	Mayflies			
Baetidae				
Baetis sp.		CG	D	D
Callibaetis sp.		CG		D
Caenidae (unid.)		CG	E	
Caenis sp.		CG	M D P E	D P

TABLE 4-48, Contd

Taxon	Common Name	Functional Group	1986[d]	1987[d]
Ephemeroptera, Contd				
Heptageniidae		CG		M
Hexageniidae				
Hexagenia		CG		P
Coleoptera	Beetles			
Hydrophilidae (unid.)		P	D	
Berosus		PH	D P	P
Gyrinidae				
Dineutus		P	M D P	
Gyrinus sp.		P		D
Dytiscidae				
Coptotomus		P	D	
Hydroporus		P	D	
Elmidae				
Ancyronyx variegatus		CG		P
Macronychus glabratus		CG	D	D
Noteridae				
Suphisellus		P	D	D
Diptera (unid.)	True flies	CG[a]	M P E	
Ceratopogonidae (unid.)	Biting midges	P	M P E	D P E
Ceratopogoniinae		P	M D P	D P
Forcipomyiinae		P	M D	D P
Chaoboridae	Phantom midges	P		
Chaoborus punctipennis		P	M D P E	M D P E
Chironomidae (unid.)	Midges	CG[a]	D E	M D P E
Tanypodinae (unid.)		P	M D P	P E
Ablabesmyia monilis		P	E	
A. ramphe		P	E	
A. cinctipes		P	E	E
Ablabesmyia spp.		P	E	E
Labrundinia becki		P	E	E
L. pilosella		P	E	E
Pentaneura inconspicua		P		E
Procladius sp.		P	E	
P. bellus		P	E	E
P. subletti		P	E	E
Tribe Pentaneurini (unid.)		P	E	
Orthocladiinae (unid.)		CG	M D P E	M D P
Cricotopus sp. 1		CG	E	E
C. sp. 2		CG	E	E
C. sp. 3		CG		E
C. sp. 4		CG		E
C. cf. *vierriensis*		CG		E

TABLE 4-48, Contd

Taxon	Common Name	Functional Group	1986[d]	1987[d]
Chironomidae, Contd	Midges			
Nanocladius cf. distinctus		CG	E	E
N. cf. mallochi		CG		E
Parakiefferiella cf. coronata		CG	E	E
Parakiefferiella sp.		CG		E
Psectrocladius sp.		CG		E
Thienemanniella sp.		CG		E
Tribe Corynoneurini (unid.)		CG	E	
Corynoneura sp. 1		CG		E
Chironominae				
Tribe Chironomini (unid.)		CG[a]	M D P E	M D P E
Asheum becki		CG		E
Cladopelma edwardsi		CG		E
Chironomus crassicaudatus		CG	E	E
C. decorus gr. sp. 1		CG	E	
C. decorus gr. sp. 2		CG	E	
Cryptochironomus cf. blarina		P	E	E
C. cf. sorex		P	E	E
Dicrotendipes modestus		CG	E	E
D. neomodestus		CG	E	E
D. nervosus		CG	E	E
Endochironomus nigricans		Sh	E	E
E. subtendens		Sh	E	E
Glyptotendipes sp.		Sh	E	
G. barbipes		Sh	E	E
G. lobiferus		Sh	E	E
G. paripes		Sh	E	E
Goeldichironomus carus		CG		E
Nilothauma babiyi		CG		E
Parachironomus carinatus		P	E	E
P. monochromus		P	E	E
P. potamogeti		P	E	E
P. tenuicaudatus		P		E
Phaenopsectra punctipes		Sc	E	
P. flavipes		Sc	E	
Polypedilum sp.		Sh	E	
P. cf. convictum		Sh	E	
P. digitifer		Sh	E	E
P. griseopunctatum		Sh	E	E
P. illinoense		Sh		E
P. halterale		Sh		E
P. scalaenum		Sh		E
P. simulans		Sh	E	E
Pseudochironomus sp.		CG	E	E
P. fulviventris		CG		E

TABLE 4-48, Contd

Taxon	Common Name	Functional Group	1986[d]	1987[d]
Chironomidae, Contd	Midges			
Stenochironomus sp.		CG	P	DP
S. macateei		CG		E
Xestochironomus subletti		CG		E
Zavreliella varipennis		CG	E	
Tribe Tanytarsini (unid.)		CF	M D P E	M D P E
Cladotanytarsus cf. *viridiventris*		CG	E	E
Rheotanytarsus cf. *exiguus*		CF	E	E
Tanytarsus sp. 1		CF	E	
T. sp. 2		CF	E	
T. sp. 3		CF	E	
T. sp. 4		CF	E	
T. cf. *curticornis* gr.		CF		E
Tanytarsus spp.		CF		E
Ephydridae	Shore flies	CG	E	D P E
Stratiomyidae	Soldier flies	CG	E	
Psychodidae	Moth flies	CG		
Psychoda alternata		P	D	D
Empididae	Dance flies	P	D P	D P
Hemerodromia sp.		P		D E
Tipulidae (unid.)	Crane flies	Sh[a]	D	D
Erioptera sp.		CG	D	D
Tipula		Sh	D	
Simuliidae (unid.)	Black flies	P		
Simulium		CF	M D P	
Tabanidae	Horse flies	P	P	
Dixidae	Dixid midges			
Dixa		CG		P
Dolichopodidae		P		D
Scathophagidae		Sh		D
Odonata	Dragon flies and Damsel flies			
Anisoptera (unid.)		P	P	D P
Libellulidae				
Pachydiplax longipennis		P	D P	
Perithemis sp.		P	D P	P
P. tenera		P	E	
Libellula sp.		P	P	
Gomphidae (unid.)		P		P
Corduliidae (unid.)		P	P	
Epicordulia regina		P	P	
Zygoptera (unid.)		P	P	
Argia sp.		P	D	
Enallagma sp.		P	D P	D P
Ischnura sp.		P	E	
Lepidoptera (unid.)	Moths	Sh		D
Pyralidae			D	

TABLE 4-48, Contd

Taxon	Common Name	Functional Group	1986[d]	1987[d]
Hemiptera	True bugs			
Belostomatidae				
Belostoma		P	D	
Corixidae (unid.)		P	P	
Trichocorixa		P	D	
Palmacorixa		P	D	
Trichoptera	Caddisflies			
Leptoceridae (unid.)		Sh	E	P
Nectopsyche candida		Sh	D	
Oecetis sp.		P	D P E	D P E
O. cinerascens		P	E	
Triaenodes sp.		Sh		E
Hydropsychidae				
Cheumatopsyche		CF	P	
Psychomyiidae				
Lype diversa		CG	P	
Philopotamidae				
Chimarra		CF	P	
Polycentropodidae				
Phylocentropus		CF	P	
Hydroptilidae (unid.)			E	D P
Hydroptila sp.		PH		D P E
Neotrichia		?[b]	P	P
Orthotrichia		PH	P E	D P
Oxyethira sp.		PH		D P E
Collembola	Spring tails	CG	P	DP
Hymenoptera	Wasps			
Trichogrammatidae		P	E	
Total			103[c,e]	99[c,a]

[a] Taxon includes more than one functional group; the most common functional group is listed. CG = Collector-Gatherer; CF = Collector-Filterer; P = Predator; Sh = Shredder; SC = Scraper; PH = Piercer-Herbivore

[b] Feeding habits have not been determined.

[c] All *Tanytarsus* spp. pooled because of differences in taxonomic resolution between years.

[d] Letters indicate the type of sampling in which each taxon was found: M = meroplankton; P = ponar grab; E = emergence trap; D = dip net.

[e] Higher level taxa and unidentified taxa were not included in total taxa count if lower level taxa were present.

Source: Gladden et al. (1988)

TABLE 4-49

Mean Annual Percentage Composition (Relative Abundance) of Benthic Macroinvertebrates Collected at 2-m and 4-m Depths in Regions 4-8 of L Lake (January 1986-December 1987)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1986		
Hydra	<0.1	<0.1	<0.1	<0.1	0.1
Turbellaria	0.1	0.2	0.2	0.1	0.1
Nematoda	0.3	0.3	1.0	1.0	0.3
Oligochaeta	9.2	8.9	8.4	3.7	7.3
Hirudinea	0.0	<0.1	0.0	0.0	0.0
Gastropoda	0.2	<0.1	0.1	<0.1	<0.1
Family Ancylidae	0.1	0.1	0.2	0.0	<0.1
Ferrissia rivularis	<0.1	0.0	<0.1	0.0	0.0
Pseudosuccinea columella	<0.1	0.0	0.0	<0.1	0.0
Physella heterostropha	0.2	0.2	0.1	0.1	0.1
Family Planorbidae	<0.1	0.0	<0.1	0.0	0.0
Helisoma spp.	0.0	0.0	0.0	<0.1	0.0
Helisoma trivolvis	<0.1	0.0	<0.1	0.0	<0.1
Menetus dilatatus	0.5	0.1	0.5	<0.1	0.2
Corbicula fluminae	1.0	0.0	0.0	0.0	0.0
Hydracarina	<0.1	<0.1	0.1	0.1	<0.1
Gammarus fasciatus	<0.1	0.0	0.0	0.0	0.0
Hyalella azteca	11.8	5.3	7.4	4.0	8.6
Palaemonetes paludosus	0.0	0.0	<0.1	0.0	0.0
Collembola	0.0	<0.1	0.0	0.0	0.0
Caenis	0.2	0.1	0.5	0.2	<0.1
Anisoptera	<0.1	0.0	<0.1	0.0	<0.1
Family Corduliidae	0.0	0.0	<0.1	0.0	0.0
Epicordulia regina	0.0	0.0	<0.1	0.0	0.0
Libellula spp.	0.0	0.0	0.0	<0.1	0.0
Pachydiplax longipennis	<0.1	0.0	0.0	0.0	0.0
Perithemis	<0.1	0.0	<0.1	<0.1	0.0
Zygoptera	<0.1	0.0	0.0	0.0	0.0
Enallagma spp.	0.0	<0.1	<0.1	0.0	<0.1
Family Corixidae	<0.1	0.0	0.0	0.0	0.0
Dineutes	0.0	0.0	<0.1	0.0	0.0
Berosus	0.1	<0.1	0.1	<0.1	<0.1
Cheumatopsyche spp.	<0.1	0.0	0.0	0.0	0.0
Neotrichia	0.0	0.0	<0.1	0.0	0.0
Orthotrichia	0.0	0.0	0.0	0.0	<0.1
Oecetis	0.4	0.4	0.4	0.3	0.3
Chimarra	0.0	0.0	<0.1	<0.1	0.0
Phylocentropus	0.0	0.0	0.0	0.0	<0.1
Lype diversa	0.0	0.0	0.0	0.0	<0.1
Diptera	0.0	0.0	0.0	0.0	<0.1
Chaoborus punctipennis	0.7	0.7	0.6	0.8	0.6
Family Simuliidae	0.0	0.0	0.0	0.1	0.0
Simulium	<0.1	<0.1	0.0	0.0	<0.1
Subfamily Ceratopogoniinae	1.0	1.0	1.9	1.2	0.5
Tribe Chironomini	60.3	63.5	60.7	70.8	66.9
Stenochironomus	0.0	<0.1	0.1	<0.1	0.0
Tribe Tanytarsini	10.7	14.9	14.2	13.7	11.8
Subfamily Orthocladiinae	<0.1	0.1	0.1	0.2	0.1
Subfamily Tanypodinae	3.2	4.1	3.3	3.8	3.1
Family Tabanidae	0.0	0.0	0.0	0.0	<0.1
Family Stratiomyidae	0.0	<0.1	0.0	0.0	0.0
Family Empididae	<0.1	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0

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TABLE 4-49, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1987		
Turbellaria	<0.1	<0.1	<0.1	<0.1	<0.1
Nematoda	0.7	0.4	0.5	0.3	0.2
Oligochaeta	9.1	8.4	13.4	11.4	9.6
Hirudinea	<0.1	<0.1	<0.1	<0.1	<0.1
Gastropoda	0.0	<0.1	0.0	0.0	0.0
Family Ancylidae	<0.1	<0.1	<0.1	<0.1	<0.1
Family Planorbidae	<0.1	<0.1	0.1	<0.1	<0.1
Helisoma trivolvis	<0.1	<0.1	<0.1	<0.1	0.0
Menetus dilatatus	<0.1	<0.1	<0.1	<0.1	<0.1
Corbicula fluminea	0.0	<0.1	0.0	0.0	<0.1
Family Sphaeriidae	<0.1	0.0	0.0	0.0	0.0
Hydracarina	0.1	<0.1	0.1	<0.1	<0.1
Asellus	<0.1	0.0	0.0	0.0	0.0
Amphipoda	0.0	<0.1	0.0	0.0	0.0
Hyalella azteca	<0.1	<0.1	<0.1	<0.1	<0.1
Collembola	0.0	0.0	<0.1	0.0	0.0
Caenis	0.2	0.2	0.3	0.1	0.1
Hexagenia	0.0	0.0	0.0	0.0	<0.1
Anisoptera	<0.1	<0.1	<0.1	<0.1	<0.1
Family Gomphidae	<0.1	0.0	0.0	0.1	0.0
Perithemis	0.0	0.0	0.0	0.1	0.0
Enallagma spp.	0.0	0.0	0.0	0.0	<0.1
Ancyronyx variegatus	0.0	0.0	0.0	0.0	<0.1
Berosus	0.0	0.0	0.0	<0.1	0.0
Family Hydroptilidae	0.0	0.0	0.0	<0.1	0.0
Neotrichia	<0.1	0.0	0.0	0.0	0.0
Orthotrichia	<0.1	<0.1	<0.1	<0.1	0.0
Oxyethira	0.0	<0.1	0.0	0.0	0.0
Oecetis	0.2	0.2	0.1	0.2	0.1
Diptera	0.0	0.0	0.0	<0.1	0.0
Dixa	0.0	0.0	<0.1	0.0	0.0
Chaoborus punctipennis	2.5	2.9	1.6	2.8	2.6
Subfamily Ceratopogoniinae	0.8	0.7	2.4	0.8	0.5
Subfamily Forcipomyiinae	<0.1	0.0	<0.1	<0.1	0.0
Family Chironomidae	0.0	0.0	0.0	0.0	<0.1
Tribe Chironomini	75.4	77.4	64.7	71.2	73.9
Stenochironomus	0.0	<0.1	<0.1	<0.1	0.0
Tribe Tanytarsini	8.7	7.5	12.8	10.3	11.1
Subfamily Orthocladiinae	0.1	0.1	0.2	0.2	0.1
Subfamily Tanypodinae	1.9	2.2	3.7	2.4	1.6
Family Empididae	0.0	0.0	0.0	0.0	<0.1
Family Ephydridae	0.0	0.0	0.0	0.0	<0.1
Total	100.0	100.0	100.0	100.0	100.0

Source: Gladden et al. (1988)

In 1986, mean annual benthic macroinvertebrate densities in the littoral areas of L Lake ranged from 3956 to 4472 organisms/m^2 (Table 4-50). Densities in 1987 were substantially higher, ranging from 7,673 to 8,676 organisms/m^2 (Table 4-50). These densities are somewhat higher than those reported for Par Pond (3416.0 to 7224.8 organisms/m^2; Wilde, 1987). Mean annual standing crop (ash-free dry weight) ranged from 0.75 to 0.91 g/m^2 in 1986 (Table 4-50). In 1987, the macroinvertebrate standing crop increased by about 80%, ranging from 1.26 to 1.45 g/m^2 (Table 4-50).

With the exception of lower densities of organisms in Region 8 in 1987, no major differences were observed among the five sampling regions. The lower densities in Region 8 were probably due to the dense clay substrate that predominates in this area of the lake. Region 4 was not distinguishable from the remaining four regions, and no regional differences were apparent that might be attributed to L-Reactor operations.

In order to examine the trophic structure of the L-Lake macroinvertebrate community, macroinvertebrates were separated into functional feeding groups, using the classification system developed by Merritt and Cummins (1984). In both years, the benthic macroinvertebrate community of L Lake was dominated numerically by collector-gatherers (primarily chironomids and oligochaetes), which accounted for 78.1 to 86.4% of the organisms collected (Table 4-51). Collector-filterers (mostly Tanytarsini chironomids) were the second most abundant functional group, accounting for 7.5 to 14.9% of the benthic organisms (Table 4-51). Predators were the third most abundant functional feeding group (4.7 to 7.9%), while the remaining functional groups combined usually accounted for less than 1% of the benthic macroinvertebrate community.

Functional groups were also compared with respect to biomass (Table 4-51). Collector-gatherers contributed most of the total macroinvertebrate biomass in all regions of L Lake in both years, ranging from 90.4 to 95.3% of the total biomass. Although predators were numerically less abundant than the collector-filterers, they contributed a larger percentage of the biomass (2.8 to 5.4%) vs. (1.4 to 2.9%; Table 4-51). This difference was due to the generally larger size of most predacious taxa. The remaining functional groups combined usually accounted for less than 1% of the total macroinvertebrate biomass (Table 4-51).

The five regions of L Lake were similar with respect to functional feeding group composition and biomass. Region 6 differed slightly from the other regions in 1987, with a greater percentage of collector-filterers, predators, and nonchironomid collector-gatherers (O'Hop and Lauritsen, 1988). These differences were probably due to localized habitat differences and were not attributed to reactor operations.

TABLE 4-50

Mean Annual Density (no./m^2) and Biomass (g AFDW/m^2) of Benthic Macroinvertebrates in Regions 4-8 of L Lake (January 1986-December 1987). Sampling was conducted at 2-m and 4-m depths in each region.

Density (no./m^2)

Region	1986	1987
4	4,091.9	8,066.4
5	4,072.8	8,676.3
6	4,471.6	8,481.9
7	3,955.5	8,503.2
8	3,955.8	7,672.5

Biomass (g AFDW/m^2)

Region	1986	1987
4	0.768	1.307
5	0.907	1.421
6	0.764	1.248
7	0.755	1.449
8	0.749	1.255

Source: Gladden et al. (1988)

TABLE 4-51

Percent Abundance[a] of Benthic Macroinvertebrate Functional Groups and Functional Group Biomass in Regions 4-8 of L Lake (January 1986 - December 1987)

Numerical Percent Composition

Functional Group	Region 4	5	6	7	8	4	5	6	7	8
	1986					1987				
Collector-gatherers	81.8	78.1	78.1	79.8	83.2	85.6	86.4	79.1	83.3	83.9
Collector-filterers	11.7	14.9	14.2	13.8	11.8	8.7	7.5	12.8	10.3	11.1
Scrapers	1.1	0.4	1.0	0.2	0.3	<0.1	<0.1	0.1	0.1	<0.1
Predators (engulfers)	5.4	6.6	6.4	6.2	4.7	5.5	6.0	7.9	6.2	4.9
Piercer-herbivores	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0
Shredders	0.0	<0.1	0.1	<0.1	<0.1	0.0	<0.1	<0.1	<0.1	0.0
Piercer-carnivores	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Total	100.0	100.0	99.9	100.0	100.0	99.9	99.8	99.9	99.9	99.9

Biomass Percent Composition

Functional Group	Region 4	5	6	7	8	4	5	6	7	8
	1986					1987				
Collector-gatherers	93.4	92.8	90.4	93.2	94.0	95.0	95.3	91.8	94.8	94.9
Collector-filterers	1.7	2.3	2.9	2.4	2.0	1.7	1.4	2.6	1.7	2.2
Scrapers	0.7	0.2	0.8	0.4	0.4	<0.1	<0.1	<0.1	<0.1	<0.1
Predators (engulfers)	3.6	3.9	4.7	3.8	3.3	3.3	3.2	5.4	3.4	2.8
Piercer-herbivores	0.8	0.8	1.2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Shredders	0.0	<0.1	<0.1	<0.1	0.0	0.0	<0.1	<0.1	<0.1	0.0
Piercer-carnivores	<0.1	<0.1	<0.1	<0.1	0.0	<0.1	<0.1	<0.1	<0.1	<0.1
Total	100.2	100.0	100.1	99.9	99.8	100.0	99.9	99.8	99.9	99.9

[a] Columns may not add to 100%, due to rounding.

Source: Gladden et al. (1988)

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4.3.5.2 Meroplankton

The meroplankton community of L Lake was dominated by Chaoborus punctipennis, which comprised 94.1 to 99.6% of the macroinvertebrates collected from the water column (Table 4-52). Chaoborus is a predatory dipteran that lives in the substrate during the day and migrates up into the water column at night to feed on zooplankton. Most of the other taxa collected in the meroplankton samples were either chironomids or oligochaetes (Table 4-52). Mean densities of meroplankton in L Lake ranged from 17,168.6 to 29,377.5 organisms/1000 m^3 in 1986 and were almost an order of magnitude higher in 1987, ranging from 112,996.5 to 206,486.4 organisms/1000 m^3 (Table 4-52). In both years, meroplankton densities tended to be higher in the upper regions of the lake and lower near the dam. This difference is not believed to be related to reactor operations, but rather was related to differences in water depth. Because meroplankton were collected with vertical tows, greater volumes of water were sampled in deeper regions of the lake than in the shallower up-lake regions. Therefore, on an areal basis, an equivalent density of Chaoborus larvae (no./m^2) would translate into fewer Chaoborus on a volume basis (no./m^3). Chaoborus occurs in high densities in many reservoirs. Meroplankton densities in L Lake in 1986 were comparable to those reported for Par Pond (see Section 4.5.5), but densities in L Lake in 1987 were much higher than those in Par Pond. Newly colonized habitats often exhibit wide fluctuations in population densities (McLachlan, 1974), and it is likely that meroplankton densities in the lake will stabilize as the ecosystem matures.

4.3.5.3 Dip Net Sampling

Quarterly dip net samples were collected in near-shore areas in L Lake to augment the benthic macroinvertebrate species list. The dip net program collected 19 taxa not collected by any other sampling program (Table 4-48). These additional taxa consisted mainly of nonchironomid dipterans, beetles, odonates, gastropods, and small crustaceans.

4.3.5.4 Emergence Sampling

A total of 79 taxa of aquatic insects were collected from emergence traps in L Lake (Table 4-48). Chironomids dominated the emergence collections in all regions, (Table 4-53). The dominant genera of chironomids in the emergence traps were Glyptotendipes, Tanytarsus, Polypedilum, Ablabesmyia, Endochironomus, Parakiefierella, Cricotopus, and Procladius (Table 4-53). The phantom midge, Chaoborus punctipennis, was also frequently collected in the emergence traps. Four genera of Trichoptera (Hydroptila, Oxyethira, Oecetis, and Trianodes) were also collected often, but in relatively low numbers in the emergence traps, while most of the remaining taxa listed in Table 4-53 were collected infrequently.

TABLE 4-52

Meroplankton Mean Density (no./1,000 m^3; averaged over all samples) for Regions 4-8 of L Lake (January 1986 - December 1987)

Taxon	Region 4 Mean Density	Region 4 Percentage Density[a]	Region 5 Mean Density	Region 5 Percentage Density	Region 6 Mean Density	Region 6 Percentage Density	Region 7 Mean Density	Region 7 Percentage Density	Region 8 Mean Density	Region 8 Percentage Density
					1986					
Oligochaeta	557.9	(2.1)	499.1	(1.7)	645.1	(3.1)	355.1	(1.5)	246.3	(1.4)
Hydracarina	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	29.5	(0.1)	0.0	(0.0)
Amphipoda										
Hyalella azteca	50.1	(0.2)	94.3	(0.3)	269.7	(1.3)	125.4	(0.5)	63.7	(0.4)
Ephemeroptera										
Caenis	11.8	(<0.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Coleoptera										
Dineutus	0.0	(0.0)	0.0	(0.0)	17.7	(0.1)	0.0	(0.0)	0.0	(0.0)
Diptera										
Chaoborus punctipennis	25,713.0	(96.2)	28,586.8	(97.3)	19,841.0	(94.5)	22,600.3	(94.1)	16,809.1	(97.9)
Simulium	0.0	(0.0)	17.7	(0.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Family Ceratopogonidae										
Subfamily Ceratopogoniinae	0.0	(0.0)	0.0	(0.0)	17.7	(0.1)	17.7	(0.1)	0.0	(0.0)
Subfamily Forcipomyiinae	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	70.7	(0.3)	0.0	(0.0)
Subfamily Chironominae										
Family Chironomidae										
Tribe Chironomini	314.1	(1.2)	74.3	(0.3)	146.4	(0.7)	538.5	(2.2)	37.7	(0.2)
Tribe Tanytarsini	47.4	(0.2)	0.0	(0.0)	16.3	(0.1)	0.0	(0.0)	0.0	(0.0)
Subfamily Orthocladiinae	0.0	(0.0)	23.6	(0.1)	16.3	(0.1)	240.6	(1.0)	0.0	(0.0)
Subfamily Tanypodinae	33.4	(0.1)	81.7	(0.3)	15.2	(0.1)	30.9	(0.1)	11.8	(0.1)
Total	26,727.7	(100.0)	29,377.5	(100.0)	20,985.3	(100.0)	24,008.8	(100.0)	17,168.6	(100.0)

M890070

TABLE 4-52, Contd

Taxon	Region 4 Mean Density	Region 4 Percentage Density	Region 5 Mean Density	Region 5 Percentage Density	Region 6 Mean Density	Region 6 Percentage Density	Region 7 Mean Density	Region 7 Percentage Density	Region 8 Mean Density	Region 8 Percentage Density
					1987					
Nematoda	0.0	(0.0)	0.0	(0.0)	15.2	(<0.1)	0.0	(0.0)	0.0	(0.0)
Oligochaeta	944.5	(0.5)	185.3	(0.1)	444.4	(0.3)	134.2	(0.1)	108.9	(0.1)
Hydracarina	0.0	(0.0)	33.6	(<0.1)	0.0	(0.0)	11.8	(<0.1)	0.0	(0.0)
Amphipoda										
Hyalella azteca	21.2	(<0.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Ephemeroptera										
Family Heptageniidae	0.0	(0.0)	18.5	(<0.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Diptera										
Chaoborus punctipennis	202,974.3	(98.3)	179,168.9	(98.8)	156,664.8	(99.3)	136,630.6	(99.6)	111,092.9	(98.3)
Family Chironomidae	17.7	(<0.1)	0.0	(0.0)	14.1	(<0.1)	0.0	(0.0)	0.0	(0.0)
Subfamily Chironominae										
Tribe Chironomini	1044.9	(0.5)	1,693.1	(0.9)	432.1	(0.3)	332.6	(0.2)	1750.1	(1.5)
Tribe Tanytarsini	1252.8	(0.6)	35.7	(<0.1)	65.6	(<0.1)	29.3	(<0.1)	12.1	(<0.1)
Subfamily Orthocladiinae	21.2	(<0.1)	54.6	(<0.1)	0.0	(0.0)	12.7	(<0.1)	20.4	(<0.1)
Subfamily Tanypodinae	209.8	(0.1)	84.6	(<0.1)	65.3	(<0.1)	67.1	(<0.1)	12.1	(<0.1)
Total	206,486.4	(100.0)	181,274.3	(100.0)	157,701.5	(100.0)	137,218.2	(100.0)	112,996.5	(100.0)

[a] Percentage of total organisms collected is indicated in parentheses.

Source: Gladden et al. (1988)

M890070

TABLE 4-53

Mean Annual Emergence Rates (no./m^2/day) in Regions 4-8 of L Lake (January 1986 - December 1987)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1986		
Perithemis tenera	0.03	0.00	0.00	0.01	0.00
Ischnura spp.	0.01	0.00	0.00	0.03	0.00
Family Caenidae	0.11	0.00	0.06	0.03	0.00
Caenis spp.	0.01	0.00	0.00	0.01	0.00
Family Hydroptilidae	0.06	0.00	0.01	0.01	0.03
Orthotrichia	0.00	0.01	0.00	0.00	0.00
Family Leptoceridae	0.00	0.01	0.00	0.00	0.04
Oecetis spp.	0.10	0.07	0.03	0.03	0.00
Oecetis cinerascens	0.00	0.00	0.00	0.01	0.00
Diptera	0.00	0.00	0.01	0.00	0.00
Chaoborus punctipennis	0.01	0.01	0.11	0.04	0.04
Family Ceratopogonidae	0.03	0.06	0.00	0.01	0.03
Family Chironomidae	0.91	1.47	2.01	0.60	0.77
Ablabesmyia spp.	0.00	0.01	0.06	0.03	0.00
Ablabesmyia (A.) monilis	0.00	0.00	0.00	0.00	0.01
Ablabesmyia (A.) ramphe	0.00	0.00	0.00	0.01	0.00
Ablabesmyia (K.) cinctipes	2.88	1.69	1.22	1.32	0.63
Labrundinia becki	0.00	0.00	0.00	0.03	0.01
Labrundinia pilosella	0.16	0.03	0.03	0.14	0.01
Procladius spp. (unid.)	0.00	0.01	0.00	0.01	0.00
Procladius (P.) bellus	0.01	0.01	0.00	0.00	0.00
Procladius (H.) sublettei	0.61	0.51	0.60	0.46	0.48
Tribe Pentaneurini (unid.)	0.03	0.01	0.03	0.07	0.01
Subfamily Orthocladiinae	0.03	0.06	0.01	0.03	0.00
Cricotopus (C.) sp. 1	0.16	0.37	0.97	0.21	0.17
Cricotopus (C.) sp. 2	0.00	0.03	0.00	0.00	0.01
Manocladius (N.) cf. distinctus	0.00	0.03	0.03	0.01	0.00
Parakiefferiella cf. coronata	0.13	0.14	0.06	0.11	0.07
Tribe Corynoneurini	0.00	0.00	0.00	0.00	0.03
Tribe Chironomini	0.49	0.28	0.40	0.30	0.41
Chironomus (C.) crassicaudatus	0.00	0.00	0.01	0.00	0.00
Chironomus decorus gr. sp. 1	0.00	0.00	0.03	0.00	0.01
Chironomus decorus gr. sp. 2	0.06	0.03	0.03	0.03	0.04
Cryptochironomus cf. blarina	0.17	0.06	0.04	0.03	0.01
Cryptochironomus cf. sorex	0.04	0.09	0.03	0.00	0.04
Dicrotendipes modestus	0.20	0.03	0.09	0.03	0.13
Dicrotendipes neomodestus	0.00	0.01	0.00	0.07	0.01
Dicrotendipes nervosus	0.01	0.04	0.00	0.00	0.00
Endochironomus nigricans	1.22	1.09	2.17	1.19	1.24
Endochironomus subtendens	0.52	0.77	0.54	0.30	0.28

TABLE 4-53, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1986 contd		
Glyptotendipes spp. (unid.)	0.00	0.00	0.00	0.36	0.06
Glyptotendipes (P.) barbipes	0.60	0.47	0.24	0.37	0.63
Glyptotendipes (P.) lobiferus	4.30	6.62	9.66	6.85	4.47
Glyptotendipes (P.) paripes	3.07	3.26	1.57	0.57	1.11
Parachironomus sp. 1	0.01	0.00	0.00	0.00	0.00
Parachironomus carinatus	0.00	0.00	0.01	0.00	0.01
Parachironomus monochromus	0.04	0.01	0.04	0.03	0.01
Parachironomus potamogeti	0.00	0.00	0.00	0.00	0.01
Phaenopsectra punctipes	0.00	0.00	0.01	0.00	0.00
Polypedilum spp.	0.01	0.00	0.00	0.00	0.00
Polypedilum (P.) cf. convictum	0.03	0.00	0.00	0.04	0.00
Polypedilum (T.) digitifer	0.04	0.09	0.20	0.14	0.11
Polypedilum (T.) griseopunctatum	0.00	0.01	0.00	0.00	0.00
Polypedilum (T.) simulans	0.04	0.00	0.06	0.00	0.00
Pseudochironomus sp.	0.00	0.00	0.00	0.01	0.01
Zavreliella varipennis	0.00	0.01	0.00	0.00	0.00
Tribe Tanytarsini	0.36	0.51	0.51	0.33	0.16
Cladotanytarsus sp. viridiventris	0.55	0.28	0.31	0.19	0.06
Rheotanytarsus cf. exiguus	0.00	0.00	0.01	0.03	0.00
Tanytarsus sp. 1	3.30	3.96	2.71	0.78	1.81
Tanytarsus sp. 2	0.09	0.06	0.16	0.21	0.10
Tanytarsus sp. 3	0.00	0.00	0.01	0.00	0.00
Tanytarsus sp. 4	0.01	0.00	0.03	0.01	0.00
Family Ephydridae	0.01	0.00	0.01	0.00	0.00
Total	20.48	22.25	24.13	15.11	13.12
Total number of taxa[a]	34	31	34	34	33

Total number of taxa, 1986 Regions 4-8 combined = 52

[a] Higher level taxa and unidentified taxa were not included in the total taxa count if lower level taxa were present.

TABLE 4-53, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1987		
Hydroptila spp.	0.07	0.03	0.00	0.00	0.00
Oxyethira spp.	0.00	0.01	0.01	0.01	0.00
Oecetis spp.	0.00	0.01	0.00	0.00	0.00
Triaenodes spp.	0.00	0.00	0.00	0.00	0.01
Chaoborus punctipennis	0.40	0.17	0.66	0.81	0.53
Family Ceratopogonidae	0.09	0.09	0.06	0.07	0.03
Family Chironomidae	0.00	0.00	0.00	0.00	0.03
Subfamily Tanypodinae	0.00	0.00	0.01	0.01	0.00
Ablabesmyia spp.	0.01	0.01	0.00	0.00	0.00
Ablabesmyia (K.) cinctipes	0.26	0.21	0.66	0.58	0.21
Labrundinia becki	0.04	0.00	0.00	0.03	0.00
Labrundinia pilosella	0.14	0.06	0.38	0.26	0.03
Pentaneura inconspicua	0.01	0.00	0.00	0.00	0.00
Procladius (P.) bellus	0.38	0.57	0.40	0.18	0.48
Procladius (H.) sublettei	0.00	0.10	0.10	0.10	0.33
Subfamily Orthocladiinae	0.07	0.03	0.06	0.19	0.07
Corynoneura sp. 1	0.00	0.01	0.01	0.01	0.03
Cricotopus spp. (unid.)	0.01	0.00	0.00	0.00	0.00
Cricotopus (C.) sp. 1	0.01	0.01	0.03	0.03	0.02
Cricotopus (C.) sp. 2	0.06	0.06	0.10	0.20	0.11
Cricotopus (C.) sp. 3	0.00	0.00	0.00	0.02	0.00
Cricotopus (C.) sp. 4	0.00	0.01	0.00	0.00	0.01
Cricopopus (C.) cf. vierriensis	0.01	0.01	0.00	0.00	0.00
Nanocladius (N.) cf. distinctus	0.13	0.04	0.18	0.21	0.04
Nanocladius (N.) cf. mallochi	0.01	0.00	0.03	0.06	0.00
Parakiefferiella sp.	0.01	0.00	0.00	0.00	0.01
Parakiefferiella cf. coronata	0.77	0.57	0.63	0.74	0.47
Psectrocladius sp.	0.04	0.06	0.00	0.00	0.03
Thienemanniella sp.	0.01	0.00	0.03	0.00	0.00
Tribe Chironomini	3.08	2.46	1.80	2.68	0.60
Asheum becki	0.09	0.01	0.11	0.43	0.01
Cladopelma edwardsi	0.07	0.60	0.20	0.32	0.01
Chironomus (C.) crassicaudatus	0.04	0.00	0.00	0.00	0.00
Cryptochironomus cf. blarina	0.17	0.09	0.14	0.03	0.03
Cryptochironomus cf. sorex	0.33	0.16	0.30	0.36	0.22
Dicrotendipes modestus	0.20	0.04	0.03	0.06	0.03
Dicrotendipes neomodestus	0.13	0.01	0.04	0.01	0.03
Dicrotendipes nervosus	0.01	0.04	0.04	0.16	0.01
Endochironomus nigricans	0.01	0.01	0.01	0.01	0.00
Endochironomus subtendens	0.01	0.00	0.01	0.04	0.00
Glyptotendipes (P.) barbipes	0.03	0.01	0.06	0.24	0.00
Glyptotendipes (P.) lobiferus	3.47	3.26	3.16	5.41	2.10
Glyptotendipes (P.) paripes	1.15	0.54	1.25	0.64	0.07

TABLE 4-53, Contd

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
			1987 contd		
Goeidichironomus carus	0.00	0.00	0.00	0.01	0.00
Nilothauma babiyi	0.01	0.00	0.00	0.00	0.00
Parachironomus carinatus	0.01	0.00	0.14	0.04	0.00
Parachironomus monochromus	0.00	0.01	0.10	0.06	0.00
Parachironomus potamogeti	0.00	0.01	0.00	0.03	0.00
Parachironomus tenuicaudatus	0.01	0.00	0.06	0.00	0.00
Phaenopsectra flavipes	0.00	0.01	0.00	0.00	0.00
Polypedilum (P.) illinoense	0.00	0.03	0.00	0.01	0.02
Polypedilum (T.) digitifer	1.99	2.01	1.28	1.46	0.39
Polypedilum (T.) griseopunctatum	0.00	0.01	0.00	0.01	0.00
Polypedilum (T.) halterale	0.00	0.03	0.00	0.00	0.00
Polypedilum (T.) scalaenum	0.00	0.00	0.00	0.01	0.00
Polypedilum (T.) simulans	0.50	0.04	0.06	0.07	0.01
Pseudochironomus sp.	0.03	0.07	0.04	0.04	0.97
Pseudochironomus fulviventris	0.03	0.00	0.00	0.01	0.00
Stenochironomus (S.) macateei	0.01	0.03	0.03	0.04	0.00
Xestochironomus sublettei	0.00	0.00	0.01	0.01	0.01
Zavreliella varipennis	0.11	0.01	0.04	0.03	0.01
Tribe Tanytarsini	5.08	3.30	4.22	9.77	2.76
Cladotanytarsus sp. viridiventris	1.78	1.42	2.55	1.95	0.46
Rheotanytarsus cf. exiguus	0.00	0.00	0.01	0.00	0.00
Tanytarsus cf. curticornis gr. sp.	0.00	0.00	0.01	0.00	0.00
Tanytarsus spp. (unid.)	4.16	2.72	2.04	2.72	2.62
Hemerodromia	0.00	0.01	0.00	0.00	0.00
Family Ephydridae	0.00	0.00	0.00	0.00	0.01
Total	25.11	19.05	21.11	30.22	12.87
Total number of taxa[a]	39	42	38	42	32

Total number of taxa, 1987 Regions 4-8 combined = 58

[a] Higher level taxa and unidentified taxa were not included in the total taxa count if lower level taxa were present.

Source: Gladden et al. (1988)

Rates of insect emergence in Regions 4 through 7 were similar, averaging about $22/m^2$/day in each region for the two years combined, but Region 8 had consistently lower emergence rates, averaging only about $13/m^2$/day during each of the two years (Table 4-53). The lower emergence rates in Region 8 do not appear to be related to reactor operations, since this region is farthest from the reactor outfall. Rather, the lower rates were probably due to the relatively poor benthic habitat that is provided by the heavy clay substrate that covers much of the littoral area in Region 8.

4.3.5.5 Impact Evaluation

The L-Lake impoundment is a young ecosystem that is still undergoing succession. Data collected during the first two years of the reservoir's development indicate that L Lake is progressing toward a diverse and balanced ecosystem. A total of 130 macroinvertebrate taxa were collected during the first two years of the lake's existence. It is likely that species richness will continue to increase until L Reactor resumes operation. Maturation of the lake ecosystem, particularly the continuing development of macrophyte beds, will increase habitat diversity. Macroinvertebrate data collected in 1986 and 1987 indicate that L Lake supports a diverse macroinvertebrate community in Regions 4-8.

Following resumption of reactor operations, the macroinvertebrate community in Regions 4-8 of L Lake are expected to be similar to the community described in this section, but species richness will probably be higher, and macroinvertebrate densities are likely to have stabilized to some extent, due to maturation of the ecosystem.

Regions 2, 3, and 4 of L Lake are not required to support a balanced ecosystem. However, it is likely that during the extended outage of L Reactor, these regions of the lake have been colonized by a diverse assemblage of macroinvertebrates. The continuation of L Reactor operations will cause many of these taxa to be lost because the upper regions of L Lake will not provide suitable habitat for most species of macroinvertebrates when the reactor is operating. However, during extended summer outages, it is expected that many species of chironomids and other species with relatively short life cycles will colonize the upper regions of the lake and successfully reproduce.

4.3.6 Fish Communities

L Lake is a 400 hectare reservoir constructed in 1985 by impounding the mid-reaches of Steel Creek. It serves as a once-through cooling reservoir for L Reactor. L Lake has been divided into eight sampling regions along its longitudinal axis (Figure 4-44); however, only Regions 4-8 have been consistently sampled. Regions 5-8 constitute the lower 50% of L Lake which must be maintained in a state of biological balance in order to satisfy NPDES permitting criteria. L Lake has been consistently sampled since the beginning of 1986 using electrofishing, hoopnetting, and hydroacoustic equipment to collect adult/juvenile fish data and plankton nets

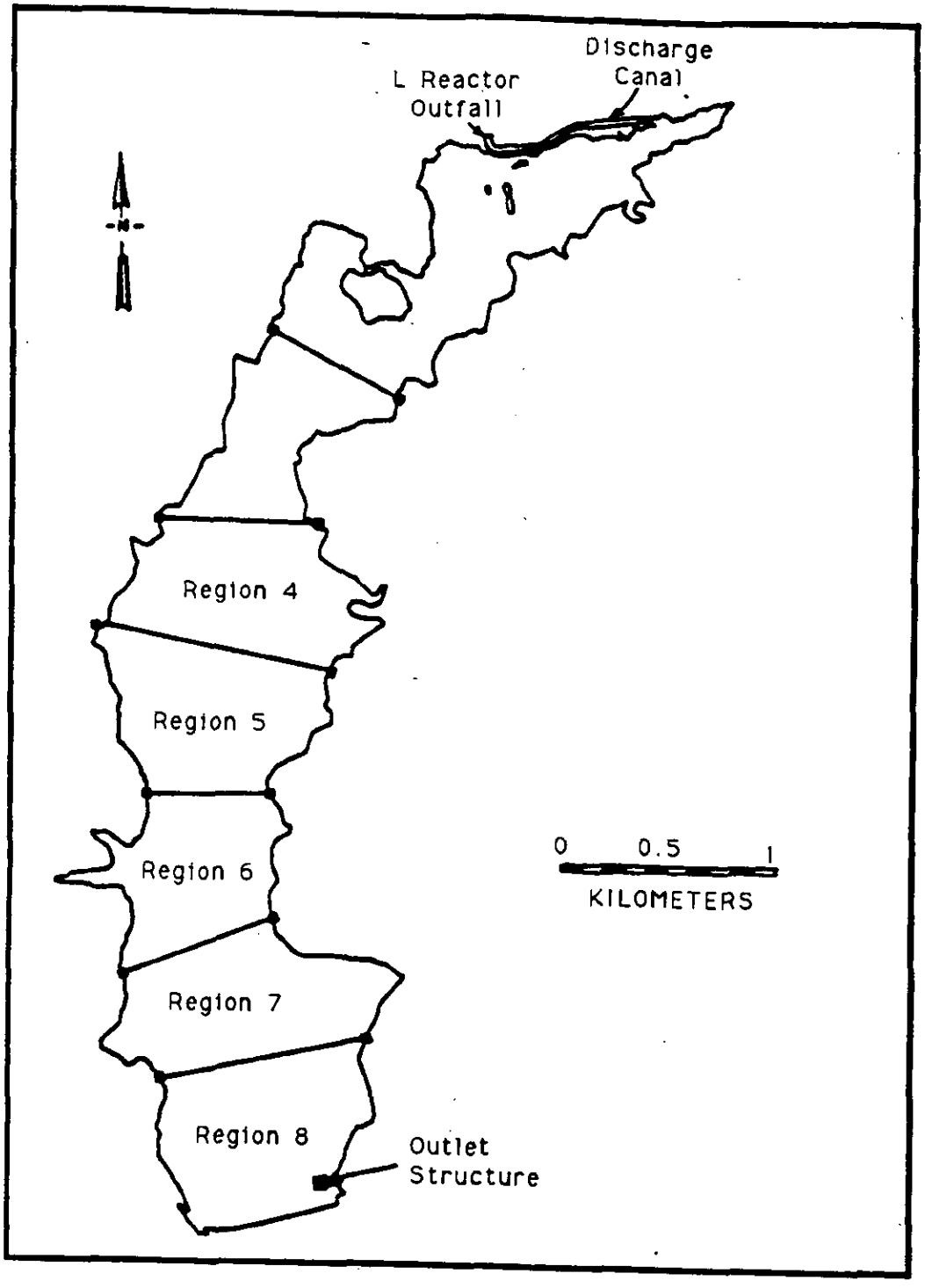

FIGURE 4-44. L Lake and its Sampling Regions

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and light traps to collect larval fish data (Paller et al., 1987; Paller et al., 1988; Heuer et al., 1989). Adult fish sampling is conducted monthly and larval fish sampling is conducted weekly during February-July and biweekly during August-January.

L Reactor was operated from January through June in 1986, 1987, and 1988, as well as during part of December in 1986 and part of November and December in 1987 (Figure 4-45). The highest temperature observed in Regions 4-8 of L Lake during these periods of reactor operation was approximately 34°C, 2 to 3°C higher than typical of southeastern reservoirs (Starkel et al., 1988). Temperatures differed little among Regions 4-8 (Figure 4-45). L Lake stratified during each summer, as is typical of southeastern reservoirs (Chimney et al., 1989). Mean dissolved oxygen concentrations remained above 5.0 mg/L in epilimnetic waters but dropped to under 1.0 mg/L in the hypolimnion during periods of stratification (Starkel et al., 1989).

Community Development

Fisheries surveys during the first half of 1986, when the reactor was operating, indicated that L Lake was initially dominated by redbreast sunfish (Lepomis auritus), shiners (Notropis spp.), mosquitofish (Gambusia affinis), golden shiner (Notemigonus chrysoleucas), spotted sunfish (Lepomis punctatus), and dollar sunfish (Lepomis marginatus) (Table 4-54). All were probably present in Steel Creek before impoundment. In the spring and summer of 1986, a major shift in fish community composition occurred as large numbers of juvenile bluegill (Lepomis macrochirus) began to appear in the collections (Figure 4-46). L Lake had been stocked with juvenile bluegill and largemouth bass in November 1985 (approximately 40,000 and 4,000 fish, respectively). Most of the bluegill were probably the progeny of fish stocked during the fall of 1985. Largemouth bass (Micropterus salmoides) also began to increase in abundance in the latter half of 1986. Concurrent with the increased catch rates for these species were decreased catch rates for a number of others including mosquitofish, dollar sunfish, spotted sunfish, shiners, brook silverside (Labidesthes sicculus), and golden shiner. These species continued to decrease in abundance until many were virtually absent from L Lake by the end of 1987 (Table 4-55). Loss of these species resulted in a net reduction in the number of species in L Lake from 30 in 1986 to 20 in 1987 (Table 4-56). In 1987, two additional species, threadfin shad (Dorosoma petenense), and gizzard shad (Dorosoma cepedianum) appeared in L Lake, probably after being introduced as larvae in water pumped from the Savannah River during a period of reactor outage. By the end of 1987, L Lake was dominated by bluegill, threadfin shad, redbreast sunfish, and largemouth bass (Table 4-55).

All of the dominant species of fish in L Lake are successfully reproducing as indicated by the collection of larvae and/or juveniles (Tables 4-57, through 4-60). Bluegill larvae are the most abundant ichthyoplankton in

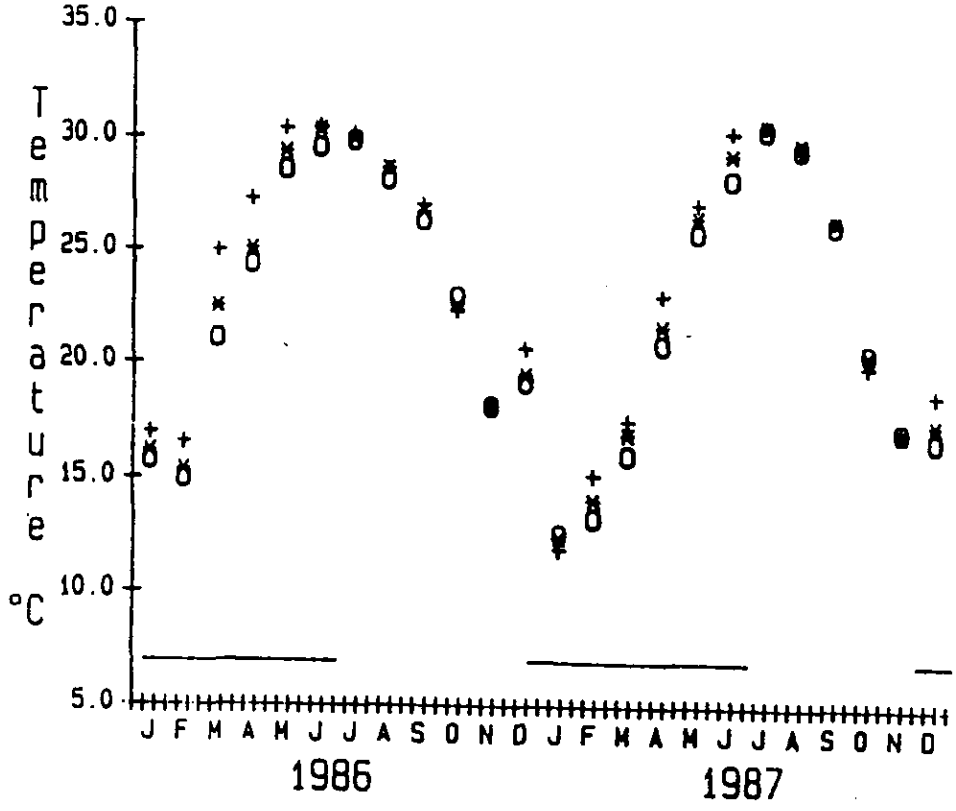

FIGURE 4-45. Monthly Average Near-Surface Water Temperatures in the Littoral Zones of Regions 4(+), 6(*), and 8(o) of L Lake. Broken horizontal line represents L-Reactor operating schedule (January 1986 - December 1987) (source: Paller et al., 1988a)

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TABLE 4-54

Mean 1986 Electrofishing Catch per 100 m of Shoreline (standard deviation) and Percent Composition in Regions 4-8 of L Lake During Periods of Reactor Operation (January - June 1986) and Reactor Outage (July - November 1986)

Reactor Operating

Taxa	Region 4 CPUE		%	Region 5 CPUE		%	Region 6 CPUE		%	Region 7 CPUE		%	Region 8 CPUE		%
Redfin pickerel	-			-			0.1	(0.3)	0.2	<0.1	(0.2)	0.1	<0.1	(0.2)	0.1
Chain pickerel	0.1	(0.4)	0.4	-			<0.1	(0.2)	0.1	<0.1	(0.2)	0.1	-	-	-
Unid. Cyprinidae	0.3	(1.4)	1.2	-			0.2	(1.0)	0.4	0.1	(0.3)	0.2	-	-	-
Chub[a]	0.2	(0.6)	0.8	0.1	(0.6)	0.4	<0.1	(0.2)	0.1	0.1	(0.3)	0.2	-	-	-
Golden shiner	6.2	(9.2)	25.1	4.6	(4.1)	17.2	4.7	(10.9)	9.4	2.5	(3.0)	5.4	2.2	(3.9)	6.8
Shiner (*Notropis* spp.)	4.6	(6.8)	18.6	6.9	(9.2)	25.8	7.6	(10.6)	15.2	14.1	(16.0)	30.7	10.4	(14.0)	32.0
Creek chubsucker	0.2	(0.5)	0.8	0.2	(0.4)	0.8	1.2	(2.6)	2.4	0.3	(1.0)	0.7	-		
Lake chubsucker	0.1	(0.3)	0.4	<0.1	(0.2)	0.2	<0.1	(0.2)	0.1	0.1	(0.3)	0.2	-		
Northern hogsucker	0.1	(0.4)	0.4	-			-			-			0.1	(0.4)	0.3
Spotted sucker	<0.1	(0.2)	0.2	-			-			-			-		
Yellow bullhead	-			-			<0.1	(0.2)	0.1	-			0.1	(0.4)	0.3
Mosquitofish	0.6	(2.3)	2.4	0.5	(1.8)	1.9	12.5	(38.6)	25.1	2.2	(8.9)	4.8	11.4	(26.7)	35.1
Brook silverside	1.6	(4.0)	6.5	0.4	(0.8)	1.5	1.4	(3.1)	2.8	1.7	(3.0)	3.7	0.4	(1.0)	1.2
Sunfish (*Lepomis* spp.)	-			-			0.2	(0.7)	0.4	<0.1	(0.3)	0.1	-		
Bluespotted sunfish	-			<0.1	(0.2)	0.2	-			0.1	(0.2)	0.2	-		
Redbreast sunfish	8.0	(9.5)	32.4	12.3	(11.3)	46.1	14.4	(14.6)	28.9	15.6	(14.7)	33.9	5.9	(6.9)	18.2
Warmouth	<0.1	(0.2)	0.2	-			-			0.1	(0.3)	0.2	-		
Bluegill	0.2	(0.5)	0.8	0.5	(1.6)	1.9	0.7	(1.0)	1.4	0.8	(1.7)	1.7	<0.1	(0.2)	0.1
Dollar sunfish	0.3	(0.6)	1.2	0.2	(0.5)	0.8	1.9	(3.3)	3.8	3.1	(6.0)	6.7	1.0	(2.4)	3.1
Redear sunfish	-			-			-			-			<0.1	(0.2)	0.1
Spotted sunfish	1.3	(2.5)	5.3	0.5	(1.0)	1.9	3.2	(3.3)	6.4	4.0	(7.4)	8.7	0.7	(1.2)	2.1
Largemouth bass	0.5	(1.1)	2.0	0.4	(0.9)	1.5	1.3	(3.1)	2.6	1.1	(2.1)	2.4	0.1	(0.3)	0.3
Black crappie	0.1	(0.3)	0.4	<0.1	(0.2)	0.2	0.3	(0.7)	0.6	0.1	(0.3)	0.2	0.1	(0.4)	0.3
Total	24.7	(19.3)	99.1	26.7	(17.3)	100.4	49.9	(54.1)	100.0	46.0	(34.1)	100.2	32.5	(33.7)	100.0

[a] Mostly the rosyface chub, some bluehead chub

Source: Paller et al. (1988a)

W890070

TABLE 4-54, Contd

Reactor Not Operating

Taxa	Region 4 CPUE		%	Region 5 CPUE		%	Region 6 CPUE		%	Region 7 CPUE		%	Region 8 CPUE		%
Redfin pickerel	<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1	0.1	(0.3)	<0.1	–			–		
Chain pickerel	<0.1	(0.2)	<0.1	0.2	(0.5)	0.1	0.1	(0.3)	<0.1	<0.1	(0.2)	<0.1	0.1	(0.3)	<0.1
Unid. Cypinidae[b]	–			0.3	(1.3)	0.1	0.2	(0.9)	0.1	0.2	(0.8)	0.1	0.1	(0.8)	<0.1
Golden shiner	1.0	(2.2)	0.5	0.7	(1.0)	0.3	1.5	(1.9)	0.5	0.7	(1.0)	0.3	0.4	(0.7)	0.1
Shiner (Notropis spp.)	0.7	(1.5)	0.4	3.7	(6.3)	1.6	2.2	(3.9)	0.7	1.2	(1.9)	0.4	3.0	(5.5)	0.9
Chubsucker (Erimyzon spp)	–			–			0.1	(0.4)	<0.1	–			–		
Creek chubsucker	<0.1	(0.2)	<0.1	–			<0.1	(0.2)	<0.1	–			–		
Lake chubsucker	–			–			–			<0.1	(0.2)	<0.1	–		
Yellow bullhead	–			<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1	–			0.1	(0.4)	<0.1
Flat bullhead	–			–			–			<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1
Mosquitofish	0.1	(0.6)	0.1	–			0.1	(0.8)	<0.1	<0.1	(0.2)	<0.1	0.1	(0.6)	<0.1
Brook silverside	–			–			–			<0.1	(0.2)	<0.1	–		
Sunfish (Lepomis spp.)	–			0.8	(4.3)	0.4	0.6	(0.2)	0.2	0.8	(3.6)	0.3	8.5	(36.0)	2.5
Bluespotted sunfish	–			–			<0.1	(3.0)	<0.1	–			–		
Redbreast sunfish	18.2	(13.9)	9.8	27.4	(17.6)	11.6	37.0	(48.1)	12.9	25.2	(22.3)	9.8	33.7	(30.4)	10.0
Bluegill	163.4	(108.2)	87.6	198.2	(170.7)	84.2	241.8	(188.1)	84.3	225.4	(211.9)	87.9	288.6	(224.3)	85.6
Dollar sunfish	0.3	(1.0)	0.2	2.0	(10.4)	0.9	0.4	(0.8)	0.1	0.2	(0.5)	0.1	0.5	(1.5)	0.2
Redear sunfish	–			<0.1	(0.2)	<0.1	–			–			–		
Spotted sunfish	0.3	(0.7)	0.2	0.2	(0.4)	0.1	0.6	(0.7)	0.2	0.4	(0.7)	0.2	0.6	(1.5)	0.2
Largemouth bass	2.2	(2.1)	1.2	1.6	(1.5)	0.7	2.2	(2.0)	0.8	2.0	(1.5)	0.8	1.4	(2.0)	0.4
Black crappie	–			–			–			0.1	(0.3)	<0.1	<0.1	(0.2)	<0.1
Yellow perch	–			<0.1	(0.2)	<0.1	–			–			–		
Total	186.5	(120.3)	100.0	235.4	(191.2)	100.0	286.9	(209.6)	99.8	256.4	(223.4)	99.9	337.2	(260.6)	99.9

[b] Primarily Notropis spp. golden shiners and chubs

W8906070

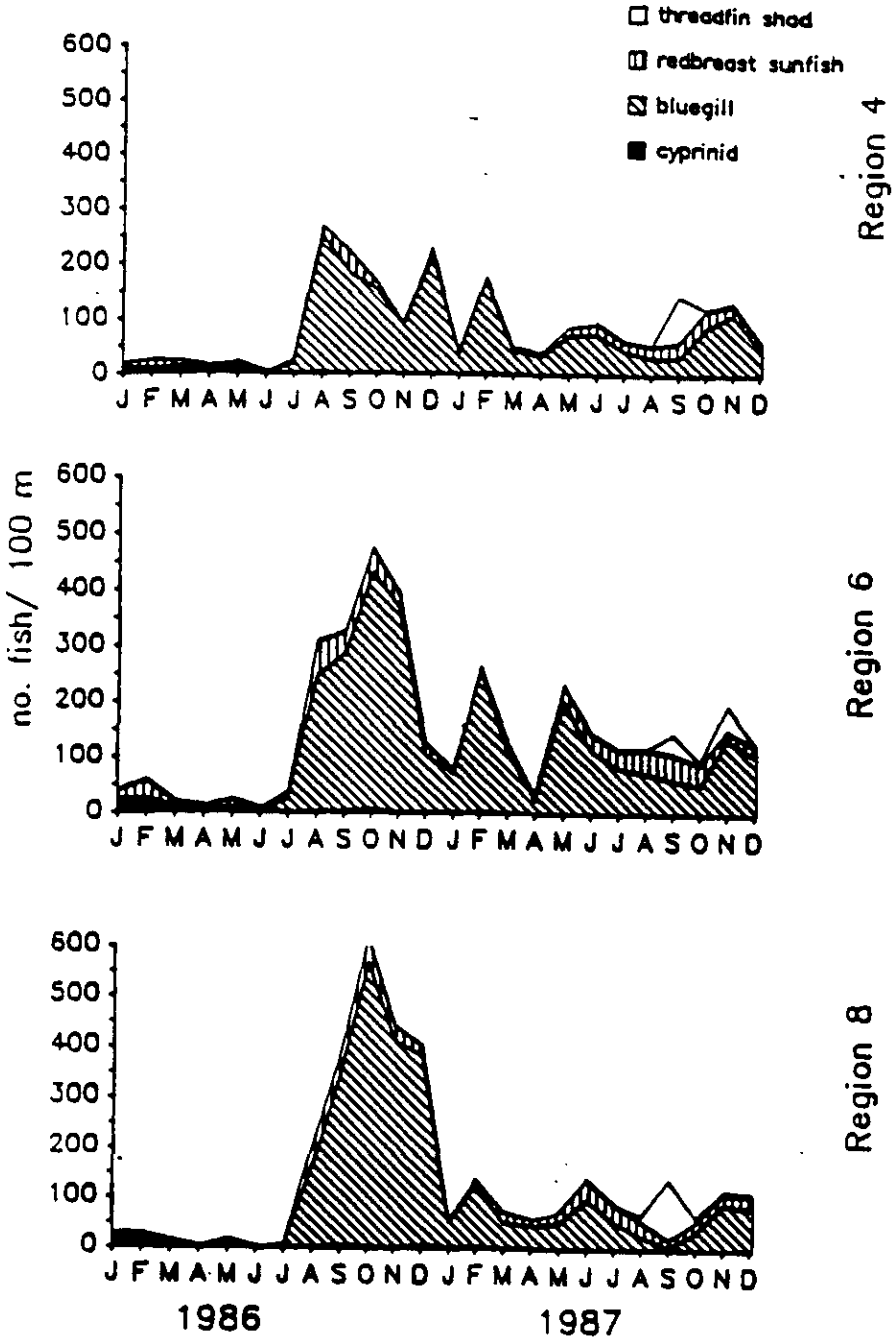

FIGURE 4-46. Mean Electrofishing Catch per 100 m of Shoreline in Regions 4-8 of L Lake. (January 1986 - December 1987) Data have been averaged over Regions 4-8. The category "other" consists primarily of mosquitofish, shiners (Notropis spp.), golden shiner, and brook silverside (source: Paller et al., 1988a)

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TABLE 4-55

Mean 1987 Electrofishing Catch per 100 m of Shoreline (standard deviation) and Percent Composition in Regions 4-8 of L Lake During Periods of Reactor Operation (January - June; December 1986) and Reactor Outage (July - November 1987)

Reactor Operating

Taxa	Region 4 CPUE		%	Region 5 CPUE		%	Region 6 CPUE		%	Region 7 CPUE		%	Region 8 CPUE		%
Gizzard shad	0.1	(0.4)	0.1	<0.1	(0.2)	<0.1	-			0.1	(0.3)	0.1	<0.1	(0.2)	<0.1
Threadfin shad	0.6	(2.0)	0.7	1.1	(4.9)	1.2	0.7	(2.2)	0.5	1.3	(4.0)	0.9	1.0	(2.3)	1.0
Unid. shad	-			-			-			-			<0.1	(0.2)	<0.1
Chain pickerel	0.1	(0.4)	0.1	<0.1	(0.2)	<0.1	-			-			<0.1	(0.2)	<0.1
Golden shiner	0.2	(0.5)	0.2	0.5	(0.9)	0.5	0.6	(1.1)	0.4	0.4	(0.7)	0.3	0.2	(0.8)	0.2
Minnow	0.3	(1.5)	0.4	0.9	(2.0)	1.0	0.7	(2.1)	0.5	0.9	(2.0)	0.7	0.6	(2.5)	0.6
Flat bullhead	-			-			-			-			-		
Hybrid sunfish	-		-	-			-			-			-		
Redbreast sunfish	10.5	(7.0)	12.6	15.0	(10.0)	16.3	16.7	(16.3)	11.4	24.6	(32.1)	17.8	21.1	(18.3)	21.7
Warmouth	<0.1	(0.2)	<0.1	-			<0.1	(0.2)	<0.1	-			<0.1	(0.2)	<0.1
Bluegill	69.2	(60.8)	83.3	73.1	(55.2)	79.5	125.7	(145.6)	85.5	108.8	(110.7)	78.9	72.3	(44.3)	74.5
Dollar sunfish	-			-			0.1	(0.3)	0.1	<0.1	(0.2)	<0.1	-		
Spotted sunfish	0.1	(0.3)	0.1	0.1	(0.3)	0.1	0.1	(0.4)	0.1	<0.1	(0.2)	<0.1	0.1	(0.3)	0.1
Unid. sunfish	-			-			-			-			-		
Largemouth bass	1.9	(1.7)	2.3	1.0	(1.4)	1.1	2.4	(2.2)	1.6	1.6	(1.6)	1.2	1.5	(1.8)	1.5
Black crappie	-			<0.1	(0.2)	<0.1	-				-		0.1	(0.3)	0.1
Yellow perch	-			-			-			-					
Total	83.1	(61.9)	99.8	91.9	(81.5)	99.8	147.0	(154.2)	100.1	137.9	(137.4)	100.0	97.10	(58.3)	99.9

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TABLE 4-55, Contd

	Reactor Not Operating														
	Region 4			Region 5			Region 6			Region 7			Region 8		
Taxa	CPUE		%	CPUE		%	CPUE		%	CPUE		%	CPUE		%
Gizzard shad	0.5	(0.9)	0.5	0.5	(0.7)	0.4	0.2	(0.6)	0.1	0.6	(1.2)	0.6	0.9	(1.8)	0.9
Threadfin shad	16.4	(39.9)	16.4	8.4	(17.6)	7.2	15.2	(33.4)	11.1	16.8	(36.8)	16.2	27.2	(57.6)	28.2
Unid. shad	-			-			-			-			<0.1	(0.2)	<0.1
Chain pickerel	<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1	-			0.1	(0.3)	0.1	-		
Golden shiner	<0.1	(0.2)	<0.1	-			0.2	(0.5)	0.1	0.2	(0.5)	0.2			
Minnow	-			0.1	(0.5)	0.1	0.6	(1.9)	0.4	0.2	(1.4)	0.2	0.3	(1.3)	0.4
Flat bullhead	-			<0.1	(0.2)	<0.1	-			<0.1	(0.2)	<0.1	-		
Hybrid sunfish	0.1	(0.4)	0.1	-			-			-			-		
Redbreast sunfish	23.0	(11.7)	23.1	33.6	(17.4)	28.7	36.9	(21.8)	27.1	25.5	(15.4)	24.6	25.4	(21.6)	26.3
Warmouth	<0.1	(0.2)	<0.1	-			<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1	0.1	(0.3)	0.1
Bluegill	56.5	(45.6)	56.7	70.0	(75.8	59.8	79.2	(55.9)	58.1	56.0	(46.1)	54.1	39.8	(36.1)	41.3
Dollar sunfish	-			-			<0.1	(0.2)	<0.1	-			-		
Spotted sunfish	-			-			0.1	(0.3)	0.1	<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1
Unid. sunfish	-			0.1	(0.04)	0.1	0.1	(0.4)	0.1	0.2	(0.5)	0.2	<0.1	(0.2)	<0.1
Largemouth bass	3.0	(2.9)	3.0	3.9	(3.0)	3.3	3.5	(2.3)	2.6	3.8	(2.5)	3.7	2.5	(1.9)	2.6
Black crappie	0.2	(0.5)	0.2	0.2	(0.4)	0.2	0.3	(0.8)	0.2	0.1	(0.3)	0.1	0.1	(0.4)	0.1
Yellow perch	-			<0.1	(0.2)	<0.1	<0.1	(0.2)	<0.1	-			-		
Total	99.7	(58.8)	100.1	117.0	(82.8)	99.9	136.4	(77.4)	100.0	103.6	(59.5)	100.1	96.4	(54.6)	100.0

Source: Paller et al. (1988a)

TABLE 4-56

Species Collected by Electrofishing, Gill Net, Shad Scoop, and Hoop Net Samples from Regions 4-8 of L Lake (January 1986 - December 1987)

Taxon	1986 J	F	M	A	M	J	J	A	S	O	N	D	1987 J	F	M	A	M	J	J	A	S	O	N	D
American eel															X									
Threadfin shad																		X	X	X	X	X	X	X
Gizzarrd shad														X	X		X	X	X	X	X	X	X	X
Redfin pickerel	X	X	X	X				X	X															
Chain pickerel	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
Rosyface chub	X	X																						
Common carp																								
Bluehead chub		X	X																					
Golden shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Rosyface shiner								X																
Ironcolor shiner												X												
Dusky shiner											X									X				
Coastal shiner								X				X	X	X	X	X	X	X	X	X	X		X	X
Creek chubsucker	X	X	X		X		X				X													
Lake chubsucker			X	X	X							X				X								
Northern hogsucker		X		X																				
Spotted sucker			X																					
Yellow bullhead	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brown bullhead								X						X										
Flat bullhead	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Madtom, *Noturus* spp.																	X							
Mosquitofish	X	X	X	X	X	X	X	X			X	X												
Brook silverside	X	X	X		X	X						X												
Mud sunfish											X													
Bluespotted sunfish		X			X					X							X							
Redbreast sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pumpkinseed			X																					

Source: Paller et al. (1988a)

M890070

TABLE 4-56, Contd

Taxon	1986 J	F	M	A	M	J	J	A	S	O	N	D	1987 J	F	M	A	M	J	J	A	S	O	N	D
Warmouth		X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X
Bluegill	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dollar sunfish	X	X	X	X	X	X	X	X	X		X		X	X	X	X		X	X	X	X			
Redear sunfish				X		X		X																
Spotted sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Largemouth bass	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Black crappie			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Yellow perch			X			X		X												X				
Monthly total	14	16	18	15	16	14	13	18	11	10	14	14	13	14	13	14	14	14	12	15	13	12	13	13
Yearly total							30											21						

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TABLE 4-57

Abundance of Larval Fishes in L Lake as Determined by Four Sampling Programs. Numbers are Mean Yearly Densities (no. larvae/1,000 m^3) for Surface and Oblique Tows, and CPUE (no. larvae/10 h illumination) for Light Traps. Values in Parentheses are Relative Abundances (%, by no. of each taxon in the total catch for each sample method) for Each Year. Larvae were Collected Weekly (except for limnetic surface tows which occurred monthly) in Regions 4-8 During February - July and Bi-Weekly in Regions 4, 6, and 8 During the Rest of the Year

	Littoral Zone				Limnetic Zone			
	Surface Tows		Light Traps		Surface Tows		Oblique Tows	
Taxon	1986	1987	1986	1987	1986	1987	1986	1987
Unknown shad sp.		6.2 (1%)		<0.1 (<1%)		15.3 (5%)		15.4 (22%)
Gizzard shad		0.3 (<1%)						0.1 (<1%)
Threadfin shad								
Cyprinid	14.9 (5%)	25.3 (5%)	1.0 (3%)	4.9 (31%)	24.5 (5%)	16.6 (6%)	1.5 (<1%)	0.5 (1%)
Common carp		0.1 (<1%)		<0.1 (<1%)				
Brook silverside		0.1 (<1%)						
Mosquitofish	23.1 (7%)	<0.1 (<1%)	4.0 (13%)		11.9 (2%)		1.2 (1%)	
Bluegill	275.6 (86%)	438.2 (90%)	22.6 (75%)	8.9 (56%)	483.2 (90%)	230.4 (80%)	107.5 (95%)	47.1 (68%)
Redbreast sunfish	N/A	1.7 (<1%)	N/A	0.1 (1%)	N/A	0.5 (<1%)	N/A	0.6 (1%)
Black crappie	0.1 (<1%)	9.3 (2%)		0.1 (1%)		2.3 (<1%)		4.5 (7%)
Other sunfish	N/A	0.8 (<1%)	0.1 (<1%)	0.2 (1%)	N/A	1.0 (<1%)	N/A	0.1 (<1%)
Damaged or misc.	7.4 (2%)	4.3 (1%)	2.7 (9%)	1.7 (11%)	16.4 (3%)	23.6 (8%)	2.4 (2%)	0.8 (1%)
Total	321.1 (100%)	486.2 (100%)	30.3 (100%)	15.8 (101%)	536.0 (100%)	289.7 (99%)	112.6 (99%)	69.1 (100%)

Note: Columns may not sum to equal totals due to rounding effects.

M890070

TABLE 4-58

Length-Frequency Distributions of Bluegill (total number collected in each length group) in L Lake (January 1986 - December 1987)

Length Group (mm)	1986 Jan/Feb	1986 Mar/Apr	1986 May/Jun	1986 Jul/Aug	1986 Sep/Oct	1986 Nov/Dec	1987 Jan/Feb	1987 May/Apr	1987 May/Jun	1987 Jul/Aug	1987 Sep/Oct	1987 Nov/Dec
1 - 10				1							1	
11 - 20	1			134	14	5			4	1	1	
21 - 30	2			2700	1384	339	190	43	173	96	26	
31 - 40	3			8234	6751	3989	2386	681	337	154	61	43
41 - 50	4		5	6943	10246	8027	2010	877	1432	754	165	129
51 - 60	11	2	6	2310	3288	4443	1259	701	1734	2322	731	585
61 - 70	7	8	1	1283	1157	1376	539	445	1844	2028	866	1397
71 - 80	4		2	486	526	496	270	306	1144	1432	666	1299
81 - 90		6		171	141	180	159	188	566	815	379	1129
91 - 100		2		92	44	43	131	83	212	245	191	479
101 - 110		8	2	128	44	51	70	86	114	142	125	297
111 - 120		4	2	183	82	133	88	219	214	287	73	202
121 - 130	1	5	3	93	128	201	116	177	230	239	77	112
131 - 140		3	9	20	108	251	135	136	167	208	64	81
141 - 150		1	9	8	98	260	139	127	162	188	68	75
151 - 160		1	8	5	53	168	147	114	149	288	92	68
161 - 170			3	23	29	104	128	96	161	271	118	95
171 - 180				20	23	42	77	50	138	193	111	119
181 - 190				15	30	16	34	17	44	68	61	110
191 - 200				2	15	9	32	14	5	8	17	97
201 - 210					6	7	20	12	10	5	6	15
211 - 220					3	4	7	1	2	2	2	3
221 - 230					1		2					
231 - 240												1
>240									1			

Source: Paller et al. (1988a)

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TABLE 4-59

Length-Frequency Distributions of Redbreast Sunfish (total number collected in each length group) in L Lake (January 1986 - December 1987)

Length Group (mm)	1986 Jan/Feb	1986 Mar/Apr	1986 May/Jun	1986 Jul/Aug	1986 Sep/Oct	1986 Nov/Dec	1987 Jan/Feb	1987 May/Apr	1987 May/Jun	1987 Jul/Aug	1987 Sep/Oct	1987 Nov/Dec
1 - 10					1						1	
11 - 20				26	6					1		
21 - 30		1	1	134	344	38	24	15	8	2	3	
31 - 40	1	2	2	629	1479	441	195	102	9	2		
41 - 50	6	4	15	1090	1330	326	175	174	49	46	9	6
51 - 60	42	13	12	745	1022	183	139	121	126	208	156	94
61 - 70	163	28	3	445	740	172	112	142	300	286	198	193
71 - 80	143	42	8	293	396	88	72	113	398	496	219	216
81 - 90	170	38	29	234	187	70	43	68	413	509	228	269
91 - 100	207	48	17	182	121	58	31	48	249	362	158	209
101 - 110	160	74	25	57	64	55	31	39	149	264	117	132
111 - 120	140	64	32	27	45	46	10	34	105	167	87	100
121 - 130	99	68	41	34	37	34	9	16	68	133	66	68
131 - 140	113	55	41	44	31	27	11	20	49	85	48	35
141 - 150	74	36	70	59	32	36	17	27	26	79	52	30
151 - 160	49	29	83	69	36	35	20	41	26	32	36	25
161 - 170	45	41	56	94	40	37	20	25	18	32	36	19
171 - 180	27	18	35	113	63	68	26	27	22	35	41	33
181 - 190	9	8	42	137	68	79	40	36	19	44	45	33
191 - 200	7	1	17	95	76	49	55	35	31	62	78	41
201 - 210	4	-	3	60	41	21	52	26	40	45	92	76
211 - 220	1	-	-	26	22	8	13	18	31	28	75	79
221 - 230	-	-	-	6	3	-	9	9	11	7	39	44
231 - 240	-	-	-	-	1	-	3	1	2	1	2	9
241 - 250	-	-	-	-	-	-	-	1	-	-	-	-
251 - 260	-	-	-	-	-	-	-	1	-	-	-	-

Source: Paller et al. (1988a)

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TABLE 4-60

Length-Frequency Distributions of Largemouth Bass (total number collected in each length group) in L Lake (January 1986 - December 1987)

Length Group (mm)	1986 Jan/Feb	1986 Mar/Apr	1986 May/Jun	1986 Jul/Aug	1986 Sep/Oct	1986 Nov/Dec	1987 Jan/Feb	1987 May/Apr	1987 May/Jun	1987 Jul/Aug	1987 Sep/Oct	1987 Nov/Dec
1 - 20	-	-	-	-	-	-	-	-	-	-	-	-
21 - 40	-	-	-	-	-	-	-	-	1	-	-	-
41 - 60	-	8	7	-	-	-	-	-	8	1	-	-
61 - 80	-	5	23	4	-	-	-	-	3	6	-	-
81 - 100	-	1	31	9	-	-	-	-	3	18	-	-
101 - 120	-	-	16	24	-	-	-	-	5	32	-	-
121 - 140	1	-	19	35	-	-	-	-	3	36	15	-
141 - 160	-	-	8	52	-	-	-	-	1	20	18	-
161 - 180	-	-	7	62	5	-	-	-	-	37	22	-
181 - 200	-	-	6	37	17	1	-	-	-	30	39	-
201 - 220	-	-	-	37	29	5	-	-	-	22	23	9
221 - 240	-	-	-	39	34	30	5	1	1	15	31	20
241 - 260	-	-	-	19	24	58	20	14	1	6	26	31
261 - 280	1	-	-	18	26	40	30	52	21	-	10	20
281 - 300	4	-	-	7	18	23	16	52	46	4	6	12
301 - 320	5	-	1	1	11	27	8	19	55	28	3	8
321 - 340	-	-	-	-	8	13	12	20	25	55	7	4
341 - 360	-	-	-	1	-	14	8	18	34	86	42	15
361 - 380	-	-	-	2	-	2	6	7	27	53	63	57
381 - 400	-	-	-	-	-	-	-	2	13	40	35	48
401 - 420	-	-	-	-	1	-	-	-	1	26	33	29
421 - 440	-	-	-	-	-	2	1	-	4	14	16	16
441 - 460	-	-	-	-	-	-	1	1	-	-	11	7
461 - 480	-	-	-	-	-	1	-	-	-	1	4	8
481 - 500	-	-	-	-	-	-	-	-	1	-	-	-
>500	-	-	-	-	-	-	-	-	-	-	1	-

Source: Paller et al. (1988a)

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both the littoral and limnetic zones of L Lake, during 1986 and 1987 (Table 4-57). Some abundant L Lake fishes, such as largemouth bass, were absent or scarce as ichthyoplankton because of the secretive behavior of their early life stages (Pflieger, 1975).

The changes observed in the L-Lake fish community during the first three years represent normal community development. The fish communities of newly filled southeastern reservoirs typically undergo successional changes as lotic species are replaced by species better adapted to lentic environments (Turner, 1971). Stream and swamp species such as the dollar sunfish, spotted sunfish, and shiners typically disappear as a reservoir matures or occur only sporadically and locally, most often where permanent tributaries enter the impoundment (Beckman and Elrod, 1971). Sport fisheries surveys in the Rough River (KY), for example, indicated decreased catches of lotic species such as rock bass (Ambloplites ruprestis), spotted sucker (Minytrema melanops), black redhorse (Moxostoma duquesnei), and golden redhorse (Moxostoma erythrurum) following impoundment and increased catches of lentic species such as crappie (Pomoxis spp.), bluegill, and largemouth bass (Turner, 1971).

Comparison of L Lake with Other Reservoirs

One way of demonstrating that the L-Lake fish community has been developing normally is to compare it to fish communities in other reservoirs. Electrofishing data from Regions 5-8 of L Lake were compared with electrofishing data from eight other cooling or former cooling reservoirs including Par Pond (SC), Pond B (SC), Dresden Cooling Pond (IL), Monticello Reservoir (SC), Robinson Impoundment (SC), Sutherland Reservoir (NE), Lake Wylie (NC/SC), and Lake Sangchris (IL) (Paller et al., 1988). The electrofishing data were summarized by separating all fish into 12 categories (gizzard/threadfin shad, minnows, carp/goldfish, suckers, catfish/bullheads, silversides, bluegill, other sunfish, largemouth bass, temperate basses (Percichthyidae), yellow perch, and miscellaneous) and calculating the percentage in each category. The percentages were subjected to principal component analysis (PCA) after being arcsine transformed (Sokal and Rohlf, 1981; Pielou, 1984). When a reservoir was sampled for several years, each year was analyzed separately, as were consecutive six month periods in L Lake.

The analysis indicated that the first and second principal components accounted for 34 and 19%, respectively, of the total variance. A plot of the scores for each reservoir/time period sample on first and second principal components indicated that community structure in L Lake during the first six months of 1986 differed from community structure in the other reservoirs (as reflected in the large separation between L Lake (period 1) and the other reservoirs in Figure 4-47). Following the establishment of lentic taxa in L Lake (bluegill, largemouth bass, and threadfin shad), however, community composition became more similar to that in the other reservoirs. Community composition was most similar to that in Robinson Impoundment, an established cooling reservoir that is also dominated by bluegill. By the end of 1987, L Lake differed from

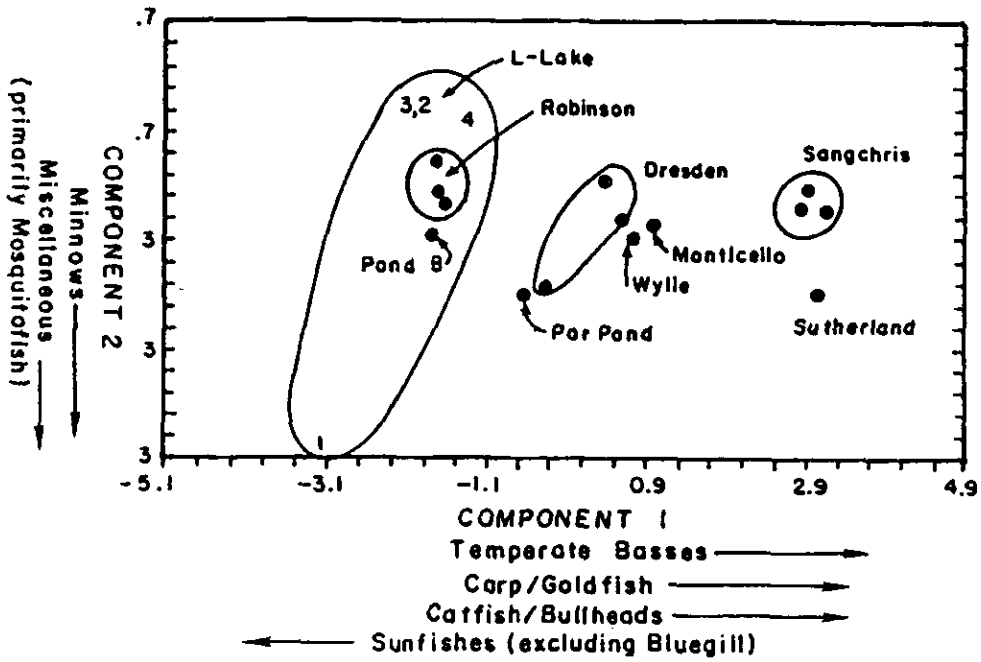

FIGURE 4-47. **Principal Component Analysis of Fish Community Structure in Nine Existing or Former Cooling Reservoirs.** When data from more than one year were available, each year is indicated separately. L-Lake data was divided into four time periods: (1) January - June 1986; (2) July - December 1986; (3) January - June 1987; (4) July - December 1987 (source: Paller et al., 1988a)

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most of the other reservoirs, primarily because of its high abundance of bluegill. Since bluegill abundance has been declining in L Lake, however, (Figure 4-46) it is likely that community composition in L Lake will come to more closely resemble that in the other reservoirs as time progresses.

The fact that a typical reservoir fish community appears to be developing in L Lake suggests that thermal discharges from L Reactor have not impacted the lower 50% of L Lake. Additional evidence supporting this conclusion can be provided by analyzing fish distribution among Regions 4-8. Electrofishing catch per unit effort was generally similar across Regions 4-8 rather than decreasing with proximity to the outfall as would be expected if reactor discharges were negatively impacting community structure (Tables 4-54, 4-55). Hoopnetting catch per unit effort has also remained similar among regions (Tables 4-61 and 4-62), as have larval fish densities estimated from plankton net catches (Table 4-63).

Growth and Condition

Size distributions of the dominant L-Lake species have varied over time. The expanding L-Lake bluegill population was initially dominated by large numbers of juvenile fish (<90 mm) (Table 4-58) which rapidly decreased in number. This decrease may have been related to predation by largemouth bass and other predators (e.g., wading and diving birds), intraspecific competition, or other factors. By the end of 1987, intermediate and large fish were well represented in the population and juvenile fish had decreased in relative and absolute abundance as expected in a more stable population. Largemouth bass and redbreast sunfish length distributions indicate continued recruitment of juvenile fish through 1987 for both species and the presence of substantial numbers of intermediate and large individuals as expected in healthy populations exhibiting growth and recruitment (Tables 4-59 and 4-60). Growth rates (as indicated by mark-recapture results, Table 4-64), for largemouth bass, bluegill, and redbreast in L Lake during 1986 and 1987 comparable to or greater than in most other reservoirs (Carlander, 1977).

A decrease in food intake as L Lake has matured is suggested by temporal trends in the condition (K) (Lagler, 1956) of L-Lake fishes. Condition is a weight-to-length ratio indicating the robustness of a fish; low condition generally reflects relatively low food intake relative to metabolic requirements (Bennett, 1970). During 1986, condition factors for largemouth bass from L Lake were well above average for U.S. reservoirs (1.41; Carlander, 1977), possibly reflecting the abundance of small (forage size) bluegill in L Lake. However, condition has gradually decreased over time (Figure 4-48). The condition of largemouth bass has shown the greatest decrease for the 151 - 300 mm size class, possibly because their principal forage (small to intermediate sunfish) has become less available as shoreline cover has increased. The condition of bluegill and redbreast sunfish has also decreased over time (Figure 4-49). These decreases do not appear to be the result of increased metabolic costs associated with artificially elevated temperatures. Maximum summer littoral temperatures in the littoral zone of L Lake were no higher in 1987 than in 1986 when condition factors were substantially higher.

TABLE 4-61

Mean 1986 Hoop Netting Catch/Net/Day (standard deviation) and Percent Composition in Regions 4-8 of L Lake During Periods of Reactor Operation (January - June, 1986) and Reactor Outage (July - November 1986)

Reactor Operating

Taxon	Region 4 CPUE		%	Region 5 CPUE		%	Region 6 CPUE		%	Region 7 CPUE		%	Region 8 CPUE		%
Minnow	<0.1	(0.1)	1.4	-			-			-			-		
Bluehead chub	-			-			-			-			<0.1	(0.1)	0.5
Golden shiner	-			<0.1	(0.1)	1.4	<0.1	(0.1)	1.0	<0.1	(0.1)	3.8	<0.1	(0.1)	0.5
Chubsucker	<0.1	(0.2)	2.8	<0.1	(0.1)	4.2	0.1	(0.2)	6.2	<0.1	(0.1)	2.5	-		
Yellow bullhead	-			<0.1	(0.1)	2.8	0.1	(0.3)	6.2	<0.1	(0.1)	2.5	0.1	(0.5)	6.0
Brown bullhead	-			-			-			-			-		
Flat bullhead	0.1	(0.3)	9.6	0.2	(0.5)	22.5	0.2	(0.5)	18.8	0.1	(0.3)	13.9	0.4	(0.8)	17.4
Mud sunfish	-			-			-			-			-		
Redbreast sunfish	0.4	(0.7)	47.9	0.4	(0.8)	57.7	0.4	(1.1)	39.6	0.4	(0.6)	43.0	1.2	(2.3)	56.3
Pumpkinseed	-			-			<0.1	(0.1)	1.0	<0.1	(0.1)	1.3	-		
Warmouth	<0.1	(0.1)	1.4	-			<0.1	(0.1)	1.0	<0.1	(0.1)	1.3	<0.1	(0.1)	0.5
Bluegill	0.1	(0.4)	13.7	<0.1	(0.1)	1.4	0.1	(0.2)	6.2	<0.1	(0.2)	3.8	0.1	(0.3)	4.5
Dollar sunfish	-			-			-			-			-		
Redear sunfish	<0.1	(0.1)	1.4	-			-			-			-		
Spotted sunfish	0.1	(0.4)	16.4	<0.1	(0.1)	5.6	0.2	(0.5)	17.8	0.2	(0.5)	27.8	0.2	(0.4)	8.9
Largemouth bass	<0.1	(0.2)	1.4	-			-			-			-		
Black crappie	-			<0.1	(0.1)	2.8	<0.1	(0.1)	1.0	-			0.1	(0.4)	5.5
Yellow perch	-			<0.1	(0.1)	1.4	<0.1	(0.1)	1.0	-			-		
Total	0.8	(1.3)	100.1	0.7	(1.1)	99.8	1.0	(1.9)	99.8	0.8	(1.0)	99.9	2.1	(3.6)	100.1

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TABLE 4-61, Contd

	Reactor Not Operating														
	Region 4			Region 5			Region 6			Region 7			Region 8		
Taxon	CPUE		%	CPUE		%	CPUE		%	CPUE		%	CPUE		%
Minnow	–			–			–			–			–		
Bluehead chub	–			–			–			–			–		
Golden shiner	<0.1	(0.1)	0.2	<0.1	(0.1)	0.2	<0.1	(0.1)	0.5	<0.1	(0.1)	(0.8)	<0.1	(0.1)	0.2
Chubsucker	–			–			<0.1	(0.1)	0.2	–			–		
Yellow bullhead	<0.1	(0.2)	0.7	<0.1	(0.1)	0.7	0.1	(0.3)	2.0	<0.1	(0.2)	1.1	0.1	(0.3)	2.4
Brown bullhead	–			–			–			<0.1	(0.1)	0.3	–		
Flat bullhead	0.4	(0.8)	7.5	0.5	(1.2)	13.1	0.2	(0.4)	4.1	0.2	(0.6)	6.8	0.3	(0.8)	8.7
Mud sunfish	<0.1	(0.1)	0.2	–			–			–			–		
Redbreast sunfish	0.4	(1.2)	9.2	0.2	(0.4)	6.1	0.4	(1.1)	10.2	0.2	(0.5)	6.5	0.7	(1.4)	16.4
Pumpkinseed	–			–			–			–			–		
Warmouth	–			–			–			<0.1	(0.1)	0.5	–		
Bluegill	3.3	(4.8)	67.2	2.5	(4.1)	64.3	2.5	(4.1)	64.2	2.0	(4.6)	60.3	1.9	(3.5)	46.7
Dollar sunfish	–			–			–			<0.1	(0.1)	0.5	–		
Redear sunfish	–			–			–			–			–		
Spotted sunfish	0.2	(0.3)	3.2	0.1	(0.3)	2.6	0.3	(0.7)	7.5	0.2	(0.5)	5.9	0.1	(0.3)	2.7
Largemouth bass	<0.1	(0.1)	0.9	0.1	(0.2)	1.6	0.1	(0.2)	1.4	0.1	(0.2)	1.9	0.1	(0.2)	2.0
Black crappie	0.5	(1.2)	10.9	0.4	(1.4)	11.4	0.4	(0.8)	10.0	0.5	(1.0)	15.4	0.8	(1.6)	20.9
Yellow perch	–			–			–			–			–		
Total	4.9	(5.1)	100.0	3.8	(4.4)	100.0	3.9	(4.8)	100.1	3.3	(5.2)	100.0	4.0	(4.8)	100.0

Source: Paller et al. (1988a)

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TABLE 4-62

Mean 1987 Hoop Netting Catch/Net/Day (standard deviation) and Percent Composition in Regions 4-8 of L Lake During Periods of Reactor Operation (January - June; December 1987) and Reactor Outage (July - November 1987)

Reactor Operating

Taxon	Region 4 CPUE		%	Region 5 CPUE		%	Region 6 CPUE		%	Region 7 CPUE		%	Region 8 CPUE		%
Gizzard shad	-			-			-			-			-		
Golden shiner	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1
Creek chubsucker	-			-			<0.1	(0.1)	<0.1	-			-		
Chubsucker	-			-			-			-			-		
Yellow bullhead	<0.1	(0.2)	<0.1	<0.1	(0.1)	<0.1	0.1	(0.3)	2.5	<0.1	(0.2)	<0.1	0.1	(0.3)	2.5
Flat bullhead	0.4	(0.8)	8.3	0.5	(1.2)	13.2	0.2	(0.4)	5.0	0.2	(0.6)	6.3	0.3	(0.8)	7.5
Brown bullhead	-			-			-			<0.1	(0.1)	<0.1	-		
Unid. catfish	-			-			-			-			-		
Mud sunfish	<0.1	(0.1)	<0.1	-			-			-			-		
Hybrid sunfish	-			-			-			-			-		
Redbreast sunfish	0.4	(1.2)	8.3	0.2	(0.4)	5.3	0.4	(1.1)	10.0	0.2	(0.5)	6.3	0.7	(1.4)	17.5
Pumpkinseed	-			-			-			-			-		
Warmouth	-			-			-			<0.1	(0.1)	<0.1	-		
Bluegill	3.3	(4.8)	68.8	2.5	(4.1)	65.8	2.5	(4.1)	62.5	2.0	(4.6)	62.5	1.9	(3.5)	47.5
Dollar sunfish	-			-			-			<0.1	(0.1)	<0.1	-		
Redear sunfish	-			-			-			-			-		
Spotted sunfish	0.2	(0.3)	4.2	0.1	(0.3)	2.6	0.3	(0.7)	7.5	0.2	(0.5)	6.3	0.1	(0.3)	2.5
Unid. sunfish	-			-			-			-			-		
Largemouth bass	<0.1	(0.1)	<0.1	0.1	(0.2)	2.6	0.1	(0.2)	2.5	0.1	(0.2)	3.1	0.1	(0.2)	2.5
Black crappie	0.5	(1.2)	10.4	0.4	(1.4)	10.5	0.4	(0.8)	10.0	0.5	(1.0)	15.6	0.8	(1.6)	20.0
Yellow perch	-			-			-			-			-		
Unknown	-			-			-			-			-		
Total	4.8	(5.1)	100.0	3.8	(4.4)	100.0	4.0	(4.8)	100.0	3.2	(5.2)	100.1	4.0	(4.8)	100.0

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TABLE 4-62, Contd

	Reactor Not Operating														
	Region 4			Region 5			Region 6			Region 7			Region 8		
Taxon	CPUE		%	CPUE		%	CPUE		%	CPUE		%	CPUE		%
Gizzard shad	–			–			<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1
Golden shiner	–			–			–			–			–		
Creek chubsucker	–			–			–			–			–		
Chubsucker	–			–			–			–			–		
Yellow bullhead	0.2	(0.4)	2.9	0.6	(2.4)	8.2	0.5	(1.5)	11.6	0.2	(0.6)	4.2	0.5	(1.8)	7.8
Flat bullhead	0.2	(0.4)	2.9	0.5	(1.0)	6.8	0.3	(0.7)	7.0	0.3	(0.7)	6.3	0.4	(1.3)	6.3
Brown bullhead	–			<0.1	(0.1)	<0.1	–			–			–		
Unid. catfish	–			–			–			–			<0.1	(0.1)	<0.1
Mud sunfish	–			–			–			–			–		
Hybrid sunfish	–			<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	–			<0.1	(0.2)	<0.1
Redbreast sunfish	0.4	(0.8)	5.8	0.7	(1.9)	9.6	0.2	(0.6)	4.7	0.3	(0.6)	6.3	0.5	(0.6)	7.8
Pumpkinseed	–			–			–			–			–		
Warmouth	<0.1	(0.2)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	–			–		
Bluegill	6.0	(12.0)	87.0	5.5	(8.6)	75.3	3.3	(5.0)	76.7	3.9	(5.3)	81.3	5.0	(6.5)	78.1
Dollar sunfish	–			–			–			–			–		
Redear sunfish	–			–			–			–			–		
Spotted sunfish	–			–			<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1
Unid. sunfish	<0.1	(0.1)	<0.1	–			–			0.1	(0.7)	2.1	<0.1	(0.1)	<0.1
Largemouth bass	–			<0.1	(0.1)	<0.1	–			<0.1	(0.1)	<0.1	<0.1	(0.1)	<0.1
Black crappie	0.1	(0.2)	1.4	<0.1	(0.1)	<0.1	<0.1	(0.2)	<0.1	<0.1	(0.1)	<0.1	<0.1	(0.2)	<0.1
Yellow perch	–			–			–			–			–		
Unknown	–			–			–			–			<0.1	(0.1)	<0.1
Total	6.9	(12.6)	100.0	7.3	(12.0)	99.9	4.5	(6.7)	100.0	4.8	(6.1)	100.2	6.6	(8.3)	100.0

Source: Paller et al. (1988a)

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TABLE 4-63

Mean Yearly Densities (no. larvae/1,000 m^3; SD in parentheses) of Fish Larvae Collected by Littoral Surface Tows in L Lake. Collections were Made Weekly in all Regions During February - July and Biweekly in Regions 4, 6, and 8 During the Rest of the Year.[a]

	Region 4		Region 6		Region 8		Region 5		Region 7	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
Unknown shad sp.		9.6 (38.7)		2.8 (13.7)		2.4 (11.8)		9.0 (43.6)		9.0 (31.9)
Gizzard shad								0.8 (3.8)		0.9 (4.1)
Threadfin shad										
Cyprinid	14.1 (34.6)	26.2 (81.3)	12.7 (24.8)	18.2 (78.5)	8.1 (22.1)	27.4 (129.2)	18.1 (32.6)	28.0 (64.4)	26.2 (57.0)	28.8 (63.8)
Common carp		0.1 (1.3)						0.2 (2.1)		
Brook silverside		0.1 (1.6)		0.1 (1.4)		0.1 (1.6)				
Mosquitofish	13.1 (40.0)	<0.1	22.2 (70.1)	<0.1	25.2 (75.6)	<0.1	23.7 (56.4)	<0.1	35.4 (63.8)	<0.1
Bluegill	266.0 (766.4)	784.7 (4331.1)	269.2 (627.0)	436.8 (1481.3)	141.5 (471.6)	168.4 (517.6)	399.1 (800.8)	472.9 (1204.9)	372.2 (840.0)	290.1 (570.9)
Redbreast Sunfish		0.7 (5.0)	N/A	2.0 (9.3)	N/A	2.2 (11.7)	N/A	2.1 (10.5)	N/A	1.7 (11.0)

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TABLE 4-63, Contd

	Region 4		Region 6		Region 8		Region 5		Region 7	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
Black crappie		2.0 (9.0)		8.7 (36.1)		5.8 (23.5)		10.9 (40.2)	0.2 (2.0)	24.8 (99.4)
Other sunfish	-	1.4 (12.4)	-	0.5 (3.2)		1.2 (9.7)	-	0.4 (4.3)	-	0.4 (2.6)
Damaged or misc.	5.2 (18.0)	5.8 (24.6)	11.7 (38.2)	5.7 (14.8)	3.0 (12.5)	2.3 (10.4)	8.4 (27.6)	4.8 (17.5)	9.5 (22.4)	2.2 (9.0)
Total	298.4 (795.9)	829.9 (4332.6)	315.8 (681.7)	474.9 (1482.6)	177.8 (489.7)	209.8 (544.3)	449.3 (853.0)	529.1 (1216.0)	443.6 (860.1)	357.8 (570.5)

Note: Columns may not sum to equal totals due to rounding effects.

[a] Because sampling effort in Regions 5 and 7 was 2/3 that of the other regions, means for Regions 5 and 7 should not be compared directly with means for Regions 4, 6, and 8. Lepomid larvae were not identified to species in 1986 and were included with bluegill for that year (January 1986 - December 1987)

Source: Paller et al. (1988a)

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TABLE 4-64

Growth of Selected Fish Species (mm/day) Based on Results of Tagging Study in L Lake (January 1986 - December 1987)

Species	No.	Average Growth (mm/day)	Standard Deviation	Yearly Estimate (mm)
Flat bullhead	36	0.06	0.058	23
Redbreast sunfish	37	0.15	0.427	55
Bluegill	74	0.08	0.081	28
Largemouth bass				
Overall	120	0.30	0.163	108
Winter	24	0.20	0.105	-

Source: Paller et al (1988a)

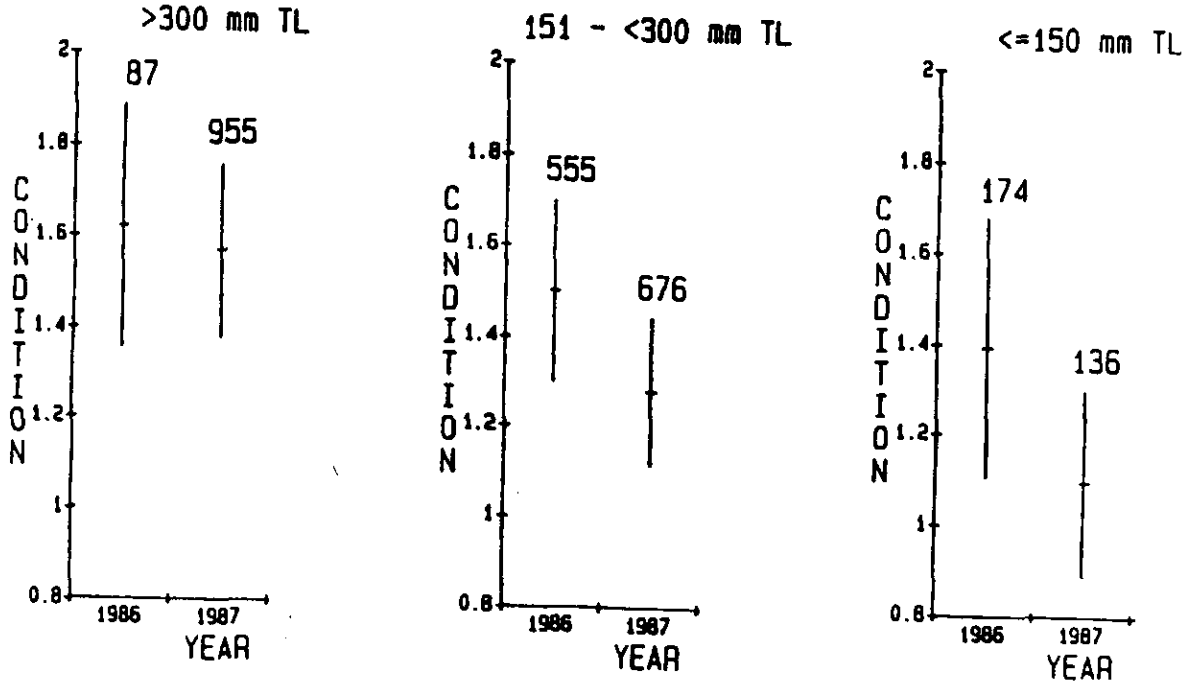

FIGURE 4-48. Differences in the Mean Condition of Three Size Classes of Largemouth Bass from Regions 4-8 of L Lake Among Years 1986 - 1988. Vertical bar either side of the mean represents one standard deviation. Number of specimens is indicated above each vertical bar (source: Paller et al., 1988a)

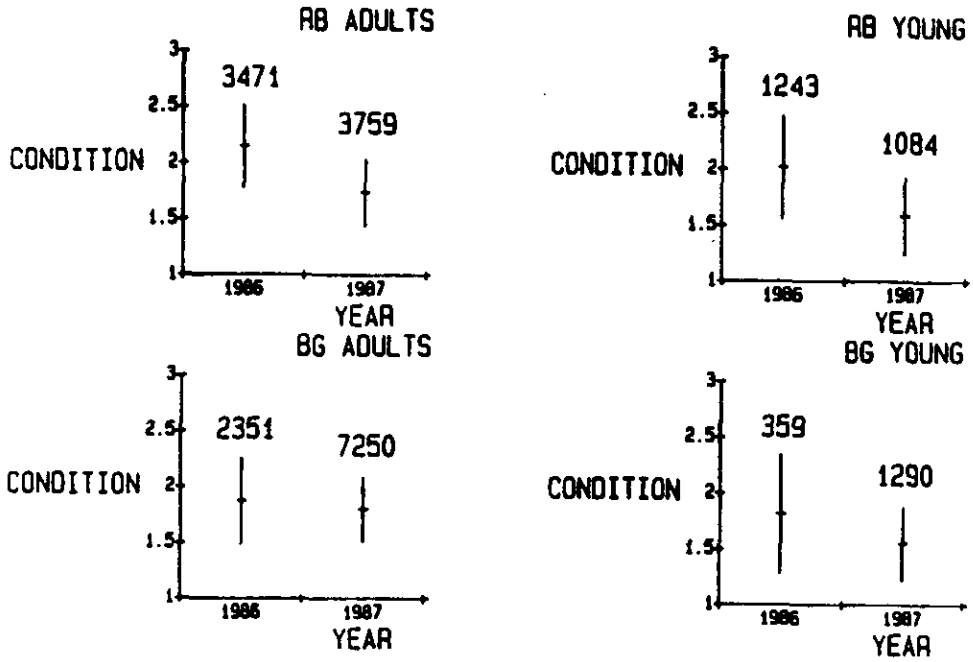

FIGURE 4-49. **Differences in the Mean Condition of Adult and Young Redbreast Sunfish and Bluegill from Regions 4-8 of L Lake Among Years 1986-1987.** Vertical bar either side of the mean represents one standard deviation. Number of specimens is indicated (source: Paller et al., 1988a)

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The fishes occupying L Lake represent all the trophic groups typically occurring in reservoir fish communities. Threadfin and gizzard shad represent the lowest trophic level, since these species can function as primary consumers (Drenner et al., 1984; Ziebell et al., 1986). Stomach content data indicate that threadfin shad in L Lake feed on microcrustaceans, green algae, filamentous algae, rotifers, and diatoms, with the relative importance of these foods exhibiting large seasonal shifts (Figure 4-50). Bluegill and redbreast sunfish have fed primarily on microcrustaceans and chironomidae larvae and pupae (Table 4-65). In 1987, largemouth bass subsisted almost entirely on small to intermediate size sunfish, and made little use of threadfin shad (Table 4-65). A shift towards greater utilization of threadfin shad is typical in maturing reservoirs (Mullan and Applegate, 1967) and is expected in L Lake in the future.

Several diseases and parasites affected the fishes of L Lake during 1986 and 1987 (Tables 4-66 and 4-67). Most have occured at low levels and have not been associated with obvious mortalities. During 1986, fin rot and redsore disease were the most common anomalies. During 1987, trematode infestation was the most common anomaly. Redsore disease, which has caused serious epizootics among Par Pond largemouth bass (Esch and Hazen, 1978), reached a maximum incidence of approximately 2% in L Lake during 1986 through 1987 (Figure 4-51).

Fish Kills

Fish kills have occurred in the upper portion (Region 2) of L Lake following L-Reactor startups. These kills occur when fish that enter the discharge area during periods of reactor outage are overcome by the relatively sudden increases in temperature that occur during reactor startups. The kills are roughly proportional to the length of the outage, since longer outages provide more time to recolonize the discharge area. The largest kill (over 3,000,000 fish) occurred in December 1986 when L Reactor was restarted following a six month summer outage (Table 4-68). The kill that followed the six month summer outage of 1987 was much smaller (approximately 27,000 fish) because fewer fish were in the discharge area (Paller et al., 1988) and because power levels (hence water temperatures) were lower than during the December 1986 restart. Approximately 99% of the fish killed during L-Reactor startups were juvenile sunfish.

Summary

While fish abundance and distribution in Region 2 were obviously affected by the kills that followed the reactor restarts in 1986 and 1987, it is not clear that the restarts impacted fish abundance in Regions 4-8 (which never attained lethal temperatures). Although catch per unit effort (CPUE) of bluegill in Regions 4 and 8 declined immediately after the large 1986 kill (i.e., in January 1987; Figure 4-46), the decline was smallest in Region 4, which was closest to the discharge area (hence most vulnerable to the negative effects of the restart), and greatest in

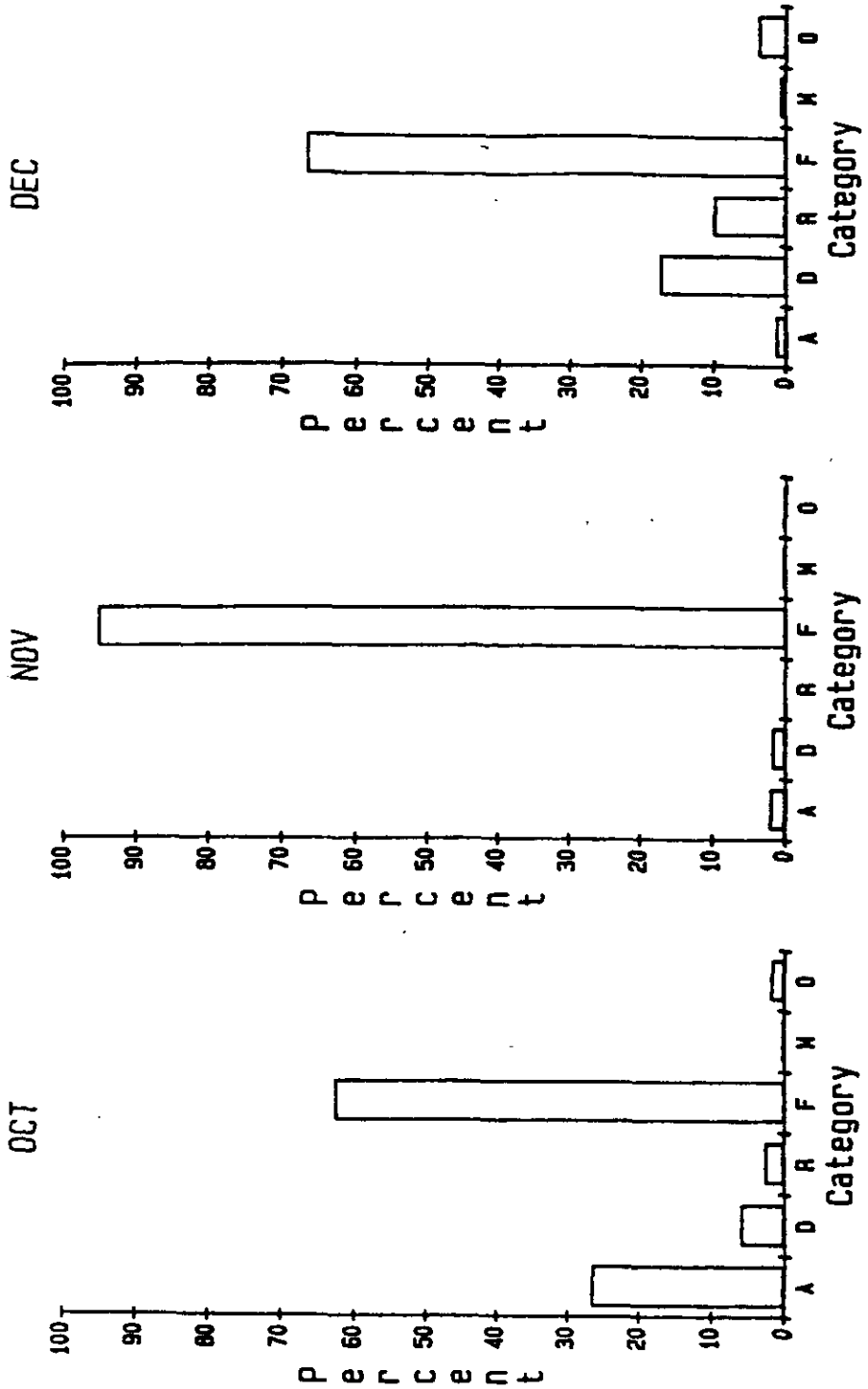

FIGURE 4-50. Percent Numerical Abundance of Food Categories Observed in Gizzards of Threadfin Shad Collected from L Lake. A = Algae (dinoflagellates and nonfilamentous green and blue-green algae), D = diatoms, R = rotifers, F = filamentous fragments, M = microcrustaceans, O = other (October - December 1987) (source: Paller et al., 1988a)

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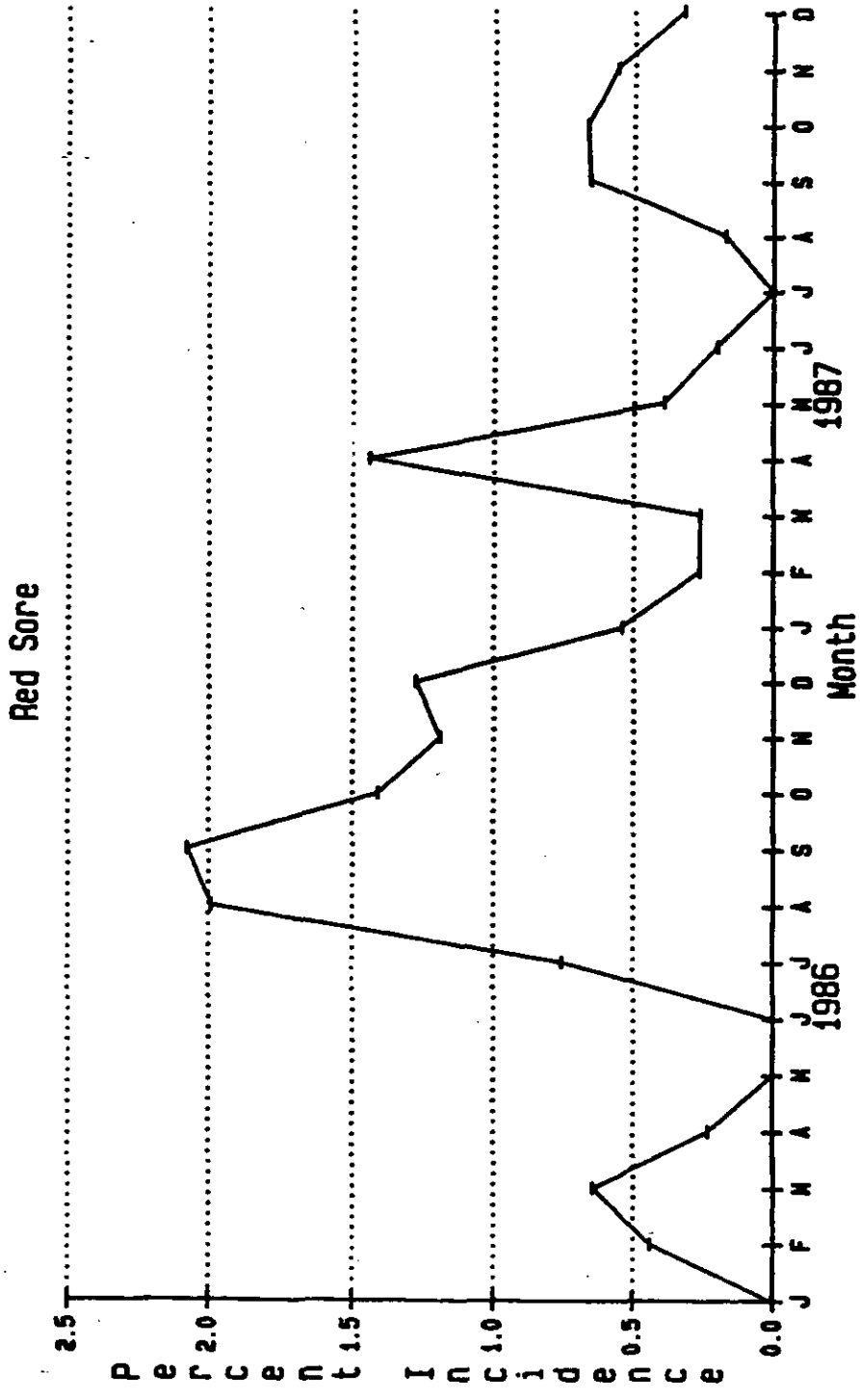

FIGURE 4-51. **Monthly Incidence (percent infected fish) of Redsore Disease in L Lake (January 1986 - December 1987)** (from: Paller et al., 1988a)

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TABLE 4-65

Percent Occurrence of Dominant Food Items in the Stomachs of Redbreast Sunfish and Largemouth Bass from L Lake (January - December 1987)

Food Item	Bluegill	Redbreast Sunfish	Largemouth Bass
Crustacea			
Cladocera	32.9	24.2	-[a]
Copepoda	18.0	19.4	-
Ostracoda	40.2	39.5	-
Amphipoda	2.1	5.6	-
Unknown	6.8	11.3	-
Insect			
Ephemeroptera	0.5	1.0	-
Odonata	0.2	0.2	-
Tricoptera	0.2	0.0	-
Lepidoptera	0.2	0.0	-
Coleoptera	1.4	0.5	-
Diptera	86.8	92.4	-
Orthoptera	0.0	0.3	-
Hymenoptera	4.4	1.8	-
Unknown	6.4	3.7	-
Fish			
Cyprinidae	-	-	0.7
Centrarchidae	-	-	76.0
Eggs	-	-	-
Unknown	-	-	23.3

[a] Item not found.

Source: Paller et al. (1988a)

TABLE 4-66

Occurrence of External Aberrances for Fish Collected in Regions 4-8 of L Lake

January - June 1986

Taxon	Disease Lesion				Abnormalities				External Parasites				Total
	Fungus	Redsore	Fin Rot	Unid.	Spinal	Pughead	Laceration	Other	Copepod	Leech	Blackspot	Trematode	
Gizzard shad													
Threadfin shad													
Chain pickerel													
Golden shiner		2	7										9
Chubsucker													
Creek chubsucker		2											2
Yellow bullhead		5		1			1						7
Brown bullhead													
Flat bullhead				1									1
Hybrid sunfish													
Redbreast sunfish		4	1				2						7
Warmouth													
Bluegill			1										1
Dollar sunfish			2										2
Spotted sunfish			2				2						4
Largemouth bass					1								1
Black crappie													
Total	0	13	13	2	1	0	5	0	0	0	0	0	34

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TABLE 4-66, Contd

July - December 1986

Taxon	Disease Lesion				Abnormalities				External Parasites				Total
	Fungus	Redsore	Fin Rot	Unid.	Spinal	Pughead	Laceration	Other	Copepod	Leech	Blackspot	Trematode	
Gizzard shad													
Threadfin shad													
Chain pickerel			1										1
Golden shiner		4					2						6
Chubsucker		1											1
Creek chubsucker													
Yellow bullhead							3						3
Brown bullhead													
Flat bullhead		3	1		1		2						7
Hybrid sunfish													
Redbreast sunfish		33	23	4	2	1	9	1	1	2			76
Warmouth													
Bluegill		15	9		10		3	3			2		42
Dollar sunfish		1	1										2
Spotted sunfish		32	15			1	6						54
Largemouth bass		9	3		2	1	4						19
Black crappie		13	1		2		3						19
Total	0	111	54	4	17	3	32	4	1	2	2	0	230

Source: Paller et al. (1988a)

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TABLE 4-67

Occurrence of External Aberrances for Fish Collected in Regions 4-8 of L Lake

January - June 1987

Taxon	Disease Lesion				Abnormalities				External Parasites				Total
	Fungus	Redsore	Fin Rot	Unid.	Spinal	Pughead	Laceration	Other	Copepod	Leech	Blackspot	Trematode	
Gizzard shad													
Threadfin shad													
Chain pickerel													
Golden shiner													
Chubsucker													
Creek chubsucker													
Yellow bullhead			1				1	5					7
Brown bullhead													
Flat bullhead													
Hybrid sunfish													
Redbreast sunfish		10	2				2	3		1	1	62	81
Warmouth		1											1
Bluegill	1	7	7	2	13	1	7	4		1	28	9	80
Dollar sunfish													
Spotted sunfish		2	1				1	1				3	8
Largemouth bass	4	10	5		1		1	4			19	17	61
Black crappie			1				2						3
Total	5	30	17	2	14	1	14	17	0	2	48	91	241

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TABLE 4-67, Contd

July - December 1986

Taxon	Disease Lesion				Abnormalities				External Parasites				Total
	Fungus	Redsore	Fin Rot	Unid.	Spinal	Pughead	Laceration	Other	Copepod	Leech	Blackspot	Trematode	
Gizzard shad								1					1
Threadfin shad												1	1
Chain pickerel							1			1			2
Golden shiner													
Chubsucker													
Creek chubsucker													
Yellow bullhead					1								1
Brown bullhead								1					1
Flat bullhead							1	1					2
Hybrid sunfish						1					1	1	3
Redbreast sunfish	1	9	11				4	3			6	458	492
Warmouth			1				1						2
Bluegill	3	12	21		6	2	2	6		2	24	39	117
Dollar sunfish													
Spotted sunfish		1	2								1		4
Largemouth bass	1	10	3	1	4	1	1	10		3	20	53	107
Black crappie					1								1
Total	5	32	38	1	12	4	10	22	0	6	52	552	734

Source: Paller et al (1988a)

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Region 8, which was farthest from the discharge area. Furthermore, CPUE in Region 6 declined before the 1986 kill (i.e., the December sample shown in Figure 4-46 was taken before the kill occurred) indicating that the December 1986 fish kill and the decline in Region 6 was unrelated. While generally declining, bluegill CPUE was highly variable during the winter of 1986 and 1987; even after the kill it sometimes temporarily approached pre-kill levels (as observed in Region 4 during February, Figure 4-46). Thus, it is unlikely that the decreases in CPUE in the lower half of the lake and the large 1986 fish kill were related. Instead, these decreases may have been caused by increases in predation or competition as expected in a newly developing reservoir.

Impacts of L-Reactor Operation

Impacts of L-Reactor operation on the L-Lake fish community are largely confined to the upper portion of L Lake. These impacts consist of the exclusion of fish from areas that reach temperatures equal to and above the avoidance temperatures of southeastern fishes and fish kills associated with reactor restarts. Fish kills primarily affect juvenile fish near the discharge point and do not appear to have affected fish distribution and abundance in the lower 50% of L Lake.

The fish community in the lower 50% of L Lake is developing towards a biologically balanced community: community composition is approaching that in other cooling reservoirs, all of the major species are successfully reproducing, and typical reservoir food chains and trophic groups are represented. While the condition of some species has declined, this phenomenon cannot be directly linked to elevated temperatures in L Lake. These data suggest that thermal discharges from L Reactor have not adversely affected fish populations in the lower 50% of L Lake.

TABLE 4-68

Total Number of Fish Observed or Estimated During Fish Kills at L Lake (January 1986 - December 1987). All the Large Kills (>100 fish) were Associated with Reactor Restarts and Confined to Region 2

Date	Total
01/29/86	7
02/24/86	116
02/25/86	14
03/07/86	69
03/12/86	354[a]
03/18/86	7
05/10/86	10
05/11/86	133
05/12/86	2,668
05/14/86	20
12/08/86	82,973[a]
12/09/86	1,843,611[a]
12/10/86	1,521,694[a]
12/12/86	64,374[a]
12/26/86	53
01/27/87	12,416[a]
01/28/87	7,804
03/13/87	12,900[a]
08/14/87	247[a]
11/18/87 - 11/20/87	27,279[a]

[a] These numbers are estimates derived from a shoreline survey of each kill event. The other numbers are total counts of all dead fish present.

Source: Paller et al. (1988a)

4.4 STEEL CREEK

4.4.1 Water Quality

Steel Creek historically received cooling water discharges from operation of the P and L Reactors. P-Reactor thermal effluents were rerouted to Par Pond in 1963, and with the shutdown of L Reactor in 1965 thermal discharges ceased and Steel Creek began undergoing successional recovery. Routine water quality monitoring from 1973 to 1982 did not identify any adverse impacts associated with previous thermal discharges (Lower, 1987). A synopsis of historical water quality monitoring of Steel Creek prior to the 1983-1985 two-year water quality program instituted under the Comprehensive Cooling Water Study (CCWS) can be found in Lower (1987).

Tables 4-69 and 4-70 summarize the pre-CCWS water quality data from Steel Creek at two sample locations. Routine monitoring of radioactive and nonradioactive parameters of the surface waters of the SRS are conducted by the Health Protection (HP) Department. Results of this monitoring program for all SRS surface waters for 1987 and 1988 can be found in Appendix A of this document.

The Comprehensive Cooling Water Study Final Report Volume 2 (Lower, 1987) reports the results of a special study to determine levels of volatile, acid, and base/neutral organic compounds in Steel Creek. Concentrations of all 88 tested organics never exceeded the lower limit of detection. Lower (1987) also reported the results of analyses for pesticides and PCBs in onsite streams and the Savannah River. The results for Steel Creek can be found in Table A-10 of Appendix A. The two-year CCWS study monitored standard parameters and general water chemistry (Table 4-71), nutrients (Table 4-72), total and dissolved major cations (Tables 4-73 and 4-74), trace elements (Table 4-75), and organic carbon (Table 4-76). Sampling locations for this study are shown in Figure A-1 of Appendix A.

Recent water quality information for Steel Creek after the construction of L Lake in 1985 can be found in Gladden et al. (1988). The range of values for 34 water quality parameters for Steel Creek from November 1985 to December 1987 can be found in Table 4-77. The effluent from L Lake has influenced the water quality of Steel Creek due to the introduction of Savannah River water into the system. Post-impoundment Steel Creek water quality parameters showed increases over preimpoundment values for temperature, conductivity, alkalinity, total phosphorus, nitrate-nitrogen, ammonia-nitrogen, total and dissolved sodium, and chloride. There were also detectable decreases in pH (Gladden et al., 1988). Water quality in Steel Creek is within the range of other representative lotic systems. Since the most recent studies encompassed periods of reactor operation and outage, continued operation of L Reactor would not be expected to effect any significant changes.

TABLE 4-69

Steel Creek Water Quality at SRS Road A, 1973 Through 1985

Parameter	Units	Mean Concentration,[a] 1973-1982[b]		Mean Concentration 1983-1985[c]	
Temperature	°C	18.0	(112)	17.7	(36)
pH (range)	-	5.7 - 9.0	(111)	6.3 - 7.8	(32)
Dissolved oxygen	mg/L	9.0	(112)	8.0	(36)
Alkalinity	mg/L	18.9	(112)	18.0	(36)
Conductivity	µmhos/cm	NA		52.4	(35)
Turbidity	NTU	NA		3.3	(35)
Suspended solids	mg/L	8.0	(113)	7.6	(35)
Volatile solids	mg/L	19.2	(113)	4.0	(36)
Total dissolved solids	mg/L	47.9	(113)	45.7	(36)
Total solids	mg/L	55.9	(113)	58.0	(36)
Biochemical oxygen demand	mg/L	0.79	(38)	NA	
Chemical oxygen demand	mg/L	10.9	(94)	10.6	(36)
Chlorides	mg/L	4.4	(113)	4.2	(36)
Kjeldahl nitrogen (N)	mg/L	<0.1	(26)	0.27	(12)
Nitrates + nitrites (N)	mg/L	0.163	(113)	0.24	(23)
Sulfates (SO_4)	mg/L	2.36	(112)	2.9	(36)
Total phosphates (P)	mg/L	0.024	(110)	0.093	(36)
Aluminum, total (Al)	mg/L	0.39	(110)	0.086	(35)
Ammonia (N)	mg/L	0.039	(110)	0.025	(24)
Calcium, total (Ca)	mg/L	7.1	(111)	6.3	(12)
Copper, total (Cu)	mg/L	NA		0.01	(24)
Cadmium, total (Cd)	mg/L	NA		<0.01	(24)
Magnesium, total (Mg)	mg/L	NA		0.73	(35)
Manganese, total (Mn)	mg/L	<0.01	(7)	0.093	(35)
Mercury, total (Hg)	mg/L	<0.001	(19)	0.00017	(13)
Nickel, total (Ni)	mg/L	NA		0.055	(24)
Sodium, total (Na)	mg/L	4.53	(111)	5.4	(33)
Iron, total (Fe)	mg/L	0.40	(111)	0.74	(35)
Lead, total (Pb)	mg/L	<0.5	(110)	<0.01	(24)
Chromium, total (Cr)	mg/L	NA		<0.01	(35)
Zinc, total (Zn)	mg/L	NA		0.034	(35)

[a] Except as noted; number of analyses in parentheses
[b] DP-1697, Vol. III, Chapter 2
[c] Du Pont, 1984; 1985; 1986

NA = no analysis conducted

Source: Lower (1987)

TABLE 4-70

Steel Creek Water Quality at Old Hattiesville Bridge, 1973 Through 1985

Parameter	Units	Mean Concentration,[a] 1973-1982[b]	Mean Concentration[a] 1983-1985[b]	
Temperature	°C	NA	18.0	(24)
pH (range)	–	NA	5.6 - 7.6	(24)
Dissolved oxygen	mg/L	NA	8.1	(24)
Alkalinity	mg/L	NA	17.5	(24)
Conductivity	µmhos/cm	NA	60.0	(24)
Turbidity	NTU	NA	4.85	(24)
Suspended solids	mg/L	NA	7.1	(24)
Volatile solids	mg/L	NA	3.1	(24)
Total dissolved solids	mg/L	NA	50.5	(24)
Total solids	mg/L	NA	57.5	(24)
Biochemical oxygen demand	mg/L	NA	NA	
Chemical oxygen demand	mg/L	NA	11.0	(24)
Chlorides	mg/L	NA	4.7	(24)
Kjeldahl nitrogen (N)	mg/L	NA	NA	
Nitrates + nitrites (N)	mg/L	NA	0.13	(12)
Sulfates (SO_4)	mg/L	NA	3.5	(24)
Total phosphates (P)	mg/L	NA	0.035	(24)
Aluminum, total (Al)	mg/L	NA	0.14	(24)
Ammonia (N)	mg/L	NA	0.02	(12)
Calcium, total (Ca)	mg/L	NA	7.1	(12)
Copper, total (Cu)	mg/L	NA	0.01	(24)
Cadmium, total (Cd)	mg/L	NA	<0.01	(24)
Magnesium, total (Mg)	mg/L	NA	0.86	(24)
Manganese, total (Mn)	mg/L	NA	0.145	(24)
Mercury, total (Hg)	mg/L	NA	0.00018	(20)
Nickel, total (Ni)	mg/L	NA	0.055	(24)
Sodium, total (Na)	mg/L	NA	4.65	(24)
Iron, total (Fe)	mg/L	NA	1.2	(24)
Lead, total (Pb)	mg/L	NA	<0.01	(24)
Chromium, total (Cr)	mg/L	NA	<0.01	(24)
Zinc, total (Zn)	mg/L	NA	0.04	(24)

[a] Except as noted; number of analyses in parentheses
[b] Water chemistry monitoring at the Old Hattiesville Bridge crossing of Steel Creek began in January 1984.

NA = no analysis conducted

Source: Lower (1987)

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TABLE 4-71

General Water Chemistry and Standard Parameters: Steel Creek Watershed

Station Number	Site	Temperature (°C)	pH	Total Alkalinity (mg/L as $CaCO_3$)	Dissolved Oxygen (mg O_2/L)	Dissolved Oxygen Saturation (%)	Specific Conductance (µmhos/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Chlorides (mg/L)	Sulfates (mg/L)
16	Steel Creek at Road B	18.1 (46) 4.6 - 27.5	7.07 (46) 6.20 - 8.30	14.8 (45) 0.75 - 20.0	8.33 (46) 5.90 - 11.4	86.0 (46) 68.4 - 102.7	58.9 (38) 27.9 - 78.6	26.0 (45) 0.25 - 345.0	76.4 (43) 4.60 - 1930.0	5.16 (46) 1.90 - 7.40	3.84 (28) 0.25 - 15.8
15	Steel Creek at SRS Road A-14	18.7 (46) 5.5 - 29.7	7.03 (46) 6.50 - 8.10	17.1 (45) 4.75 - 32.7	7.92 (46) 4.60 - 11.5	82.7 (46) 56.9 - 101.8	67.0 (38) 27.2 - 166.9	21.4 (45) 0.25 - 134.1	37.5 (43) 2.80 - 200.0	5.63 (46) 1.60 - 27.4	4.24 (28) 0.25 - 11.0
14	Steel Creek upstream of Meyers confluence branch	17.8 (44) 6.4 - 31.7	7.00 (46) 6.10 - 8.10	17.1 (42) 6.15 - 26.4	7.94 (43) 4.70 - 11.9	81.4 (43) 58.1 - 100.0	68.5 (36) 36.4 - 128.0	17.0 (43) 0.40 - 97.2	40.9 (41) 8.30 - 283.0	5.33 (44) 2.30 - 16.4	4.93 (26) 1.06 - 13.4
12	Meyers Branch at SRS Road B-6.2	15.5 (46) 0.6 - 25.2	6.73 (46) 5.80 - 8.30	15.0 (45) 3.25 - 27.8	7.09 (44) 4.20 - 11.6	68.4 (44) 48.0 - 91.0	52.7 (38) 26.8 - 70.9	6.13 (45) 0.25 - 93.2	5.50 (43) 1.50 - 35.0	3.95 (46) 2.10 - 6.90	1.85 (27) 0.03 - 8.45
11	Meyers Branch at SRS Road 9	15.0 (46) 0.5 - 22.5	6.90 (46) 5.90 - 8.30	13.7 (45) 3.54 - 25.3	8.20 (45) 5.20 - 12.2	79.8 (45) 59.7 - 94.0	43.1 (38) 25.0 - 61.0	4.78 (45) 0.25 - 31.2	7.00 (43) 1.60 - 47.0	2.80 (45) 1.30 - 4.20	0.91 (26) 0.13 - 5.61
10	Meyers Branch upstream of Steel Creek confluence	16.7 (44) 0.1 - 25.5	6.93 (44) 6.00 - 8.30	16.9 (44) 3.75 - 26.9	7.94 (44) 5.10 - 12.4	77.7 (44) 58.2 - 95.6	48.3 (37) 30.4 - 72.4	4.67 (44) 0.25 - 17.2	5.60 (42) 1.60 - 18.8	2.66 (45) 1.60 - 6.40	0.81 (25) 0.06 - 5.48
13	Steel Creek at Old Hattiesville Bridge	16.3 (46) 2.6 - 27.5	7.01 (46) 6.00 - 8.40	17.8 (44) 4.83 - 31.3	7.42 (45) 3.50 - 10.9	73.8 (45) 40.3 - 94.7	62.5 (38) 34.2 - 116.5	10.8 (45) 1.20 - 69.2	26.3 (43) 6.70 - 240.0	4.52 (46) 2.10 - 14.4	3.65 (28) 0.25 - 14.7
8	Steel Creek swamp upstream of Pen Branch confluence	17.6 (43) 1.0 - 28.0	6.90 (44) 6.10 - 8.10	18.0 (43) 10.5 - 24.6	6.69 (44) 3.50 - 13.6	66.7 (43) 40.2 - 95.8	68.5 (36) 38.4 - 93.4	2.49 (43) 0.25 - 7.60	6.10 (41) 1.70 - 24.8	5.21 (44) 2.20 - 8.10	4.60 (26) 1.09 - 8.45
7	Steel Creek upstream of confluence with Savannah River	17.3 (46) 0.8 - 27.5	6.93 (46) 6.40 - 8.10	18.4 (45) 11.8 - 26.2	6.83 (46) 3.40 - 13.1	67.8 (38) 39.2 - 92.5	71.5 (38) 46.2 - 91.6	5.18 (45) 0.25 - 16.3	7.00 (43) 2.50 - 25.3	5.59 (46) 2.20 - 7.90	5.23 (28) 1.90 - 8.98

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.
Source: Lower (1987)

W890070

TABLE 4-72

Nutrient Concentrations (mg P/L or mg N/L): Steel Creek Watershed

Station Number	Site	Total Phosphorus	Total Orthophosphates	Dissolved Orthophosphates	Nitrates	Nitrites	Ammonia	Total Kjeldahl Nitrogen
16	Steel Creek at SRS Road B	0.036 (46) <0.010 - 0.391	0.009 (39) 0.002 - 0.033	0.006 (40) <0.001 - 0.028	0.201 (42) 0.019 - 0.450	0.003 (44) <0.001 - 0.020	0.028 (46) <0.005 - 0.340	0.227 (46) 0.012 - 0.900
15	Steel Creek at SRS Road A-14	0.067 (46) <0.010 - 0.362	0.034 (40) 0.005 - 0.123	0.021 (41) 0.005 - 0.080	0.207 (43) 0.005 - 0.400	0.004 (44) <0.001 - 0.013	0.037 (46) <0.005 - 0.450	0.252 (46) 0.020 - 0.920
14	Steel Creek upstream of Meyers Branch confluence	0.062 (45) <0.010 - 0.181	0.031 (39) 0.003 - 0.201	0.013 (39) 0.003 - 0.035	0.207 (41) 0.072 - 0.410	0.004 (42) <0.001 - 0.012	0.037 (43) <0.005 - 0.430	0.218 (45) 0.048 - 0.910
12	Meyers Branch at SRS Road 9	0.028 (46) <0.010 - 0.406	0.004 (41) <0.010 - 0.013	0.004 (41) <0.001 - 0.014	0.109 (42) 0.019 - 0.206	0.002 (43) <0.001 - 0.010	0.026 (46) <0.005 - 0.390	0.276 (46) 0.057 - 1.00
10	Meyers Branch upstream of Steel Creek confluence	0.022 (46) <0.010 - 0.072	0.007 (40) <0.001 - 0.028	0.004 (40) <0.001 - 0.007	0.092 (42) 0.010 - 0.188	0.002 (43) <0.001 - 0.008	0.030 (45) <0.005 - 0.060	0.251 (45) 0.010 - 0.870
13	Steel Creek at Old Hattiesville Bridge	0.056 (46) <0.010 - 0.261	0.022 (41) 0.003 - 0.062	0.009 (41) 0.003 - 0.033	0.144 (43) 0.005 - 0.305	0.003 (44) <0.001 - 0.010	0.036 (46) <0.005 - 0.280	0.224 (46) 0.038 - 0.900
8	Steel Creek swamp upstream of Pen Branch confluence	0.054 (44) <0.010 - 0.161	0.036 (39) 0.005 - 0.096	0.012 (40) 0.002 - 0.033	0.075 (41) 0.005 - 0.240	0.002 (42) <0.001 - 0.005	0.027 (44) 0.005 - 0.390	0.219 (44) 0.028 - 0.560
7	Steel Creek upstream of confluence with Savannah River	0.057 (45) <0.010 - 0.152	0.035 (40) 0.005 - 0.077	0.016 (41) 0.002 - 0.041	0.075 (42) 0.003 - 0.228	0.003 (43) <0.001 - 0.012	0.024 (46) 0.005 - 0.210	0.250 (46) 0.028 - 0.950

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-73

Total and Dissolved Major Cation Concentrations: Al, Fe, Mn (mg/L): Steel Creek Watershed

Station Number	Site	Aluminum, Total	Aluminum, Dissolved	Iron, Total	Iron, Dissolved	Manganese, Total	Manganese, Dissolved
16	Steel Creek at SRS Road B	3.51 (39) 0.201 - 75.1	0.043 (38) <0.038 - 0.307	1.87 (39) 0.289 - 35.9	0.055 (38) <0.003 - 0.347	0.141 (16) <0.0004 - 1.43	0.030 (16) <0.0004 - 0.084
15	Steel Creek at SRS Road A-14	1.80 (39) 0.390 - 9.88	0.082 (39) <0.038 - 1.56	1.52 (39) 0.712 - 5.04	0.164 (39) 0.030 - 0.411	0.070 (16) <0.0004 - 0.141	0.039 (17) <0.0004 - 0.098
14	Steel Creek upstream of Meyers Branch confluence	1.85 (37) 0.312 - 14.4	0.045 (37) <0.038 - 0.140	1.60 (37) 0.448 - 6.24	0.183 (37) 0.025 - 0.518	0.076 (16) <0.0004 - 0.210	0.049 (17) <0.0004 - 0.084
12	Meyers Branch at SRS Road B-6.2	0.480 (39) <0.038 - 3.80	0.060 (39) <0.038 - 0.290	0.979 (39) 0.198 - 5.89	0.249 (39) 0.062 - 0.734	0.089 (15) <0.0004 - 0.294	0.057 (16) <0.0004 - 0.170
11	Meyers Branch at SRS Road 9	0.460 (38) 0.087 - 1.94	<0.038 (39) <0.038 - 0.145	0.845 (38) 0.248 - 1.73	0.221 (39) 0.055 - 0.507	0.092 (16) <0.0004 - 0.430	0.039 (17) <0.0004 - 0.076
10	Meyers Branch upstream of Steel Creek confluence	0.619 (36) 0.070 - 2.40	0.054 (38) <0.038 - 0.695	0.794 (36) 0.258 - 1.26	0.264 (38) 0.048 - 0.647	0.082 (16) <0.0004 - 0.286	0.041 (17) <0.0004 - 0.080
13	Steel Creek at Old Hattiesville Bridge	1.45 (39) 0.248 - 19.2	0.051 (39) <0.038 - 0.392	1.70 (39) 0.577 - 7.83	0.301 (39) 0.064 - 1.03	0.125 (16) <0.0004 - 0.293	0.086 (16) <0.0004 - 0.161
8	Steel Creek swamp upstream of Pen Branch confluence	0.462 (37) <0.038 - 2.87	<0.038 (37) <0.038 - 0.103	1.54 (37) 0.316 - 18.2	0.202 (37) 0.037 - 0.734	0.095 (17) <0.0004 - 0.182	0.058 (19) <0.0004 - 0.152
7	Steel Creek swamp near confluence with Savannah River	0.461 (39) 0.147 - 1.48	0.054 (39) <0.038 - 0.570	0.976 (39) 0.329 - 1.56	0.229 (39) 0.040 - 0.567	0.080 (17) <0.0004 - 0.281	0.044 (18) <0.0004 - 0.114

All values reported at means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W890070

TABLE 4-74

Dissolved Major Cation Concentrations: Ca, Mg, Na, K (mg/L): Steel Creek Watershed

Station Number	Site	Calcium	Magnesium	Sodium	Potassium
16	Steel Creek at SRS Road B	4.27 (38) 0.894 - 6.19	0.893 (38) 0.283 - 1.26	4.84 (38) 1.97 - 8.26	0.933 (38) <0.368 - 1.87
15	Steel Creek at SRS Road A-14	4.60 (39) 2.01 - 9.30	1.03 (39) 0.517 - 1.33	6.13 (39) 1.83 - 27.1	1.18 (39) <0.368 - 2.80
14	Steel Creek upstream of Meyers Branch confluence	4.66 (37) 2.45 - 7.17	1.03 (37) 0.643 - 1.34	6.13 (37) 2.40 - 17.9	1.13 (37) 0.543 - 2.36
12	Meyers Branch at SRS Road B-6.2	5.30 (39) 2.14 - 8.88	0.813 (39) 0.533 - 0.996	3.13 (39) 1.59 - 4.28	0.846 (39) <0.368 - 2.08
11	Meyers Branch at SRS Road 9	5.04 (39) 2.80 - 6.66	0.540 (39) 0.397 - 0.692	2.12 (39) 1.30 - 3.39	0.450 (39) <0.368 - 2.23
10	Meyers Branch upstream of Steel Creek confluence	6.24 (38) 3.18 - 9.01	0.534 (38) 0.362 - 1.12	1.99 (38) 1.40 - 5.92	0.386 (38) <0.368 - 1.32
13	Steel Creek at Old Hattiesville Bridge	5.38 (39) 2.68 - 9.50	0.898 (39) 0.581 - 1.09	4.77 (39) 2.10 - 14.8	0.846 (39) <0.368 - 2.13
8	Steel Creek swamp upstream of Pen Branch confluence	3.99 (37) 2.72 - 5.76	1.16 (37) 0.822 - 1.40	6.80 (37) 2.24 - 12.8	1.17 (37) <0.368 - 2.34
7	Steel Creek upstream of confluence with Savannah River	3.71 (39) 2.80 - 4.57	1.26 (39) 1.08 - 1.48	7.36 (39) 3.19 - 13.1	1.27 (39) 0.380 - 2.12

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W8906070

TABLE 4-75

Total Trace Elemental Concentrations (μg/L): Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
16	Steel Creek at SRS Road B	2.8 (16) <0.4 - 12.0	0.32 (16) <0.04 - 1.20	4.9 (16) <0.4 - 41.0	3.8 (16) <0.4 - 24.0	2.0 (16) <0.4 - 9.0	4.6 (16) <0.4 - 26.3	4.8 (16) <0.4 - 26.1
15	Steel Creek at SRS Road A-14	3.9 (16) <0.4 - 22.1	0.50 (16) <0.04 - 5.00	6.2 (16) <0.4 - 46.0	2.9 (16) <0.4 - 5.2	1.8 (16) <0.4 - 9.3	3.7 (16) <0.4 - 12.0	6.2 (16) <0.4 - 28.8
14	Steel Creek upstream of Meyers Branch confluence	2.4 (16) <0.4 - 8.1	0.50 (16) <0.04 - 4.50	6.1 (16) <0.4 - 46.0	2.3 (16) <0.4 - 5.0	2.2 (16) <0.4 - 7.3	4.0 (16) <0.4 - 14.1	12.4 (16) <0.4 - 119.0
12	Meyer's Branch at SRS Road B-6.2	1.7 (15) <0.4 - 6.8	0.76 (15) <0.04 - 6.20	8.3 (15) <0.4 - 59.0	1.9 (15) <0.4 - 4.2	2.6 (15) <0.4 - 19.8	2.0 (15) <0.4 - 7.0	6.0 (15) <0.4 - 30.0
11	Meyers Branch at SRS Road 9	1.3 (16) <0.4 - 16.0	0.54 (16) <0.04 - 3.10	6.1 (16) <0.4 - 50.0	2.7 (16) <0.4 - 12.8	1.5 (16) <0.4 - 3.7	2.1 (16) <0.4 - 8.4	5.1 (16) <0.4 - 23.5
10	Meyers Branch upstream of Steel Creek confluence	1.7 (16) <0.4 - 7.8	0.49 (16) <0.04 - 2.50	6.9 (16) <0.4 - 47.0	2.2 (16) <0.4 - 6.7	1.3 (16) <0.4 - 5.3	4.7 (16) <0.4 - 44.5	5.3 (16) <0.4 - 21.6
13	Steel Creek at Old Hattiesville Bridge	2.4 (16) <0.4 - 8.2	0.26 (16) <0.04 - 1.40	7.8 (16) <0.4 - 55.0	2.6 (16) <0.4 - 9.5	1.7 (16) <0.4 - 7.0	3.9 (16) <0.4 - 13.0	6.3 (16) <0.4 - 25.8
8	Steel Creek swamp upstream of Pen Branch confluence	1.5 (17) <0.4 - 8.9	0.61 (17) <0.04 - 5.00	4.0 (17) <0.4 - 31.0	1.7 (17) <0.4 - 4.2	1.4 (17) <0.4 - 3.3	2.0 (17) <0.4 - 7.0	5.2 (17) <0.4 - 22.0
7	Steel Creek swamp near confluence with Savannah River	1.5 (17) <0.4 - 6.4	0.71 (17) <0.04 - 7.00	8.8 (17) <0.04 - 58.0	2.1 (17) <0.4 - 8.1	2.0 (17) <0.4 - 7.3	2.3 (17) <0.4 - 6.7	4.0 (17) <0.4 - 12.4

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W896070

TABLE 4-76

Organic Carbon Concentrations (mg C/L): Steel Creek Watershed

Station Number	Site	Total Organic Carbon	Dissolved Organic Carbon	Particulate Organic Carbon
16	Steel Creek at SRS Road B	5.07 (25) <0.05 - 14.5	3.09 (10) 1.30 - 4.57	2.35 (9) 0.360 - 6.50
15	Steel Creek at SRS Road A-14	6.90 (25) 1.78 - 13.8	4.34 (10) 3.18 - 7.30	2.86 (10) 0.510 - 10.7
14	Steel Creek upstream of Meyers Branch confluence	7.18 (24) 1.93 - 18.6	4.20 (9) 3.02 - 5.70	2.58 (10) 0.670 - 7.10
12	Meyers Branch at SRS Road B-6.2	7.76 (25) 2.50 - 14.0	6.99 (9) 3.10 - 11.9	3.37 (9) 0.240 - 17.3
11	Meyers Branch at SRS Road 9	6.62 (25) 0.300 - 15.2	5.66 (10) 2.37 - 9.30	2.80 (10) 0.270 - 10.2
10	Meyers Branch upstream of Steel Creek confluence	6.76 (25) 0.290 - 13.4	6.25 (10) 2.75 - 10.1	2.42 (10) 0.230 - 7.20
13	Steel Creek at Old Hattiesville Bridge	7.73 (25) 0.640 - 17.2	6.00 (10) 3.28 - 16.7	1.95 (10) 0.450 - 5.50
8	Steel Creek swamp upstream of Pen Branch confluence	6.98 (23) 2.42 - 11.6	5.04 (10) 3.36 - 9.70	1.23 (11) 0.290 - 3.40
7	Steel Creek swamp near confluence with Savannah River	6.47 (25) 0.350 - 12.0	4.86 (10) 3.40 - 8.70	0.990 (11) 0.300 - 2.30

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W8906070

TABLE 4-77

Water-Quality Data (range of values) for Steel Creek (November 1985 - December 1987)

Parameter	Temperature (°C)	DO (mg/L)	pH	Conductance (µS/cm)	TDS (mg/L)	TSS (mg/L)	TOC (mg/L)
1985/86:[a]							
Steel Creek corridor	10.9 - 29.9	4.9 - 11.1	5.4 - 6.2	41 - 97	29 - 74	<1 - 204	4 - 12
Steel Creek swamp/delta	7.6 - 27.7	0.6 - 11.4	4.8 - 7.3	22 - 135	7 - 84	4 - 40	3 - 13
1987:							
Steel Creek corridor	9.1 - 29.3	4.7 - 12.0	5.8 - 8.0	60 - 93	36 - 83	1 - 59	3 - 8
Steel Creek swamp/delta	8.8 - 27.9	1.9 - 10.1	5.3 - 9.5	23 - 114	23 - 91	<1 - 20	2 - 10

Parameter	DOC (mg/L)	TIC (mg/L)	ALK (mg/t)	OP TP (µg/L)	NO_2 (µg/L)	NO_3 (µg/L)	(µg/L)
1985/86:							
Steel Creek corridor	4 - 9	2 - 8	6.4 - 23.7	<5 - 87	18 - 343	1 - 20	<10 - 402
Steel Creek swamp/delta	3 - 12	1 - 13	1.8 - 50.0	<5 - 51	8 - 154	<1 - 5	<10 - 582
1987:							
Steel Creek corridor	2 - 10	2 - 6	13 - 23	<5 - 136	25 - 180	<1 - 82	<10 - 611
Steel Creek swamp/delta	2 - 14	2 - 10	10 - 37	5 - 59	19 - 153	1 - 13	<10 - 366

Parameter	NH_4 (µg/L)	TIN (µg/L)	SiO_2 (mg/L)	Total Al (µg/L)	Diss. Al (µg/L)	Total Ca (mg/L)	Diss. Ca (mg/L)
1985/86:							
Steel Creek corridor	11 - 764	27 - 808	3.2 - 10.7	<100 - 991	<100 - 905	2.6 - 4.4	2.8 - 5.8
Steel Creek swamp/delta	<10 - 190	21 - 664	1.2 - 13.3	<100 - 1210	<100 - 1270	2.7 - 11.5	2.4 - 11.1
1987:							
Steel Creek corridor	10 - 1080	34 - 1119	0.8 - 9.7	<100 - 1216	<100 - 202	3.1 - 4.8	3.1 - 4.8
Steel Creek swamp/delta	<10 - 157	15 - 407	0.7 - 19.1	<100 - 449	<100 - 155	2.6 - 7.8	2.7 - 7.8

WB90607D

TABLE 4-77, Contd

Parameter	Total Fe (mg/L)	Diss. Fe (mg/L)	Total Mg (mg/L)	Diss. Mg (mg/L)	Total Mn (µg/L)	Diss. Mn (µg/L)	Total K (mg/L)
1985/86:							
Steel Creek corridor	0.1 - 3.8	<0.1 - 3.2	0.74 - 1.94	0.70 - 2.01	<20 - 563	<20 - 466	1.06 - 1.98
Steel Creek swamp/delta	0.3 - 7.4	0.1 - 0.7	0.64 - 2.66	0.62 - 2.59	<20 - 3590	<20 - 3590	0.45 - 4.12
1987:							
Steel Creek corridor	0.1 - 1.2	<0.1 - 1.1	0.98 - 1.40	0.95 - 1.41	<20 - 310	<20 - 311	0.95 - 1.92
Steel Creek swamp/delta	0.2 - 4.3	0.1 - 0.8	0.96 - 1.87	0.88 - 1.83	<20 - 4173	<20 - 4067	0.79 - 1.98

Parameter	Diss. K (mg/L)	Total Na (mg/L)	Diss. Na (mg/L)	Cl (mg/L)	H_2S (mg/L)	SO (mg/L)
1985/86:						
Steel Creek corridor	1.00 - 1.94	4.0 - 13.1	3.7 - 12.1	7 - 8	<0.1	3 - 11
Steel Creek swamp/delta	0.38 - 3.35	6.0 - 14.6	6.0 - 14.8	6 - 10	<0.1	1 - 12
1987:						
Steel Creek corridor	0.24 - 1.65	6.6 - 11.4	6.9 - 10.7	5 - 9	<0.1	4 - 7
Steel Creek swamp/delta	0.54 - 1.90	5.8 - 11.3	5.4 - 11.9	3 - 11	<0.1	3 - 9

[a] Sampling initiated November 1985.

Definition of parameter abbreviations in table headings:

Temp. = temperature
DO = dissolved oxygen
Cond. = conductivity
TDS = total dissolved solids
TSS = total suspended solids
TOC = total organic carbon
DOC = dissolved organic carbon
TIC = total inorganic carbon
ALK = alkalinity
OP = ortho-phosphorus
TP = total phosphorus
NO_2 = nitrite-nitrogen
NO_3 = nitrate-nitrogen
TIN = total inorganic nitrogen
SiO_2 = silica
Al = aluminum
Ca = calcium
Fe = iron
Mg = magnesium
Mn = manganese
K = potassium
Na = sodium
Cl = chloride
H_2S = hydrogen sulfide
SO_4 = sulfate

Source: Gladden et al. (1988)

M890070

4.4.2 Phytoplankton

Primary producers in Steel Creek consist primarily of periphyton and macrophytes. Phytoplankton are believed to contribute insignificantly to the food base, as is typically the case in shallow lotic systems. Thus, the restarting of L Reactor is not expected to have any significant impact on the phytoplankton community of Steel Creek.

4.4.3 Periphyton

The Steel Creek periphyton community was sampled from a variety of substrates at 13 stations (Figure 4-52) between January 1986 and December 1987 (Gladden et al., 1988). Four periphytometers, each containing eight glass slides, were incubated for four weeks and collected monthly. Each periphytometer was assessed for chlorophyll a, pheophytin a, dry weight, and ash-free dry weight. Taxonomic determinations and algal counts were performed quarterly. Wood substrates (freshly cut alder rods) were collected quarterly in groups of six replicates at seven stations. Each replicate was then assessed for the periphyton parameters used above for the glass substrates. Duplicate leaf substrate samples (sycamore) were incubated for one week at seven stations. Chlorophyll a and pheophytin a was then estimated for each leaf. In addition to these substrates, endemic substrates in the form of sediment and macrophyte scrapings were sampled to characterize periphyton populations.

4.4.3.1 Community Composition

Table 4-78 provides a comprehensive species list derived from the two years of sampling. Spatial heterogeneity was evaluated in Steel Creek by dividing the system into four regions: the corridor region encompassing Stations 275, 280, 285, and 290; Stations 300, 310, 320, and 330, called the deforested delta region; the forested swamp area encompassing Stations 340 and 350; and the channel region, Stations 360 and 370, which leads into the Savannah River. A single station, 400, was located in Meyers Branch immediately before it flows into Steel Creek (Figure 4-52).

Table 4-79 shows the relative abundance of the major taxonomic groups of periphyton on glass slide substrates based on total annual estimates. Diatoms, green algae, and blue-green algae were the dominant types of algae at all stations. Other groups (i.e., Chrysophyte, Cryptophyte, and Euglenophytes) collectively comprised <1% of the total algae, with a few exceptions.

Diatoms tended to be the most abundant group, followed by green algae and blue-green algae. Blue-green algae tended to decrease in relative abundance with proximity to L Lake (Table 4-79). An examination of the dominant species (Table 4-80) showed that the planktonic blue-green algal species *Microcystis aeruginosa* was a dominant "periphyton" taxon at

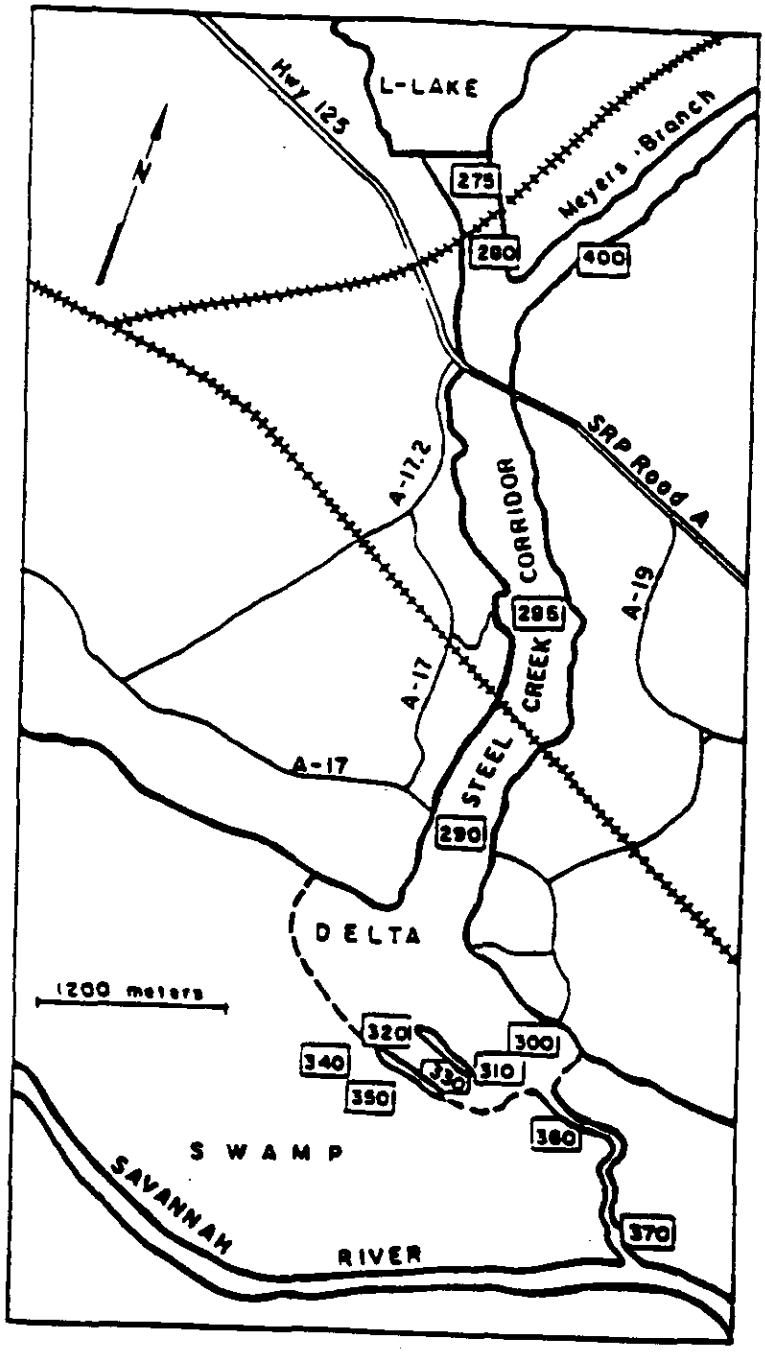

FIGURE 4-52. Periphyton Sampling Locations in Steel Creek, Meyers Branch, and the Steel Creek Delta/Swamp
(source: Gladden et al., 1988)

W8906070

TABLE 4-78

Periphyton Taxa Collected from Steel Creek Sampling Locations Using Core Samples (C), Periphytometers (P), Wood (W), and Macrophyte Substrates (M) (January 1986 - December 1987)

BACILLARIOPHYTHA	Substrates			
Achnanthes clevei		P		
Achnanthes exigua	C	P	W	
Achnanthes hungarica	C	P	W	M
Achnanthes lanceolata	C	P	W	M
Achnanthes lanceolata var. apiculata	C	P	W	
Achnanthes linearis		P		
Achnanthes minutissima	C	P	W	M
Achnanthes peragalli	C			
Achnanthes reimeri		P	W	
Achnanthes sublaevis		P		
Amphipleura pellucida			W	
Amphora perpusilla	C	P	W	
Amphora spp.	C			
Amphora veneta		P		
Bacillaria paradoxa	C	P		
Caloneis bacillum	C			
Caloneis ventricosa v. minula	C	P	W	
Capartogramma crucicula	C	P		
Cocconeis diminuta	C	P	W	M
Cocconeis fluviatilis	C	P	W	M
Cocconeis pediculus		P		
Cocconeis placentula	C	P	W	M
Cocconeis thumensis	C			
Cyclotella atomus		P		
Cyclotella meneghiniana	C	P	W	M
Cyclotella pseudostelligera	C	P	W	
Cyclotella stelligera	C	P	W	
Cymbella aspera			W	
Cymbella minuta	C	P	W	M
Cymbella minuta var. silesiaca		P	W	M
Cymbella naviculiformis		P	W	M
Cymbella tumida	C	P	W	
Desmogonium rabenhorstianum			W	M
Diploneis elliptica	C			
Diploneis subovalis		P		M
Epithemia adnata	C			
Eunotia curvata	C	P	W	M
Eunotia incisa	C	P	W	M
Eunotia pectinalis	C	P	W	M
Eunotia sp.	C			
Eunotia tenella	C	P		

TABLE 4-78, Contd

BACILLARIOPHYTHA, Contd	Substrates			
Fragilaria construens	C	P	W	
Fragilaria crotonensis			W	M
Fragilaria leptostauron	C	P		
Fragilaria spp.	C	P		
Fragilaria vaucheriae		P	W	M
Frustulia rhomboides			W	M
Frustulia vulgaris	C	P	W	M
Frustulia weinholdii			W	
Gomphonema angustatum		P		
Gomphonema augur	C	P		M
Gomphonema carolinense			W	
Gomphonema clevei	C	P		
Gomphonema gracile	C	P	W	M
Gomphonema intricatum			W	
Gomphonema parvulum	C	P	W	M
Gomphonema rhombicum	C	P	W	M
Gomphonema sphaerophora	C	P	W	M
Gomphonema subclavatum	C	P	W	M
Gomphonema truncatum	C			
Gomphonema turris	C	P	W	M
Gyrosigma scalproides	C			
Gyrosigma spencerii	C	P	W	
Melosira ambigua	C			
Melosira granulata	C	P	W	M
Melosira granulata var. *augustissima*	C			
Melosira italica	C		W	M
Melosira sp. 1	C	P	W	M
Melosira sp.	C		W	
Melosira undulata	C		W	
Melosira varians	C	P	W	M
Meridion circulare	C	P	W	M
Navicula agnita	C			
Navicula arvensis			W	M
Navicula atomus		P	W	M
Navicula bacillum	C			
Navicula biconica		P		
Navicula capitata	C	P	W	M
Navicula confervacea	C	P	W	M
Navicula contenta			W	
Navicula cryptocephala	C	P	W	M
Navicula cryptocephala v. *veneta*	C	P		
Navicula decussis	C	P	W	M
Navicula difficillima		P	W	M
Navicula elginensis v. *neglecta*			W	
Navicula gastrum	C	P	W	M

TABLE 4-78, Contd

BACILLARIOPHYTHA, Contd	Substrates			
Navicula gibbosa	C			
Navicula gregaria	C	P		
Navicula gysingensis	C	P	W	
Navicula halophiloides		P		
Navicula laevissima	C			
Navicula lateropunctata	C	P		
Navicula luzonensis	C	P	W	
Navicula menisculus	C	P	W	M
Navicula mensuilus upsaliensis	C			
Navicula minima	C	P	W	M
Navicula mutica			W	
Navicula paucivisitata	C	P	W	M
Navicula pupula	C	P	W	M
Navicula radiosa	C	P	W	M
Navicula rhynchocephala	C			
Navicula rhynchocephala germainii	C	P	W	M
Navicula salinarum				M
Navicula schroeteri v. escambii	C	P	W	M
Navicula seminulum	C	P	W	M
Navicula spp.	C	P	W	M
Navicula viridula	C		W	M
Navicula spp. 1		P		
Neidium affine	C			
Neidium hankensis	C			
Neidium spp.			W	
Nitzschia acicularis	C	P	W	M
Nitzschia agnita	C	P	W	M
Nitzschia amphibia	C	P	W	M
Nitzschia biacrula			W	
Nitzschia clausii	C	P	W	
Nitzschia dissipata		P	W	
Nitzschia filiformis		P	W	M
Nitzschia fonticola	C		W	
Nitzschia frustulum	C			M
Nitzschia gracilis	C	P	W	M
Nitzschia ignorata	C	P	W	M
Nitzschia intermedia	C		W	M
Nitzschia linearis		P	W	
Nitzschia lorenziana				M
Nitzschia microcephala		P		
Nitzschia palea	C	P	W	M
Nitzschia paleacea	C	P	W	M
Nitzschia reversa				M
Nitzschia spp.	C	P	W	M

TABLE 4-78, Contd

BACILLARIOPHYTHA, Contd	Substrates			
Opephora martyi	C	P	W	
Pinnularia abaujensis	C	P	W	M
Pinnularia acrosphaeria	C	P	W	M
Pinnularia appendiculata	C			
Pinnularia biceps	C			
Pinnularia braunii	C	P	W	M
Pinnularia major		P		
Pinnularia mesogongyla		P		
Pinnularia mesolepta		P		
Pinnularia microstauron			W	
Pinnularia obscura			W	
Pinnularia spp.	C	P	W	M
Pinnularia subcapitata	C			
Pinnularia viridis	C		W	M
Rhizosolenia longiseta				M
Rhopalodia gibberula	C	P	W	
Skeletonema potamos	C	P		
Stauroneis anceps			W	
Stauroneis smithii	C	P		
Surirella angusta	C	P	W	
Surirella delicatissima	C	P		M
Surirella linearis	C			
Surirella ovata	C			
Synedra delicatissima	C	P	W	M
Synedra parasitica		P	W	
Synedra pulchella		P	W	
Synedra rumpens	C	P	W	M
Synedra tenera	C	P	W	M
Synedra ulna	C	P	W	M
Synedra ulna var. oxyrhynchus	C			
Terpsinoe musica	C			
Thalassosira weissflogii				M
CHLOROPHYTA				
Ankistrodesmus falcatus	C	P	W	M
Ankistrodesmus spiralis	C	P	W	M
Ankistrodesmus spiroides			W	
Chaetophora elegans	C	P	W	M
Chaetophora spp.			W	
Chaetophoraceae unid.			W	
Characium spp.	C	P	W	M
Chlamydomonas sp. 1			W	
Chlamydomonas spp.				M
Chlamydomonas spp. <5 µm			W	

TABLE 4-78, Contd

CHLOROPHYTA, Contd	Substrates			
Chlamydomonas spp. >15 µm		P		
Chlamydomonas spp. 10 - 15 µm		P		M
Chlamydomonas spp. 5 - 9.9 µm	C	P	W	M
Chloroflagellate spp. <5 µ		P	W	
Chloroflagellate spp. 5 - 9.9 µm		P		M
Chlorophyta			W	M
Cladophora spp.			W	
Closterium acutum		P		
Closterium gracile				M
Closterium kuerzingii				M
Closterium lineatum				M
Closterium moniliferum			W	M
Closterium praelongum	C			
Closterium spp.	C	P		M
Coccoid chlorophyta spp.	C		W	
Coccoid chlorophyta spp. <5 µm		P	W	
Coccoid chlorophyta spp. 10 - 15 µm		P	W	M
Coccoid chlorophyta spp. 5 - 9.9 µm	C	P	W	M
Coccoid chlorophyta colony #1		P	W	
Coelastrum microporum	C			M
Coelastrum spaericum			W	M
Cosmarium angulosum		P	W	M
Cosmarium candianum			W	M
Cosmarium contractum	C	P	W	
Cosmarium granatum				M
Cosmarium pseudibroemei				M
Cosmarium regnelli	C	P	W	M
Cosmarium spp.	C		W	M
Cosmarium subtumidum		P		
Cosmarium tumidum			W	
Cosmarium undulatum			W	M
Crucigenia crucifera	C		W	M
Crucigenia quadrata	C		W	
Dictyosphaerium pulchellum	C			
Didymocystis fina	C	P	W	M
Dispora crucigenioides		P		
Elakatothrix viridis		P		
Euastrum abruptum				M
Euastrum binale			W	M
Euastrum denticulatum				M
Gleocystis ampulla		P		
Gleocystis planctonica		P	W	
Gomontia sp.			W	
Hyalotheca dissilens				M
Kirchneriella lunaris				M
Kirchneriella obesa				M

TABLE 4-78, Contd

CHLOROPHYTA, Contd	Substrates			
Lagerheimia subsalsa			W	
Mougeotia spp.		P	W	M
Oedogonium spp. lg	C	P	W	M
Oedogonium spp. sm	C	P	W	M
Palmella spp.		P		
Pediastrum tetras	C		W	M
Pseudoulvella americana		P	W	
Scenedesmus acutus	C			
Scenedesmus brevispina		P		
Scenedesmus denticulatus	C	P	W	M
Scenedesmus dimorphus	C	P	W	M
Scenedesmus ecornis		P		
Scenedesmus quadricauda	C	P	W	M
Scenedesmus spinosus	C	P	W	M
Schroderia setigera			W	M
Selenastrum minutum	C	P	W	M
Selenastrum westii		P		
Sphaerocystis schroeteri		P	W	
Spirogyra spp. lg				M
Staurastrum chaetoceros	C	P		
Staurastrum cingulum		P		
Staurastrum excavatum	C			
Staurastrum margaritaceum				M
Staurastrum punctulatum		P	W	M
Staurastrum setigerum				M
Staurastrum sp.	C			
Tetraedron caudatum		P		
Tetraedron gracile			W	
Tetraedron minimum	C	P	W	M
Tetraedron trigonum		P		
Ulothrix aequalis		P	W	
Ulothrix spp.		P	W	
Ulothrix subtilisma	C	P	W	M
Ulothrix zonata		P		
CHRYSOPHYTA				
Chromulina <5 µm		P		
Chrysoflagellate <5 µm	C	P	W	M
Chrysoflagellate spp.	C	P		
Chrysoflagellate 10 - 15 µm		P		
Chrysoflagellate 5 - 9.9 µm	C	P	W	M
Coccoid chrysophyta spp. <5 µm		P	W	M
Coccoid chrysophyta spp. 10 - 15 µm		P		
Coccoid chrysophyta spp. 5 - 9.9 µm	C	P	W	M

TABLE 4-78, Contd

CHRYSOPHYTA, Contd	Substrates			
Dinobryon divergens		P		
Ophiocytium cochleare		P		
Synura uvella				M
CRYPTOPHYTA				
Cryptomonas erosa	C	P	W	M
Physomonas spp.	C			
Rhodomonas minuta		P		M
CYANOPHYTA				
Anabaena sp. 1	C	P		
Anabaena sp. 2				M
Anabaena spiroides	C		W	
Anabaena spp.	C	P	W	M
Anabaena subcylindrica	C	P		M
Aphanocapsa elachista				M
Calothrix sp. 1				M
Chamaesiphon minimum			W	
Chroococcus dispersus			W	
Chroococcus minor				M
Chroococcus minutus	C			
Coccoid cyanophyta spp.	C		W	
Coccoid cyanophyta spp. <5 µm	C	P	W	M
Coccoid cyanophyta spp. <5 - 9 9 µm	C	P	W	M
Coccoid cyanophyta 10 - 15 µm	C	P		
Coelosphaerium naegelianum		P		
Coelosphaerium pallidum		P		
Cyanophyte colony #1		P		
Cyanophyte colony #2		P		
Lyngbya lutea	C			
Lyngbya nordgaardii			W	
Lyngbya spp.	C	P	W	
Lyngbya subtilis	C	P	W	M
Merismopedia glauca	C			
Merismopedia minima		P	W	
Microcystis aeruginosa	C	P	W	M
Microcystis incerta		P	W	
Oscillatoria acutissima		P		M
Oscillatoria amphibia			W	
Oscillatoria anguina	C		W	
Oscillatoria chalybea		P		
Oscillatoria geminata	C	P	W	M

TABLE 4-78, Contd

CYANOPHYTA, Contd	Substrates			
Oscillatoria limosa	C	P	W	M
Oscillatoria nigra	C	P	W	M
Oscillatoria ornata	C		W	M
Oscillatoria princeps		P	W	M
Oscillatoria sancta		P		M
Oscillatoria sp. 1		P	W	M
Oscillatoria spp.	C		W	M
Oscillatoria subtilissima		P	W	
Oscillatoria tenuis	C	P	W	M
Phormidium molle			W	
Phormidium retzii		P		
Phormidium sp. 1	C	P	W	M
Phormidium spp.	C	P	W	M
Plectonema gracillimum		P		
Plectonema sp. 1		P		
Schizothrix spp.	C	P		
Unid. cyanophyta filament				M
EUGLENOPHYTA				
Euglena spp.	C	P	W	M
Phacus acuminatus			W	M
Phacus spp.	C			
Trachelomonas hispida	C			M
Trachelomonas verrucosa	C	P		
Trachelomonas volvocina	C	P	W	M
PYRRHOPHYTA				
Peridinium inconspicuum	C			

Source: Starkel et al. (1988a)

TABLE 4-79

Relative Abundance of Major Algal Groups Collected from Glass Slides Incubated in Steel Creek and Meyers Branch (January 1986 - December 1987)

Station	Division[a]	1986 %	1987 %
275	Diatoms	69.3	16.1
	Green algae	17.9	3.7
	Blue-green algae	12.8	80.1
	Others	0	<0.1
280	Diatoms	71.8	54.2
	Green algae	18.4	6.7
	Blue-green algae	9.8	39.1
	Others	<0.1	0
285	Diatoms	81.8	85.4
	Green algae	5.8	1.8
	Blue-green algae	12.4	12.8
	Others	<0.1	0
290	Diatoms	28.6	82.2
	Green algae	62.9	13.9
	Blue-green algae	8.4	3.8
	Others	0.1	0.1
300	Diatoms	43.4	60.8
	Green algae	49.9	29.0
	Blue-green algae	6.4	10.1
	Others	<0.1	0.1
310	Diatoms	23.0	61.6
	Green algae	72.0	30.8
	Blue-green algae	5.0	7.3
	Others	<0.1	0.3
320	Diatoms	33.4	50.7
	Green algae	56.1	33.4
	Blue-green algae	10.4	15.7
	Others	<0.1	0.1
330	Diatoms	58.4	80.7
	Green algae	27.8	16.0
	Blue-green algae	13.7	3.2
	Others	<0.1	0

TABLE 4-79, Contd

Station	Division[a]	1986 %	1987 %
340	Diatoms	23.9	28.3
	Green algae	69.3	42.1
	Blue-green algae	6.5	29.3
	Others	0.3	0.4
350	Diatoms	76.9	52.4
	Green algae	14.2	30.6
	Blue-green algae	8.7	16.7
	Others	0.1	0.2
360	Diatoms	81.1	87.1
	Green algae	14.9	8.9
	Blue-green algae	4.0	3.9
	Others	0	0.1
370	Diatoms	40.8	72.1
	Green algae	58.0	15.2
	Blue-green algae	1.1	12.4
	Others	<0.1	0.3
400	Diatoms	78.3	89.3
	Green algae	3.2	7.2
	Blue-green algae	18.5	3.2
	Others	0	0.2

Note: Percentages are based on total annual cell densities.

Source: Gladden et al. (1988)

TABLE 4-80

Annual Common Algal Taxa (>5% abundance listed in order of importance) on Glass Slide Substrates Incubated in Steel Creek and Meyers Branch (January - December 1987)

Station	Division[a]	Dominant Taxon
275	BG	Coccoid Cyanophyta spp. (<5 µm)
	BG	*Microcystis aeruginosa*
	D	*Achnanthes minutissima*
280	BG	Coccoid Cyanophyta spp. (<5 µm)
	D	*Gomphonema parvulum*
285	D	*Gomphonema parvulum*
	D	*Cymbella minuta*
	BG	*Microcystis incerta*
290	D	*Gomphonema parvulum*
	D	*Navicula minima*
	D	*Achnanthes minutissima*
300	D	*Gomphonema parvulum*
	D	*Synedra rumpens*
	D	*Nitzschia palea*
	G	*Chaetophora elegans*
	D	*Synedra tenera*
	D	*Achnanthes minutissima*
	G	Coccoid Chlorophyta spp. (5-9.9 µm)
310	D	*Gomphonema parvulum*
	G	*Chaetophera elegans*
	D	*Navicula minima*
	BG	Coccoid Cyanophyta spp. (<5 µm)
	G	Coccoid Chlorophyta (5-9.9 µm)
	D	*Cocconeis placentula*
320	G	*Chaetophora elegans*
	D	*Melosira varians*
	D	*Achnanthes ianceolata*
	BG	Coccoid Cyanophyta spp. (<5 µm)
	G	Coccoid Chlorophyta spp. (5-9.9 µm)
	D	*Gomphonema parvulum*
	BG	*Microcystis incerta*

TABLE 4-80, Contd

Station	Division[a]	Dominant Taxon
330	D	Gomphonema parvulum
	D	Synedra rumpens
	G	Coccoid Chlorophyta spp. (5-9.9 μm)
340	BG	Cyanophyte colony #2
	G	Coccoid Chlorophyta spp. (5-9.9 μm)
	D	Gomphonema parvulum
	G	Ulothrix subtilisma
350	D	Achnanthes lanceolata
	D	Gomphonema parvulum
	G	Pseudoulvella americana
	BG	Cyanophyte colony #2
	BG	Coccoid Cyanophyta spp. (<5 μm)
	D	Navicula seminulum
	G	Coccoid Chlorophyta spp. (5-9.9 μm)
360	D	Gomphonema parvulum
	D	Synedra tenera
	D	Achnanthes lanceolata
370	D	Gomphonema parvulum
	BG	Coccoid Cyanophyta spp. (<5 μm)
	D	Chaetophora elegans
400	D	Gomphonema parvulum
	D	Achnanthes minutissima
	D	Achnanthes reimeri
	D	Eunotia pectinalis
	D	Synedra rumpens

[a] D = diatoms; BG = blue-green algae; G = green algae.

Source: Gladden et al. (1988)

Station 275. This species apparently attached to the slides after being discharged from L Lake. Other dominant species included the common diatoms Achnanthes minutissima and Gomphonema parvulum.

The periphyton on sediment core substrates during 1986 and 1987 was dominated by diatoms in every region of Steel Creek (Table 4-82). Only at Station 280 in the corridor region was another group, the blue-green algae, equally dominant, constituting 44.5% of the community. In other regions of Steel creek, blue-green algae comprised between 1.8% and 29.2% of the total periphyton density. Common taxa, those greater than 5% abundance in at least one sample, included the diatoms Navicula cryptocephala, Melosira granulata, Eunotia Pectinalis, and the blue-green species Microcystis aeruginosa (Table 4-83).

There were spatial differences in periphyton composition on wood substrates during 1986 and 1987 (Table 4-84). In the corridor region, diatoms and blue-green algae dominated the community with green algae becoming relatively more abundant in and below the delta. Diatoms were dominant in Meyers Branch (83.8%) along with green algae, which formed 10.2% of the total abundance. This spatial heterogeneity did not change significantly between 1986 and 1987 in the corridor or delta regions, but did change in the swamp and channel areas. At Station 370 the percentage of diatoms increased from 32.3% to 51.1% from 1986 to 1987, while green algae increased from 19.0% to 37.5%. Concurrently, blue-green algae declined from 48.8% to 11.4%. In Meyers Branch, green algae nearly tripled, while diatoms decreased from 83.8% to 53.0%. The diatom Gomphonema parvulum was a dominant taxon in the corridor, delta, and channel areas.

Collections from the macrophyte (Ceratophyllum demersum) substrate in the Steel Creek delta and swamp were dominated by diatoms at all locations sampled (Table 4-85). Blue-green algae were the second most abundant group in 1986, with green algae being almost equally abundant during 1987. The relative abundance of diatoms at Stations 300, 330, and 340 increased during 1987 at the expense of blue-green populations. Common dominant taxa included the diatoms Cocconeis placentula, Navicula cryptocephala, and at Station 340, the blue-green alga Oscillatoria sancta (Table 4-86). Taxa richness on macrophyte substrates at Stations 300, 330, and 340 was similar in 1986 and 1987 for all seasons except spring in which it was lower in 1987 than in 1986 (Table 4-87).

4.4.3.2 Ash-Free Dry Weight

Annual means of periphyton ash-free dry weight AFDW (g/m^2) at the stations in each of the different regions of Steel Creek are shown in (Table 4-88). AFDW values tended to decrease with distance from L Lake, while the means were relatively low and showed only small annual changes at most stations, the AFDW at Station 275 in 1986 averaged 12.26 g/m^2, and decreased to an annual mean of 6.97 g/m^2 during 1987. Because of the high variability of the data at Station 275 within each of the two years meaningful conclusions are difficult to draw. This variability may be associated with the transitory nature of the stream just below L-Lake Dam.

TABLE 4-81

Similarity (S) of Periphyton Communities Between January 1986 and December 1987

Location	Station	Sorenson's Coefficient
Corridor	275	0.55
	280	0.56
	285	0.64
	290	0.65
Delta	300	0.57
	310	0.60
	320	0.59
	330	0.62
Swamp	340	0.62
	350	0.64
Channel	360	0.63
	370	0.61
Meyers Branch	400	0.64

Note: S is Sorensen's Coefficient of similarity calculated by $S = 2C/AB$, where A = number of taxa in 1986, B = number of taxa in 1987, and C = number of taxa common to both years.

Source: Gladden et al. (1988)

TABLE 4-82

Relative Abundance of Major Algal Groups Collected from Sediment Cores from Steel Creek and Meyers Branch (January 1986 - December 1987)

Station	Division[a]	1986 %	1987 %
280	Diatoms	49.1	69.7
	Green algae	5.9	19.6
	Blue-green algae	44.5	9.5
	Others	0.4	1.0
290	Diatoms	64.8	80.4
	Green algae	3.3	7.5
	Blue-green algae	8.4	11.7
	Others	0.1	0.4
300	Diatoms	86.3	70.1
	Green algae	10.9	8.7
	Blue-green algae	1.8	18.3
	Others	1.0	2.4
370	Diatoms	68.1	82.0
	Green algae	18.7	7.5
	Blue-green algae	12.7	8.8
	Others	0.6	1.6
400	Diatoms	88.4	66.9
	Green algae	0.6	0.4
	Blue-green algae	10.8	29.2
	Others	0.2	3.5

Note: Percentages are based on total annual densities.

Source: Gladden et al. (1988)

TABLE 4-83

Major Taxa of Periphytic Algae (>5% abundance listed in order of importance) in Sediment Cores Collected from Steel Creek and Meyers Branch (January - December 1987)

Station	Division[a]	Taxa
280	D	*Navicula decussis*
	D	*Melosira granulata*
	D	*Navicula lateropunctata*
	D	*Navicula cryptocephala*
290	D	*Melosira granulata*
	D	*Navicula decussis*
	D	*Navicula cryptocephala*
	BG	Coccoid Cyanophyta spp. (<5 μm)
300	D	*Melosira granulata*
	D	*Navicula cryptocephala*
	D	*Navicula confervacea*
	BG	Coccoid Cyanophyta spp. (<5 μm)
370	D	*Melosira granulata*
	D	*Navicula cryptocephala*
	BG	*Microcystis aeruginosa*
	D	*Eunotia pectinalis*
400	BG	*Microcystis aeruginosa*
	D	*Opephora martyi*
	D	*Cocconeis diminuta*
	D	*Navicula seminulum*
	D	*Navicula minima*

[a] D = diatoms; BG = blue-green algae; G = green algae.

Source: Gladden et al. (1988)

TABLE 4-84

Percentage Periphyton Community Composition on Introduced Wood Substrates Incubated in Steel Creek and Meyers Branch (January 1986 - December 1987)

Station	Division[a]	1986 %	1987 %
280	Diatoms	41.6	48.2
	Green algae	5.3	6.3
	Blue-green algae	35.7	45.5
	Others	17.4	0
290	Diatoms	83.5	75.3
	Green algae	9.1	8.7
	Blue-green algae	7.4	15.8
	Others	<0.1	0.1
300	Diatoms	49.4	54.3
	Green algae	44.6	33.6
	Blue-green algae	5.9	11.5
	Others	<0.1	0.5
330	Diatoms	53.9	68.4
	Green algae	22.8	19.8
	Blue-green algae	23.2	11.4
	Others	0.1	0.5
340	Diatoms	73.3	42.0
	Green algae	19.6	34.2
	Blue-green algae	7.1	23.8
	Others	0	0
370	Diatoms	32.3	51.1
	Green algae	19.0	37.5
	Blue-green algae	48.8	11.4
	Others	0	0
400	Diatoms	83.8	53.0
	Green algae	10.2	38.6
	Blue-green algae	6.0	8.2
	Others	0	0.2

Note: Percentages are based on total annual counts.

Source: Gladden et al. (1988)

TABLE 4-85

Periphyton Relative Abundance on Macrophytes (*Ceratophyllum demersum*) in Steel Creek (January 1986 - December 1987)

Station	Division[a]	1986 %	1987 %
300	Diatoms	51.1	71.1
	Green algae	26.6	17.7
	Blue-green algae	22.0	10.1
	Others	0.3	1.0
330	Diatoms	55.9	77.8
	Green algae	8.7	9.6
	Blue-green algae	34.8	10.7
	Others	0.7	1.5
340	Diatoms	44.9	54.4
	Green algae	16.2	23.3
	Blue-green algae	37.6	20.8
	Others	1.3	1.6

Note: Percentages are based on total annual counts.

Source: Gladden et al. (1988)

TABLE 4-86

Annual Common Algal Taxa (>5 abundance listed in order of importance) on Macrophytes (*Ceratophyllum demersum*) in Steel Creek (January - December 1987)

Station	Division[a]	Dominant Taxon
300	D	*Cocconeis placentula*
	D	*Navicula cryptocephala*
330	D	*Navicula cryptocephala*
	D	*Eunotia pectinalis*
	D	*Cocconeis placentula*
	D	*Achnanthes lanceolata*
	D	*Gomphonema parvulum*
340	BG	*Oscillatoria sancta*
	D	*Melosira italica*
	D	*Melosira* sp. 1
	G	coccoid Chlorophyta (5-9.9 μm)
	D	*Nitzschia gracilis*

[a] D = diatoms; BG = blue-green algae; G = green algae.

Source: Gladden et al. (1988)

TABLE 4-87

Seasonal Periphyton Taxa Richness on Macrophytes (*Ceratophyllum demersum*) in Steel Creek (January 1986 - December 1987)

Station	Season[a]	1986 Taxa Richness	1987 Taxa Richness
300	W	30	33
	Sp	39	24
	Su	39	41
	F	41	40
330	W	35	34
	Sp	30	23
	Su	47	38
	F	49	41
340	W	40	42
	Sp	42	29
	Su	38	34
	F	38	43

[a] W = Winter; Sp = Spring; Su = Summer; F = Fall.

Source: Gladden et al. (1988)

TABLE 4-88

Annual Means (g/m^2) for Periphyton Ash-Free Dry Weight Accumulated on Glass Slides Incubated in Steel Creek and Meyers Branch (January 1986 - December 1987)

Location	Station	1986 Mean	1986 Std Dev[a]	1987 Mean	1987 Std Dev[a]
Corridor	275	12.26	(24.96)	6.97	(8.74)
	280	3.31	(2.37)	4.09	(5.06)
	285	3.82	(3.00)	3.43	(4.07)
	290	2.31	(1.37)	2.01	(1.68)
Delta	300	1.70	(1.18)	1.21	(1.18)
	310	1.30	(1.02)	1.26	(1.01)
	320	0.85	(0.66)	1.02	(0.67)
	330	1.23	(1.04)	0.94	(0.78)
Swamp	340	0.71	(0.52)	0.63	(0.47)
	350	0.74	(0.70)	0.58	(0.45)
Channel	360	0.61	(0.81)	0.41	(0.37)
	370	0.94	(1.30)	0.54	(0.47)
Meyers Branch	400	1.28	(1.19)	1.05	(0.82)

[a] Standard deviation.

Source: Gladden et al. (1988)

Changes in the annual mean AFDW based on sediment corings from 1986 to 1987 were pronounced only in the corridor and delta regions (Table 4-89). While showing a decrease at Station 280, AFDW nearly doubled at Station 290 from 1986 to 1987. Even so, the mean AFDW at Station 290 was still less than half that at Station 280. The single delta station sampled (Station 300), had the highest mean AFDW of the five stations studied. At Station 300 AFDW increased substantially from 1986 to 1987 (from 321.73 g/m^3 to 521.35 g/m^3).

4.4.3.3 Periphyton Chlorophyll a

Table 4-90 shows the mean annual chlorophyll a concentrations based on samples from glass slide substrates in Steel Creek and Meyers Branch from January 1986 to December 1987. Values were lowest in Meyers Branch and swamp Station 350. However, large standard deviations suggest a significant degree of overlap among stations regardless of the creek's region. During both 1986 and 1987, means were higher in the corridor and declined going downstream, with the exception of corridor Station 280 and channel Station 370.

Annual means of chlorophyll a based on sediment core substrates were higher at the delta, channel, and Meyers Branch stations in 1986 than in 1987, while the reverse was true for other stations (Table 4-91).

The greatest concentrations of chlorophyll a, accumulated on wood (alder rods) after a 4-week incubation period, were observed at Station 290 in the corridor (Table 4-92). Standard deviations were high, implying that differences in the corridor and delta areas could be random. Swamp Station 340, however, had consistently lower means than the other Steel Creek sampling sites while the Meyers Branch station had annual mean concentrations that were, on the average, the lowest of all (<2.0 mg/m^2).

The annual means for chlorophyll a on leaf substrates in the different regions of Steel Creek followed patterns similar to those observed with other substrates (Table 4-93). Meyers Branch, consistently had the lowest averages for 1984-1985 through 1987. Only at Stations 340 in the swamp in 1987 and 370 in the lower part of the channel for all years were concentrations near the levels in Meyers Branch. However, standard deviations at all stations were of the magnitude that random variation, due to natural spatial heterogeneity, resulted in significant overlap among stations.

4.4.3.4 Expected Impacts

The expected impacts on the periphyton community of Steel Creek from L Reactor operations are expected to be similar to the impacts demonstrated by past reactor operation. These impacts include an increased relative abundance of blue-green algae and increased periphyton productivity resulting from the addition of thermally enhanced nutrient-rich Savannah River water to Steel Creek.

TABLE 4-89

Annual Means (g/m^2) for Ash-Free Dry Weight in Sediment Cores Collected from Steel Creek and Meyers Branch (January 1986 - December 1987)

Habitat	Station	1986[a] Mean	1986[a] Std Dev[b]	1987 Mean	1987 Std Dev[b]
Corridor	280	193.27	(313.73)	145.02	(118.20)
	290	37.13	(21.10)	61.37	(59.12)
Delta	300	321.73	(137.50)	521.35	(131.48)
Channel	370	164.93	(61.36)	175.43	(132.44)
Meyers Branch	400	122.90	(118.01)	131.13	(164.04)

[a] From Firth (1987).
[b] Standard deviation.

Source: Gladden et al. (1988)

TABLE 4-90

Annual Means (mg/m^2) for Periphyton Chlorophyll a Content Accumulated on Glass Slides Incubated in Steel Creek and Meyers Branch (January 1986 - December 1987)

Location	Station	1986 Mean	1986 Std Dev[a]	1987 Mean	1987 Std Dev[b]
Corridor	275	9.44	(5.74)	12.53	(10.10)
	280	9.29	(5.79)	4.97	(5.38)
	285	11.26	(5.89)	12.45	(6.67)
	290	12.66	(6.02)	12.82	(7.65)
Delta	300	7.73	(4.41)	8.14	(8.57)
	310	9.69	(5.89)	9.23	(7.19)
	320	7.35	(4.93)	4.53	(4.59)
	330	8.19	(5.10)	8.81	(7.30)
Swamp	340	5.07	(4.77)	3.58	(4.18)
	350	2.26	(3.76)	3.06	(4.36)
Channel	360	4.65	(5.50)	3.57	(3.54)
	370	7.00	(5.54)	6.10	(5.94)
Meyers Branch	400	3.93	(5.34)	2.88	(4.76)

[a] From Firth (1987)
[b] Standard deviation.

Source: Gladden et al. (1988)

TABLE 4-91

Annual Means (mg/m^2) for Periphyton Chlorophyll a Accumulated on Sediment Cores Collected from Steel Creek and Meyers Branch (January 1986 - December 1987)

		1986[a]		1987	
Location	Station	Mean	Std Dev[b]	Mean	Std Dev[b]
Corridor	280	21.23	(17.60)	30.62	(6.70)
	290	7.32	(8.19)	23.68	(18.20)
Delta	300	47.08	(34.29)	19.38	(15.17)
Channel	370	17.54	(26.54)	14.70	(10.41)
Meyers Branch	400	20.43	(19.53)	7.02	(2.10)

[a] From Firth (1987).
[b] Standard deviation.

Source: Gladden et al. (1988)

TABLE 4-92

Annual Means (mg/m^2) for Periphyton Chlorophyll a Accumulated on Introduced Wood Substrates Incubated in Steel Creek and Meyers Branch (January 1986 - December 1987)

Habitat	Station	1986[a] Mean	1986[a] Std Dev[b]	1987 Mean	1987 Std Dev[b]
Corridor	280	8.86	(9.99)	2.77	(5.75)
	290	16.23	(10.87)	12.15	(19.99)
Delta	300	3.82	(3.36)	3.57	(3.06)
	330	4.00	(5.07)	3.46	(5.51)
Swamp	340	2.85	(2.43)	1.07	(0.94)
Channel	370	6.33	(7.01)	7.28	(28.39)
Meyers Branch	400	1.97	(2.15)	1.25	(1.47)

[a] From Firth (1987).
[b] Standard deviation.

Source: Gladden et al. (1988)

TABLE 4-93

Annual Means (mg/m^2) for Periphyton Chlorophyll a Accumulated on Leaf Substrates Incubated in Steel Creek and Meyers Branch, 1984-85, 1986, and 1987

Habitat	Station	1984-85[a] Mean	1984-85[a] Std Dev[c]	1986[b] Mean	1986[b] Std Dev[c]	1987 Mean	1987 Std Dev[c]
Corridor	280	2.07	(2.95)	1.88	(1.19)	1.21	(1.28)
	290	1.95	(0.97)	2.90	(1.93)	3.23	(2.61)
Delta	300	[d]		3.03	(1.7)	5.74	(4.22)
	310	3.52	(5.17)	[e]		[e]	
	320	2.58	(1.75)	[e]		[e]	
	330	3.02	(2.02)	1.68	(0.50)	1.96	(1.07)
Swamp	340	2.56	(2.23)	2.41	(0.80)	1.23	(0.58)
	350	2.84	(2.50)	[e]		[e]	
Channel	360	2.01	(1.54)	[e]		[e]	
	370	1.49	(0.72)	1.25	(0.53)	1.30	(0.88)
Meyers Branch	400	1.29	(1.06)	1.18	(0.56)	0.96	(0.99)

[a] From Firth et al. (1986).
[b] From Firth (1987).
[c] Standard deviation.
[d] Not sampled during 1984-85.
[e] Not sampled during 1986 and 1987.

Source: Gladden et al. (1988)

4.4.4 Zooplankton

Studies of the zooplankton community in Steel Creek include a study where zooplankton were comparatively examined in several SRS stream systems prior to the construction of L Lake (Chimney and Cody, 1986) and a study where zooplankton were sampled at seven locations (Figure 4-53) of the Steel Creek system in 1986 and 1987 following the construction of L Lake (Starkel and Chimney, 1988).

4.4.4.1 Species Composition and Abundance

A comprehensive list of taxa identified from monthly zooplankton collections in Steel Creek at corridor and swamp/delta stations during 1986 and 1987 is given in Table 4-94. These taxa represented four broad taxonomic categories including: the phylum Rotifera (33 taxa), and within the phylum Arthropoda, the order Cladocera (16 taxa), the subclass Copepoda (9 taxa), and the subclass Ostracoda (1 taxon).

Spatial and temporal differences in zooplankton abundance and species composition were observed in the 1986-1987 studies (Starkel and Chimney, 1988). Taxa richness (number of taxa identified per sample), tended to decrease with distance downstream from L Lake (Table 4-95). Substantial decreases occurred in both 1986 and 1987 at stations below the upper corridor stations (275 and 280). This trend probably reflects a decreasing influence from zooplankton discharged to Steel Creek from L Lake. Another major decrease in species richness was apparent at stations below Station 290 where the corridor gives way to the delta/swamp region of the drainage system (Table 4-95).

A similar pattern of reduced zooplankton density with increasing distance from L Lake was also apparent (Table 4-96). The trend was evident in both 1986 and 1987 for copepods (Figure 4-54), rotifers (Figure 4-55), and cladocerans (Figure 4-56). These declines were expected because limnetic species do not ordinarily survive well in lotic systems (Gladden et al., 1988).

Copepod densities at the corridor stations showed some indication of spring and fall maxima during both years with slightly lower peaks in 1987 than in 1986 (Figure 4-54). No discernible seasonal pattern or major difference between 1986 and 1987 were evident for copepod densities at the swamp/delta stations.

Monthly trends in Rotifera densities differed from those of the cyclopoid and calanoid copepods and in general, showed less seasonality. At the corridor stations, total rotifera abundance was highly variable, with densities shifting within a range of zero to approximately 180 organisms/L within a single month (Figure 4-55). This magnitude is common within the pelagic rotifer group (Stemberger, 1984). Densities tended to be higher in 1987 than in 1986. Rotifer densities at the swamp/delta stations were

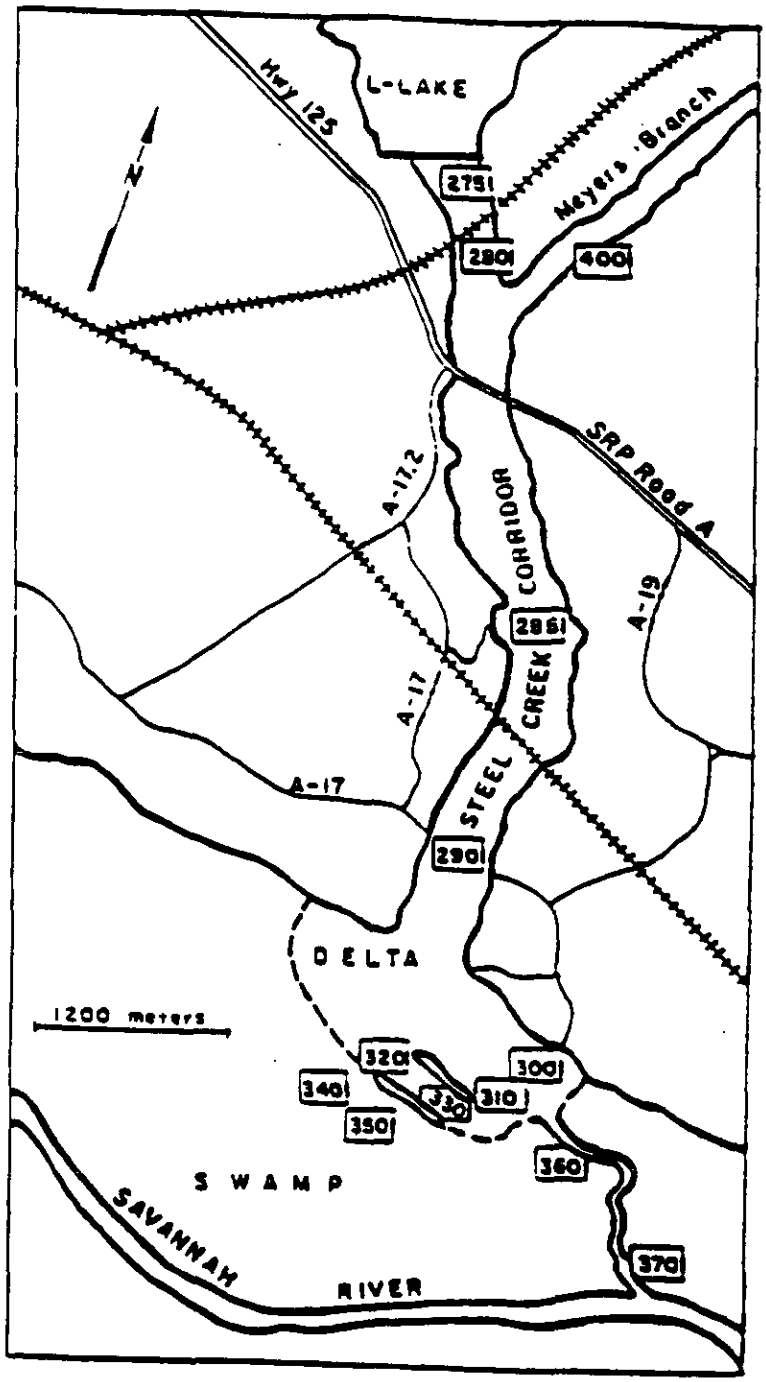

FIGURE 4-53. Location of Zooplankton Sampling Stations in the Steel Creek Corridor, Delta, and Swamp (January 1986 - December 1987) (source: from Gladden et al., 1988)

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TABLE 4-94

Zooplankton Collected from Steel Creek Sampling Stations
(January 1986 - December 1987)

Taxon	Station 275	280	290	310	330	350	370
PHYLUM ROTIFERA							
Anuraeopsis sp.			X				
Ascomorpha sp.	X	X	X	X	X		X
Asplanchna sp.	X	X	X	X	X	X	X
Brachionus bidentata		X	X		X	X	
Brachionus caudatus			X				
Brachionus havanaensis	X	X	X	X	X	X	X
Brachionus rubens		X					
Brachionus sp.				X	X	X	X
Cephalodella sp. 1		X					
Cephalodella spp.			X				
Collothea mutabulis	X	X					
Collotheca pelagica			X				
Colurella spp.		X	X				
Conochiloides dossuarius	X	X					
Conochilus unicornis	X	X	X		X	X	
Epiphanes macrourus			X				
Euchlanis alata	X		X				
Euchlanis sp.	X	X	X	X	X	X	X
Filinia longiseta	X	X	X	X	X	X	
Gastropus stylifer					X		
Hexarthra mira	X	X	X				X
Kellicottia bostoniensis	X	X	X	X	X	X	X
Kellicottia longispina			X				
Keratella cochlearis	X	X	X	X	X	X	X
Keratella cochlearis var. *hispida*			X				
Keratella cochlearis var. *tecta*	X						
Lecane leontina					X		
Lecane luna	X	X			X		
Lecane mira		X			X		
Lecane spp.	X		X	X	X	X	
Lecane stokesi							X
Lecane unqulata				X	X		X
Lepadella cristata					X	X	
Lepadella ovalis				X		X	X
Macrochaetus sp.						X	
Manfredium eudactylatum					X		
Monostyla bulla	X	X	X	X		X	X
Monostyla lunaris			X	X	X		X
Monostyla spp.	X	X	X	X		X	
Monostyla stenroosi					X	X	
Notholca acuminata	X	X	X	X			

TABLE 4-94, Contd

Taxon	Station 275	280	290	310	330	350	370
PHYLUM ROTIFERA, Contd							
Platyias patulus			X				
Platyias quadricornis		X	X	X			X
Ploesoma sp. 1	X	X	X	X		X	X
Ploesoma truncatum	X	X					
Polyarthra euryptera	X	X					
Polyarthra remata	X	X	X		X		X
Polyarthra vulgaris	X	X	X	X	X	X	X
rotifer sp. 100 - 200 µm		X					
rotifera sp. 50 - 99 µm	X	X					
rotifera sp. 1		X	X				
Synchaeta oblonga	X	X	X				X
Synchaeta spp.	X	X	X				
Testudinella sp.	X	X			X	X	
Trichocerca bicristata							X
Trichocerca chattoni						X	X
Trichocerca cylindrica	X					X	X
Trichocerca elongata	X	X	X	X	X		X
Trichocerca longiseta	X	X	X				
Trichocerca multicrinis		X					
Trichocerca similis		X					
Trichocerca sp. 1	X	X	X	X	X	X	X
Trichocerca spp.	X		X		X	X	X
Trichotria tetractis			X	X	X	X	
Tylotrocha monopus			X				
PHYLUM ARTHROPODA							
Class Crustacea							
Subclass Brachiopoda							
Order Cladocera							
Alona sp.	X		X	X	X	X	X
Bosmina longirostris	X	X	X	X	X		X
Ceriodaphina spp.	X	X	X				
Chydorus brevilabris	X	X		X	X	X	X
Chydorus sp.		X					
Daphnia parvula	X	X	X				
Daphnia retrocurva	X	X	X				
Diaphanosoma brachyurum	X	X	X	X	X		X
Eubosmina sp.	X						
Eurycercus (bullatifrons) sp.					X	X	X
Holopedium gibberum		X					
Leptodora kindti	X	X					
Moina micrura	X					X	
Scapholebris kingi							X
Sida crystallina	X		X				
Simocephalus sp.	X						

TABLE 4-94, Contd

Taxon	Station 275	280	290	310	330	350	370
PHYLUM ARTHROPODA, Contd							
Class Crustacea							
Subclass Copepoda							
Cyclops sp.	X	X	X	X	X	X	X
Cyclops varicans rubellus	X	X					
Diaptomus sp.	X	X	X		X		X
Macrocyclops sp.	X	X	X				X
Mesocyclops edax	X	X	X	X	X	X	X
Nitocra sp.		X	X				
Nauplius larvae	X	X	X	X	X	X	X
Paracyclops fimbriatus poppei	X	X	X		X	X	
Tropocyclops prasinus	X	X	X			X	
Subclass Ostracoda							
Ostracoda spp.	X	X	X	X	X	X	X

Source: Starkel and Chimney (1988)

TABLE 4-95

Descriptive Statistics for Zooplankton Taxa Richness (no. of taxa) at Steel Creek Sampling Stations (January 1986 - December 1987)

Station	N	Mean	Median	Std[a]	CV[b]	Min	Max
			1986				
275	12	10.6	10.5	2.8	26.6	4	14
280	12	7.2	6.5	4.1	57.3	0	14
290	12	4.8	4.0	3.7	78.3	0	12
310	12	1.9	1.5	1.5	78.5	0	5
330	12	2.8	2.5	2.3	80.8	0	7
350	12	2.4	2.0	1.9	77.8	0	6
370	12	2.0	1.0	2.5	126.1	0	8
			1987				
275	12	12.1	13.5	4.0	33.0	3	17
280	12	12.3	11.5	3.6	29.6	8	18
290	12	7.3	7.0	4.5	61.1	1	16
310	12	3.4	3.5	2.0	57.8	0	7
330	12	4.2	3.0	2.4	57.7	2	8
350	12	2.9	3.0	2.1	70.8	0	6
370	12	3.1	3.5	2.2	71.1	0	6

[a] Std = standard deviation
[b] CV = coefficient of variation

Source: Gladden et al. (1988)

TABLE 4-96

Descriptive Statistics for Total Zooplankton Density (organisms/L) at Steel Creek Sampling Stations (January 1986 - December 1987)

Station	N	Mean	Median	Std[a]	CV[b]	Min	Max
			1986				
275	24	142.2	114.1	96.3	67.7	18.1	435.3
280	24	64.8	36.3	72.9	112.5	0.0	297.0
290	24	19.8	5.5	27.7	139.6	0.0	86.2
310	24	2.5	1.6	2.5	101.1	0.0	7.1
330	24	2.7	2.0	2.6	98.8	0.0	7.8
350	24	2.0	1.2	3.0	153.3	0.0	12.4
370	24	2.6	1.1	3.5	134.7	0.0	10.9
			1987				
275	24	142.0	143.1	92.1	64.9	4.4	325.2
280	24	75.5	66.1	54.1	71.6	2.6	227.8
290	24	34.2	14.1	41.0	120.2	0.0	143.1
310	24	7.5	5.0	5.9	78.4	0.0	22.7
330	24	7.9	4.0	11.2	141.4	0.0	51.0
350	24	3.7	2.6	3.6	97.4	0.0	15.0
370	24	4.1	2.4	4.4	105.7	0.0	16.3

[a] Std = standard deviation
[b] CV = coefficient of variation

Source: Gladden et al. (1988)

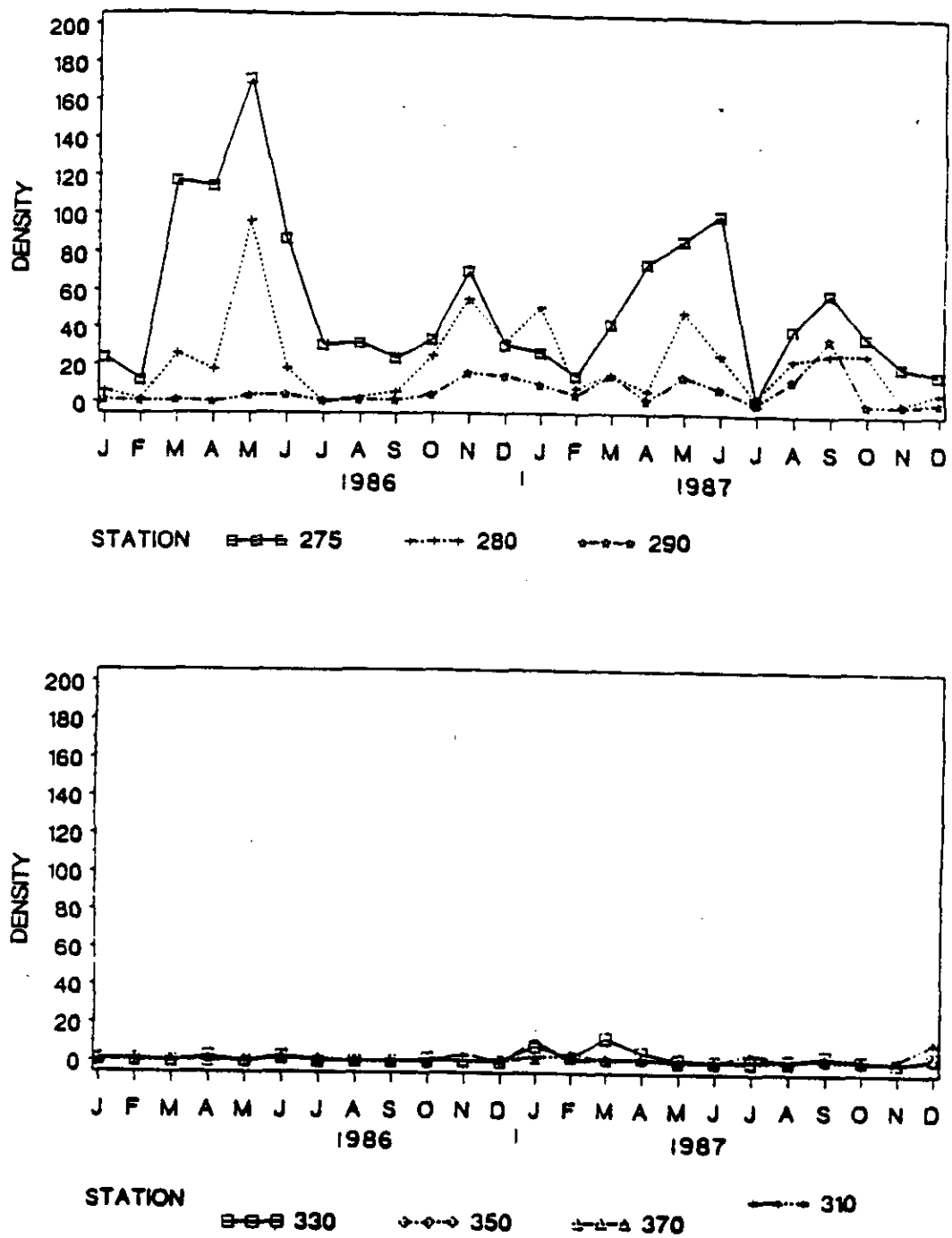

FIGURE 4-54. Mean Density of Cyclopoida/Calanoida (organisms/L) at Steel Creek Sampling Stations (January 1986 - December 1987). Top panel: creek corridor stations; bottom panel: swamp/delta stations (source: Gladden et al., 1988)

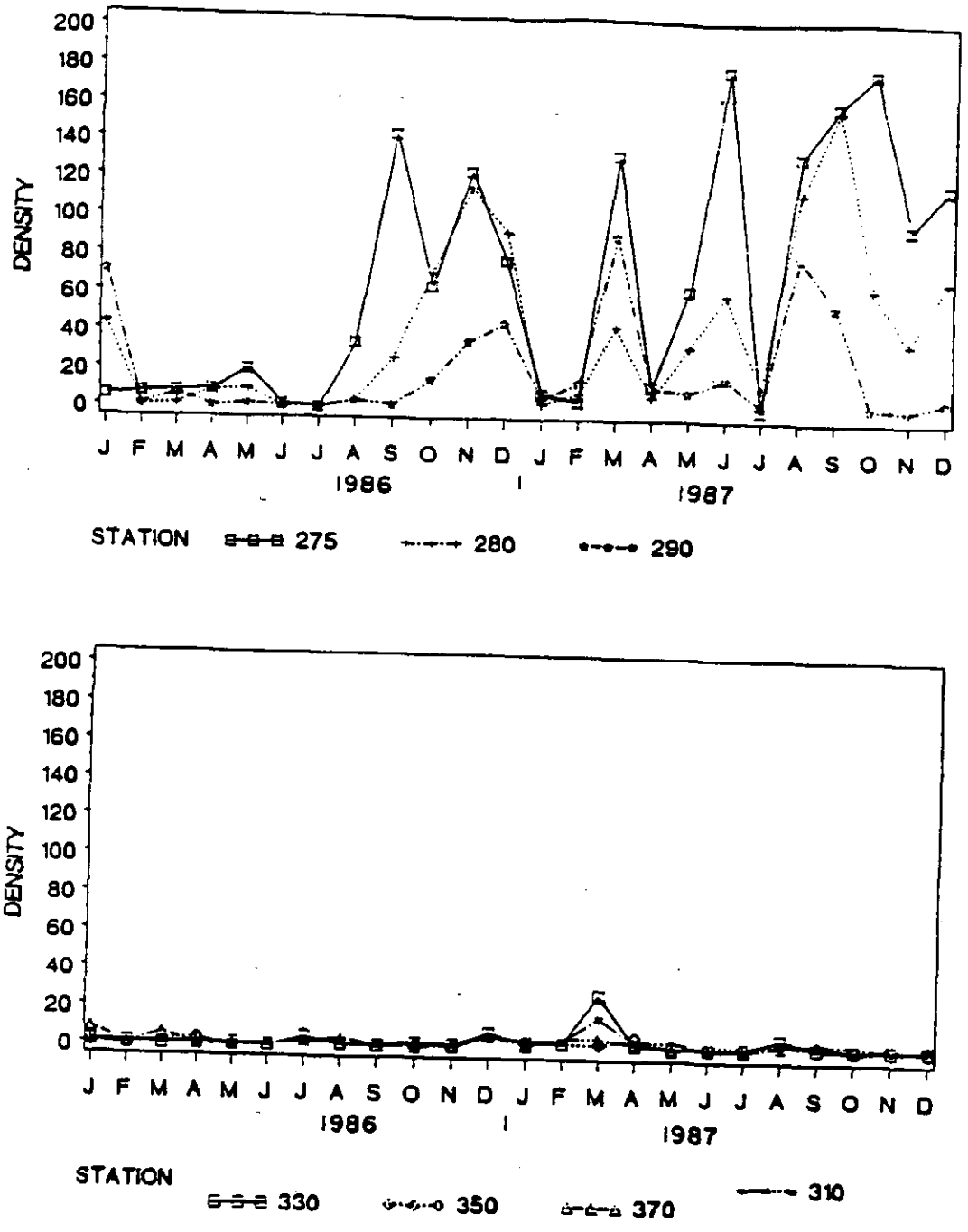

FIGURE 4-55. Mean Density of Rotifera (organisms/L) at Steel Creek Sampling Stations (January 1986 - December 1987). *Top* panel: creek corridor stations; bottom panel: swamp/delta stations (source: Gladden et al., 1988)

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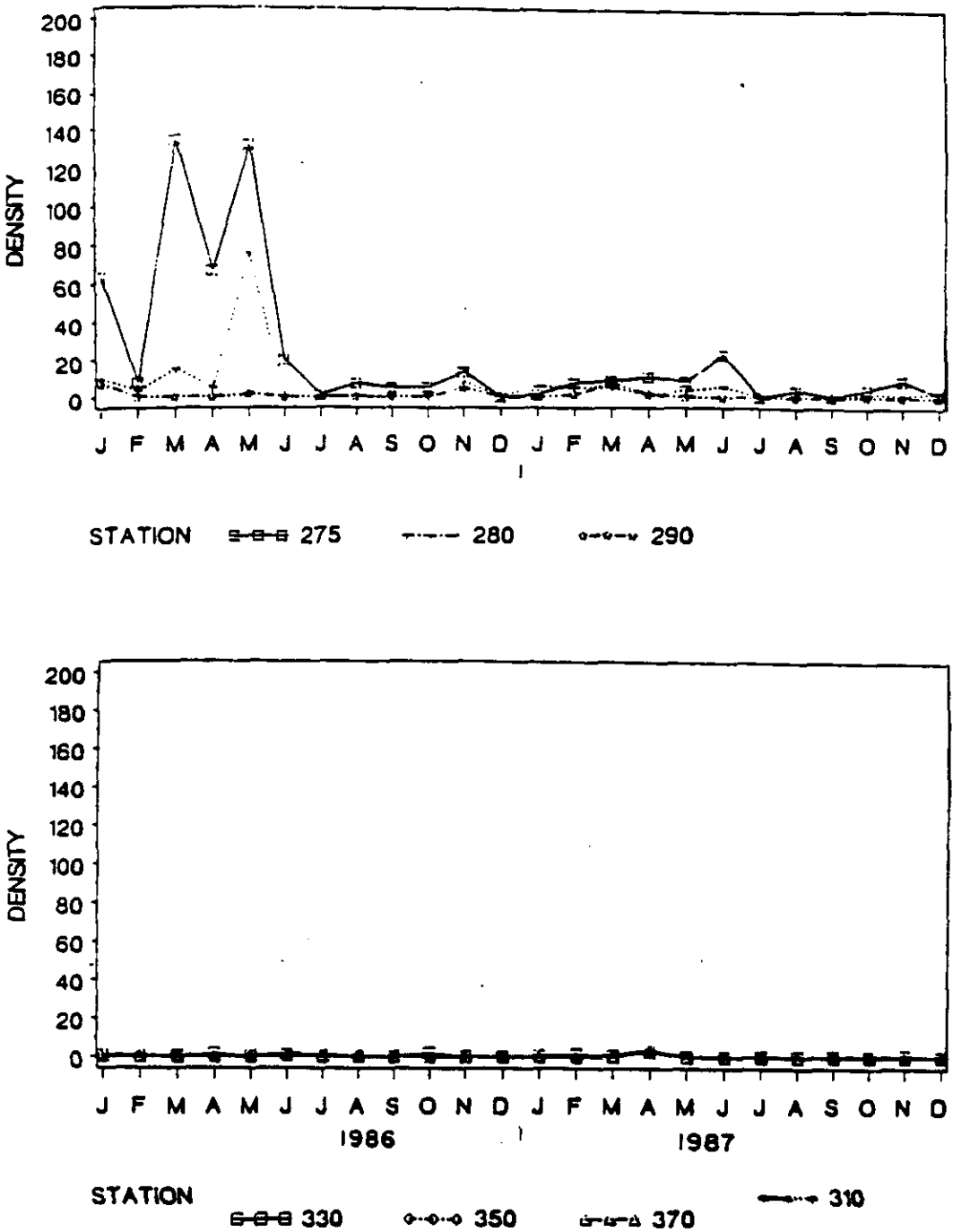

FIGURE 4-56. Mean Density of Cladocera (organisms/L) at Steel Creek Sampling Stations (January 1986 - December 1987). Top panel: creek corridor stations; bottom panel: swamp/delta stations (source: Gladden et al., 1988)

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relatively constant throughout the two years with the exception of March 1987, when the total rotifer density was approximately 30 rotifers/L at Station 330 and 17 rotifers/L at Station 310 (Figure 4-55). Rotifer densities also showed peaks during March 1987 at all the (upstream) corridor stations.

The annual and monthly trends in cladoceran abundance were different from those for both the Rotifera and Cyclopoida/Calanoida groups at the corridor stations, but were similar to these groups in the swamp/delta region (Figure 4-56). Station 275, located just below the dam, showed the highest and most variable densities. In January 1986, cladoceran density at Station 275, was approximately 65 organisms/L. In February, cladoceran densities were below 20 organisms/L at all three corridor stations. However, densities from near 80 organisms/L to greater than 130 organisms/L (the highest of the study) were observed at Station 275 in March through May of 1986. With the single exception of Station 275 June 1987, Cladocera were not abundant (<20 organisms/L at all stations) for the remainder of the two years. At the delta/swamp stations, Cladocera were present only during April 1987.

The annual and monthly trends for copepods, cladocerans, and rotifers appeared to follow population strategies that are historically well described (Allan, 1976; Allen and Goulden, 1980). These temporal patterns are comparable to other freshwater systems throughout North America. Figure 4-54 indicates rates of change for copepods that are much more gradual than those for the rotifers and cladocerans (Figures 4-55 and 4-56, respectively).

Zooplankton were also collected in the swamp/delta region during 1985 (Chimney and Cody, 1986), providing an opportunity for before and after impoundment comparison with data collected during 1986 and 1987 (Starkel and Chimney, 1988). However, the comparison is compromised by several factors. The corridor region (Stations 275, 280, and 290) of the stream was not sampled during 1985, making a comparison with 1986-1987 data for this region impossible. Comparison of the species richness in the two studies is compressed by the different sampling methods employed. Finally, during 1986, samples were collected from areas of low flow velocity near the shoreline, while in 1986-1987 samples were collected in the middle of the channel.

As shown in Table 4-97, during 1985, Rotifera and Cladocera constituted over 75% of the total number of zooplankton species in the Steel Creek swamp/delta. By 1986, the number of species had decreased by about 50% for rotifers, cladocerans, and copepods. By 1987 the rotifera had increased to 29 species, five more than in 1985. On the other hand, cladoceran taxa richness continued to decline (from 11 taxa in 1985 to 3 taxa in 1987). The number of copepod species increased from four to five between 1985 and 1987. Based only on the number of species, the impoundment of Steel Creek during 1984 and 1985 and the subsequent beginning of L-Lake discharge significantly affected the number of zooplankton taxa in the Steel Creek swamp/delta during 1985 and 1986, but recovery of taxa richness for all groups but cladocerans, had occurred in 1987.

TABLE 4-97

Comparison of Zooplankton Taxa Richness (total number of taxa identified) in the Steel Creek Delta/Swamp Between 1985, 1986, and 1987

Taxonomic Group	1985 Study	This Study 1986	This Study 1987
Rotifera	24	13	29
Cladocera	11	5	3
Copepoda	4	2	5
Ostracoda	1	1	1
Total	40	21	38

Source: Gladden et al. (1988)

TABLE 4-98

Comparison of Habitat Preferences of Zooplankton Taxa Found in Steel Creek/Swamp (combined Stations 310, 330, and 350) Between a 1985 Study (Chimney and Cody, 1986) and a 1986/1987 Study (Starkel and Chimney, 1988)

Taxon	Habitat Preference	Lost by 1986	Added in 1986	Lost by 1987	Added in 1987
ROTIFERA					
Anuraeopsis spp.	B	-	-	-	X
Ascomorpha spp.	P	-	X	-	-
Asplanchna spp.	P	-	X	-	-
Brachionus havanaensis	Unk	-	-	-	X
Brachionus spp.	B	-	X	-	-
Cephalodella spp.	L	X	-	-	-
Colurella obtusa	L	X	-	-	-
Conochilus unicornis	P	-	-	-	X
Filinia longiseta	P	-	X	-	-
Gastropus stylifer	P	-	-	-	X
Kellicottia bostoniensis	P	-	X	-	-
Keratella crassa	P	X	-	-	-
Lecane inermis	L	X	-	-	-
Lecane leontina	L	-	-	-	X
Lecane luna	L	X	-	-	X
Lecane mira	L	X	-	-	X
Lecane ungulata	L	-	-	-	X
Lepadella cristata	L	-	-	-	X
Lepadella ovalis	L	X	-	-	X
Lepadella patella	L	X	-	-	-
Macrochaetus subquadratus	L	X	-	-	-
Macrochaetus spp.	L	-	-	-	X
Manfredium eudactylatum	Unk	-	-	-	X
Monostyla bulla	L	X	-	-	X
Monostyla lunaris	L	X	-	-	X
Monostyla stenroosi	L	-	-	-	X
Ploesoma sp. 1	P	-	-	-	X
Polyarthra remata	P	-	-	-	X
Polyarthra vulgaris	P	-	X	-	-
Testudinella spp.	L	-	-	-	X
Trichocerca chattoni	Unk	-	-	-	X
Trichotria tetractis	L	X	-	-	X
Trichocerca cylindrica	P	-	-	-	X
Trichocerca elongata	B	-	-	-	X

TABLE 4-98, Contd

Taxon	Habitat Preference	Lost by 1986	Added in 1986	Lost by 1987	Added in 1987
CLADOCERA					
Camptocercus rectirostris	L	X	-	-	-
Chydorus brevilabris	B	X	-	-	X
Chydorus piger	Unk	X	-	-	-
Diaphanosoma brachyurum	-	-	X	X	-
Eurycercus (bullatifrons) spp.	L	-	-	X	-
Illyocryptis spinifer	L	X	-	-	-
Moina micrura	L	-	X	X	-
Pleuroxus spp.	L	X	-	-	-
Scapholebris kingi	L	X	-	-	-
Simocephalus sp.	L	X	-	-	-
COPEPODA					
Cyclops spp.	B	X	-	-	X
Diaptomus spp.	B	-	-	-	X
Macrocyclops spp.	B	X	-	-	-
Mesocyclops edax	P	-	X	-	-
Tropocyclops prasinus	P	-	-	-	X

Note: L = littoral; P = planktonic; B = both littoral and planktonic; Unk = unknown habitat preference.

Source: Gladden et al. (1988)

TABLE 4-99

Comparison of Zooplankton Mean Densities (organisms/L) in the Steel Creek Delta/Swamp Between a 1985 Study (Chimney and Cody, 1986) and 1986/1987 Study (Starkel and Chimney, 1988)

		1985 Study	This Study 1986	This Study 1987
Rotifera	Mean	2.8 (53%)	1.4 (58%)	3.3 (52%)
	Min	0.0	0.0	0.0
	Max	27.5	9.9	37.5
Cladocera	Mean	0.7 (13%)	0.2 (8%)	0.4 (6%)
	Min	0.0	0.0	0.0
	Max	6.9	2.4	7.4
Copepoda	Mean	1.6 (30%)	0.7 (9%)	2.4 (37%)
	Min	0.0	0.0	0.0
	Max	14.2	5.1	13.6
Ostracoda	Mean	0.2 (4%)	0.1 (4%)	0.3 (5%)
	Min	0.0	0.0	0.0
	Max	2.8	2.3	4.6

Note: Figures in parentheses are percentage contribution of major taxonomic groups to total mean density.

Source: Gladden et al. (1988)

A comparison of the species present or absent in the swamp/delta region during 1985-1987 reveals the nature of the changes in community composition after Steel Creek impoundment (Table 4-98). The litoral rotifers dominated the community during 1985, and suffered severe losses during 1986, following impoundment. Those littoral rotifers were replaced by planktonic rotifers from L Lake during 1986, while in 1987, littoral rotifer species returned. Many of the original littoral cladoceran species were lost by 1986 only to be replaced by a single cladoceran, Chydorus brevilabris, and several new species of copepods.

A summary of changes during the three-year period in terms of density and relative abundance is given in Table 4-99. By 1987, the Steel Creek swamp/delta region appeared to be reaching a new, steady-state post-impoundment community structure. However, successional changes were probably not complete in this habitat and the community is expected to continue to change for several years.

4.4.4.2 Comparisons with Regional Streams

Chimney and Cody (1986) conducted a monthly sampling program from December 1984 to August 1985 in which zooplankton in the Steel Creek corridor and swamp/delta regions were compared to other streams and the Savannah River within and adjacent to the SRS site. The local streams were Beaver Dam Creek, Four Mile Creek, and Pen Branch. Steel Creek compared favorably with these other systems in terms of species composition and total densities.

The disappearance of limnetic zooplankton is common to reaches of streams located below reservoirs throughout the United States. Ward's (1975) study on the South Platte River below a large reservoir is a good example. Relative abundances of cladocerans, copepods, and rotifers decreased 79%, 91%, and 61%, respectively, over an 8.5 km stretch downstream from the reservoir. Goodard and McDiffett (1983) estimated rotifer abundance and distribution in a downstream Pennsylvania marsh, in which 32 species were collected in macrophyte beds. Rotifer densities were 0.3 to 0.9 organisms/L, while in the swamp/delta of Steel Creek rotifer densities ranged from 0 to 37.5 organisms/L. In the Great Dismal Swamp, an aquatic environment having many diverse microhabitats, Anderson et al. (1977) found 61 zooplankton species, including 18 cladocerans and five copepods. In the swamp/delta of Steel Creek, there were 29 taxa of rotifers, six cladocerans, and five copepods during 1987. These examples suggest that the zooplankton community in Steel Creek is similar in nature to communities elsewhere.

4.4.4.3 Status of Zooplankton Community in Steel Creek

The most distinctive feature of the zooplankton in Steel Creek following the construction of L Lake was the presence of limnetic zooplankton and a decline in abundance of zooplankton from the corridor to the channel stations at the Savannah River. Species richness, total zooplankton

densities, and relative abundance all declined downstream from L-Lake Dam, which is expected because lake species normally decline in stream habitats that receive lake outflow. Canonical discriminant analyses (Starkel and Chimney, 1988) indicated that large-bodied species, principally Daphnia and diaptomid copepods, comprised most of these decreases. Annual trends of Cyclopoida, Calanoida, Cladocera, and Rotifera in the corridor region followed abundance patterns in L Lake.

In the delta/swamp regions, zooplankton populations were primarily endemic, highly variable, and experienced significant changes from 1985 to 1987. During 1985, before the completion of L Lake and the restart of L Reactor, taxa in Steel Creek included 24 Rotifera taxa, 11 Cladocera taxa, and four Copepoda taxa (Table 4-97). In 1986, after the lake was built and the reactor restarted, there were 13 Rotifera taxa, five Cladocera taxa, and only two taxa of Copepoda. However, by 1987, 29 taxa of rotifers (littoral and benthic), three Cladocera taxa, and five Copepoda taxa were present in the region, indicating that the area had recovered with regard to total taxa richness.

4.4.4.4 Expected Impacts from Restarting the L Reactor

The abundance, diversity, and turnover of zooplankton populations in Steel Creek reflect zooplankton community composition and population densities in L Lake and flow rates from the L-Lake dam. Whether L Reactor is operational or not, zooplankton are continually introduced into the corridor region of Steel Creek, above the delta/swamp region. When L Reactor is restarted, populations of limnetic zooplankton are introduced into the corridor region of Steel Creek at an accelerated rate. Most of the zooplankton originating in L Lake is consumed before reaching the delta/swamp regions where flow rates are considerably less influenced by reactor operation, and zooplankton community dynamics are not strongly correlated with reactor operating status.

4.4.5 Steel Creek Macroinvertebrates

Macroinvertebrates were sampled from January 1986 through December 1987 at 12 locations in Steel Creek (O'Hop et al., 1988). Four stations (Stations 275-290) were located in the creek corridor downstream from L Lake, six (Stations 300-350) were located in the delta/swamp, and two (Stations 360 and 370) were located in the lower stream channel downstream from the swamp (Figure 4-57). Triplicate quantitative samples were collected monthly using Hester-Dendy multiplate samplers, and qualitative samples were taken semiannually using dip nets. In addition, supplemental sampling was conducted at seven of the 12 stations by collecting drift and emergence samples monthly, and quantitative samples from three types of natural substrates (snags, macrophytes, and sediment) semiannually. Detailed sampling methods can be found in O'Hop et al. (1988); the results of the sampling program are summarized in Gladden et al. (1988).

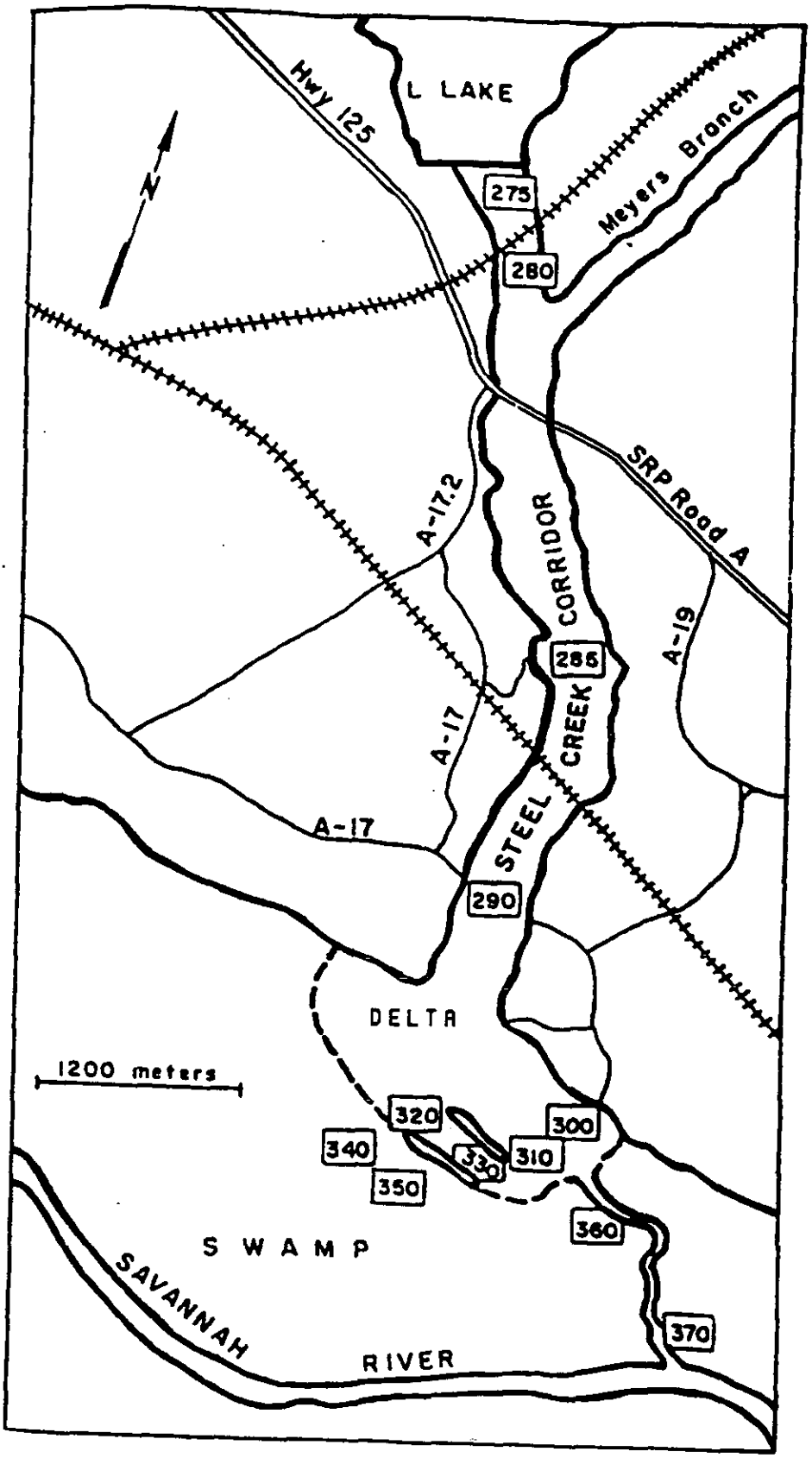

FIGURE 4-57. Macroinvertebrate Sampling Locations in Steel Creek (January 1986 - December 1987)

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In 1986 and 1987, 300 macroinvertebrate taxa were collected in Steel Creek (Table 4-100). The macroinvertebrate community of Steel Creek was dominated by Diptera (true flies), which comprised 44.0 to 91.9% of the organisms on the multiplate samplers (Table 4-101). Chironomid (midge) and simulid (blackfly) larvae were by far the most abundant families of dipterans (Table 4-101). Other abundant insect orders at most stations included Trichoptera (caddisflies; 1.0 to 22.1%) and Ephemeroptera (mayflies; 0.1 to 16.3%). Oligochaetes (segmented worms; 0.3 to 27.1%) and gastropods (snails; 0.1 to 17.6%) were also abundant at some stations.

In 1986, mean annual macroinvertebrate densities on the multiplate samplers ranged from 486 organisms/m^2 (Station 360) to 15,078 organisms/m^2 (Station 275), while in 1987, densities ranged from 414 organisms/m^2 (Station 360) to 8,258 organisms/m^2 (Station 275; Table 4-102). Mean annual biomass (ash-free dry weight) on the multiplate samplers ranged from 0.13 g/m^2 (Station 350) to 4.63 g/m^2 (Station 275) in 1986 and from 0.10 g/m^2 (Station 360) to 1.22 g/m^2 (Station 275) in 1987 (Table 4-102).

Because of the different habitats present in the stream corridor, the delta/swamp, and the lower creek channel, the macroinvertebrate communities of these three areas are very different and will be discussed separately.

4.4.5.1 Steel Creek Corridor

The Steel Creek corridor, which extends from just downstream of L-Lake Dam to the delta, has been physically altered by discharges from L Lake to a greater extent than either the delta or the lower channel section of the creek. Discharges from L Lake have resulted in relatively high water velocities and have scoured the stream substrate. Inputs of lake seston have greatly influenced the structure of the macroinvertebrate community of the stream corridor by favoring the establishment of filter-feeding insects such as Simuliidae (blackflies) and caddisflies (mostly hydropsychids), which can utilize the seston as a food source. Blackfly and caddisfly larvae were most abundant just below the dam (Station 275), where they accounted for 53.2% and 13.4%, respectively, of the organisms collected in 1986 and 11.5% and 2.3%, respectively, of the organisms collected in 1987 (Table 4-101). Dominance by filter-feeders is a common occurrence below most reservoirs (Ward, 1976; Brooker, 1981) and is due primarily to discharges of organic seston from the reservoirs rather than thermal discharges. Other relatively abundant macroinvertebrate taxa in the stream corridor were the Chironomidae tribes, including Chironomini (4.5 to 27.1% in 1986; 2.8 to 30.0% in 1987) and Tanytarsini (0.1 to 37.7% in 1986; 36.4 to 56.2% in 1987), and the Chironomidae subfamily Orthocladiinae (3.7 to 28.7% in 1986; 10.3 to 33.6% in 1987; Table 4-101). The number of macroinvertebrate taxa collected from multiplate samplers at the corridor stations was lowest just below the dam (Station 275; 38 in 1986 and 35 in 1987; Table 4-102) and increased with increasing distance from the dam. Taxa richness in the corridor was highest at Station 290, the most downstream of the corridor stations (54 taxa in 1986 and 59 taxa in 1987; Table 4-102).

TABLE 4-100

Macroinvertebrate Species List for Stations in Steel Creek (January 1986 - December 1987)
Data from all sampling methods combined.

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Phylum Coelenterata												
Hydra	X	X	-	X	-	-	X	X	-	X	-	X
Phylum Platyhelminthes												
Class Turbellaria	X	X	X	X	X	X	X	X	X	X	X	X
Phylum Nematoda	X	X	X	X	X	X	X	X	X	X	X	X
Phylum Annelida												
Class Polychaeta												
Manayunkia	-	X	-	X	-	-	-	-	X	X	-	X
Class Oligochaeta	X	X	X	X	X	X	X	X	X	X	X	X
Family Enchytraeidae	-	-	-	X	-	-	-	X	-	-	-	-
Family Lumbriculidae	-	X	-	-	-	-	-	-	-	-	-	-
Family Naididae	X	-	-	-	-	-	-	-	-	-	-	X
Dero pectinata	-	-	-	-	-	-	-	X	-	-	-	-
Nais behningi	-	X	-	-	-	-	-	-	-	-	-	-
Nais communis	X	X	-	-	-	X	-	-	-	-	-	-
Nais sp.	-	-	-	X	-	X	-	-	-	-	-	-
Slavina appendiculata	-	-	-	X	-	X	-	X	-	-	-	-
Stylaria lacustris	-	X	-	-	X	X	X	X	X	X	-	-
Family Tubificidae	X	X	-	X	-	X	-	X	-	-	-	X
Limnodrilus hoffmeisteri	X	-	-	-	-	-	-	-	-	-	-	X
Class Hirudinea	X	X	X	X	X	X	X	X	X	X	X	X
Phylum Mollusca												
Class Gastropoda	X	X	X	X	X	X	X	X	X	X	-	X
Family Ancylidae	X	X	X	X	X	X	X	X	X	X	X	X
Ferrissia rivularis	X	X	-	X	-	X	-	-	-	-	-	-
Laevapex fuscus	-	-	-	-	-	-	X	-	-	-	-	-

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Hydrobiidae												
Amnicola spp.	X	X	X	X	X	X	X	X	X	X	X	X
Amnicola?	–	–	–	–	–	X	X	X	–	–	–	–
Somatogyrus sp.	–	–	–	–	–	X	X	–	X	–	–	–
Family Lymnaeidae												
Pseudosuccinea columella	X	X	X	X	X	X	X	X	X	X	–	X
Family Physidae												
Physella heterostropha	X	X	X	X	X	X	X	X	X	X	X	X
Family Planorbidae	X	X	–	X	X	X	X	–	X	X	–	X
Gyraulus parvus	–	–	X	X	X	–	X	X	X	X	X	–
Helisoma spp.	X	X	X	X	X	X	X	–	X	X	–	X
Helisoma trivolvis	–	X	X	X	X	X	X	X	X	X	X	X
Menetus dilatatus	X	X	X	X	X	X	X	X	X	X	X	X
Family Viviparidae												
Campeloma decisum	–	X	–	X	X	X	X	X	X	X	–	X
Family Succineidae												
Succinea	–	X	–	–	–	–	X	–	–	–	–	–
Class Pelecypoda	–	X	X	X	X	X	X	X	X	–	–	X
Family Corbiculidae												
Corbicula fluminea	X	X	X	X	–	X	X	X	X	X	X	X
Family Sphaeriidae	X	X	X	X	X	X	X	X	X	X	–	X
Elliptio complanata	–	X	–	–	–	–	–	–	–	–	–	–
Phylum Arthropoda												
Class Arachnida												
Order Hydracarina	X	X	X	X	X	X	X	X	X	X	X	X
Class Crustacea												
Order Isopoda	–	–	–	–	–	X	–	X	–	–	–	X
Family Asellidae												
Asellus	–	X	X	X	X	X	X	X	X	X	X	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Order Amphipoda	X	–	–	X	X	X	X	X	X	X	X	X
Family Gammaridae												
Crangonyx	–	–	–	–	X	–	–	–	–	–	–	–
Gammarus fasciatus	X	X	X	X	X	X	X	X	X	X	X	X
Family Talitridae												
Hyalella azteca	X	X	X	X	X	X	X	X	X	X	X	X
Order Decapoda	–	–	–	–	–	–	–	–	–	–	–	X
Family Palaemonidae												
Palaemonetes paludosus	–	X	–	X	X	X	X	X	X	X	X	X
Family Cambaridae	–	X	–	X	–	–	–	–	–	X	–	X
Procambarus	–	–	–	–	–	X	X	X	X	X	X	X
Order Collembola	X	X	–	X	X	X	X	X	–	X	X	X
Family Isotomidae	–	X	–	–	–	–	–	–	–	–	–	–
Family Poduridae												
Podura aquatica	–	–	–	–	–	–	–	–	–	–	–	X
Family Sminthuridae												
Sminthurides spp.	X	–	–	X	–	–	–	X	–	X	–	X
Order Ephemeroptera	–	X	X	X	X	X	–	X	X	X	–	X
Family Baetidae	X	X	X	X	X	X	X	X	X	X	X	X
Baetis	X	X	X	X	X	X	X	X	X	X	X	X
Callibaetis	–	–	X	X	X	X	X	X	X	X	–	X
Pseudocloeon parvulum	–	X	X	X	–	X	–	X	–	X	–	X
Family Caenidae	X	X	–	X	–	–	–	–	–	X	–	–
Caenis	X	X	X	X	X	X	X	X	X	X	X	X
Family Ephemerellidae	–	–	X	X	–	–	–	X	X	X	–	–
Ephemerella	–	–	–	–	–	–	–	–	–	X	–	–
Ephemerella invaria	X	X	X	X	–	–	–	–	–	X	–	–
Eurylophella temporalis	–	–	–	X	X	X	X	X	X	X	X	X
Serratella deficiens	–	–	–	X	–	–	–	–	–	–	–	–

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Heptageniidae	–	X	X	X	–	X	X	X	X	X	X	X
Heptagenia	–	–	X	X	–	–	–	–	–	X	–	X
Stenacron interpunctatum	–	–	–	X	X	X	X	X	X	X	X	X
Stenonema modestum	X	X	X	X	X	X	X	X	X	X	X	X
Family Leptophlebiidae												
Leptophlebia	–	–	–	X	–	–	–	–	–	–	–	–
Paraleptophlebia	–	–	–	–	–	–	–	–	X	–	–	–
Family Neoephemeridae												
Neoephemera youngi	–	–	–	X	–	X	–	X	X	–	–	–
Family Tricorythidae	–	–	–	X	–	–	–	–	–	–	–	–
Leptohyphes	–	–	–	X	–	–	–	–	–	–	–	–
Tricorythodes	X	X	X	X	–	–	–	X	–	X	–	X
Order Odonata												
Suborder Anisoptera	X	X	X	X	X	X	X	X	X	X	X	X
Family Aeshnidae	–	–	–	–	–	X	–	–	X	–	–	–
Basiaeschna janata	–	–	–	X	–	X	–	X	–	X	–	–
Boyeria vinosa	–	–	–	X	X	X	–	X	X	X	–	–
Coryphaeschna ingens	–	–	–	–	–	–	–	–	–	X	–	–
Nasiaeschna pentacantha	–	–	–	–	–	–	–	X	–	–	–	–
Family Corduliidae	–	–	–	X	–	X	–	X	X	X	–	X
Epicordulia regina	–	X	–	X	X	X	X	X	X	X	–	X
Neurocordulia	–	–	–	X	–	–	–	–	–	–	–	–
Neurocordulia molesta	–	X	–	X	–	X	–	X	X	X	–	–
Tetragoneuria cynosura	–	–	–	–	X	X	X	X	X	X	–	X
Family Gomphidae	X	X	–	X	X	X	X	X	–	X	X	X
Aphylla williamsoni	–	–	–	–	–	–	–	–	–	X	–	–
Gomphus lividus	–	–	–	–	–	–	–	–	–	–	X	–
Hagenius brevistylus	–	–	–	–	–	–	–	X	–	–	–	–

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Libellulidae	–	X	–	X	X	X	–	X	–	X	–	X
Erythemis simplicicollis	–	X	–	–	X	X	X	X	X	X	–	X
Erythrodiplax berenice	–	–	–	–	X	–	–	–	–	–	–	–
Libellula spp.	–	–	–	–	X	X	–	–	–	X	–	–
Pachydiplax longipennis	–	X	–	X	X	X	X	X	X	X	–	X
Perithemis tenera	–	–	–	–	–	–	X	–	X	–	–	–
Family Macromiidae												
Didymops transversa	–	–	–	X	–	–	–	–	–	–	–	–
Macromia spp.	–	X	–	–	–	–	–	–	–	–	–	–
Suborder Zygoptera	X	X	–	X	X	X	X	X	X	X	–	X
Family Calopterygidae	–	–	–	X	–	X	X	X	–	X	–	–
Calopteryx spp.	X	–	–	–	–	X	–	X	X	X	X	X
Hetaerina spp.	–	–	–	–	–	–	–	X	X	X	–	–
Family Coenagrionidae	X	X	X	X	X	X	X	X	X	X	X	X
Argia spp.	X	X	–	X	X	X	X	X	X	X	–	X
Enallagma spp.	X	X	X	X	X	X	X	X	X	X	X	X
Enallagma signatum?	–	X	–	–	–	–	–	–	–	–	–	–
Ischnura spp.	–	–	X	–	X	X	–	X	X	X	–	X
Ischnura posita	–	–	–	–	X	–	–	–	–	–	–	–
Nehalennia spp.	–	–	–	–	–	X	X	X	–	X	–	X
Family Lestidae												
Lestes	–	–	–	–	–	X	–	X	X	X	–	–
Order Plecoptera	–	–	X	X	–	–	–	–	X	X	–	–
Family Perlidae	–	X	X	X	–	–	–	X	–	–	–	–
Acroneuria	–	–	–	X	–	–	–	–	–	–	–	–
Acroneuria abnormis	–	–	–	X	–	–	–	–	–	–	–	–
Beloneuria	–	–	–	X	–	–	–	–	–	–	–	–
Paragnetina fumosa	–	–	X	X	–	–	–	–	–	–	–	X
Perlesta placida	X	X	X	X	X	–	–	–	X	X	–	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Perlodidae	–	–	–	X	–	–	–	–	–	–	–	–
Clioperla clio	–	–	–	X	–	–	–	–	–	X	–	–
Helopicus bogaloosa	–	–	X	X	–	–	–	–	–	–	–	–
Isoperla	–	–	X	X	–	–	–	–	–	–	–	–
Family Pteronarcidae												
Pteronarcys dorsata	–	–	X	X	–	–	–	–	–	–	–	–
Family Taeniopterygidae	–	–	–	X	–	–	–	–	–	–	–	–
Taeniopteryx spp.	–	–	–	X	–	–	–	–	–	–	–	X
Taeniopteryx lonicera	–	X	–	–	–	–	–	–	–	–	–	–
Taeniopteryx robinae	–	X	X	–	–	–	–	–	–	–	–	–
Order Hemiptera	X	–	–	–	–	–	X	X	–	X	–	X
Family Belostomatidae												
Belostoma	–	–	–	X	X	X	X	X	–	X	–	X
Family Corixidae	X	X	–	X	X	X	–	X	–	X	–	X
Ramphocorixa	–	–	–	–	–	–	–	–	–	–	–	X
Sigara	–	–	–	–	–	X	–	–	–	–	–	–
Trichocorixa spp.	X	X	–	X	–	X	–	X	X	X	–	X
Trichocorixa calva	–	–	–	–	X	–	–	–	–	–	–	–
Trichocorixa macroceps	–	–	–	–	X	–	–	–	–	–	–	X
Trichocorixa sexcinta	–	–	–	–	X	–	–	–	–	–	–	–
Superfamily Gerroidea	–	–	–	–	–	–	–	–	–	–	–	X
Family Gerridae	–	X	–	X	–	X	–	–	–	–	X	X
Gerris spp.	–	–	–	–	–	X	–	–	–	X	–	–
Family Hebridae												
Hebrus	–	X	–	–	–	–	–	–	–	–	–	X
Merragata	–	–	–	–	X	–	–	–	–	–	–	–
Family Hydrometridae	–	–	–	X	–	X	–	X	–	–	–	X
Hydrometra	–	–	–	X	–	X	X	X	–	X	–	X
Family Mesoveliidae												
Mesovelia mulsanti	–	–	–	X	X	X	–	X	X	X	–	X
Family Naucoridae												
Pelocoris femoratus	–	–	–	X	X	X	X	X	X	X	–	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Veliidae	–	–	–	–	–	–	–	–	–	X	–	–
Microvelia	–	–	–	–	X	–	X	X	–	–	–	X
Microvelia americana	–	–	–	–	X	–	–	–	–	–	–	–
Order Coleoptera	–	–	–	–	–	X	X	X	–	–	–	–
Family Chrysomelidae	–	X	–	X	–	–	–	–	–	–	–	X
Agasicles hygrophila	–	X	–	–	–	–	–	–	–	–	–	–
Family Curculionidae	X	X	–	X	X	X	X	X	X	X	X	X
Family Dytiscidae	–	–	–	X	X	X	–	X	–	X	–	X
Agabus	–	–	X	–	X	–	–	–	–	–	–	X
Bidessonotus spp.	–	–	–	X	–	X	–	X	–	X	–	X
Celina sp.	–	–	–	X	X	X	–	–	–	–	–	–
Copelatus caelatipennis	–	X	–	X	–	–	–	–	–	–	–	–
Coptotomus	–	–	–	–	X	–	–	–	–	X	–	X
Cybister fimbriolatus	–	–	–	–	–	–	–	–	–	X	–	–
Hydroporus	–	–	X	X	X	X	X	X	–	X	X	X
Hydrovatus	–	X	–	X	X	X	X	X	–	–	–	X
Hygrotus	–	–	–	–	–	X	–	X	–	X	–	X
Laccobius	–	X	–	–	–	–	–	–	–	–	–	–
Laccophilus	–	–	–	–	–	X	–	–	–	–	–	–
Liodessus	–	–	–	X	–	–	–	–	–	–	–	–
Matus	–	–	–	–	–	X	–	–	–	–	–	–
Family Elmidae	–	X	X	X	–	X	–	–	–	X	–	X
Ancyronyx variegatus	X	X	X	X	–	X	–	X	X	X	X	X
Dubiraphia	–	–	–	X	–	–	–	X	X	–	–	X
Macronychus glabratus	X	X	X	X	X	X	X	X	X	X	X	X
Microcylloepus pusillus	X	X	X	X	–	X	–	X	–	X	–	X
Oulimnius latiusculus	–	–	–	–	–	–	–	X	X	–	–	–
Stenelmis	X	X	X	X	–	–	–	X	–	X	X	X
Family Eubriidae												
Ectopria nervosa	–	X	X	X	X	–	–	–	–	–	–	–
Family Gyrinidae	–	–	–	X	–	X	–	–	–	X	–	X
Dineutus	X	X	X	X	X	X	X	X	X	X	X	X
Gyrinus	–	–	X	X	X	X	X	X	X	X	X	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Haliplidae												
Haliplus spp.	–	–	–	–	X	–	–	X	X	–	–	X
Haliplus fasciatus	–	–	–	X	–	–	–	–	–	–	–	–
Haliplus triopsis	–	–	–	–	X	–	–	–	–	–	–	–
Peltodytes spp.	–	X	X	X	X	X	X	X	X	X	–	X
Peltodytes cf. *oppositus*	–	–	–	–	–	–	–	X	–	–	–	–
Family Helodidae	–	–	–	X	–	–	–	–	–	–	–	X
Cyphon	–	–	–	X	–	–	–	–	–	–	–	
Family Hydraenidae												
Hydraena	–	–	–	–	–	–	–	–	–	–	–	X
Family Hydrochidae												
Hydrochus spp.	–	X	–	X	–	–	–	X	–	–	–	X
Hydrochus excavatus	–	–	–	X	X	–	–	–	–	–	–	–
Hydrochus inaequalis	–	–	–	–	X	–	–	–	–	–	–	–
Family Hydrophilidae	–	X	–	X	–	–	–	–	–	–	–	X
Anacaena	–	–	–	–	–	–	–	–	–	–	–	X
Berosus	X	X	–	X	X	–	X	X	–	–	–	X
Helochares	–	–	–	X	–	–	–	–	–	–	–	–
Paracymus	–	–	–	–	–	–	–	–	–	–	–	–
Tropisternus	X	X	–	X	X	–	–	–	–	X	–	X
Family Noteridae	–	X	–	–	–	X	–	–	–	–	–	X
Notomicrus	–	X	–	X	–	X	–	X	–	–	–	X
Suphisellus	–	–	–	–	X	X	–	–	–	–	–	X
Family Ptilodactylidae												
Anchytarsus	–	X	–	–	–	–	–	–	–	–	–	–
Order Megaloptera	–	X	–	–	–	–	–	–	–	–	–	–
Family Corydalidae	–	X	X	X	–	X	–	X	X	–	–	X
Chauliodes	–	–	–	–	–	–	–	X	X	X	–	X
Corydalus cornutus	X	X	X	X	–	X	–	X	–	X	X	X
Nigronia	X	X	–	X	–	X	–	–	–	–	–	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Sialidae												
Sialis	-	-	-	-	X	-	-	X	-	-	-	X
Family Sisyridae	-	-	-	-	-	-	-	-	-	X	-	-
Climacia areolaris	-	-	-	-	-	-	-	-	-	X	-	X
Sisyra	-	-	-	-	-	-	-	-	-	-	-	X
Order Trichoptera	X	X	X	-	X	X	X	X	X	X	-	-
Family Brachycentridae	-	-	-	-	-	-	-	-	-	X	-	-
Brachycentrus	-	-	-	X	-	-	-	X	-	X	-	-
Family Hydropsychidae	X	X	X	X	X	X	X	X	-	X	X	X
Cheumatopsyche spp.	X	X	X	X	X	X	X	X	X	X	X	X
Cheumatopsyche pettiti	-	-	-	-	-	X	-	X	-	X	-	X
Hydropsyche spp.	X	X	X	X	X	X	X	X	X	X	X	X
Macrostemum carolina	-	-	-	X	-	X	X	X	-	X	X	X
Family Hydroptilidae	-	X	-	X	-	X	-	-	-	X	-	X
Hydroptila	X	X	X	X	X	X	X	X	X	X	-	X
Hydroptila cf. *waubesiana*	-	-	-	X	-	-	-	-	-	-	-	-
Ochrotrichia	-	-	-	X	-	-	-	-	X	X	-	-
Orthotrichia	-	-	-	-	X	X	-	X	X	X	-	X
Oxyethira	X	X	X	X	X	X	X	X	X	X	X	X
Family Leptoceridae	X	X	X	X	-	X	X	X	-	X	-	X
Ceraclea	-	-	-	X	-	-	-	-	-	-	-	-
Leptocerus americanus	-	-	-	-	-	-	-	-	-	-	-	X
Nectopsyche spp.	X	X	X	X	X	X	-	X	-	-	-	-
Nectopsyche candida	-	X	X	X	-	X	-	X	-	-	-	X
Oecetis spp.	X	X	X	X	X	X	X	X	X	X	X	X
Oecetis cinerascens	-	-	-	-	-	X	-	-	-	-	-	-
Oecetis persimilis?	-	-	-	-	-	X	-	-	-	-	-	-
Triaenodes spp.	-	-	-	-	-	X	X	X	-	X	-	X
Triaenodes ignitis	-	-	-	X	-	-	-	X	-	-	-	-
Triaenodes cf. *marginata*	-	-	-	-	-	-	-	X	-	-	-	-
Triaenodes tardus	X	X	-	X	X	X	X	X	-	X	X	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Limnephilidae	–	X	–	X	–	X	–	X	–	X	–	X
Ironoquia	–	–	–	X	–	X	–	–	–	–	–	–
Pycnopsyche	–	–	–	–	–	–	–	–	–	X	–	X
Pycnopsyche indiana	–	–	–	–	–	–	–	X	–	X	–	–
Family Philopotamidae	–	–	–	–	–	–	–	–	–	X	–	X
Chimarra	X	X	X	X	X	X	–	X	–	X	X	X
Chimarra mosleyi	–	–	–	–	–	–	–	–	–	–	–	X
Family Phryganeidae	–	–	–	–	–	–	–	–	–	–	–	X
Family Polycentropodidae	–	–	–	X	–	X	X	X	X	X	–	X
Cernotina	–	X	–	–	–	–	X	–	X	X	–	–
Cyrnellus	–	–	–	–	–	–	–	–	X	–	–	–
Neureclipsis	X	X	–	X	X	–	X	–	–	X	–	–
Neureclipsis crepuscularis	–	–	–	–	–	–	–	–	–	–	–	X
Phylocentropus	–	–	–	–	–	–	–	X	–	X	–	–
Polycentropus	–	–	–	–	X	X	X	X	X	X	X	X
Family Psychomyiidae												
Lype diversa	X	X	X	–	–	–	–	X	–	–	–	–
Order Lepidoptera	X	X	X	X	–	X	X	X	X	X	X	X
Family Arctiidae	–	–	–	–	–	–	–	–	–	X	–	–
Family Noctuidae	–	X	–	–	–	–	–	–	–	X	–	X
Family Pyralidae	X	X	–	X	X	X	X	X	X	X	X	X
Munroessa	–	X	–	X	–	X	X	X	–	X	X	X
Neargyractis	–	X	–	X	X	X	X	X	X	X	–	X
Parapoynx	–	X	X	X	X	X	X	X	X	X	X	X
Synclita	–	–	–	X	X	X	X	X	X	X	X	X

TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Order Diptera	X	X	–	X	–	–	–	X	–	X	–	X
Family Tipulidae	X	X	–	X	–	–	–	X	–	–	–	X
Erioptera	X	X	–	X	–	–	–	–	–	–	–	X
Helius	–	–	–	–	–	–	–	X	–	–	–	–
Hexatoma	–	–	–	–	–	–	–	–	X	–	–	–
Pilaria	X	–	–	–	–	–	–	–	–	–	–	–
Pseudolimnophila	–	X	–	–	–	–	–	–	–	–	–	–
Tipula	X	X	–	X	–	–	–	X	–	–	–	X
Family Sciaridae	–	X	–	–	–	–	–	–	–	–	–	–
Sciara	–	X	–	–	–	–	–	–	–	–	–	–
Family Psychodidae	–	X	X	X	–	–	–	–	–	–	–	X
Pericoma	–	X	–	X	–	–	–	–	–	–	–	X
Psychoda spp.	–	X	–	–	–	–	–	–	–	–	–	X
Psychoda alternata	X	X	–	X	–	–	–	–	–	–	–	–
Telmatoscopus	X	X	–	X	–	–	–	–	–	–	–	X
Family Ptychopteridae												
Bittacomorpha	–	X	–	–	–	–	–	–	–	–	–	X
Family Chaoboridae												
Chaoborus punctipennis	X	X	X	X	X	X	–	X	X	X	X	X
Corethrella	–	–	–	X	–	X	–	–	–	–	–	–
Family Culicidae	–	X	–	X	–	X	–	–	X	X	–	–
Aedes	–	X	–	X	–	X	–	–	–	X	–	X
Anopheles	–	X	–	X	X	X	–	X	–	X	–	X
Culex	–	X	–	X	X	X	–	X	–	–	–	X
Culiseta	–	X	–	–	–	–	–	–	–	–	–	–
Mansonia	–	–	–	X	–	X	–	X	–	–	–	X
Uranotaenia	–	–	–	–	X	X	X	–	X	X	–	X
Family Simuliidae	X	X	–	X	–	–	–	–	–	–	–	X
Simulium	X	X	X	X	X	X	X	X	X	X	X	X
Family Ceratopogonidae	X	X	–	X	X	X	X	X	X	X	–	X
Subfamily Ceratopogoniinae	X	X	X	X	X	X	X	X	X	X	X	X
Bezzia	–	–	–	–	–	–	–	–	–	X	–	–

TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Subfamily Forcipomyiinae	X	X	X	X	X	X	X	X	X	X	–	X
Forcipomyia	–	X	–	X	–	–	–	–	–	–	–	–
Family Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X
Subfamily Tanypodinae	X	X	X	X	X	X	X	X	X	X	X	X
Tribe Coelotanypodini												
Clinotanypus	–	–	–	–	–	–	–	–	–	X	–	–
Clinotanypus (*C.*) *pinguis*	–	–	–	–	–	X	–	X	–	X	–	X
Tribe Macropelopiini												
Macropelopia	–	–	–	–	–	X	–	–	–	–	–	–
Procladius (*P.*) *bellus*	–	X	–	X	–	X	–	X	–	X	–	X
Procladius (*H.*) *sublettei*	–	–	–	X	–	X	–	X	–	X	–	X
Tribe Pentaneurini (unid.)	–	–	–	X	–	X	–	X	–	X	–	–
Ablabesmyia spp.	X	X	–	X	–	X	–	X	–	X	–	X
Ablabesmyia (*A.*) *janta*	–	–	–	X	–	X	–	–	–	X	–	–
Ablabesmyia (*A.*) *mallochi*	X	X	–	X	–	X	–	X	–	–	–	X
Ablabesmyia (*A.*) *monilis*	–	–	–	X	–	–	–	–	–	X	–	X
Ablabesmyia (*A.*) *ramphe*	X	X	–	X	–	X	–	X	–	X	–	X
Ablabesmyia (*A.*) *annulata*	–	X	–	X	–	X	–	X	–	X	–	–
Ablabesmyia (*K.*) *cinctipes*	X	X	–	X	–	–	–	X	–	X		–
Conchapelopia spp.	–	X	–	–	–	–	–	–	–	–	–	–
Conchapelopia gr.	–	–	–	–	–	X	–	X	–	–	–	–
Conchapelopia rurika	–	–	–	X	–	X	–	–	–	–	–	–
Labrundinia spp.	X	X	–	X	–	X	–	X	–	X	–	–
Labrundinia becki	X	X	–	X	–	X	–	X	–	X	–	X
Labrundinia pilosella	X	X	–	X	–	X	–	X	–	X	–	X
Larsia spp.	–	–	–	–	–	X	–	X	–	–	–	–
Larsia planesis	X	–	–	–	–	X	–	–	–	–	–	–
Nilotanypus fimbriatus	–	–	–	X	–	X	–	–	–	–	–	X
Pentaneura inconspicua	X	X	–	X	–	X	–	X	–	X	–	X
Tribe Tanypodini												
Tanypus (*T.*) *concavus*	–	–	–	X	–	X	–	–	–	–	–	–
Tanypus (*T.*) *punctipennis*	–	–	–	X	–	–	–	–	–	–	–	–

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Subfamily Orthocladiinae	X	X	X	X	X	X	X	X	X	X	X	X
Antillocladius? sp.	X	–	–	–	–	–	–	–	–	–	–	–
Chaetocladius	–	–	–	–	–	–	–	X	–	–	–	–
Corynoneura spp.	–	–	–	X	–	X	–	X	–	X	–	–
Corynoneura sp. 1	X	X	–	X	–	X	–	X	–	X	–	X
Corynoneura sp. 2	–	–	–	–	–	–	–	X	–	–	–	–
Cricotopus spp. (unid.)	X	X	–	X	–	X	–	X	–	X	–	X
Cricotopus bicinctus gr.	X	X	–	X	–	X	–	X	–	X	–	X
Cricotopus (*C.*) sp. 1	X	X	–	X	–	X	–	X	–	X	–	X
Cricotopus (*C.*) sp. 2	X	X	–	X	–	X	–	X	–	X	–	X
Cricotopus (*C.*) sp. 3	–	–	–	X	–	–	–	–	–	–	–	–
Cricotopus (*C.*) sp. 4	X	X	–	X	–	X	–	X	–	X	–	X
Cricotopus (*C.*) cf. *vierriensis*	X	X	–	X	–	X	–	X	–	–	–	X
Eukiefferiella sp.	X	X	–	–	–	–	–	–	–	–	–	–
Nanocladius spp. (unid.)	X	X	–	–	–	X	–	X	–	X	–	X
Nanocladius (*N.*) cf. *distinctus*	X	X	–	X	–	X	–	X	–	X	–	X
Nanocladius (*N.*) cf. *mallochi*	X	X	–	X	–	X	–	X	–	X	–	X
Nanocladius (*N.*) cf. *minimus*	X	X	–	X	–	X	–	X	–	–	–	X
Orthocladius (*O.*) spp.	–	–	–	X	–	–	–	–	–	X	–	X
Orthocladius cf. *carlatus*	–	–	–	–	–	–	–	X	–	–	–	–
Parakiefferiella	–	X	–	X	–	X	–	X	–	X	–	X
Parakiefferiella cf. *coronata*	X	–	–	X	–	X	–	X	–	–	–	–
Parametriocnemus lundbecki	X	X	–	X	–	X	–	X	–	X	–	X
Rheocricotopus	–	–	–	–	–	–	–	X	–	–	–	–
Rheocricotopus sp.	–	X	–	X	–	X	–	X	–	X	–	X
Psectrocladius	–	–	–	–	–	–	–	–	–	X	–	–
Pseudosmittia cf. *forcipata*	–	–	–	X	–	–	–	–	–	–	–	–
Thienemanniella spp.	X	X	–	X	–	X	–	X	–	X	–	X
Thienemanniella sp.	X	X	–	X	–	X	–	X	–	X	–	X
Thienemanniella sp. 2	X	–	–	X	–	X	–	–	–	X	–	–
Tvetenia sp.	X	X	–	X	–	X	–	X	–	X	–	X
Tvetenia discoloripes gr. sp.	–	–	–	X	–	X	–	X	–	–	–	X

TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Subfamily Diamesiinae	X	X	–	–	–	X	–	X	–	X	–	X
Potthastia	X	X	X	X	X	X	X	X	X	X	–	X
Potthastia longimanus	–	–	–	–	–	X	–	X	–	–	–	–
Tribe Chironomini	X	X	X	X	X	X	X	X	X	X	X	X
Asheum becki	X	X	–	–	–	–	–	–	–	–	–	–
Chironomus spp.	–	–	–	X	–	X	–	–	–	–	–	X
Chironomus decorus gr. sp. 1	X	–	–	X	–	X	–	–	–	X	–	X
Chironomus decorus gr. sp. 2	X	X	–	X	–	X	–	–	–	–	–	–
Cladopelma edwardsi	–	X	–	–	–	–	–	–	–	–	–	–
Cryptochironomus cf. *blarina*	X	X	–	–	–	X	–	–	–	–	–	–
Cryptochironomus cf. *sorex*	X	–	–	–	–	X	–	–	–	X	–	–
Cryptotendipes casuarius	–	–	–	–	–	–	–	X	–	–	–	–
Cryptotendipes emorsus	–	–	–	–	–	–	–	X	–	X	–	–
Dicrotendipes	X	X	–	X	–	X	–	X	–	X	–	X
Dicrotendipes modestus	X	X	–	X	–	X	–	X	–	X	–	X
Dicrotendipes neomodestus	X	–	–	–	–	X	–	X	–	X	–	–
Einfeldia dorsalis	–	–	–	X	–	–	–	–	–	–	–	–
Einfeldia paganus	–	–	–	–	–	X	–	–	–	–	–	–
Endochironomus nigricans	X	X	–	–	–	–	–	–	–	–	–	–
Glyptotendipes spp. (unid.)	X	X	–	–	–	–	–	X	–	–	–	–
Glyptotendipes (*P.*) *lobiferus*	X	X	–	X	–	X	–	X	–	X	–	–
Glyptotendipes (*P.*) *paripes*	X	–	–	–	–	–	–	–	–	–	–	X
Goeldichironomus carus	X	X	–	–	–	–	–	–	–	–	–	–
Goeldichironomus holoprasinus	X	–	–	–	–	–	–	–	–	–	–	–
Microtendipes	–	–	–	–	–	–	–	X	–	–	–	–
Microtendipes pedellus	–	–	–	X	–	X	–	X	–	X	–	–
Parachironomus spp.	X	X	–	–	–	–	–	–	–	–	–	–
Parachironomus sp. 1	X	X	–	–	–	–	–	–	–	–	–	–
Parachironomus carinatus	X	–	–	–	–	–	–	–	–	–	–	–
Parachironomus monochromus	X	–	–	–	–	–	–	–	–	–	–	–
Paralauterborniella nigrohalteralis	–	–	–	–	–	–	–	X	–	–	–	–
Phaenopsectra	–	–	–	X	–	–	–	X	–	X	–	X

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TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Phaenopsectra flavipes	–	X	–	X	–	X	–	X	–	X	–	X
Polypedilum spp.	X	X	–	X	–	X	–	X	–	X	–	X
Polypedilum (*P.*) nr. *frequens*	X	X	–	–	–	–	–	–	–	–	–	–
Polypedilum (*P.*) *illinoense*	X	X	–	X	–	X	–	X	–	X	–	X
Polypedilum (*P.*) cf. *obtusum*	X	–	–	X	–	–	–	–	–	–	–	–
Polypedilum (*P.*) *vibex*	–	–	–	–	–	–	–	–	–	–	–	X
Polypedilum (*T.*) *digitifer*	X	X	–	X	–	X	–	–	–	X	–	X
Polypedilum (*T.*) *halterale*	–	–	–	X	–	–	–	–	–	X	–	X
Polypedilum (*T.*) *scalaenum*	–	–	–	X	–	–	–	–	–	–	–	X
Polypedilum (*T.*) *simulans*	–	–	–	X	–	X	–	–	–	X	–	X
Pseudochironomus sp.	X	–	–	–	–	–	–	–	–	X	–	–
Robackia claviger	–	–	–	X	–	–	–	–	–	–	–	–
Stenochironomus spp.	X	X	X	X	X	X	X	X	X	X	X	X
Stenochironomus (*P.*) *cinctus*	–	–	–	–	–	X	–	X	–	X	–	–
Stenochironomus (*S.*) *hilaris*	–	X	–	X	–	X	–	X	–	–	–	X
Stenochironomus (*S.*) *macateei*	–	X	–	X	–	X	–	X	–	X	–	X
Tribelos spp.	–	–	–	–	–	–	–	–	–	X	–	X
Tribelos fuscicornis	–	X	–	X	–	X	–	X	–	X	–	X
Tribelos jucundum	–	–	–	–	–	X	–	–	–	X	–	X
Xestochironomus sublettei	X	–	–	X	–	–	–	–	–	–	–	X
Zavreliella varipennis	–	–	–	X	–	X	–	–	–	–	–	–
Tribe Tanytarsini	X	X	X	X	X	X	X	X	X	X	X	X
Cladotanytarsus sp. *viridiventris*?	X	X	–	X	–	X	–	X	–	X	–	–
Paratanytarsus sp.	–	–	–	X	–	X	–	X	–	X	–	–
Rheotanytarsus spp.	X	X	–	X	–	X	–	X	–	X	–	X
Rheotanytarsus distinctissimus	X	X	–	X	–	X	–	X	–	X	–	X
Rheotanytarsus cf. *exiguus*	X	X	–	X	–	X	–	X	–	X	–	X
Tanytarsus spp. (unid.)	X	X	–	X	–	X	–	X	–	X	–	X
Tanytarsus (*T.*) spp.	X	X	–	X	–	X	–	X	–	X	–	X
Tanytarsus cf. *curticornis* gr. sp	–	–	–	X	–	X	–	X	–	X	–	X
Tanytarsus sp. 1	–	–	–	–	–	X	–	X	–	–	–	–
Tanytarsus sp. 2	–	X	–	X	–	X	–	X	–	X	–	X
Tanytarsus sp. 3	–	–	–	–	–	X	–	X	–	X	–	X
Tanytarsus sp. 4	–	X	–	–	–	X	–	X	–	X	–	–

TABLE 4-100, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
Family Tabanidae	–	–	–	–	X	–	–	X	–	–	–	–
Chrysops	–	X	–	X	–	X	–	–	–	–	–	X
Tabanus	–	–	–	–	–	X	–	–	–	–	–	X
Family Stratiomyidae	–	–	–	–	X	–	–	–	–	–	–	–
Odontomyia sp.	–	–	–	–	X	X	–	–	–	–	–	–
Family Empididae	X	X	X	X	X	X	X	X	–	X	X	X
Chelifera	–	X	X	–	–	–	–	–	–	–	–	X
Hemerodromia	X	X	X	X	X	X	–	X	–	X	X	X
Hemerodromia cf. *superstitiosa*	X	–	–	–	–	–	–	–	–	–	–	–
Tachyempis	–	X	–	–	–	–	–	–	–	–	–	–
Family Dolichopodidae	X	X	–	X	–	X	–	–	–	–	–	X
Condylostylus cf. *chrysoprasius*	X	–	–	–	–	–	–	–	–	–	–	–
Family Phoridae	–	X	–	–	–	–	–	–	–	–	–	–
Family Syrphidae	–	–	–	–	–	–	–	–	–	–	–	X
Family Sciomyzidae	–	–	X	X	–	X	X	X	–	X	–	X
Sepedon floridensis	X	–	–	–	–	–	–	–	–	–	–	–
Family Sphaeroceridae	–	–	–	–	–	–	–	–	–	–	–	X
Family Ephydridae	X	X	–	X	–	X	–	X	–	X	–	X
Hydrellia	–	X	–	–	–	X	–	–	–	X	–	–
Notiphila (*Dichaeta*) *caudata* gr.	–	–	–	–	–	–	–	–	–	X	–	–
Number of taxa[a]	113	153	68	190	93	167	76	166	79	161	54	176

[a] Higher level categories excluded if lower level taxa present at a station.

Source: Gladden et al. (1988)

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TABLE 4-101

Percent Abundance of Major Taxa Collected on Multiplate Samplers in Steel Creek (January 1986 - December 1987)

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
					1986							
Coelenterata	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turbellaria	<0.1	<0.1	0.6	<0.1	0.1	0.9	1.7	0.5	1.7	0.3	0.2	<0.1
Nematoda	<0.1	0.1	0.2	0.4	0.1	0.5	0.7	0.9	0.3	0.4	0.3	<0.1
Polychaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Oligochaeta	1.4	4.1	6.5	1.2	27.1	5.6	5.0	6.8	3.9	1.4	0.5	0.3
Hirudinea	<0.1	0.0	<0.1	0.1	1.3	0.2	0.3	0.2	0.8	0.1	0.1	0.1
Gastropoda	0.1	0.2	0.8	0.6	14.3	6.8	8.8	3.5	17.6	2.2	0.9	0.1
Pelecypoda	0.0	<0.1	<0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	<0.1	0.0
Hydracarina	<0.1	0.3	1.5	1.7	0.1	0.5	0.2	0.9	0.4	0.5	0.2	0.2
Isopoda	0.0	0.0	<0.1	<0.0	8.8	4.8	2.2	0.5	0.0	<0.1	<0.1	<0.1
Amphipoda	<0.1	<0.1	<0.1	0.1	1.2	13.4	14.4	12.9	2.2	7.1	3.2	0.8
Decapoda	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	<0.1	0.0	0.0
Collembola	<0.1	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	<0.1	0.7	3.5	4.2	0.7	6.1	3.3	12.0	7.4	6.9	7.4	2.7
Odonata	<0.1	0.0	0.0	<0.1	0.8	0.8	1.2	1.5	0.7	0.5	0.2	<0.1
Plecoptera	0.0	<0.1	0.1	0.4	<0.1	0.0	0.0	<0.1	0.0	0.0	0.0	<0.1
Hemiptera	0.0	0.0	0.0	0.0	0.1	<0.1	<0.1	<0.1	0.0	<0.1	0.0	0.0
Coleoptera	<0.1	0.2	0.7	0.2	0.2	0.6	0.1	0.4	0.6	0.9	0.5	0.3
Megaloptera	<0.1	0.1	0.2	0.1	0.0	<0.1	0.0	<0.1	0.0	0.0	0.2	0.2
Trichoptera	13.5	22.1	6.6	16.2	1.2	9.3	2.1	6.5	2.6	2.8	9.4	4.3
Hydropsychidae[a]	(13.4)	(21.2)	(6.0)	(15.7)	(0.5)	(8.2)	(0.3)	(5.4)	(0.3)	(1.8)	(8.0)	(2.6)
Lepidoptera	0.0	<0.1	<0.1	0.0	<0.1	<0.1	0.2	0.2	<0.1	<0.1	0.1	<0.1
Diptera	84.9	72.2	79.2	74.7	44.0	50.2	59.7	53.1	61.8	76.7	76.7	91.2
Simuliidae[b]	(53.2)	(36.0)	(3.9)	(7.3)	(0.4)	(1.1)	(0.3)	(0.9)	(1.8)	(0.6)	(25.7)	(60.8)
Chironomini[b]	(27.1)	(12.5)	(4.5)	(6.9)	(19.6)	(9.7)	(16.0)	(11.3)	(10.2)	(13.3)	(11.6)	(2.9)
Tanytarsini[b]	(0.1)	(11.7)	(37.7)	(33.0)	(8.7)	(26.6)	(29.1)	(25.3)	(34.7)	(49.7)	(15.2)	(17.1)
Orthocladiinae[b]	(3.7)	(9.9)	(28.7)	(23.2)	(10.6)	(14.9)	(9.8)	(8.9)	(6.9)	(9.8)	(23.1)	(8.5)
Tanypodinae[b]	(0.3)	(1.2)	(1.2)	(3.3)	(4.1)	(2.8)	(3.5)	(6.3)	(7.1)	(2.7)	(0.5)	(0.3)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Gladden et al. (1988)

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TABLE 4-101, Contd

Taxon	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
					1987							
Coelenterata	<0.1	<0.1	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Turbellaria	<0.1	0.1	0.1	0.1	3.3	2.0	4.5	1.1	4.0	2.0	0.1	0.5
Nematoda	0.1	0.1	0.4	0.5	1.3	1.3	1.4	0.7	0.3	0.4	0.6	0.2
Polychaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Oligochaeta	4.1	6.8	2.8	1.2	7.6	5.6	18.1	6.5	8.1	6.7	0.6	1.1
Hirudinea	0.1	<0.1	<0.1	<0.1	2.3	0.2	0.6	0.5	0.3	0.1	0.6	0.2
Gastropoda	1.4	0.3	0.7	0.5	14.6	8.2	12.8	12.8	11.2	4.1	0.3	0.7
Pelecypoda	0.0	0.9	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Hydracarina	<0.1	0.6	0.8	2.0	0.2	0.4	1.2	0.7	0.5	0.5	1.1	0.4
Isopoda	0.0	<0.1	<0.1	<0.1	6.0	2.5	4.3	1.2	0.1	0.3	0.1	<0.1
Amphipoda	<0.1	0.0	0.0	<0.1	7.3	12.1	4.1	7.4	1.1	5.6	2.8	2.5
Decapoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
Collembola	0.0	<0.1	0.0	0.0	0.0	0.1	<0.1	0.1	0.0	0.1	0.1	0.0
Ephemeroptera	<0.1	0.6	1.9	5.1	2.8	7.7	2.5	11.1	16.3	8.4	15.3	10.3
Odonata	<0.1	<0.1	0.0	<0.1	1.4	0.7	0.3	0.6	0.6	0.3	0.0	0.0
Plecoptera	0.0	<0.1	0.1	0.3	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.1
Hemiptera	0.0	0.0	0.0	0.0	<0.1	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Coleoptera	<0.1	0.3	0.6	0.2	0.1	0.2	<0.1	0.3	0.4	1.1	0.9	1.2
Megaloptera	0.0	0.2	0.3	0.1	0.0	0.0	0.0	<0.1	0.1	<0.1	<0.1	0.5
Trichoptera	2.3	13.9	3.5	16.5	1.0	1.8	2.1	6.8	1.5	2.3	8.7	11.0
Hydropsychidae[a]	(2.3)	(13.6)	(2.8)	(14.7)	(<0.1)	(0.9)	(0.9)	(5.1)	(<0.1)	(1.0)	(7.7)	(5.5)
Lepidoptera	0.0	0.0	0.0	<0.1	0.1	0.1	<0.1	0.2	<0.1	0.1	<0.1	0.2
Diptera	91.9	76.2	88.9	73.4	51.9	56.9	47.9	49.8	55.5	68.1	68.9	71.1
Simuliidae[b]	(11.5)	(3.0)	(7.0)	(2.6)	(0.2)	(0.2)	(0.2)	(0.1)	(0.0)	(0.1)	(2.8)	(27.7)
Chironomini[b]	(30.0)	(3.0)	(2.8)	(6.5)	(23.5)	(19.0)	(11.6)	(10.5)	(12.0)	(12.9)	(11.8)	(13.9)
Tanytarsini[b]	(36.4)	(56.2)	(39.6)	(40.1)	(11.5)	(19.6)	(24.7)	(21.2)	(27.6)	(44.6)	(22.9)	(14.0)
Orthocladiinae[b]	(11.5)	(10.3)	(33.6)	(20.8)	(10.9)	(12.1)	(7.7)	(12.7)	(5.8)	(5.2)	(29.0)	(11.7)
Tanypodinae[b]	(0.7)	(0.9)	(0.8)	(2.1)	(3.5)	(4.8)	(2.5)	(4.0)	(7.5)	(3.9)	(0.4)	(0.7)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Included in Trichoptera.
[b] Included in Diptera.

Source: Gladden et al. (1988)

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TABLE 4-102

A Comparison of Macroinvertebrate Taxa Richness, Average Number of Taxa Per Sampler, Average Densities, and Average Biomass in Steel Creek (January 1985 - December 1987)

		Taxa Richness					Average Number of Taxa per Sampler			Average Density (no./m^2)			Average Biomass (g AFDW/m^2)		
		Multiplates			Multiplates and Dip Nets										
Location	Station	1985[a]	1986	1987	1986	1987	1985[a]	1986	1987	1985[a]	1986	1987	1985[a]	1986	1987
Corridor	275	b	38	35	41	39	b	8.8	9.0	b	15078.1	8258.5	b	4.634	1.217
	280	63	41	48	47	50	13.0	14.6	15.5	1680.0	6888.8	5853.8	0.197	1.428	1.033
	285	b	49	47	52	57	b	16.0	16.1	b	3400.4	2347.5	b	0.370	0.336
	290	59	54	59	72	67	17.5	15.2	20.2	826.5	3113.6	3635.6	0.552	0.335	0.356
Delta/ Swamp	300	59	55	49	76	68	10.9	12.9	13.8	443.9	1138.7	732.5	0.146	0.184	0.107
	310	58	53	46	58	62	14.1	14.6	15.5	770.6	864.5	770.3	0.379	0.407	0.157
	320	54	54	54	59	71	12.3	15.6	17.4	585.8	1751.4	1548.7	0.644	0.551	0.204
	330	66	54	60	63	72	16.3	15.6	18.5	1497.1	889.7	1202.4	0.314	0.197	0.220
	340	59	50	55	60	70	14.9	16.7	17.5	628.2	1086.7	1032.9	0.220	0.204	0.145
	350	52	51	51	59	67	15.9	16.3	16.0	1444.3	1176.9	880.5	0.252	0.126	0.128
Channel	360	b	36	36	44	48	b	10.6	9.9	b	486.0	414.2	b	0.323	0.103
	370	51	41	52	52	59	14.0	12.9	13.9	712.6	2996.3	995.1	0.175	0.494	0.289

[a] Calculated from Firth et al. (1986), Chimney and Cody (1986), O'Hop et al. (1987), and unpublished SRL data.
[b] Not sampled in 1985.

Source: Gladden et al. (1988)

Conversely, macroinvertebrate densities in the stream corridor were highest just below the dam and declined in a downstream direction (Table 4-102). The high densities below the dam were due primarily to large numbers of filter-feeders that were exploiting the seston inputs from L Lake. Mean annual densities in the corridor ranged from 3114/m^2 (Station 290) to 15,078/m^2 (Station 275) in 1986 and from 2348/m^2 (Station 285) to 8258/m^2 (Station 275) in 1987 (Table 4-102). In contrast, mean macroinvertebrate densities in the stream corridor in 1985 did not exceed 1680 organisms/m^2 at the two stations that were sampled (Table 4-102). Macroinvertebrate biomass (ash-free dry weight) was also highest at Station 275, just below the dam, averaging 4.6 g/m^2 in 1986 and 1.2 g/m^2 in 1987, as compared to 0.3 to 1.4 g/m^2 at the other corridor stations in 1986 and 0.3 to 1.0 g/m^2 in 1987 (Table 4-102). Macroinvertebrate biomass at Station 280 in 1985 was much lower than in subsequent years, while biomass at Station 290 was slightly higher prior to impounding Steel Creek (Table 4-102).

In order to compare the trophic structure of the macroinvertebrate communities at the 13 sampling stations, macroinvertebrates from the multiplate collections were assigned to one of seven functional feeding groups, based on the classification system described by Merritt and Cummins (1984).

In both years, the stream corridor was dominated by collector-filterers which accounted for 48.0% (Station 285, 1986) to 73.8% (Station 280, 1987) of the macroinvertebrates collected (Table 4-103). Collector-filterers are often abundant downstream of impoundments, due to inputs of organic seston (mostly algae) from the reservoirs. Collector-gatherers were consistently the second most abundant functional group at all of the corridor stations (21.0 to 45.8%), followed by predators (0.6 to 6.2%). Together, collector-filterers and collector-gatherers accounted for 90 to >99% of the organisms collected from the corridor stations. Each of the remaining functional groups generally accounted for less than 2% of the organisms collected (Table 4-103). Collector-filterers also generally had the greatest biomass at all of the corridor stations (25.2 to 87.6%), while collector-gatherers (4.0 to 36.8%) or predators (0.1 to 61.4%) were always the second or third most abundant functional group with respect to biomass (Table 4-104). The relatively greater biomass of the predators as compared to their densities is due to the large size of some predators (e.g., megalopterans, stoneflies). Each of the remaining functional groups generally contributed less than 2% of the total biomass at the corridor stations.

4.4.5.2 Steel Creek Delta/Swamp

In the delta/swamp, the total number of macroinvertebrate taxa collected on the multiplate samplers ranged from 50 (Station 340) to 55 (Station 300) in 1986 and from 46 (Station 310) to 60 (Station 330) in 1987 (Table 4-102). Multiplate samples from the delta/swamp were dominated by Chironomidae (primarily Chironomini, 9.7 to 23.5%; Tanytarsini, 8.7 to 49.7%; Orthocladiinae, 5.2 to 14.9%; and Tanypodinae, 2.5 to 7.5%), gastropods (2.3 to 17.6%), and oligochaetes (1.4 to 27.1%; Table 4-101).

TABLE 4-103

Percent Abundance of Macroinvertebrate Functional Feeding Groups on Multiplate Samplers in Steel Creek (January 1985 - December 1987)

Functional Group	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
January-December 1985[a]												
Collector-gatherers	b	37.2	c	57.4	66.6	69.1	59.0	42.3	44.9	40.1	b	66.2
Collector-filterers	-	54.9	-	27.3	4.6	8.8	15.2	50.1	29.1	54.3	-	27.7
Scrapers	-	3.1	-	1.8	7.0	11.7	10.9	1.0	6.6	0.6	-	0.6
Predators	-	3.8	-	11.5	20.5	9.4	13.5	5.3	17.3	3.8	-	4.3
Piercer-herbivores	-	<0.1	-	0.1	0.5	0.3	0.9	0.5	1.6	0.3	-	0.2
Shredders	-	0.6	-	1.2	0.2	0.1	0.1	0.1	0.2	0.1	-	<0.1
Piercer-carnivores	-	0.4	-	0.7	0.6	0.7	0.5	0.7	0.4	0.8	-	1.0
Total	-	100.0	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	-	100.0
January-December 1986[d]												
Collector-gatherers	32.5	26.9	42.9	35.3	68.3	55.5	51.9	53.4	31.2	38.6	46.1	16.3
Collector-filterers	66.8	69.7	48.0	56.2	9.7	31.1	29.7	31.7	36.7	52.2	50.3	82.1
Scrapers	0.1	0.2	0.9	0.6	14.3	6.8	8.9	3.7	17.6	2.2	0.9	0.1
Predators	0.6	2.3	5.0	5.0	7.0	5.3	7.5	9.3	11.9	4.5	1.6	1.1
Piercer-herbivores	<0.1	<0.1	0.1	0.2	0.4	0.7	1.6	0.5	1.8	0.3	<0.1	<0.1
Shredders	<0.1	0.6	1.6	1.0	0.1	0.1	0.2	0.4	0.4	1.6	0.8	0.2
Piercer-carnivores	<0.1	0.3	1.5	1.7	0.2	0.6	0.2	0.9	0.4	0.5	0.2	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
January-December 1987[e]												
Collector-gatherers	45.8	21.0	41.2	32.2	53.1	59.2	50.0	49.3	41.2	35.5	58.0	38.6
Collector-filterers	50.2	73.8	49.6	57.5	11.9	20.9	25.9	26.5	27.7	45.9	34.3	52.0
Scrapers	1.4	0.3	0.8	0.6	14.6	8.2	12.8	12.8	11.2	4.1	0.3	0.8
Predators	2.6	4.1	6.2	4.7	12.9	8.4	9.1	7.1	15.4	8.2	2.8	5.3
Piercer-herbivores	<0.1	<0.1	0.3	0.6	0.5	0.7	0.9	1.4	1.0	0.2	0.0	0.2
Shredders	<0.1	0.2	1.2	2.4	6.8	2.2	0.1	2.0	3.0	5.6	3.6	2.6
Piercer-carnivores	<0.1	0.6	0.8	2.0	0.2	0.4	1.2	0.7	0.5	0.5	1.1	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Calculated from Firth et al. (1986), Chimney and Cody (1986), and SRL unpublished data.
[b] Not sampled in 1985.
[c] Sampled in November and December of 1985 only.
[d] O'Hop and Trapp (1987).
[e] O'Hop et al. (1988)
Source: Gladden et al. (1988)

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TABLE 4-104

Percent Abundance of Macroinvertebrate Functional Group Biomass on Multiplate Samplers in Steel Creek (January 1985 - December 1987)

Functional Group	Station: Corridor 275	280	285	290	Delta/Swamp 300	310	320	330	340	350	Channel 360	370
January-December 1985[a]												
Collector-gatherers	b	18.9	b	10.8	13.3	24.2	4.2	40.9	18.5	46.9	b	42.6
Collector-filterers	-	32.2	-	4.8	0.6	0.5	0.5	42.1	1.3	21.5	-	21.6
Scrapers	-	1.4	-	0.9	10.9	60.6	71.5	1.2	45.3	0.4		0.6
Predators	-	46.3	-	75.7	45.5	14.3	23.6	10.1	11.4	10.7	-	34.7
Piercer-herbivores	-	0.2	-	0.9	3.0	0.1	0.2	0.3	0.2	0.2	-	0.3
Shredders	-	0.9	-	6.9	26.7	0.2	0.1	5.5	23.3	20.3	-	0.3
Total	-	100.0	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	-	100.0
January-December 1986[c]												
Collector-gatherers	12.2	7.2	16.3	17.6	25.2	27.5	17.4	52.5	36.7	62.7	9.3	12.2
Collector-filterers	87.6	87.4	44.1	42.0	2.0	5.9	1.7	17.6	4.4	22.8	16.7	44.9
Scrapers	0.1	0.2	1.6	0.8	50.9	42.2	52.9	3.8	37.9	3.4	0.2	<0.1
Predators	0.1	4.9	31.4	38.6	21.4	23.1	26.7	25.5	19.9	8.5	73.8	42.7
Piercer-herbivores	<0.1	<0.1	5.7	0.3	0.1	0.1	0.2	0.1	0.6	0.1	<0.1	<0.1
Shredders	<0.1	0.1	0.6	0.4	0.3	1.2	0.4	0.3	0.3	1.0	<0.1	0.1
Piercer-carnivores	<0.1	0.1	0.3	0.3	0.1	<0.1	0.7	0.1	0.2	1.4	<0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
January-December 1987[d]												
Collector-gatherers	36.8	4.0	10.7	17.5	30.3	77.1	29.2	44.9	48.2	63.8	68.5	18.2
Collector-filterers	54.4	73.1	25.2	57.6	1.4	2.6	5.2	9.2	3.1	6.5	12.0	19.9
Scrapers	1.0	0.1	1.7	0.5	27.7	8.2	50.3	12.7	28.3	6.6	0.1	0.5
Predators	7.8	22.6	61.4	22.2	38.1	11.4	14.7	10.8	18.3	20.9	18.6	60.5
Piercer-herbivores	<0.1	<0.1	0.1	0.2	0.1	0.2	0.3	0.3	0.5	<0.1	0.0	<0.1
Shredders	<0.1	0.1	0.7	1.6	2.2	0.4	<0.1	22.1	1.3	2.1	0.6	0.6
Piercer-carnivores	<0.1	0.1	0.1	0.4	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Calculated from Firth et al. (1986), Chimney and Cody (1986), and SRL unpublished data.
[b] Not sampled in 1985.
[c] O'Hop and Trapp (1987)
[d] O'Hop et al. (1988)

Source: Gladden et al. (1988)

Other taxa abundant at one or more stations were isopods, amphipods, mayflies (primarily heptageniids), and caddisflies (primarily hydropsychids). Densities of macroinvertebrates collected from multiplate samplers in the delta/swamp ranged from 732/m^2 (Station 300; 1987) to 1751/m^2 (Station 320; 1986; Table 4-102). No consistent trends or patterns were observed in the density data from the delta/swamp, except that densities at Station 320 were consistently higher than the other delta/swamp stations in both years (Table 4-102). In 1986, macroinvertebrate biomass (AFDW) at the delta/swamp stations ranged from 0.13 g/m^2 (Station 350) to 0.55 g/m^2 (Station 320), while in 1987, biomass was lower at four of the six stations, ranging from 0.11 g/m^2 (Station 300) to 0.22 g/m^2 (Station 330; Table 4-102).

The macroinvertebrate community of the delta/swamp was generally dominated by collector-gatherers (41.2 to 68.3%) except at Station 350, which was dominated by collector-filterers in both years (45.9 to 52.2%), and Station 340, which was dominated by collector-filterers at (36.7%) in 1986 (Table 4-103). Collector-filterers were generally the second most abundant functional group in the delta/swamp (9.7 to 52.2%). Together, collector-gatherers and collector-filterers accounted for 65 to 92% of the macroinvertebrates collected from multiplates in the delta/swamp. Scrapers (mostly snails; 2.2 to 17.6%) and predators (4.5 to 15.4%) ranked third and fourth in abundance. In 1987, shredders were fairly abundant at Stations 300 (6.8%), 340 (3.0%), and 350 (5.6%) (Table 4-103). Stations 340 and 350 are closed-canopy sites with abundant litterfall, while Station 300 is at the upper end of the delta and undoubtedly had litter inputs from the corridor that settled out due to the slower water velocity in the delta. The remaining functional groups each accounted for less than 2% of the organisms collected in the delta/swamp (Table 4-103).

Collector-gatherers contributed the greatest biomass at some of the delta/swamp stations (17.4 to 77.1%), while scrapers (3.4 to 52.9%) or predators (8.5 to 38.1%) contributed the greatest biomass at others (Table 4-104). The large size of some scrapers and predators accounted for the large biomass of these groups. Collector-filterer biomass ranged from 1.4 to 22.8% of total biomass. Shredder biomass was uncharacteristically high at Station 330 in 1987 (22.1%) due to the collection of one large crayfish, which greatly increased shredder biomass at this station. In reality, shredder biomass was usually very low at this station as well as at the other delta stations. Biomass of the remaining functional groups each accounted for less than 1% of the total biomass at all delta/swamp stations.

4.4.5.3 Lower Steel Creek Channel

In the lower stream channel (Stations 360 and 370), the total number of taxa collected from the multiplate samplers was generally lower than in the delta, ranging from 36 (Station 360, 1986 and 1987) to 52 (Station 370, 1987; Table 4-102). Taxa richness was higher at the creek mouth station (Station 370) during both years and was probably due to the proximity of this station to the Savannah River, with its diverse macroinvertebrate fauna. The channel stations were dominated by blackflies in 1986 (25.7% at Station 360 and 60.8% at Station 370; Table 4-101). In 1987, the relative

abundance of blackflies decreased at Station 360 (2.8% of organisms collected) but remained the dominant taxon at Station 370 (27.7%). Chironomids (primarily Orthocladiinae, Tanytarsini, and Chironomini), mayflies and caddisflies were also abundant taxa at the stream channel stations (Table 4-101).

Average macroinvertebrate densities in the creek channel were consistently much lower at Station 360 (annual means of 486/m^2 in 1986 and 414/m^2 in 1987) than at Station 370 (annual means of 2996/m^2 in 1986 and 995/m^2 in 1987; Table 4-102). The high density at Station 370 in 1986 was due, in part, to high densities of blackfly larvae (Table 4-101). Macroinvertebrate biomass at the creek channel stations ranged from 0.10 g/m^2 (Station 360, 1987) to 0.49 g/m^2 (Station 370, 1986; Table 4-102).

Collector-filterers were the most abundant functional group at both stream channel stations in 1986 (50.3 to 82.1%) and at Station 370 in 1987 (52.0%) (Table 4-103). Together, collector-filterers and collector-gatherers accounted for 91 to 98% of the organisms collected in the stream channel. Predators were 1.1 to 5.3% of the organisms collected, while shredders accounted for 0.2 to 3.6% (Table 4-103). Each of the remaining functional groups made up less than 2% of the total number of organisms collected from the multiplate samplers. With respect to biomass, predators contributed more biomass than any other functional group at Station 360 in 1986 (73.8%) and at Station 370 in 1987 (60.5%). Collector-filterers contributed the greatest amount at Station 370 in 1986 (44.9%), and collector-gatherers accounted for the largest percentage of biomass at Station 360 in 1987 (68.5%; Table 4-104). Each of the remaining functional groups accounted for less than 1% of the total biomass.

4.4.5.4 Supplemental Sampling Programs

In order to supplement the species list generated from the Hester-Dendy multiplate sampling program, additional macroinvertebrate sampling was conducted. These supplemental sampling programs included the use of dip nets to sample the edge of the stream and the periphery of macrophyte beds, sampling of natural substrates (wood, macrophytes, and sediment); the collection of drift (meroplankton) samples, and the collection of emerging adult insects, using emergence traps. Because many insects (particularly dipterans) can only be identified to species using adult specimens, the emergence collections greatly improved the taxonomic resolution of the macroinvertebrate sampling program.

Macroinvertebrate habitat in the corridor and channel sections of Steel Creek consisted primarily of a shifting sand substrate and numerous woody snags, while in the delta/swamp, sand and organic substrates and extensive beds of macrophytes were the dominant habitat types. These natural substrates (sediment, woody snags, and macrophytes) were sampled in May and September of 1986 and 1987 at three locations in the Steel Creek corridor (Stations 275, 280, and 290), three locations in the delta/swamp (Stations 310, 330, and 350), and in the creek mouth (Station 370) O'Hop et al. (1988).

Most of the macroinvertebrate taxa collected from the natural substrates were also collected by at least one of the other sampling methods. However, the relative abundance of taxa collected from the natural substrates sometimes differed substantially from that of the multiplate samplers. As discussed previously, the multiplates were generally dominated by dipterans (mostly chironomids). In contrast, the sediment cores had higher percentages of nematodes (0 to 77.7%), amphipods (0 to 41.6%), pelecypods (mussels; 0 to 50.0%), and gastropods (0 to 43.1%; Tables 4-105 and 4-106). Percentages of dipterans were usually lower on natural substrates than on the multiplate samplers, although dipterans were still the dominant taxon at Station 275, where they accounted for 100% of the organisms collected from cores in 1986 and 44.6% in 1987 (Tables 4-105 and 4-106). The macrophytes generally had higher percentages of gastropods (1.4 to 53.6%), amphipods (0 to 45.5%), mayflies (0.0 to 29.1%), and caddisflies (2.4 to 18.0%; Tables 4-105 and 4-106) than the multiplates. The snags were dominated by dipterans at most stations (28.6 to 94.1%) but also contained substantial percentages of caddisflies (0 to 57.9%, beetles (Coleoptera; 0 to 45.3%), and mayflies (0 to 9.1%; Tables 4-105 and 4-106). In general, natural substrates in the corridor had higher percentages of dipterans, while the delta stations had higher percentages of amphipods, gastropods, pelecypods, and mayflies (Tables 4-105 and 4-106).

Macroinvertebrate drift samples were dominated by dipterans, which comprised 31.8% (Station 310, 1986) to 86.2% (Station 275, 1987) of the organisms collected (Table 4-107). In the corridor, most of the dipterans were represented by the phantom midge, Chaoborus punctipennis, or the blackfly, Simulium, while in the delta/swamp most of the dipterans were C. punctipennis and Tanytarsini chironomids. C. punctipennis was the most commonly collected taxon in the meroplankton of L Lake (see Section 4.3.5), and the phantom midges collected in Steel Creek undoubtedly originated in L Lake, since this species is primarily found in lakes. Other abundant taxa at the corridor stations included oligochaetes (16.0 to 20.2%), caddisflies (Trichoptera; <0.1 to 6.8%), and snails (Gastropoda; 0.1 to 24.7%). Other abundant taxa in the delta/swamp included oligochaetes (15.6 to 35.6%), water mites (Hydracarina; 2.4 to 10.2%), amphipods (1.5 to 17.1%), and caddisflies (2.7 to 8.4%). In the creek mouth, oligochaetes (7.2 to 12.8%), water mites (5.8 to 8.9%), and caddisflies (5.3 to 7.7%) were commonly collected (Table 4-107).

Drift densities were generally higher in 1987 (2974 to 6422/1000 m^3) than in 1986 (1977 to 4976/1000 m^3; Table 4-108). Drift densities were highly variable among months and stations, and no clear patterns were discerned among stations that could be attributable to seston inputs from L Lake or to reactor operations.

In 1986, emergence rates of adult aquatic insects ranged from 7.3/m^2/day (Station 280) to 111.6/m^2/day (Station 275). Station 275 had a much higher emergence rate than the other stations, due primarily to the emergence of large numbers of the chironomid Glyptotendipes lobiferus, which accounted for 77% of the emerging insects collected at this station. This chironomid was very common in L Lake, and it is likely that many of

TABLE 4-105

Percent Abundance of Major Macroinvertebrate Taxa Collected from Natural Substrates (Snags, Sediments, and Macrophytes) in Steel Creek, May and September 1986

Taxon	Station: Corridor 275	Corridor 280	Corridor 290	Delta/Swamp 310	Delta/Swamp 330	Delta/Swamp 350	Channel 370
				Sediment Cores			
Nematoda	0.0	0.0	0.0	4.5	0.0	11.8	0.0
Oligochaeta	0.0	0.0	14.3	13.6	2.1	2.0	8.7
Hirudinea	0.0	0.0	0.0	0.0	2.1	0.0	0.0
Gastropoda	0.0	0.0	14.3	4.5	18.8	43.1	8.7
Pelecypoda	0.0	50.0	14.3	13.6	4.2	7.8	0.0
Hydracarina	0.0	0.0	0.0	4.5	2.1	2.0	4.3
Isopoda	0.0	0.0	0.0	4.5	6.3	0.0	0.0
Amphipoda	0.0	0.0	14.3	18.2	41.7	13.7	8.7
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Coleoptera	0.0	0.0	0.0	0.0	0.0	3.9	0.0
Trichoptera	0.0	0.0	0.0	0.0	0.0	2.0	4.3
Diptera	100.0	50.0	42.9	36.4	22.9	11.8	65.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				Macrophytes			
Turbellaria	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Nematoda	0.0	0.0	0.2	0.1	<0.1	<0.1	0.1
Oligochaeta	0.0	0.1	0.2	1.8	0.1	0.1	0.0
Hirudinea	<0.1	<0.1	0.3	0.4	0.3	0.2	0.0
Gastropoda	2.2	53.7	4.4	2.7	1.5	2.0	2.0
Pelecypoda	0.0	<0.1	0.2	0.0	0.0	0.0	0.0
Hydracarina	0.0	1.2	4.1	1.3	5.3	2.7	1.9
Amphipoda	0.3	0.4	0.1	35.4	20.8	37.4	11.1
Decapoda	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Ephemeroptera	0.0	<0.1	0.8	4.7	10.3	5.2	8.1
Odonata	0.3	1.9	<0.1	0.7	0.4	9.7	0.3
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Coleoptera	0.2	0.1	0.5	0.5	0.1	0.6	0.4
Megaloptera	0.1	0.0	<0.1	<0.1	0.0	<0.1	0.0
Trichoptera	4.8	2.9	17.9	4.5	3.0	2.4	2.7
Lepidoptera	0.2	0.2	0.3	1.0	1.1	0.7	0.5
Diptera	91.8	39.6	70.9	46.9	57.2	38.5	72.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4-105, Contd

Taxon	Station Corridor 275	280	290	Delta/Swamp 310	330	350	Channel 370
				Snags			
Turbellaria	0.0	0.0	0.0	0.0	0.0	1.4	0.0
Hirudinea	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Gastropoda	0.0	2.4	1.0	1.5	0.4	0.7	0.0
Hydracarina	0.0	0.2	6.0	0.0	0.0	4.4	0.4
Isopoda	0.0	0.0	0.0	8.5	0.0	0.0	0.0
Amphipoda	0.1	0.0	0.0	4.8	3.9	9.7	0.3
Ephemeroptera	0.4	3.2	1.6	3.9	2.3	9.1	1.0
Coleoptera	0.0	2.9	9.9	19.2	15.3	45.3	4.2
Megaloptera	0.0	0.3	0.6	0.0	0.0	0.0	0.0
Trichoptera	48.5	58.0	24.1	0.0	6.5	0.0	2.4
Diptera	50.9	33.0	56.7	62.1	71.5	28.7	91.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Gladden et al. (1988)

TABLE 4-106

Percent Abundance of Major Macroinvertebrate Taxa Collected from Natural Substrates (Snags, Sediments, and Macrophytes) in Steel Creek, May and September 1987

Taxon	Station: Corridor 275	Corridor 280	Corridor 290	Delta/Swamp 310	Delta/Swamp 330	Delta/Swamp 350	Channel 370
Sediment Cores							
Nematoda	0.0	0.0	77.8	19.3	1.9	5.4	5.9
Oligochaeta	46.4	16.7	0.0	5.3	5.7	0.0	14.7
Hirudinea	7.1	0.0	0.0	3.5	0.0	1.8	0.0
Gastropoda	0.0	0.0	0.0	8.8	22.6	39.3	2.9
Pelecypoda	0.0	25.0	11.1	3.5	3.8	17.9	11.8
Hydracarina	0.0	0.0	0.0	5.3	5.7	7.1	0.0
Isopoda	0.0	0.0	0.0	8.8	7.5	0.0	0.0
Amphipoda	0.0	4.2	0.0	7.0	24.5	8.9	8.8
Ephemeroptera	0.0	0.0	0.0	1.8	1.9	1.8	0.0
Odonata	0.0	0.0	0.0	0.0	0.0	1.8	0.0
Coleoptera	0.0	0.0	0.0	3.5	0.0	0.0	0.0
Trichoptera	1.8	4.2	0.0	0.0	1.9	1.8	0.0
Lepidoptera	0.0	0.0	0.0	0.0	0.0	1.8	0.0
Diptera	44.6	50.0	11.1	33.3	24.5	12.5	55.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Macrophytes							
Nematoda	0.0	0.0	1.5	0.0	0.1	0.1	0.0
Oligochaeta	0.6	1.2	2.6	0.0	<0.1	<0.1	0.1
Hirudinea	0.0	0.0	0.9	0.0	<0.1	0.2	0.0
Gastropoda	1.8	10.5	18.9	9.9	5.7	4.1	2.9
Pelecypoda	0.0	0.1	0.9	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.7	3.6	3.6	3.1	6.8	7.9
Isopoda	0.0	0.0	0.0	0.1	0.2	0.0	0.2
Amphipoda	0.0	0.0	0.0	45.6	22.1	7.8	31.2
Decapoda	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Ephemeroptera	0.3	1.5	14.9	9.1	13.3	29.1	17.6
Odonata	0.0	0.0	0.0	0.6	0.4	2.4	1.2
Plecoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Coleoptera	0.0	0.3	1.3	0.1	<0.1	0.3	0.8
Trichoptera	14.4	6.4	6.7	18.0	8.1	11.7	8.3
Lepidoptera	0.0	0.0	0.5	0.7	0.5	0.4	0.4
Diptera	82.9	79.2	48.2	12.3	46.4	37.0	28.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4-106, Contd

Taxon	Station Corridor 275	280	290	Delta/Swamp 310	330	350	Channel 370
				Snags			
Turbellaria	0.0	0.0	1.2	0.0	0.0	0.0	0.0
Nematoda	0.0	0.1	1.3	0.2	0.0	0.0	0.0
Oligochaeta	0.2	0.1	1.2	1.8	0.6	0.2	0.0
Gastropoda	0.1	0.3	5.4	2.5	5.4	8.8	0.0
Pelecypoda	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Hydracarina	0.0	1.0	13.5	4.2	2.0	2.4	1.7
Isopoda	0.0	0.0	0.0	1.0	0.5	0.0	0.0
Amphipoda	0.1	0.1	0.0	1.5	3.2	1.3	2.7
Ephemeroptera	0.0	2.0	2.3	0.4	5.5	7.3	0.7
Odonata	0.0	0.0	0.0	0.0	1.6	1.2	0.0
Coleoptera	0.0	0.8	11.5	0.6	5.7	16.5	5.1
Trichoptera	5.5	9.4	15.4	6.0	26.7	0.2	12.4
Lepidoptera	0.0	0.0	0.0	0.0	0.0	0.5	0.2
Diptera	94.2	86.1	46.9	81.9	48.6	61.6	77.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Gladden et al. (1988)

TABLE 4-107

Percent Abundance of Major Macroinvertebrate Taxa Collected in Drift Samples in Steel Creek (January 1986 - December 1987)

Taxon	Station: Corridor 275	Corridor 280	Corridor 290	Delta/Swamp 310	Delta/Swamp 330	Delta/Swamp 350	Channel 370
				1986			
Coelenterata	0.0	0.1	0.1	0.0	0.0	0.0	<0.1
Turbellaria	0.2	0.6	1.1	2.4	1.0	0.2	1.5
Nematoda	0.1	0.4	0.4	0.3	0.8	0.1	0.1
Oligochaeta	11.8	20.2	15.6	16.0	35.6	21.2	12.8
Hirudinea	0.0	<0.1	0.1	0.2	0.1	0.0	0.8
Gastropoda	0.4	7.0	24.7	3.8	0.8	1.4	1.5
Pelecypoda	0.0	2.8	0.2	0.3	0.1	0.0	0.1
Hydracarina	1.0	1.9	3.3	10.2	8.4	3.6	8.9
Isopoda	0.0	0.0	0.0	2.1	0.2	0.1	0.1
Amphipoda	2.6	0.4	0.2	17.1	4.7	3.9	6.3
Decapoda	0.0	0.0	0.0	0.2	<0.1	<0.1	0.1
Collembola	<0.1	0.5	1.9	0.1	0.2	0.2	3.0
Ephemeroptera	0.6	3.1	2.9	7.2	7.4	3.7	6.8
Odonata	<0.1	0.1	0.3	1.9	1.1	0.5	0.6
Plecoptera	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Hemiptera	0.1	0.4	1.5	0.3	0.2	<0.1	0.2
Coleoptera	0.0	0.1	0.7	0.4	0.2	0.2	0.6
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Trichoptera	0.5	3.2	2.2	5.8	5.2	2.7	5.3
Lepidoptera	0.0	<0.1	0.2	0.1	0.2	0.2	3.3
Diptera	82.7	59.1	44.5	31.8	33.9	62.0	48.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				1987			
Coelenterata	0.5	0.2	0.1	0.0	0.1	0.0	0.0
Turbellaria	<0.1	0.9	1.7	4.4	0.5	0.8	0.6
Nematoda	<0.1	0.4	1.0	5.1	0.2	0.6	0.2
Polychaeta	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
Oligochaeta	12.8	18.8	16.9	27.7	34.2	17.1	7.2
Hirudinea	0.0	<0.1	0.0	0.1	<0.1	0.0	0.1
Gastropoda	0.1	1.1	7.3	1.2	1.7	1.1	1.8
Pelecypoda	0.0	5.8	0.8	<0.1	<0.1	0.0	<0.1
Hydracarina	0.1	0.7	2.4	3.4	2.4	2.8	5.8
Isopoda	0.0	0.0	<0.1	0.2	0.2	<0.1	0.2
Amphipoda	0.0	0.0	0.4	8.9	4.6	1.5	3.0
Decapoda	0.0	0.0	0.0	0.1	<0.1	0.1	0.1
Collembola	<0.1	0.1	0.1	0.2	0.2	0.2	1.0
Ephemeroptera	0.1	0.4	5.0	6.2	15.3	6.0	2.5
Odonata	0.0	0.1	0.2	1.5	0.7	1.9	0.6
Plecoptera	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	<0.1	0.1	0.1	0.1	0.1
Coleoptera	<0.1	0.2	0.4	0.2	0.1	0.1	0.4
Megaloptera	0.0	<0.1	<0.1	0.0	0.0	0.0	<0.1
Trichoptera	<0.1	2.5	6.8	8.4	6.1	5.5	7.7
Lepidoptera	0.0	<0.1	<0.1	0.1	0.2	0.7	2.8
Diptera	86.2	68.6	56.8	32.2	33.4	61.5	65.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Gladden et al. (1988)

TABLE 4-108

Densities (no./1,000 m^3) of Major Macroinvertebrate Taxa Collected in Drift Samples in Steel Creek (January 1986 - December 1987)

Taxon	Station: Corridor 275	Corridor 280	Corridor 290	Delta/Swamp 310	Delta/Swamp 330	Delta/Swamp 350	Channel 370
1986							
Coelenterata	0.0	4.5	4.5	0.0	0.0	0.0	0.4
Turbellaria	3.7	30.3	38.6	112.5	25.8	6.9	41.7
Nematoda	2.0	21.9	13.4	14.7	21.7	3.7	3.1
Oligochaeta	232.5	1,002.8	534.2	759.7	950.1	723.4	345.3
Hirudinea	0.0	0.6	2.1	10.2	2.5	0.0	20.6
Gastropoda	8.5	346.0	846.6	180.4	22.3	47.2	41.1
Pelecypoda	0.0	141.6	6.6	13.7	2.6	0.0	2.5
Hydracarina	19.1	95.8	112.0	485.4	224.9	122.5	239.8
Isopoda	0.0	0.0	0.0	99.5	5.2	1.8	2.2
Amphipoda	51.4	20.2	6.0	811.3	125.7	134.0	170.4
Decapoda	0.0	0.0	0.0	7.7	0.7	1.1	2.3
Collembola	1.0	26.0	65.1	2.5	5.8	5.6	80.7
Ephemeroptera	12.2	153.5	99.1	339.4	197.7	125.9	182.4
Odonata	0.6	6.1	10.8	88.3	28.5	18.6	15.3
Plecoptera	0.0	0.0	3.5	0.0	0.0	0.0	0.0
Hemiptera	1.0	19.8	51.3	14.8	4.1	1.0	4.2
Coleoptera	0.0	5.7	24.5	17.0	4.2	6.2	14.9
Megaloptera	0.0	0.0	0.0	0.0	0.0	2.9	2.0
Trichoptera	9.3	161.4	75.8	272.6	138.8	92.6	141.8
Lepidoptera	0.0	0.8	0.6	4.7	4.9	6.5	87.7
Diptera	1,635.7	2,939.1	1,526.0	1,506.7	903.8	2,118.3	1,297.7
Total	1,976.9	4,976.1	3,426.2	4,741.0	2,669.4	3,417.9	2,696.3
1987							
Coelenterata	25.2	13.3	6.8	0.0	8.2	0.0	0.0
Turbellaria	0.9	48.8	107.3	203.6	31.4	23.7	19.2
Nematoda	0.6	19.5	63.9	235.6	14.1	18.1	4.7
Polychaeta	0.0	0.0	0.9	0.0	0.0	0.0	0.0
Oligochaeta	598.6	1,007.6	1,088.0	1,283.5	2,127.5	515.2	215.6
Hirudinea	0.0	1.6	0.0	2.7	1.6	0.0	2.3
Gastropoda	5.7	61.6	469.2	57.6	104.0	33.9	52.3
Pelecypoda	0.0	312.9	48.8	0.9	1.9	0.0	1.1
Hydracarina	4.5	39.6	152.7	157.5	149.6	83.4	172.2
Isopoda	0.0	0.0	0.9	8.2	10.0	0.8	5.8
Amphipoda	0.0	0.0	25.9	411.4	288.2	44.3	89.5
Decapoda	0.0	0.0	0.0	5.1	0.9	2.6	2.1
Collembola	1.8	7.7	7.0	11.2	12.2	6.6	28.8
Ephemeroptera	4.3	20.1	318.0	289.2	952.0	180.3	75.0
Odonata	0.0	3.7	13.3	70.6	40.9	58.7	19.1
Plecoptera	0.0	0.0	2.4	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	1.7	4.9	3.7	3.1	2.6
Coleoptera	1.6	12.5	28.4	9.5	4.5	3.1	12.9
Megaloptera	0.0	1.1	2.1	0.0	0.0	0.0	0.5
Trichoptera	1.7	134.5	435.8	387.6	380.1	166.2	230.2
Lepidoptera	0.0	1.3	3.0	5.4	12.5	20.8	84.5
Diptera	4,039.9	3,677.8	3,646.2	1,495.0	2,073.3	1,855.8	1,955.9
Total	4,684.7	5,363.4	6,422.3	4,639.6	6,216.8	3,016.7	2,974.3

Source: Gladden et al. (1988)

WB96070

TABLE 4-109

Aquatic Insects with Mean Annual Emergence Rates of at Least 1/m²/day at One or More Stations in Steel Creek (January 1986 - December 1987)

Taxon	Station 1986 Emergence Rates (no./m²/day) 275	280	290	310	330	350	370	1987 Emergence Rates (no./m²/day) 275	280	290	310	330	350	370
Baetis sp.	0.00	0.00	0.14	0.46	0.60	0.26	0.00	0.00	0.00	0.11	1.71	0.71	0.11	0.09
Oxyethira sp.	0.00	0.00	0.11	0.48	0.14	0.20	0.03	0.00	0.03	0.37	9.97	1.85	1.22	0.09
Simulium sp.	14.90	0.89	0.31	0.09	0.09	0.00	1.58	1.42	0.14	0.14	0.00	0.03	0.00	8.24
Ceratopogonidae	0.03	0.03	0.26	0.00	0.06	0.00	0.00	0.47	0.00	0.11	1.57	0.20	0.03	0.15
Ablabesmyia spp.	0.03	0.20	0.46	0.37	0.11	0.34	0.06	0.03	0.11	0.84	12.13	3.87	1.31	0.41
Labrundinia becki	0.03	0.34	3.73	0.48	0.17	0.06	0.21	0.02	0.11	0.44	4.61	1.03	0.51	0.26
Labrundinia pilosella	0.00	0.26	0.26	0.85	0.71	0.34	0.45	0.22	0.14	0.42	66.42	10.65	2.73	0.54
Pentaneura inconspicua	0.37	0.71	0.74	0.60	0.26	0.00	0.92	0.17	0.28	0.69	6.75	0.63	0.06	1.29
Corynoneura sp. 1	0.00	0.03	0.09	0.06	0.06	0.03	0.03	0.45	1.31	0.66	6.38	3.22	0.26	0.14
Cricotopus sp. 1	1.50	0.83	0.37	1.94	2.78	0.68	0.12	0.14	0.09	0.03	1.31	0.17	0.03	0.29
Cricotopus sp. 2	1.45	0.03	0.06	2.16	0.28	0.14	0.12	5.83	0.97	0.90	7.12	2.14	3.87	0.69
Cricotopus vierriensis	1.05	0.09	0.37	0.83	0.83	0.00	0.12	0.23	0.00	0.03	0.03	0.00	0.00	0.00
Nanocladius distinctus	1.40	0.00	0.00	0.06	0.00	0.00	0.00	1.36	1.45	0.03	0.31	0.14	0.20	0.03
Nanocladius minimus	0.00	0.34	0.06	1.14	0.28	0.00	0.12	0.05	0.00	0.12	0.54	0.20	0.00	0.03
Thienemanniella sp.	0.00	0.20	0.14	0.14	0.00	0.03	0.24	5.60	3.78	0.22	3.13	0.43	0.26	0.51
Dicrotendipes modestus	0.00	0.03	0.57	0.68	0.20	0.46	0.18	0.02	0.14	0.31	2.11	0.23	0.88	0.11
Glyptotendipes lobiferus	85.98	0.09	0.03	0.00	0.00	0.06	0.00	2.10	0.06	0.06	0.03	0.03	0.00	0.00
Parachironomus sp. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.31	0.00	0.00	0.00	0.00	0.00
Rheotanytarsus distinctissimus	0.00	0.20	0.23	1.14	0.23	0.00	0.30	0.46	1.77	0.14	11.59	0.43	0.48	0.23
Rheotanytarsus exiguus	0.28	0.40	1.25	0.94	1.25	1.05	2.04	14.27	3.36	0.80	2.62	0.80	0.94	0.28
Tanytarsus spp.	0.00	0.06	0.34	4.10	0.18	0.69	0.12	0.43	0.28	0.96	11.93	3.84	2.08	0.31
Other	4.60	2.62	4.92	10.22	5.55	4.52	6.02	26.54	8.66	8.62	44.72	17.99	17.61	7.37
Total	111.62	7.35	14.44	26.74	13.78	8.89	12.66	59.84	23.99	16.00	194.98	48.59	32.58	21.06

Source: Gladden et al. (1988)

the emerging adults completed their early life stages in the lake. Other common taxa collected during 1986 included the blackfly Simulium and several species of the chironomids, Cricotopus, Nanocladius, and Rheotanytarsus (Table 4-109).

Emergence rates in 1987 (16.0 to 195.0/m^2/day) were higher than in 1986 except at Station 275 (Table 4-109). Station 310 had the highest emergence rate in 1987, due in part to the emergence of large numbers of the chironomid Labrundinia pilosella, but numerous other chironomids, including Ablabesmyia, Rheotanytarsus, and Tanytarsus, were also abundant (Table 4-109). During both years, emergence rates were highest during the summer months, although emerging insects were collected during every month of the year.

4.4.5.5 Impact Evaluation

The data discussed in this section were collected during 1986 and 1987, when L Reactor was operating. Subsequent to the restart of L Reactor, it is anticipated that the macroinvertebrate community of Steel Creek will not differ from that described in this section, since flow and temperature conditions in the stream will be similar to those present in 1986 and 1987.

Steel Creek supports a very diverse macroinvertebrate community, due undoubtedly to the diversity of habitats present in the stream. From all sampling methods combined, 300 macroinvertebrate taxa were collected from the stream during this study. Like most coastal plain streams in the southeast, the macroinvertebrate community of Steel Creek is numerically dominated by chironomids (primarily Chironomini, Tanytarsini, and Orthocladiinae) and to a lesser extent by caddisflies, mayflies, gastropods, amphipods, and oligochaetes.

The macroinvertebrate data indicate that the structure of the macroinvertebrate community of Steel Creek was altered to some extent following the restart of L Reactor. These changes appear to be due to increased discharge and to inputs of organic seston from L Lake and not to any change in the thermal regime of the creek. The macroinvertebrate community of the stream corridor has been altered to the greatest extent, particularly just downstream of L-Lake Dam. These changes include increases in the density and biomass of macroinvertebrates (mostly filter-feeders), decreases in species richness, and shifts in the structure of the community. However, a comparison of the 1986 and 1987 data shows lower densities and biomass in 1987, which may indicate a trend back toward a community similar to that which existed prior to the construction of L Lake.

In summary, Steel Creek supports a diverse and productive macroinvertebrate community. Although some shifts in species composition were observed subsequent to the restart of L Reactor, these changes were largely restricted to the stream corridor and were due primarily to seston inputs from L Lake and to changes in the flow regime of the creek rather than to changes in the thermal regime of Steel Creek.

4.4.6 Fish Communities

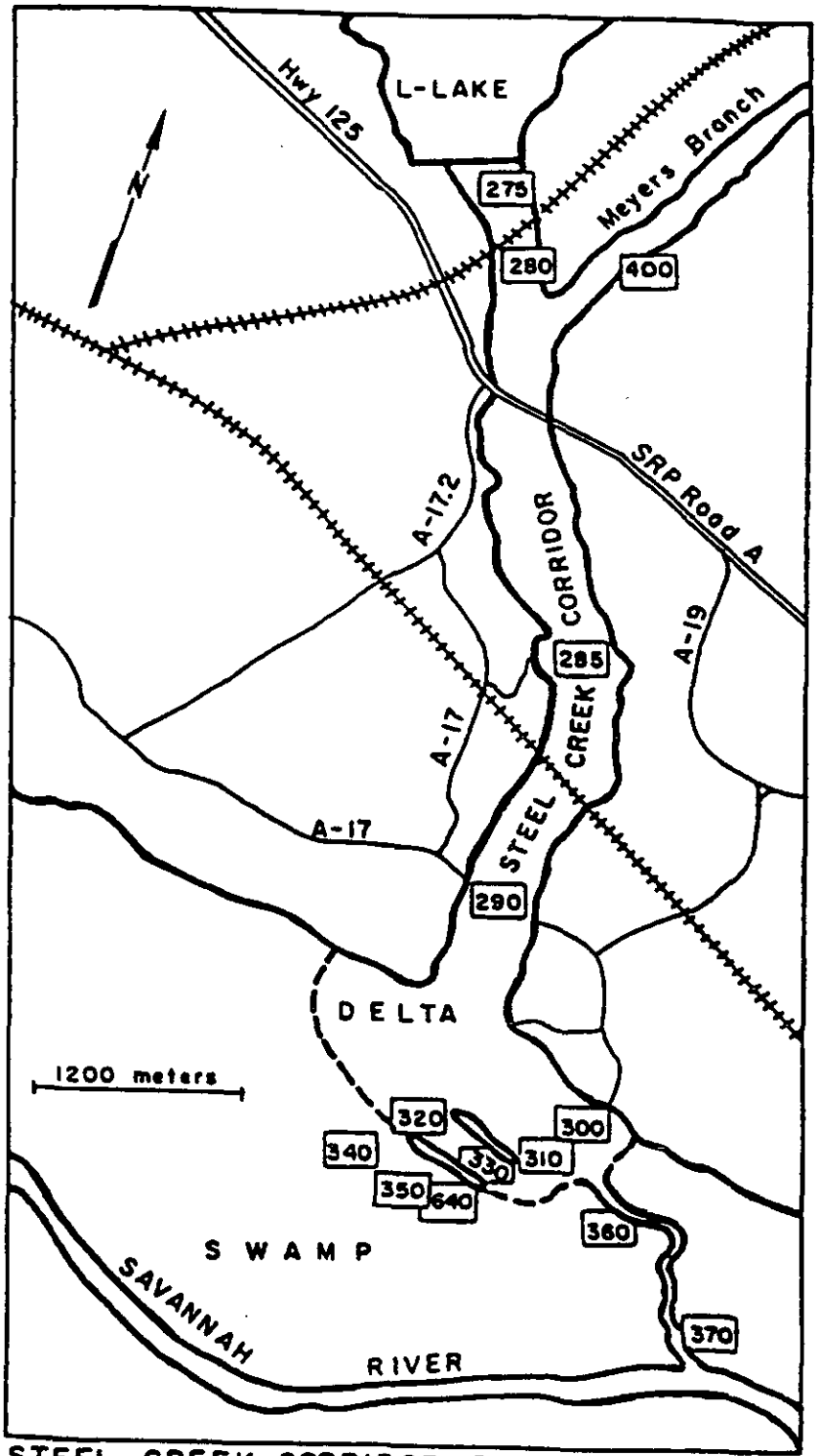
From 1954 to 1968, Steel Creek received high temperature cooling water from L Reactor. This discharge resulted in scouring and erosion in the mid-reaches of the stream and partial elimination of the cypress-tupelo (Taxodium distichium - Nyssa aquatica) canopy vegetation in the lower reaches of the stream (Gladden et al., 1985). When L Reactor was placed on stand-by status in 1968, reactor discharge to the creek ceased for the next 17 years (except for a brief period in the mid-1970s). During this period, ecological succession resulted in the development of a secondary growth of shrubs, bushes, and emergent and submerged macrophytes in areas where the overstory vegetation had previously been eliminated. In preparation for the restart of L Reactor in 1985, L Lake, a 400-ha cooling reservoir, was constructed by damming Steel Creek approximately 12 km from its confluence with the Savannah River. Cooling water from L Reactor now enters at the upper end of L Lake and discharges into Steel Creek through a multiple level outlet near the dam (Figure 4-58).

Paller et al. (1986b) conducted an intensive two-year study of fish community structure at 14 sample stations located throughout Steel Creek (Figure 4-58). Sampling methods for this study included electrofishing, fykenetting, and the use of plankton nets to collect ichthyoplankton. Electrofishing and fykenetting surveys were conducted monthly or quarterly. Ichthyoplankton sampling was conducted weekly during the spawning season (February - July) and monthly during the rest of the year.

The reach of Steel Creek below L Lake can be separated into three basic habitats: the corridor (a stream habitat extending from the L-Lake dam to the delta Stations 275, 280, 285, and 290), the delta/swamp formed where Steel Creek enters the Savannah River floodplain, and the relatively deep channel draining the delta/swamp into the Savannah River (Stations 360 and 370) (Figure 4-58). The delta (Stations 300, 310, 320, and 330) is an open canopy habitat, now dominated by a secondary growth of emergent, submergent, and herbaceous vegetation where thermal effluents previously killed the cypress and tupelo gum overstory. The swamp (Stations 340, 350, and 640) is a relatively unimpacted closed-canopy habitat dominated by a climax forest of cypress and tupelo gum. A sampling station was also located in the mouth of Meyers Branch, a tributary entering the mid-reaches of Steel Creek below L Lake.

Community Structure

Approximately 60 species of fish were collected from Steel Creek during the three year study (Paller et al., 1988b), two of which (American shad and blueback herring) are anadromous fish that temporarily enter the lower reaches of Steel Creek to spawn in the spring. With the exception of the striped mullet and American eel, the remaining species are permanent residents of Steel Creek and contiguous wetlands and watercourses. The dominant taxa in the Steel Creek corridor (Stations 275, 280, 285, and 290) included bluegill, minnows, redbreast sunfish, largemouth bass,



STEEL CREEK CORRIDOR, DELTA AND SWAMP

FIGURE 4-58. Location of Fish Sampling Stations in Steel Creek, January 1986 - December 1988

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TABLE 4-110

Relative Abundance of Adult and Juvenile Fishes at Sample Stations in Steel Creek (January - December 1986)

Taxa	Steel Creek Corridor 275	280	285	290	Meyers Branch 400	Steel Creek Delta/Swamp 300	310	320
Longnose gar	0.1	a		1.5			0.6	0.4
Bowfin	0.1			1.5	0.5	0.1	0.9	3.0
American eel	1.3			4.4	8.0	0.4	1.9	1.2
Blueback herring								
American shad								
Herring/shad								
Gizzard shad								
Redfin pickerel					1.5	0.6	0.6	0.2
Chain pickerel	0.1	0.9		5.8		0.4	0.9	1.6
Minnow[b]	0.4		2.2	39.7	28.1	73.0	28.8	14.3
Golden shiner						1.1	5.3	3.8
Creek chubsucker	0.7	15.8	4.4	2.9	3.5	0.6	2.5	2.8
Lake chubsucker		2.6				0.2		14.5
Northern hog sucker	0.9	3.6	6.7	1.5	2.0			
Spotted sucker		3.6	6.7	5.8		0.4	6.9	3.2
Yellow bullhead	0.2				1.0	0.1	0.3	0.4
Brown bullhead								
Flat bullhead		1.7				0.1	0.9	0.2
Madtom					2.5			0.6
Pirate perch	0.4			1.5	4.5	0.2	4.7	3.8
Mosquitofish						0.7		8.3
Brook silverside						1.7	3.8	2.6
Bluespotted sunfish						0.2	0.3	0.2
Redbreast sunfish	5.7	15.8	6.7	17.6	4.5	1.1	5.0	3.0
Warmouth					0.5		0.6	0.4
Bluegill[c]	78.5	42.1	66.7		24.6	0.4	1.9	2.6
Dollar sunfish	0.1						0.3	
Redear sunfish						0.2	0.6	0.2
Spotted sunfish	0.6	1.7		4.4	7.5		13.8	11.7

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TABLE 4-110, Contd

Taxa	Steel Creek Corridor 275	280	285	290	Meyers Branch 400	Steel Creek Delta/Swamp 300	310	320
Largemouth bass	10.4	11.4	6.7	8.9	1.5	17.9	14.1	18.3
Black crappie	0.1						0.3	
Darter	0.2			1.5	3.0			
Blackbanded darter	0.2	0.9		1.5	2.5		1.6	1.0
Tesselated darter	0.2				3.5	0.1		0.2
Yellow perch					0.5		2.5	
Other (including rare taxa)	0.1			1.5		0.2	0.6	1.2
Total percent	100.3	100.1	100.1	100.0	99.7	99.7	99.7	99.7
No./100 m^d	113.3	7.6	5.0	7.6	33.2	77.6	26.6	13.8

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TABLE 4-110, Contd

Taxa	Steel Creek Delta/Swamp 275	280	285	290	Steel Creek Channel 360	370
Longnose gar	1.6	3.9	1.0	3.8	2.2	0.7
Bowfin	3.8	5.0	3.7	8.2	0.6	2.8
American eel	1.0	2.1	2.1	1.1	3.3	0.4
Blueback herring					0.6	0.4
American shad				0.4	0.6	0.7
Herring/shad						2.1
Gizzard shad		1.0		0.8		1.4
Redfin pickerel					0.6	1.8
Chain pickerel	3.2	3.4	1.7	1.1		3.6
Minnow[b]	30.2	14.5	30.4	13.9	35.0	27.3
Golden shiner	2.0	3.7	9.1			
Creek chubsucker	2.4	2.6	1.3	0.8		0.7
Lake chubsucker	2.0	1.8	1.0	0.8		
Northern hog sucker			0.4		0.6	
Spotted sucker	5.6	15.1	10.5	31.4	4.9	4.6
Yellow bullhead	0.2	0.7	0.4	0.8	1.1	
Brown bullhead	0.2	0.6				0.4
Flat bullhead		0.3		0.8	1.1	0.7
Madtom	0.2		0.7	0.4	0.6	0.4
Pirate perch	0.5	2.3	0.7	0.8		2.4
Mosquitofish	0.6		0.4	0.8	1.1	0.7
Brook silverside	2.2	4.4	3.7	3.0	1.1	7.8
Bluespotted sunfish		0.3				1.8
Redbreast sunfish	1.2	0.6	0.7	1.9	13.6	7.2
Warmouth	0.2					0.4
Bluegill	1.0	0.3			0.6	0.7
Dollar sunfish	0.2					0.4
Redear sunfish	0.3	3.1		1.5	0.6	0.4
Spotted sunfish	13.5	1.6	5.7	8.2	9.3	14.6
Largemouth bass	24.4	21.1	12.2	10.5	14.2	8.5
Black crappie	0.2	0.6				0.7
darter	0.6		0.4			0.7

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TABLE 4-110, Contd

Taxa	Steel Creek Delta/Swamp 330	340	350	640	Steel Creek Channel 360	370
Blackbanded darter	1.9		2.3	1.1	3.3	2.4
Tesselated darter						2.4
Yellow perch	1.1	9.9	10.1	6.7	1.6	0.7
Other (including rare taxa)		1.3	1.7	1.5	3.7	0.4
Total percent	100.3	100.2	100.2	100.3	100.3	100.2
No./100 m[d]	17.7	10.7	8.2	7.4	5.1	7.8

[a] Blank indicates no fish collected.
[b] Primarily various species of Notropis.
[c] Primarily juveniles.
[d] Mean number of fish collected per 100 m electrofishing transect.

Source: Paller et al. (1988b)

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TABLE 4-111

Relative Abundance of Adult and Juvenile Fishes at Sample Stations in Steel Creek (January - December 1987)

Taxa	Steel Creek Corridor 275	280	285	290	Meyers Branch 400	Steel Creek Delta/Swamp 300	310	320
Longnose gar	a	0.1	1.3					0.5
Florida gar							0.2	0.2
Bowfin				1.2		1.9	0.6	0.5
American eel	1.4		2.7	1.2	21.3	0.2	0.2	0.3
American shad								
Gizzard shad			1.3	3.6				
Eastern mudminnow						0.5		
Redfin pickerel						1.4	0.4	0.8
Chain pickerel	0.1		2.7			2.3	1.2	0.7
Minnow[b]	1.9	63.2	13.6	19.2	12.1	39.5	38.5	65.8
Golden shiner	0.2	1.7		3.6		7.0	12.7	3.7
Chubsucker	0.1					0.2	0.6	0.1
Creek cubsucker	0.6	1.5	5.4		4.6	2.1	2.0	1.9
Lake chubsucker						2.5	1.2	3.3
Northern hog sucker	0.2	0.1	7.5		0.9			
Spotted sucker	0.2		8.2	9.7		0.7	4.2	2.9
Bullhead catfishes		0.3						
Snail bullhead								0.1
Yellow bullhead		0.8			6.5	1.2	1.0	0.2
Brown bullhead						0.5	0.2	0.1
Flat bullhead		3.0	1.3		4.6		0.2	
Channel catfish								
Madtom					0.9			
Tadpole madtom								
Speckled madtom	0.1							
Swampfish						0.5		
Pirate perch					4.6	6.5	2.8	1.7
Mosquitofish						10.5	3.0	1.8
Brook silverside		0.1				2.3	0.8	0.7
Mud sunfish								
Pygmy sunfish						0.5		0.2

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TABLE 4-111, Contd

Taxa	Steel Creek Corridor 275	280	285	290	Meyers Branch 400	Steel Creek Delta/Swamp 300	310	320
Everglades pygmy sunfish						0.2		
Banded pygmy sunfish						0.2		
Bluespotted sunfish						0.9	0.2	
Unid. sunfish							1.2	0.2
Hybrid sunfish		0.1						
Redbreast sunfish	2.7	5.8	19.0	10.8	12.1	3.7	0.6	0.8
Warmouth						0.7	0.4	
Bluegill	90.7	19.4	16.3	19.2	21.3	10.2	7.7	3.3
Dollar sunfish					0.9			
Redear sunfish							0.2	0.2
Spotted sunfish		0.3	2.7		7.4	0.9	9.3	3.5
Largemouth bass	1.8	1.1	10.2	20.5		2.8	8.9	5.9
Black crappie							0.4	0.2
Tesselated darter					0.9			
Yellow perch	0.1	0.1			0.9		0.8	
Blackbanded darter	0.1	2.4	7.5	9.7	0.9		0.4	0.3
Darter				1.2				0.4
Striped mullet							0.2	
Unknown								
Total	100.2	100.0	99.7	99.9	99.9	99.9	100.1	100.3
No./100 m^c	104.3	62.0	6.7	6.9	18.0	31.9	42.0	28.8

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TABLE 4-111, Contd

Taxa	Steel Creek Delta/Swamp 330	340	350	Steel Creek Channel 360	370
Longnose gar		6.4		1.1	
Florida gar					0.3
Bowfin	3.1	2.6	2.6	0.4	0.8
American eel	0.3	0.5	1.3	1.1	0.6
American shad				9.7	1.1
Gizzard shad		2.1			0.3
Eastern mudminnow					0.3
redfin pickerel	0.3		0.7	0.4	
Chain pickerel	2.0	0.9	4.3		1.1
Minnow[b]	47.5	28.5	37.1	38.8	56.0
Golden shiner	5.5	3.8	4.3		
Chubsucker			0.4	0.4	
Creek chubsucker	1.8	3.4	2.0		
Lake chubsucker	2.0	1.2	2.3		
Northern hog sucker					0.3
Spotted sucker	5.1	13.2	5.3	5.5	4.3
Bullhead catfishes	0.2	0.5	0.4	0.4	
Snail bullhead					
Yellow bullhead	0.8	1.7	0.4		
Brown bullhead					
Flat bullhead				0.8	
Channel catfish				0.4	0.6
Madtom					
Tadpole madtom		0.5			
Speckled madtom				0.4	
Swampfish			1.0		
Pirate perch	0.9	0.5	2.3	0.4	0.8
Mosquitofish	2.3	0.9	3.7	0.8	
Brook silverside	0.8	2.9	5.1		7.4
Pygmy sunfish				0.4	
Everglades pygmy sunfish					

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TABLE 4-111, Contd

Taxa	Steel Creek Delta/Swamp 330	340	350	Steel Creek Channel 360	370
Banded pygmy sunfish					
Bluespotted sunfish					0.3
Unid. sunfish	0.3	0.5	0.4		
Hybrid sunfish					
Redbreast sunfish	0.4		0.4	7.5	3.7
Warmouth	0.2				
Bluegill	2.7	0.9	1.3	11.0	8.0
Dollar sunfish					
Redear sunfish	0.3			0.4	
Spotted sunfish	8.6	2.6	6.7	4.4	4.5
Largemouth bass	11.5	19.1	9.7	11.0	4.8
Black crappie	0.3				
Tesselated darter					0.3
Yellow perch	0.9	6.7	6.4	1.6	0.6
Blackbanded darter	2.1	0.9	2.0	2.4	1.7
Darter					
Striped mullet6				0.8	1.4
Unknown					0.3
Total Percent	99.9	100.3	100.1	100.1	99.8
No./100 m[c]	18.3	6.5	8.3	7.1	9.7

[a] Blank indicates no fish collected.
[b] Primarily various species of Notropis.
[c] Mean number of fish collected per 100 m electrofishing transect.

Source: Paller et al (1988b)

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black banded darter, creek chubsucker, spotted sucker, and northern hog-sucker (Tables 4-110 and 4-111). The dominant species in the Steel Creek swamp (Stations 300, 310, 320, 330, and 340) included minnows, spotted sunfish, largemouth bass, spotted sucker, and golden shiner; and the dominant taxa in the lower channel (Stations 360 and 370) include minnows, redbreast sunfish, spotted sunfish, and largemouth bass. Dominant taxa in Meyers Branch included minnows, bluegill, American eel, redbreast sunfish, and spotted sunfish.

The fish assemblages in Steel Creek exhibit variations in composition associated with current velocity, water depth, canopy cover, proximity to the Savannah River, and proximity to L Lake. To provide a descriptive summary of differences in fish assemblage structure among sample stations in Steel Creek, Paller et al. (1988b) used principal component analysis to ordinate the annual mean electrofishing catch per unit effort (CPUE) data. Analysis of the 1986 data indicated that Station 275 (located in the Steel Creek corridor just below the L-Lake dam) was distinctly different from the other sample stations, mainly because of high bluegill catches. Two other corridor sample stations (280 and 285) and the sample station in Meyers Branch (Station 400) yielded relatively high catches of bluegill and redbreast sunfish, and low catches of shiners causing them to separate from the sample stations in the delta/swamp. Open canopy delta stations (Stations 300, 310, 320, and 330) separated from each other because of differences in shiner and largemouth bass catch rates. There was also a general tendency for the open canopy stations to separate from the closed canopy swamp stations (Stations 340 and 350), because of higher catches of shiners and largemouth bass in the former. Station 300, which was located in an exceptionally shallow, with large amounts of submerged and emergent vegetation area at the northeastern edge of the delta, produced the highest average shiner and largemouth bass catches, although all of the largemouth bass were small juveniles. The results of the principal component analysis also indicated that the structure of the adult/juvenile fish assemblage in the lower channel (Stations 360 and 370) was fairly similar to that in the closed canopy swamp.

The relationship among sample stations during 1987 was generally similar to that during 1986 (Figure 4-59). Station 275 separated from the other stations along principal component 1, primarily due to high catches of bluegill. As in 1986, there was some separation among open canopy, closed canopy, and channel stations, with the open canopy stations characterized by higher catches of shiners and golden shiners.

Like the adult and juvenile fish assemblages, the ichthyoplankton assemblages in Steel Creek exhibited prominent differences among sample stations (Tables 4-112 and 4-113). During 1986 and 1987, the ichthyoplankton collections from the Steel Creek corridor were dominated by Lepomis spp., darter, and minnow larvae. Most of the Lepomis spp. larvae were probably bluegill originating in L Lake and transported into Steel Creek via L-Lake discharge. In 1988 this pattern changed, with shad larvae becoming numerically dominant and bluegill larvae decreasing in relative abundance. These changes paralleled changes in ichthyoplankton composition in L Lake (Section 4.3.6). The ichthyoplankton assemblage in

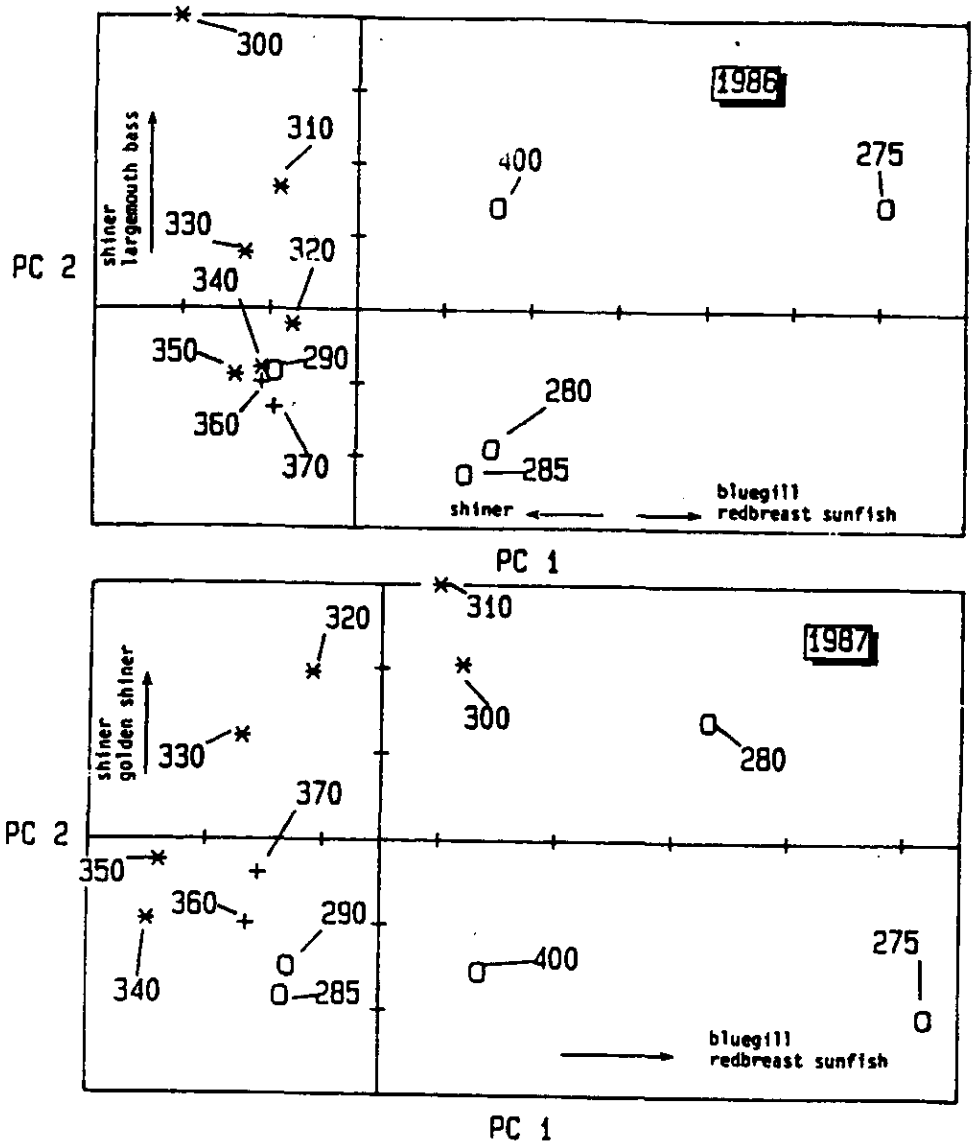

FIGURE 4-59. **Principal Component Analysis of Mean Yearly Electrofishing Catch per Unit Effort (CPUE; no. fish/100 m) at Stations in Steel Creek, January 1986 - December 1987.** Taxa primarily responsible for separation along each axis are indicated with arrows showing direction of increasing abundance. (* = delta/swamp, + = channel, and O = corridor) (source: Paller et al. (1988b)

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TABLE 4-112

Relative Abundance of Ichthyoplankton at Sample Stations at Steel Creek (February - July 1986)

Taxa	Steel Creek Corridor				Steel Creek Delta/Swamp			
	275	280	285	290	300	310	320	330
Unid. herring/shad								
Blueback herring					1.3	14.0		10.5
American shad								
Pickerel				1.6	2.0	0.6		1.6
Other minnow	2.5	7.5	22.7	22.3	4.0	3.7	15.4	1.6
Ironcolor shiner			2.2	1.6	7.8	8.3	1.0	14.2
Chubsucker			2.2	6.9	3.9	1.0		1.3
Spotted sucker			2.2					
Redhorse					1.1			
Pirate perch								
Mosquitofish	2.0	2.5	1.3		2.2	0.6		
Brook silverside		2.8			0.3	2.4		15.4
Pygmy sunfish				2.7	13.8	28.2	11.4	5.3
Bluespotted sunfish		1.9	2.2	25.0	56.6	18.9	41.5	24.8
Sunfish (*Lepomis* spp.)	95.3	76.2	57.3	20.2	3.6	4.4	23.4	20.9
Redbreast sunfish								
Warmouth								
Spotted sunfish								
Largemouth bass				2.1				
Darter (*Etheostoma* spp.)			5.3	10.1	0.7	15.7	5.5	2.1
Unknown	0.2	9.1	4.7	7.4	2.6	2.1	1.7	2.1
Total percent	100.0	100.0	100.1	99.9	99.9	99.9	99.9	99.8
No./100 m^{3a}	81.0	36.1	15.0	18.8	148.7	67.7	40.2	19.1

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TABLE 4-112, Contd

Taxa	Steel Creek Corridor 340	Steel Creek Corridor 350	Steel Creek Corridor 640	Steel Creek Channel 360	Steel Creek Channel 370	Meyers Branch 400
Unid. herring/shad				0.4	1.4	
Blueback herring		2.2	7.9	73.0	50.3	
American shad				2.0	8.2	
Pickerel						
Ironcolor shiner	1.6	12.8	4.3	2.9	5.2	
Other minnow	5.2	6.7	1.4	0.1	2.2	46.9
Chubsucker				0.8	0.6	
Spotted sucker					0.3	
Redhorse					0.5	
Pirate perch					0.3	
Mosquitofish		3.9				
Brook silverside	18.6	14.0	19.3	2.5	1.6	
Pygmy sunfish	8.5	1.7		1.2	1.3	
Bluespotted sunfish	2.3	20.1	17.1	6.3	5.3	
Sunfish (*Lepomis* spp.)	53.1	30.2	31.4	3.7	9.6	1.8
Redbreast sunfish						
Warmouth						
Spotted sunfish						
Largemouth bass				0.4		
Darter (*Etheostoma* spp.)	10.7	4.5	7.9	3.1	8.5	48.1
Unknown		3.9	10.7	3.5	4.7	3.2
Total percent	100.0	100.0	100.0	99.9	100.0	100.0
No./100 m^3[a]	30.7	17.9	14.0	113.8	63.8	12.9

[a] Mean density (no./100 m^3) at each sample station.

Source: Paller et al. (1988b)

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TABLE 4-113

Relative Abundance of Ichthyoplankton at Sample Stations at Steel Creek (February - July 1987)

	Steel Creek Corridor				Steel Creek Delta/Swamp							Lower Channel		Meyers Branch
Taxa	275	280	285	290	300	310	320	330	340	350	640	360	370	400
Longnose gar						0.6								
Unid. herring/shad													1.9	
Blueback herring					0.7						1.7	62.3	41.8	
American shad												1.4	13.5	
Shad (*Dorosoma* spp.)	3.6												1.1	
Pickerel						0.8								
Ironcolor shiner			1.8	11.2	1.0	2.1		13.9		4.8	5.6	5.0	9.1	
Other minnow	0.6	2.1	1.3		14.5	9.6		3.0		3.2	1.7	1.3	4.2	42.4
Chubsucker			4.4	16.3	34.2	53.3	9.8	5.0	25.3		1.3	2.5	1.3	6.6
Spotted sucker												0.3		3.3
Pirate perch					0.8	0.6								
Brook silverside				3.6		0.6		16.5			1.33	3.0	0.8	
Pygmy sunfish					13.9	2.3		3.0	10.8	11.1	7.2	2.8	5.7	
Bluespotted sunfish				3.1	25.6	8.6	12.8	19.9	18.4	11.9	2.8	6.3	5.9	
Sunfish (*Lepomis* spp.)	79.7	33.3		4.6						4.0		0.3	1.1	
Redbreast sunfish		3.5												
Warmouth			1.8	3.6						25.8	6.5	0.3	0.4	
Spotted sunfish			1.8				6.1							
Other sunfishes	1.1	2.1		2.0	4.0	2.6	2.4	7.0		1.3	1.3			
Crappie	12.0	4.3			0.3									
Darter (*Etheostoma* spp.)		3.5	8.0	7.1	0.5	4.9	12.2	4.5	38.6	22.2	28.6	11.3	8.6	14.6
Blackside darter		16.3	58.7	17.9	0.7		4.9				2.5	0.3	1.1	28.5
Unknown	3.1	34.8	22.[illegible]	30.6	3.9	13.9	51.8	33.8		19.0	39.5	1.6	3.4	4.6
Total percent	100.1	99.9	100.0	100.0	100.1	99.9	100.0	100.0	100.1	100.0	100.0	100.0	99.9	100.0
No./100 m^3 [a]	35.9	14.1	22.5	19.6	137.6	65.3	16.4	20.1	15.8	12.6	23.1	63.6	47.4	14.4

[a] Mean density (no./100 m^3) at each sample station.

Source: Paller et al. (1988b)

the Steel Creek open-canopy delta during 1986 and 1987 was dominated by varying combinations of bluespotted sunfish, pygmy sunfish, chubsucker, and darter larvae. Lepomis spp. and brook silverside larvae were also relatively abundant at some sample stations. The assemblage in the closed-canopy swamp was fairly similar to that in the open-canopy delta except for the absence or scarcity of pygmy sunfish and bluespotted sunfish larvae. The ichthyoplankton assemblage in the lower creek channel was dominated by blueback herring. American shad were also relatively abundant in the mouth of Steel Creek (Station 370). Both species are anadromous. Other relatively abundant larvae in the lower channel were darters, ironcolor shiner, and various types of sunfish. Some of these may have been transported into the lower channel from the swamp, rather than being spawned in the channel itself.

The results of the preceding analyses indicate that the corridor supports a fauna that differs substantially from that in the lower reaches of Steel Creek. The relatively high current velocities and well defined channels in the corridor favor lotic species such as the redbreast sunfish and blackbanded darter and preclude the establishment of species (such as pygmy sunfish) that prefer the slow-flowing water and heavy aquatic vegetation found further downstream (Table 4-114). Fish assemblage structure in the corridor is also influenced by L Lake. The bluegill found at Station 275 and the other corridor sample stations apparently entered Steel Creek in discharge water from L Lake, where juvenile bluegill were extremely abundant during the first two years after impoundment (Paller et al., 1988a).

The passage of Steel Creek from the corridor into the relatively flat Savannah River floodplain results in a reduction in current velocity and a broadening and braiding of the creek channel to form the Steel Creek delta/swamp. The delta/swamp supports a more diverse fish assemblage than the corridor, with greater representation by taxa such as spotted sunfish, bluespotted sunfish, swampfish, topminnows, and banded pygmy sunfishes, that are characteristic of swamps and slowly flowing waters (Table 4-114). The fish assemblage in the Steel Creek delta/swamp exhibited structural changes depending on depth and canopy (i.e., cypress-tupelo overstory) cover. These two factors influence the type and extent of submerged and emergent macrophyte growth, which is an important determinant of fish community structure (Shireman et al., 1983). Shallow, heavily vegetated areas in the open-canopy delta (exemplified by Station 300) were dominated by small fish as indicated by a preponderance of shiners in the electrofishing collections (Figure 4-59, Tables 4-110 and 4-111) and pygmy sunfish in the ichthyoplankton collections from this area (Tables 4-112 and 4-113). Dense macrophyte growth typically supports large numbers of small fishes, probably because predators find it difficult to forage in such areas (Shireman et al., 1983). While also supporting shiners, the deeper channels within the open canopy delta (Stations 320 and 330) supported more large fish such as spotted sunfish, largemouth bass, and chubsuckers. All are sometimes associated with heavy macrophyte growth (Trautman, 1981; Hardy, 1978; Pfleiger, 1975), but may require somewhat deeper and more open water than is found in the shallow, heavily overgrown areas in the open-canopy delta. Differences

TABLE 4-114

Occurrence of Fishes in Three Habitats Within Steel Creek (corridor, delta/swamp, and channel) and Meyers Branch During 1986 and 1987

	Steel Creek			
	Corridor	Delta/Swamp	Channel	Meyers Branch
Bowfin	x	x	x	x
Longnose gar	x	x	x	
Florida gar	x	x	x	
American eel	x	x	x	x
Blueback herring			x	
American shad		x	x	
Gizzard shad	x	x	x	
Eastern mudminnow	x	x		
Redfin pickerel	x	x	x	x
Chain pickerel	x	x	x	
Bluehead chub	x			x
Golden shiner	x	x	x	
Ironcolor shiner		x	x	
Dusky shiner	x	x	x	x
Pugnose shiner		x	x	
Spottail shiner	x		x	
Yellowfin shiner	x	x	x	x
Taillight shiner		x		
Whitefin shiner			x	
Coastal shiner	x	x	x	x
Creek chubsucker	x	x	x	x
Lake chubsucker	x	x		
Northern hog sucker	x	x	x	x
Spotted sucker	x	x	x	
Snail bullhead		x	x	
White catfish		x	x	
Yellow bullhead	x	x	x	x
Brown bullhead	x	x	x	
Flat bullhead	x	x	x	x
Channel catfish		x	x	
Tadpole madtom		x		x
Margined madtom		x		
Speckled madtom	x		x	x
Swampfish		x		
Pirate perch	x	x	x	x
Atlantic needlefish			x	
Golden topminnow		x		
Lined topminnow		x	x	

TABLE 4-114, Contd

	Steel Creek Corridor	Steel Creek Delta/Swamp	Steel Creek Channel	Meyers Branch
Mosquitofish		x	x	
Brook silverside		x	x	
Striped bass			x	
Mud sunfish			x	
Flier	x			
Everglades pygmy sunfish		x		
Banded pygmy sunfish		x		x
Bluespotted sunfish		x	x	x
Redbreast sunfish	x	x	x	x
Green sunfish			x	
Warmouth	x	x	x	x
Bluegill	x	x	x	x
Dollar sunfish	x	x	x	x
Redear sunfish		x	x	
Spotted sunfish	x	x	x	x
Largemouth bass	x	x	x	x
Black crappie	x	x	x	
Savannah darter				x
Swamp darter		x		
Christmas darter				x
Tessellated darter	x	x	x	x
Sawcheek darter		x		
Yellow perch	x	x	x	x
Blackbanded darter	x	x	x	x
Striped mullet		x	x	
Total	35	52	47	27

Source: Paller et al. (1988b)

between the fish assemblages in the open canopy delta (Stations 300, 320, and 330) and the less heavily vegetated closed canopy swamp (Stations 340 and 350) consisted primarily of greater abundances of shiners and spotted sunfish in the former habitat (Tables 4-110 and 4-111).

The braided channels that drain the delta/swamp coalesce to form a single large, well-defined channel that continues to the Savannah River. The channel is a lotic environment characterized by moderate current velocities, a scoured bottom generally lacking macrophyte growth, and occasional log and brush snags (Firth et al., 1988). The channel is used as a spawning area by anadromous fishes as indicated by the collection of American shad and blueback herring ichthyoplankton and adult American shad during the spring and early summer months (Tables 4-112 and 4-113). Relatively large numbers of adult channel catfish and, to a lesser extent, white catfish (both prominent Savannah River species have also been collected from the channel with fyke nets, indicating that this habitat is heavily used by these riverine species (Table 4-115). The proximity of the channel to the Savannah River, with its diverse fish community, has influenced the fish assemblage in this habitat and contributed to its species richness (Table 4-114).

Effects of Impoundment on the Steel Creek Corridor

Impoundments can influence the biota of downstream waters by releasing lentic fauna into tailwater areas and by altering water temperature, water quality, and flow regime (Ward and Stanford, 1979; Walburg et al., 1971). Paller et al. (1988b) investigated the effects of L Lake and the L-Reactor restart on the Steel Creek corridor fish community by comparing pre-impoundment and post-impoundment data. L-Lake discharge now constitutes most of the flow through the Steel Creek corridor and largely determines water quality and the flow regime in this habitat. The large increase in flow (due to the added discharge of L-Reactor cooling water) has caused an increase in current velocity and increased erosion of the creek bed and adjoining floodplain (Firth et al., 1988). Comparisons between the species present just after these changes began and those present at the end of 1987 suggested the loss of several taxa (eastern mudminnow, mud sunfish, banded pygmy sunfish, and Christmas darter) that are characteristic of small streams and slow flowing waters (Pfleiger, 1975; Trautman, 1981) (Table 4-116).

Superimposed on fish assemblage changes resulting from habitat alterations in the corridor, are those resulting from the release of juvenile bluegill from L Lake into Steel Creek. The escapement of fish (often young-of-the-year) from reservoirs, possibly resulting from passive entrainment in discharge currents, has also been documented in other systems (Walburg et al., 1971). The impacts of fish escapement from L Lake were greatest just below the dam (Station 275) (Figure 4-59; Tables 4-110 and 4-111). Bluegill have not been highly abundant in the delta/swamp, although their numbers have increased during 1987, reflecting downstream dispersal from the corridor.

TABLE 4-115

Mean Fykenetting Catch per Unit of Effort (CPUE; no./net/day [standard deviation]) and Relative Abundance (% composition) at Sampling Stations in Steel Creek.

Taxon	Station 290						Station 370					
	1986			1987			1986			1987		
	CPUE		%	CPUE		%	CPUE		%	CPUE		%
Longnose gar	0.19	(0.81)[a]	15.33	0.32	(1.19)	28.46	0.38	(1.02)	32.29	0.43	(1.11)	35.71
Florida gar	0.08	(0.27)	6.64	0.06	(0.23)	5.38	0.02	(0.09)	1.46	0.05	(0.15)	4.29
Bowfin	0.04	(0.15)	3.20	0.02	(0.09)	1.54	0.07	(0.20)	6.31	0.07	(0.46)	5.71
American eel	0.01	(0.04)	0.46	0.02	(0.13)	1.54	0.01	(0.07)	0.73	0.01	(0.07)	0.71
Alosa spp.	–		–	–		–	0.02	(0.12)	1.94	–		–
Blueback herring	–		–	–		–	0.02	(0.12)	1.94	–		–
American shad	–		–	–		–	0.07	(0.24)	6.06	0.30	(0.96)	25.00
Gizzard shad	0.01	(0.04)	0.46	0.01	(0.07)	0.77	–		–	0.08	(0.28)	6.43
Redfin pickerel	0.01	(0.04)	0.46	0.01	(0.07)	0.77	–		–	–		–
Chain pickerel	0.01	(0.04)	0.46	–		–	–		–	–		–
Bluehead chub	0.01	(0.04)	0.46	–		–	–		–	–		–
Golden shiner	0.08	(0.23)	6.41	0.03	(0.11)	2.31	0.01	(0.07)	0.73	–		–
Chubsucker	0.04	(0.19)	3.19	–		–	0.01	(0.07)	0.97	–		–
Creek chubsucker	0.13	(0.31)	10.53	0.16	(0.57)	13.85	–		–	–		–
Lake chubsucker	0.04	(0.23)	3.43	0.02	(0.09)	1.54	–		–	–		–
Northern hogsucker	–		–	0.01	(0.07)	0.77	–		–	–		–
Spotted sucker	0.01	(0.07)	0.69	–		–	0.02	(0.09)	1.46	0.02	(0.09)	1.43
Unidentified catfish & bullheads	0.01	(0.04)	0.46	–		–	–		–	–		–
Snail bullhead	–		–	–		–	0.01	(0.07)	0.73	–		–
White catfish	–		–	–		–	0.09	(0.42)	7.53	0.02	(0.09)	1.43
Yellow bullhead	0.03	(0.13)	2.29	0.01	(0.07)	0.77	0.01	(0.08)	1.21	–		–
Brown bullhead	0.01	(0.04)	0.46	–		–	0.01	(0.04)	0.49	–		–
Flat bullhead	0.05	(0.18)	4.12	0.04	(0.22)	3.85	0.05	(0.15)	4.13	0.03	(0.15)	2.14
Channel catfish	–		–	–		–	0.28	(0.97)	23.30	0.11	(0.30)	9.29
Striped bass	–		–	–		–	–		–	0.01	(0.07)	0.71
Sunfishes	–		–	0.02	(0.09)	1.54	0.01	(0.04)	0.48	–		–

Source: Paller et al. (1988b)

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TABLE 4-115, Contd

Taxon	Station 290 1986 CPUE		%	Station 290 1987 CPUE		%	Station 370 1986 CPUE		%	Station 370 1987 CPUE		%
Flier	0.05	(0.24)	4.35	0.01	(0.07)	0.77	–		–	–		–
Redbreast sunfish	0.06	(0.21)	5.04	0.03	(0.16)	3.08	0.04	(0.16)	3.40	0.04	(0.17)	3.57
Warmouth	0.15	(0.34)	12.13	0.02	(0.09)	1.54	–		–	–		–
Bluegill	0.01	(0.06)	0.91	0.30	(0.68)	26.92	0.01	(0.07)	0.73	–		–
Redear sunfish	0.01	(0.04)	0.46	–		–	0.01	(0.08)	1.21	0.02	(0.13)	1.43
Spotted sunfish	0.18	(0.43)	14.42	0.04	(0.14)	3.85	0.01	(0.07)	0.73	–		–
Largemouth bass	0.01	(0.07)	0.69	0.01	(0.07)	0.77	–		–	–		–
Black crappie	0.03	(0.10)	2.06	–		–	0.03	(0.12)	2.18	0.02	(0.09)	1.43
Unknown	0.01	(0.06)	0.91	–		–	–			0.01	(0.07)	0.71
Total[b,c]	1.27		100.02	1.14		100.02	1.19		100.01	1.22		99.99

[a] Numbers in parentheses are standard deviation.
[b] CPUE columns may not sum exactly to totals due to rounding.
[c] Totals in percentage columns not equalling 100.00% are due to rounding.

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TABLE 4-116

Occurrence of Fishes in the Steel Creek Corridor Observed in Quarterly Electrofishing Samples During 1986-1987

	1986				1987			
	Feb	May	Sept	Dec	Feb - Apr	June	Sept	Dec
Longnose gar		x				x		
Florida gar		x						
Bowfin	x		x					x
American eel	x	x	x	x	x	x	x	x
Gizzard shad					x	x		
Eastern mudminnow	x							
Redfin pickerel		x	x					
Chain pickerel		x	x		x	x		
Bluehead chub	x	x	x	x	x			
Golden shiner						x	x	
Dusky shiner		x	x	x	x		x	
Spottail shiner						x		
Yellowfin shiner	x		x	x	x	x	x	
Coastal shiner	x	x	x	x	x		x	x
Carpsucker		x						
Creek chubsucker	x	x	x	x	x	x	x	x
Lake chubsucker			x		x			
Northern hog sucker	x	x	x	x	x		x	x
Spotted sucker	x	x		x	x	x	x	x
Yellow bullhead		x	x			x	x	x
Flat bullhead			x	x		x	x	x
Madtom		x					x	
Tadpole madtom								
Speckled madtom	x		x		x			
Pirate perch	x	x	x				x	x
Brook silverside							x	
Mud sunfish	x							
Hybrid sunfish							x	
Redbreast sunfish	x	x	x	x	x	x	x	x
Warmouth		x		x				
Bluegill			x	x	x	x	x	x
Dollar sunfish	x							x
Spotted sunfish	x	x	x	x	x	x	x	x
Largemouth bass	x	x	x	x	x	x	x	x
Black crappie		x						
Christmas darter	x							
Tesselated darter	x	x		x		x		
Yellow perch		x				x	x	
Blackbanded darter	x	x	x	x	x	x	x	x

Source: Paller et al. (1988b)

Effects of Impoundment on the Steel Creek Swamp

The influence of L Lake on the fish assemblage in the Steel Creek swamp was evaluated by comparing pre-impoundment (Aho et al., 1986a) and post-impoundment (Paller et al., 1986b) fisheries data. Unlike the corridor, there was relatively little evidence of change in fish assemblage structure in the delta/swamp (Tables 4-117 and 4-118). The number of species collected was higher after impoundment, although this was probably the result of an increase in sampling intensity. Species composition changed only slightly during the post-impoundment years of 1986 and 1987, with brook silverside abundance decreasing and bluegill abundance increasing. Total (i.e., all species summed) mean annual catch per unit effort during the post-impoundment years was somewhat lower than during most of the pre-impoundment years. It is not yet known whether this difference reflects annual variation, methodological differences between the studies of Aho et al. (1986a) and Paller et al. (1986b), or a true decrease in the abundance of some taxa.

Effects of Impoundment on the Lower Channel of Steel Creek

Habitat changes in the creek channel below the delta/swamp included an increase in discharge and subsequent erosion of the stream bed. These changes, however, were not as extreme as in the corridor. The adult fish assemblage in the mouth of Steel Creek (the only portion of the channel consistently sampled prior to the impoundment of L Lake) exhibited few interpretable changes following the restart of L Reactor and impoundment of L Lake (Table 4-119). Apparent post-impoundment increases in species richness were probably the result of more intensive sampling rather than habitat alterations. The lower channel continued to be used as a spawning area for anadromous fish after the restart of L Reactor and impoundment of L Lake as indicated by the collection of American shad and blueback herring larvae and eggs from this habitat (Figure 4-60).

Comparison of Steel Creek with Other Southeastern Streams

The preceding comparisons suggest that impacts caused by the restart of L Reactor and impoundment of L Lake are largely limited to the Steel Creek corridor, and that the fish community in Steel Creek as a whole remains diverse and balanced. To assess the status of the Steel Creek fish community, Paller et al. (1988b) compared it to fish communities in other southeastern streams. Because of differences in methodology among studies, these comparisons were based only on species number and relative abundance. Of the eight streams selected for comparison with Steel Creek, seven are in the southeast and one is in the central states. None of the streams were considered severely impacted by the researchers studying them.

TABLE 4-117

Mean Electrofishing Catch per Unit of Effort (CPUE; no./100 m) and Relative Abundance (% composition) of Common Species in a Closed-Canopy Swamp Habitat (Stations 340 and 350) in the Steel Creek Swamp Before and After the Impoundment of L Lake and Restart of L Reactor, 1983-1987

	Before						After			
	1983[a]		1984[a]		1985[a]		1986		1987	
Taxon	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
Longnose gar	0.42	4.3	0.94	4.7	2.29	15.1	0.25	2.7	0.21	2.8
Florida gar										
Bowfin	0.47	4.8	1.36	6.8	0.39	2.6	0.42	4.5	0.19	2.6
American eel	0.14	1.4	0.36	1.8			0.20	2.1	0.07	0.9
Gizzard shad	0.08	0.8	0.44	2.2	0.28	1.8	0.06	0.6	0.07	0.9
Chain pickerel							0.25	2.7	0.21	2.8
Golden shiner	0.06	0.6	1.11	5.6	0.50	3.3	0.57	6.1	0.31	4.1
Minnow	1.75	17.9	6.66	33.3	4.34	28.7	2.03	21.5	2.47	33.3
Chubsucker	0.14	1.4	0.25	1.2	0.17	1.1	0.35	3.7	0.35	4.7
Spotted sucker	0.73	7.5	1.42	7.1	1.95	12.9	1.24	13.2	0.65	8.8
Pirate perch			0.34	1.7	0.28	1.8	0.15	1.6	0.11	1.5
Lined topminnow							0.01	0.1		
Mosquitofish	0.11	1.1	0.11	0.6			0.01	0.1	0.18	2.4
Brook silverside	3.84	39.3	2.74	13.7	2.06	13.6	0.39	4.1	0.31	4.1
Redbreast sunfish	0.08	0.8	0.22	1.1	0.06	0.4	0.06	0.6	0.01	0.2
Bluegill							0.01	0.1	0.08	1.1
Redear sunfish							0.17	1.8		
Spotted sunfish	0.28	2.9	0.59	3.0	0.72	4.8	0.32	3.4	0.36	4.9
Largemouth bass	1.00	10.2	1.23	6.2	1.05	6.9	1.63	17.3	1.03	13.9
Yellow perch	0.50	5.1	1.27	6.4	0.66	4.4	0.94	10.0	0.49	6.6
Blackbanded darter	0.06	0.6	0.39	2.0	0.28	1.8	0.10	1.1	0.11	1.5
Striped mullet	0.11	1.1	0.56	2.8	0.11	0.7	0.01	0.1		
Other							0.25	2.5	0.17	2.4
Total	9.77	99.8	19.99	100.2	15.14	99.9	9.42	99.9	7.42	99.5

[a] Adapted from Aho et al. 1986.
[b] Deviations between arithmetic sum of the column and the indicated total for CPUE and the differences from 100.0 for percent composition are due to rounding.

Source: Paller et al. (1988b)

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TABLE 4-118

Mean Electrofishing Catch per Unit of Effort (CPUE; no./100 m) and Relative Abundance (% composition) of Common Species in a Closed-Canopy Swamp Habitat (Stations 320 and 330) in the Steel Creek Swamp. Samples were Collected from Between the Islands Before and After the Impoundment of L Lake and Restart of L Reactor (1983-1987)

	Before						After			
	1983[a]		1984[a]		1985[a]		1986		1987	
Taxon	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
Longnose gar							0.17	1.1	0.07	0.3
Bowfin	0.36	1.5	0.59	1.3	0.72	1.8	0.54	3.4	0.35	1.5
American eel	0.10	0.4	0.12	0.3	1.66	4.1	0.16	1.1	0.07	0.3
Redfin pickerel	0.39	1.7	0.68	1.5	0.22	0.5	0.01	0.1	0.14	0.6
Chain pickerel							0.39	2.5	0.28	1.2
Golden shiner	1.50	6.4	1.80	4.0	1.01	2.5	0.44	2.8	1.03	4.4
Minnow	12.34	52.4	24.22	54.1	10.80	26.4	3.66	23.2	13.83	58.7
Chubsucker	1.05	4.5	3.02	6.8	2.72	6.7	1.61	10.2	1.11	4.7
Spotted sucker	0.59	2.5	0.69	1.5	0.67	1.6	0.72	4.6	0.89	3.8
Pirate perch	0.44	1.9	2.02	4.5	1.96	4.8	0.31	2.0	0.33	1.4
Mosquitofish	0.78	3.3	0.67	1.5	0.11	0.3	0.62	3.9	0.47	2.0
Brook silverside	2.11	9.0	4.50	10.0	5.85	14.3	0.38	2.4	0.17	0.7
Redbreast sunfish							0.32	2.0	0.15	0.6
Bluegill							0.27	1.7	0.72	3.1
Spotted sunfish	1.80	7.6	3.08	6.9	10.50	25.7	2.00	12.7	1.29	5.5
Largemouth bass	2.11	9.0	3.35	7.5	4.71	11.5	3.43	21.8	1.90	8.1
Black banded darter							0.24	1.5	0.24	1.0
Other							0.44	3.1	0.53	2.1
Total[b]	23.57	100.2	44.74	99.9	40.93	100.2	15.71	100.1	23.57	100.0

[a] From Aho et al. 1986.

[b] Deviations between arithmetic sum of the column and the indicated total for CPUE and the differences from 100.0 for percent composition are due to rounding.

Source: Paller et al. (1988b)

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TABLE 4-119

Mean Electrofishing Catch Per Unit Effort (CPUE; no./100 m) at a Sample Station (370) in the Mouth Of Steel Creek Before (1983, 1984, and 1985) and After (1986 and 1987) the Impoundment of L Lake and Restart of L Reactor (1983-1987)

Taxa	1983[a]	1984[b]	1985[c]	1986	1987
Longnose gar				0.06	
Florida gar		0.08			0.03
Bowfin	0.63	0.33	0.22	0.22	0.08
American eel				0.03	0.06
Herring/shad				0.17	
Blueback herring				0.03	
American shad				0.06	0.11
Gizzard shad	0.13			0.11	0.03
Eastern mudminnow					0.03
Redfin pickerel		0.83		0.14	
Chain pickerel		0.08	0.11	0.28	0.11
Minnow			0.44	2.14	5.44
Creek chubsucker				0.06	
Northern hogsucker					0.03
Spotted sucker	0.75	0.17	0.11	0.36	0.42
Silver redhorse	0.13				
Snail bullhead			0.11		
Brown bullhead				0.03	
Flat bullhead				0.06	
Channel catfish	0.13		0.11		0.06
Madtom				0.03	
Pirate perch	0.13		0.11	0.19	0.08
Atlantic needlefish				0.03	
Mosquitofish				0.06	
Brook silverside	0.25	0.08	0.11	0.61	0.72
Mud sunfish					0.03
Bluespotted sunfish			0.11	0.14	0.03
Redbreast sunfish	0.50	0.17	1.22	0.56	0.36
Warmouth			0.11	0.03	
Bluegill	0.25			0.06	0.78
Dollar sunfish				0.03	
Redear sunfish	0.13			0.03	
Spotted sunfish	2.00	0.33	1.44	1.14	0.44
Largemouth bass	1.25	0.33	0.44	0.67	0.47
Black crappie				0.06	
Darter				0.06	
Tesselated darter				0.19	0.03
Yellow perch	0.38	0.08	0.22	0.06	0.06
Blackbanded darter			0.11	0.19	0.17
Striped mullet					0.14
Other		0.08	0.33		0.03
Total[d]	6.66	2.56	5.30	7.83	9.72

[a] Paller et al (1984)
[b] Paller and Osteen (1985)
[c] Paller and Saul (1986)
[d] Deviations between arithmetic sum of the column and the indicated total for CPUE are due to rounding error.

Source: Paller et al. (1988b)

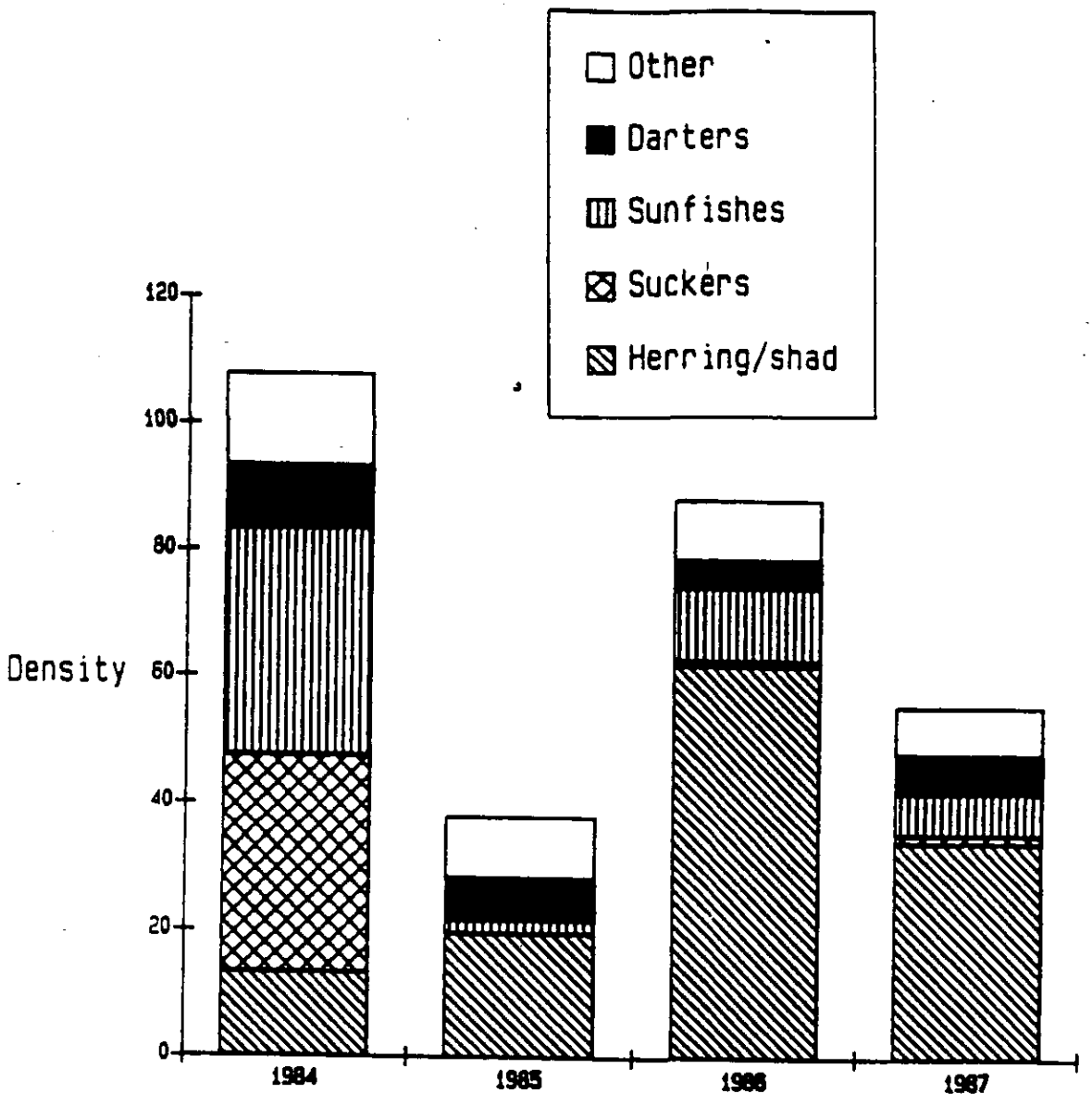

FIGURE 4-60. Mean Ichthyoplankton Densities (no./1,000 m^3) in the Steel Creek Channel Preceding (1984 and 1985) and Following (1986 and 1987) the Restart of L Reactor (1984-1987) (source: Paller et al., 1988b)

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Total species number ranged from 24 in Duke swamp to 60 in Steel Creek (Table 4-120). The only stream acomparable to Steel Creek in species richness was the Tennessee-Tombigbee Waterway, a fairly large watercourse, with 49 species. While species richness is influenced by sampling effort (Odum, 1971), the high richness in Steel Creek is at least partly the result of Steel Creek's unusual habitat diversity (corridor, open-canopy delta, closed-canopy swamp, and channel). Species richness in Steel Creek is also enhanced by its connection with the Savannah River, which results in incursions by riverine species such as the larger catfishes, anadromous species, and euryhaline marine species such as the Atlantic needlefish and striped mullet. Examinations of Table 4-120 indicates that Steel Creek supports particularly rich ictalurid (catfish), centrarchid (sunfish and black bass), and cyprinid (minnow) faunas.

TABLE 4-120

Species Number and Relative Abundance (% composition) of Fishes in Nine Southeastern Streams. Relative Abundances are Based on the Number of Individual Fish in Each Family.

Family	Otter Creek, IN[a]		Shoal Creek, AL[b]		Barbaree Creek, AL[c]		Tombigbee Waterway, TN[d]		Duke Swamp, NC[e]	
	No.	%	No.	%	No.	%	No.	%	No.	%
Bowfin									1	1
Gars							1	<1	1	<1
Freshwater eels									1	2
Herrings	1	1[f]	1	<1			1	<1		
Mudminnow									1	4
Pikes	1	<1	1	<1					2	28
Suckers	4	3	3	7	2	3	4	2	1	10
Minnows	16	86	14	55	10	81	18	72	1	3
Catfishes	2	2	2	1	1	1<1	4	4	3	10
Killfishes	1	1	1	<1			2	2		
Livebearers							1	5	1	<1
Pirate perch									1	21
Cavefishes									1	2
Silversides	1	<1								
Sunfishes & black basses	7	2	11	22	6	2	6	7	9	18
Perches	6	8	7	9	5	11	11	6	1	<1
Drums							1	2		
Sculpins			1	5	1	3				
Total	39		41		25		49		24	

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TABLE 4-120, Contd

Family	Haggard Mill Creek, NC[a] No.	%	Steel Creek[g] - 1986 No.	%	Steel Creek, 1987[g] No.	%	Lower Three Runs[h] No.	%	Upper Three Runs[e] No.	%
Bowfin	1	<1	1	2	1	1	1	1	1	3
Gars			2	3	2	1	1	<1		
Freshwater eels	1	6	1	1	1	1	1	6	1	10
Herrings	1	1	3	1	2	<1			1	2
Mudminnow	1	10	1	<1	1	<1	1	<1		
Pikes	2	11	2	2	1	1	1	1	1	2
Suckers	1	3	4	9	4	6	3	8	3	13
Minnows	2	1	10	26	10	40	5	1	2	16
Catfishes	3	4	9	2	9	2	5	2	2	2
Needlefishes			1	<1	1	<1	1	<1		
Killifishes		2	<1	2	<1			1	2	
Livebearers	1	8	1	1	1	2	1	1		
Pirate perch	1	24	1	1	1	2	1	4	1	4
Cavefishes	1	8	1	<1	1	<1				
Silversides			1	2	1	1	1	<1	1	1
Temperate basses					1	<1				
Sunfishes & black basses	11	22	12	47	13	39	9	69	7	46
Perches	2	4	6	3	6	3	4	6		
Mullets			1	<1	1	<1				
Total	28		60		60		35		21	

[a] Grossman et al., 1982
[b] Kelly et al., 1981
[c] Boschung and O'Neil, 1981
[d] Mundy and Boschung, 1981
[e] Pardue and Huish, 1981
[f] Value quoted directly from original paper
[g] Paller et al. (1988a)
[h] Paller and Saul, 1986

Source: Paller et al. (1988a)

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4.5 PAR POND/LOWER THREE RUNS CREEK

4.5.1 Water Quality

Par Pond, formed in 1957 by damming Lower Three Runs Creek, was the primary cooling water source for R Reactor from 1958 to 1964 and a partial source for P Reactor from 1961 to 1964. P Reactor has used Par Pond as the primary source of cooling water since 1964 when R Reactor was placed on standby.

Lower Three Runs Creek has undergone post-thermal recovery since the completion of Par Pond in 1958 (Lower, 1987). Prior to the 1983-1985 two-year water quality program instituted under the CCWS, Lower Three Runs Creek water quality was monitored at two locations from 1973 to 1985. The results of that monitoring are shown in Tables 4-121 and 4-122.

Water chemistry data available from three primary sources (Chimney et al., 1985; Newman et al., 1986; Tilly, 1981) for Par Pond between 1972 and 1985 was summarized by Wilde (1985) and follows below.

The water chemistry of Par Pond has been described in detail by Gladden et al. (1985a), and Chimney et al. (1985). Water chemistry data for Par Pond taken from these comprehensive sampling programs are shown in Table 4-123. The data in Table 4-123 indicate that the water quality of Par Pond has not changed substantially for at least the last decade.

Table 4-124, taken from Chimney et al. (1985), shows statistical comparisons of several water quality parameters measured in various locations in Par Pond and Pond B. Details of statistical methods can be found in Chimney et al. (1985). These comparisons show that a sampling location near the Hot Dam of Par Pond (H2) differed significantly ($P < 0.05$) from other sampling locations in Par Pond for only one of the measured parameters, total phosphorus, which was highest near the Hot Dam. Compared to Pond B, the water of Par Pond had significantly higher mean concentrations of total phosphorus, nitrate, silica, potassium, magnesium, calcium, sodium, chloride, inorganic carbon, alkalinity, and total dissolved solids. Pond B, however, had significantly higher mean concentrations of iron, manganese, and total organic carbon than Par Pond. The reason(s) for these higher values in Pond B are currently unknown.

Changes in vertical profiles of dissolved oxygen (DO) corresponded to changes in thermal conditions at all Par Pond and Pond B stations in the study by Chimney et al. (1985). Before the establishment of stable thermal stratification through the development of a thermocline, the entire water column in both reservoirs was well oxygenated (Figure 4-61). Concentrations were often near or above saturation levels (Figure 4-62) and reached a maximum of 12.6 mg/L in Par Pond and 12.3 mg/L in Pond B. After the ponds became stratified, oxygen loss from the lower strata (hypolimnion) was evident in Par Pond by March or April and by March in Pond B. Complete hypolimnetic anoxia (≤ 0.1 mg/L) was observed at several stations (B1, D2, H2, and N2) and persisted through the summer (approximately March to November) at the deepest stations (D2 and B1) in

TABLE 4-121

Lower Three Runs Creek Water Quality at SRS Road B, 1973 Through 1985

Parameter	Units	Mean Concentration,[a] 1973-1982[b]		Mean Concentration,[a] 1983-1985[b]
Temperature	°C	20.3	(101)	NA
pH (range)	-	3.3 - 8.4	(101)	NA
Dissolved oxygen	mg/L	6.7	(100)	NA
Alkalinity	mg/L	23.0	(100)	NA
Conductivity	µmhos/cm	NA		NA
Turbidity	NTU	NA		NA
Suspended solids	mg/L	10.3	(101)	NA
Volatile solids	mg/L	18.3	(101)	NA
Total dissolved solids	mg/L	48.5	(101)	NA
Total solids	mg/L	60.0	(101)	NA
Biochemical oxygen demand	mg/L	1.27	(38)	NA
Chemical oxygen demand	mg/L	9.8	(82)	NA
Chlorides	mg/L	5.7	(101)	NA
Kjeldahl nitrogen (N)	mg/L	<1.0	(26)	NA
Nitrates + nitrites (N)	mg/L	0.052	(101)	NA
Sulfates (SO_4)	mg/L	2.5	(100)	NA
Total phosphates (P)	mg/L	0.053	(98)	NA
Aluminum, total (Al)	mg/L	0.43	(94)	NA
Ammonia (N)	mg/L	0.23	(98)	NA
Calcium, total (Ca)	mg/L	5.74	(94)	NA
Copper, total (Cu)	mg/L	NA		NA
Cadmium, total (Cd)	mg/L	NA		NA
Magnesium, total (Mg)	mg/L	NA		NA
Manganese, total (Mn)	mg/L	0.04	(7)	NA
Mercury, total (Hg)	mg/L	<0.001	(19)	NA
Nickel, total (Ni)	mg/L	NA		NA
Sodium, total (Na)	mg/L	6.7	(94)	NA
Iron, total (Fe)	mg/L	1.5	(94)	NA
Lead, total (Pb)	mg/L	0.46	(94)	NA
Chromium, total (Cr)	mg/L	NA		NA
Zinc, total (Zn)	mg/L	NA		NA

[a] Except as noted; number of analyses in parentheses
[b] DP-1697, Vol. III, Chapter 2

NA = no analysis conducted

Source: Lower (1987)

TABLE 4-122

Lower Three Runs Creek Water Quality at Pattersons Mill, 1973 Through 1985

Parameter	Units	Mean Concentration,[a] 1973-1982[b]		Mean Concentration,[a] 1983-1985[b]	
Temperature	°C	17.9	(111)	17.0	(36)
pH (range)	-	3.9 - 9.0	(110)	6.5 - 7.8	(36)
Dissolved oxygen	mg/L	8.6	(110)	8.1	(36)
Alkalinity	mg/L	32.2	(110)	34.3	(36)
Conductivity	µmhos/cm	NA		85.5	(36)
Turbidity	NTU	NA		1.18	(35)
Suspended solids	mg/L	10.5	(111)	5.4	(36)
Volatile solids	mg/L	21.1	(111)	3.9	(36)
Total dissolved solids	mg/L	60.4	(111)	64.7	(36)
Total solids	mg/L	71.2	(111)	70.0	(36)
Biochemical oxygen demand	mg/L	0.89	(38)	NA	
Chemical oxygen demand	mg/L	13.5	(92)	13.2	(36)
Chlorides	mg/L	3.9	(111)	3.9	(36)
Kjeldahl nitrogen (N)	mg/L	<1.0	(26)	NA	
Nitrates + nitrites (N)	mg/L	0.114	(111)	0.091	(23)
Sulfates (SO_4)	mg/L	2.69	(110)	2.7	(36)
Total phosphates (P)	mg/L	0.044	(109)	0.04	(36)
Aluminum, total (Al)	mg/L	0.58	(108)	0.078	(35)
Ammonia (N)	mg/L	0.018	(109)	0.03	(24)
Calcium, total (Ca)	mg/L	12.4	(109)	16.0	(12)
Copper, total (Cu)	mg/L	NA		0.01	(24)
Cadmium, total (Cd)	mg/L	NA		<0.01	(24)
Magnesium, total (Mg)	mg/L	NA		0.75	(35)
Manganese, total (Mn)	mg/L	<0.01	(7)	0.091	(35)
Mercury, total (Hg)	mg/L	<0.001	(19)	0.00018	(20)
Nickel, total (Ni)	mg/L	NA		0.055	(24)
Sodium, total (Na)	mg/L	4.02	(109)	2.9	(35)
Iron, total (Fe)	mg/L	0.37	(109)	0.52	(35)
Lead, total (Pb)	mg/L	<0.5	(108)	<0.01	(18)
Chromium, total (Cr)	mg/L	NA		<0.01	(35)
Zinc, total (Zn)	mg/L	NA		0.02	(35)

[a] Except as noted; number of analyses in parentheses
[b] DP-1697, Vol. III, Chapter 2

NA = no analysis conducted

Source: Lower (1987)

TABLE 4-123

Summary of Par Pond Water Chemistry Data

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
Temperature (°C)			
Range	5.7 - 36.0	14.8 - 43.0	
Mean	19.7	30.3	21.4
No. anal.[a]	228	43	7556
pH (units)			
Range	4.3 - 9.5	6.8 - 8.2	
Mean	6.6	6.8 - 8.2	7.3
No. anal.	216	43	2341
D.O. (mg/L)			
Range	0.5 - 10.1	3.5 - 10.4	
Mean	7.3	6.6	6.6
No. anal.	226	43	1745
Cond. (μmhos/cm)			
Range	44 - 120	57 - 77.4	
Mean	64.8	65.2	54.6
No. anal.	228	33	5197
Total P (μg/L)			
Range	2.0 - 150.5	5 - 692	
Mean	18.1	40.0	
No. anal.	228	41	
Ortho PO_4 (P) (μg/L)			
Range	0.2 - 15.7	0.5 - 26.0	
Mean	1.8	6.0	7.0
No. anal.	228	40	710
NO_3+NO_2- (N) (μg/L)			
Range	4 - 171	3 - 168	
Mean	44	54	23.5
No. anal.	228	41	707

[a] Number of analyses

Source: Wilde (1985)

TABLE 4-123, Contd

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
NH_3-N (µg/L)			
Range	2 - 89	12 - 170	
Mean	25	36	
No. anal.	228	41	
Si (mg/L)			
Range	0.9 - 6.3		
Mean	4.2		
No. anal.	228		
Mn (µg/L)			
Range	0 - 428	0.1 - 160	
Mean	7.5	39	
No. anal.	216	12	
Na (mg/L)			
Range	4.1 - 7.5	4.4 - 6.9	
Mean	6.1	5.9	5.6
No. anal.	156	29	658
Ca (mg/L)			
Range	2.0 - 5.2	0.01 - 6.0	
Mean	3.4	3.6	3.8
No. anal.	228	29	645
Alk ($mgCaCO_3/L$)			
Range	2.8 - 17.5	12.7 - 19.0	
Mean	13.1	15.4	15.6
No. anal.	228	43	971
Cl (mg/L)			
Range	5.3 - 8.3	5.0 - 7.6	
Mean	6.7	6.3	6.3
No. anal.	180	43	664

TABLE 4-123, Contd

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
K (mg/L)			
Range	0.1 - 2.0	0.6 - 2.0	
Mean	1.2	1.2	1.1
No. anal.	216	29	657
Fe (μg/L)			
Range	0 - 141	1 - 148	
Mean	24	51	
No. anal.	216	29	
Turb. (NTU)			
Range	0.6 - 6.1	0.6 - 23.3	
Mean	1.7	2.9	6.1
No. anal.	228	40	993
Tot. susp sol. (mg/L)			
Range		0.3 - 14.1	
Mean		2.2	
No. anal.		39	
SO_4 (mg/L)			
Range		1.3 - 7.6	
Mean		5.0	3.7
No. anal.		24	685
TOC (mg/L)			
Range		2.3 - 12.3	
Mean	4.4	6.5	
No. anal.	228	28	
DOC (mg/L)			
Range		2.9 - 4.5	
Mean		3.7	
No. anal.		10	

TABLE 4-123, Contd

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
POC (mg/L)			
Range		0.3 - 3.1	
Mean		1.2	
No. anal.		10	
Total N (μg/L)			
Range		70 - 680	
Mean		237	
No. anal.		41	
BOD (5-day mgO_2/L)			
Range		1.5 - 4.8	
Mean		3.2	
No. anal.		2	
Al (mg/L)			
Range		0.05 - 2.38	
Mean		0.3	
No. anal.		29	
As (μg/L)			
Range		0.2 - 15.0	
Mean		2.4	
No. anal.		10	
Cd (μg/L)			
Range		0.02 - 0.7	
Mean		0.2	
No. anal.		10	
Cr (μg/L)			
Range		0.2 - 98.0	
Mean		13.6	
No. anal.		10	

TABLE 4-123, Contd

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
CU (µg/L)			
Range		0.5 - 6.6	
Mean		3.1	
No. anal.		10	
Pb (µg/L)			
Range		0.2 - 3.9	
Mean		1.6	
No. anal.		10	
Mg (mg/L)			
Range	0.8 - 8.3	1.0 - 1.2	
Mean	1.1	1.1	1.0
No. anal..	228	29	660
Hg (µg/L)			
Range		0.05 - 0.4	
Mean		0.09	
No. anal.		18	
Ni (µg/L)			
Range		0.2 - 10.0	
Mean		2.6	
No. anal.		10	
U (µg/L)			
Range		5.0 - 5.0	
Mean		5.0	
No. anal.		12	
Zn (µg/L)			
Range		2.4 - 31.0	
Mean		9.2	
No. anal.		10	

TABLE 4-123, Contd

Parameter	Source, Sampling Period, and Location		
	Chimney et al. (1985) Jan 1983 - June 1985 Lakewide	Newman et al. (unpub.) Nov 1983 - July 1985 Near Hot Dam	Tilly (1981) 1972 - 1976 Lakewide
Hardness (mg/L)			
Range			
Mean			13.7
No. anal.			545
TDS (mg/L)			
Range	7 - 141		
Mean	47.3		
No. anal.	216		
Secchi Disk (m)			
Range	1.5 - 6.3		
Mean	3.2		2.6
No. anal.	167		251

Source: Wilde (1985)

TABLE 4-124

Comparisons Between Par Pond and Pond B for Integrated Mean Physical and Chemical Parameters. Also, Multiple Comparison Tests (Tukey's Studentized Range, HSD) from ANOVA Among Par Pond Stations (January 1984 - June 1985).[a] Underlined stations are not significantly different from each other.

Parameter	Par Pond vs. Pond B	Par Pond Stations[b]			
Temperature (water column)	Par > B	H2	I3	N2	D2
Temperature (oxygenated zone)	Par > B	H2	N2	I3	D2
Total phosphorus	Par > B	H2	D2	I3	N2
Ortho-phosphorus	NS[c]	D2	H2	I3	N2
Nitrite-nitrogen (NO_2-N)	Par > B	D2	H2	I3	N2
Nitrate-nitrogen (NO_3-N)	Par > B	D2	H2	I3	N2
Ammonia-nitrogen (NH_4-N)	NS[c]	N2	H2	D2	I3
Silica (SiO_2)	Par > B	D2	H2	I3	N2
Potassium	Par > B	D2	H2	I3	N2
Iron	B > Par	D2	H2	I3	N2
Manganese	B > Par	D2	H2	I3	N2
Magnesium	Par > B	D2	H2	I3	N2
Calcium	Par > B	D2	H2	I3	N2
Sodium	Par > B	D2	H2	I3	N2
Inorganic carbon	Par > B	D2	H2	I3	N2
Organic carbon	B > Par	D2	H2	I3	N2
Total carbon	Par > B	D2	H2	I3	N2
Alkalinity	Par > B	D2	H2	I3	N2
Chloride	Par > B	D2	H2	I3	N2
Total dissolved solids	Par > B	D2	H2	I3	N2
Turbidity	NS	D2	H2	I3	N2
Secchi disk transparency	NS	I3	D2	N2	H2

[a] Data were $\log_e$ transformed prior to analysis
[b] H2 = near Hot Dam
I3 = Intake Arm
N2 = North Arm
D2 = near Cold Dam
[c] NS = no significant difference

Source: Wilde (1985)

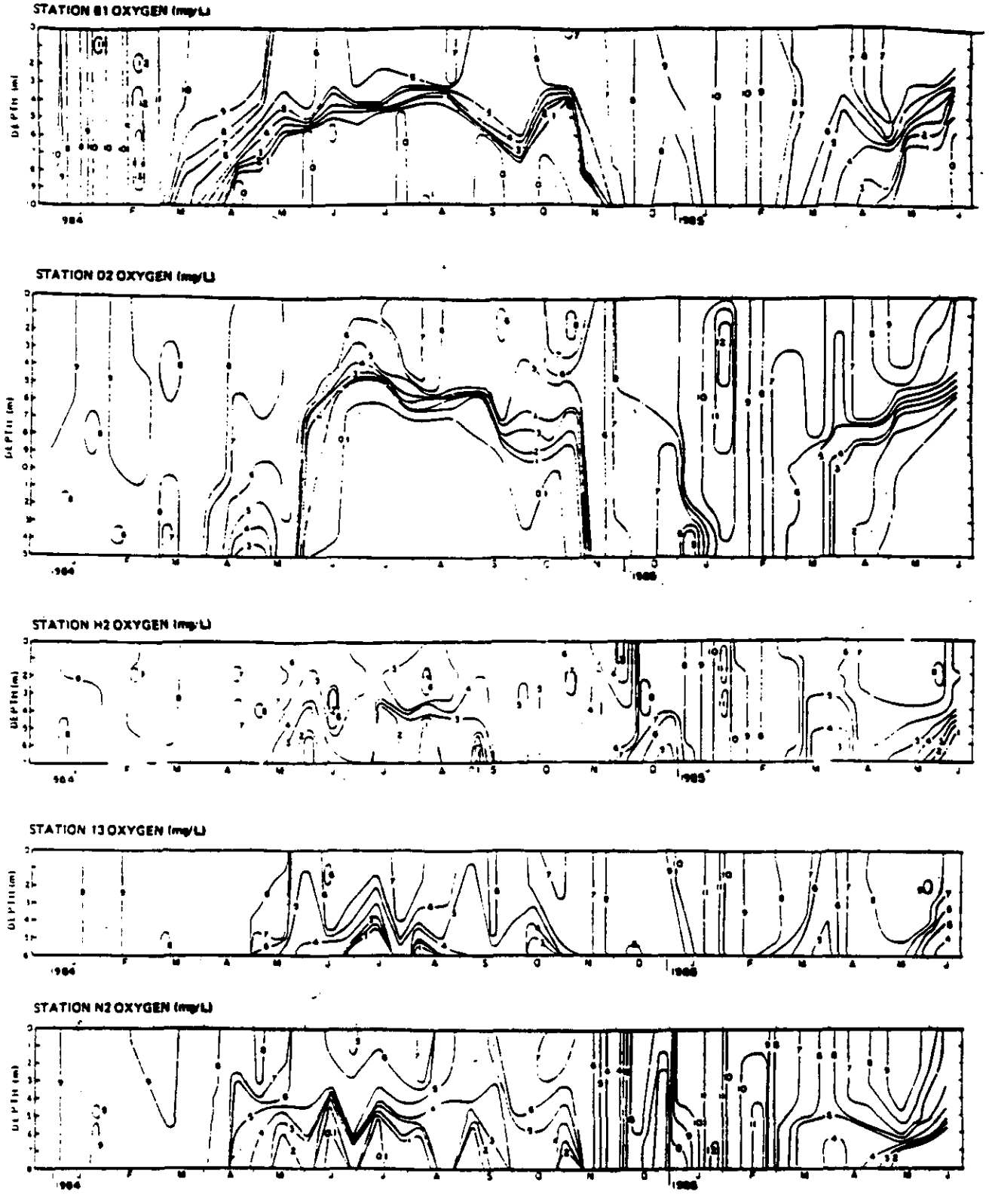

FIGURE 4-61. Time-Depth Diagrams of Oxygen for Par Pond and Pond B. January 1984 - June 1985 (source: Chimney et al., 1985; Wilde, 1985)

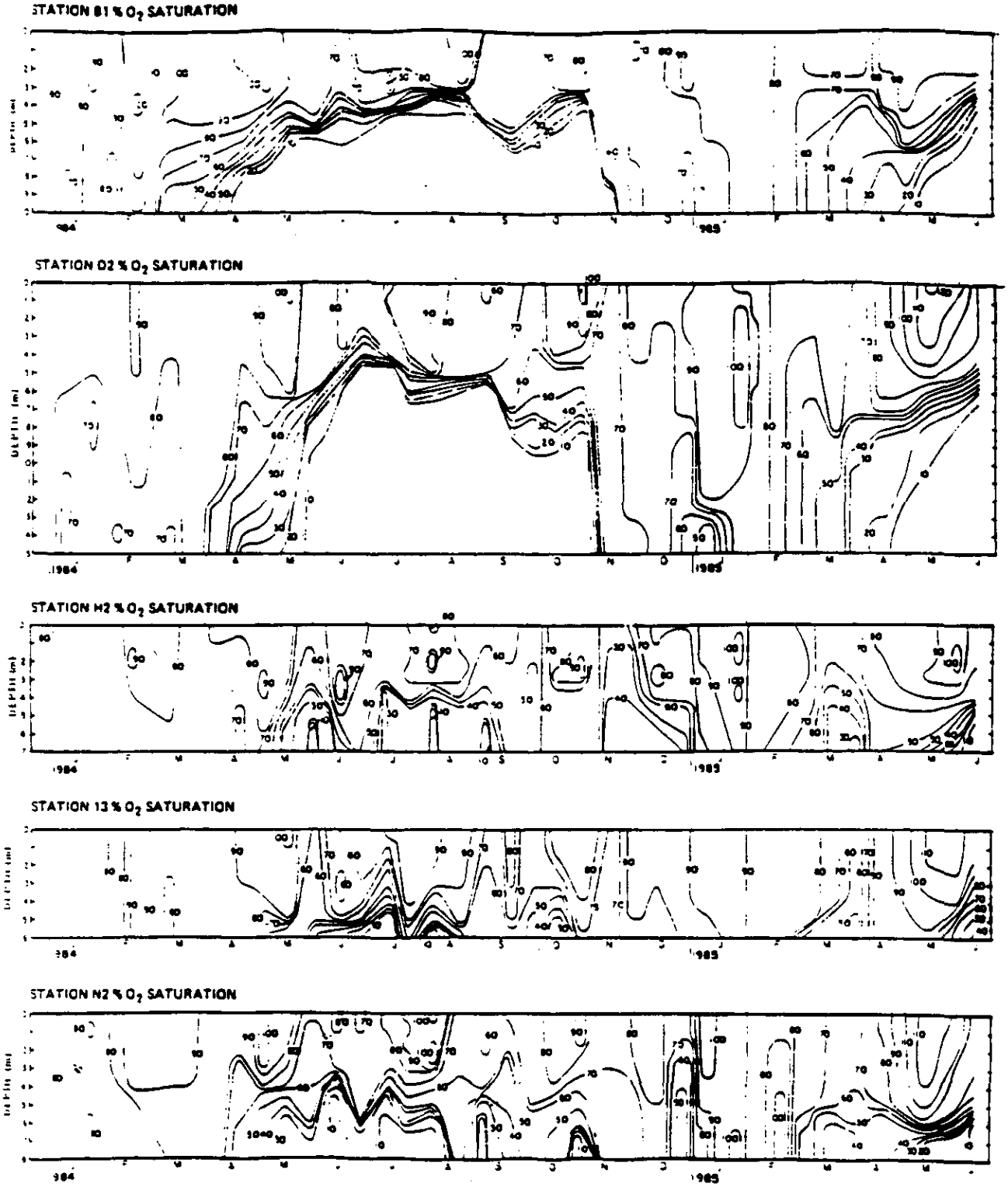

FIGURE 4-62. Time-Depth Diagrams of Percent Oxygen Saturation for Par Pond and Pond B (January 1984 - June 1985)
(source: Chimney et al., 1985; Wilde, 1985)

both ponds. When the ponds became isothermal in the fall from surface cooling, the water column of each became completely mixed and reoxygenated.

Water chemistry data for Par Pond and other lakes in the southeast are shown in Table 4-125. The values from Par Pond are within the ranges of other lakes for all parameters (except temperature near the Hot Dam). Typically, the Par Pond values are at the lower end of the ranges listed for other lakes.

Light transmission was lower during the summer than during the winter at all stations in Par Pond and Pond B (Chimney et al., 1985). Light penetration through the upper 2 m of the water column was fairly constant in both reservoirs during the course of this study (Figure 4-63). However, at greater depths, light levels were more variable. The depth in the water column to which 1% of the surface light is transmitted is considered the lower limit of the euphotic zone (Wetzel, 1983). At Stations B1 and D2 this limit tended to move up in the water column from April through September. At Pond B Station B1, the 1% depth moved from 8 m to 4 m, and at Par Pond Station D2, the 1% depth moved from 12 m to 4 m. Thus, the euphotic zone was reduced considerably at these stations by the end of the summer. The 1% light level often extended to the bottom at the shallower stations, but was above the bottom every time the deeper Stations B1 and N2 were sampled (Figure 4-63).

Integrated mean organic carbon within the euphotic zone ranged from 1.45 to 9.55 mg/L in Par Pond and from 3.15 to 10.65 mg/L in Pond B during the study by Chimney et al. (1985) (Table 4-124). There were no significant differences detected in organic carbon levels among the stations within Par Pond; however, organic carbon concentrations were significantly higher in Pond B than in Par Pond. The lowest concentrations of organic carbon within the euphotic zones of both ponds occurred in late spring 1984, but no consistent seasonal pattern was apparent. Organic carbon concentrations accounted for 50 and 80% of the total carbon in Par Pond and Pond B, respectively.

Integrated mean concentrations of total carbon (inorganic carbon + organic carbon) within the euphotic zone ranged from 5.06 to 13.12 mg/L in Par Pond and 4.40 to 12.32 mg/L in Pond B (Table 4-125). Total carbon levels in Par Pond were, on average, 1.1 to 1.25 times those of Pond B. The differences between the two reservoirs were found to be statistically significant ($P < 0.05$). There were no significant differences in total carbon levels detected among the stations of Par Pond.

Routine monitoring of radioactive and nonradioactive parameters of the surface waters of the SRS are conducted by the Environmental Monitoring (EM) Section. Results of this monitoring program for all SRS surface waters, including Par Pond and Lower Three Runs Creek, for 1987 and 1988 can be found in Appendix A of this document. A general discussion of radioactivity in onsite waters and its monitoring from 1978 to 1984 can be found in Lower (1987), and a summary table can be found in Appendix A of this document.

TABLE 4-125

Water Quality Data for Lakes in the Southeastern United States

Parameter	Monticello Res. SC[a]	Clarks Hill Res. SC[b]	39 SC Lakes[c]	43 GA, SC, NC Lakes[d]	165 FL Lakes[e]	N. Amer. Surface Waters[f]	Par Pond[g]	Pond B[h]
Temp. (°C)								
Range	1-33	6-32		9-31			7-37	6-30
Dissolved oxygen (mg/L)								
Range	1.1-15	0.0-11.3	0.0-4.6	1.5-10.6			0-9.8	0-13.2
Conductivity (µmhos/cm)								
Range	32-116	40-170			11-5600		50-109	16-154
Mean					209			
pH								
Range	6.2-9.1	4.4-9.5		5.4-8.0	4.1-9.2		4.5-8.0	4.8-7.5
Mean					6.8			
Total P (µg/L)								
Range		6-1000	30-180	7-388	3-834	10-50	8-62	8-42
Mean		65			50			
PO_4-P (µg/L)								
Range		<10-20	20-200	2-210		0.3-6.4	0.3-4.4	
Mean		11						
NO_3+NO_2-N (µg/L)								
Range		<1-809		22-690		0-10,000	7-146	7-84
Mean		116						
NH_4-N (µg/L)								
Range		<10-679		34-1000			2-79	6-55
Mean		73						
Si (mg/L)								
Range					0-13		0.9-6.3	0.5-1.5
Mean					1.6	9		
K (mg/L)								
Range					0.1-51		1.0-1.7	0.1-0.5
Mean					2.7	1.4		
Fe (µg/L)								
Range					6.6-1200	50-250	6-75	8-524
Mean					192			

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TABLE 4-125, Contd

Parameter	Monticello Res. SC[a]	Clarks Hill Res. SC[b]	43 GA, 39 SC Lakes[c]	SC, NC Lakes[d]	N. Amer. 165 FL Lakes[e]	Surface Waters[f]	Par Pond[g]	Pond B[h]
Mn (µg/L)								
Range						10-850	0-198	3-268
Mean						35		
Na (mg/L)								
Range					1-1200		4.6-7.2	1.5-2.5
Mean					27	9		
Ca (mg/L)								
Range							2.2-5.2	0.9-1.5
Mean					21			
Alkalinity (mg $CaCO_3$/L)								
Range		<1-24		1.5-10.6	0-204		11.0-16.4	1.5-4.3
Mean		13		26				
Chloride (mg/L)								
Range					1.7-2300		6.1-7.1	2.3-3.0
Mean					49	8.3		
Secchi disk (m)								
Range			0.5-5.0	0.3-4.7	0.1-8.1		1.5-6.3	1.7-6.1
Mean					1.9			

[a] Bennet et al. (1984). Ranges pertain to raw data.
[b] Applied Biology, Inc. (1982). Ranges pertain to raw data.
[c] Kimsey et al. (1982). Ranges pertain to median values for each lake.
[d] Taylor et al. (1978). Ranges pertain to "total depth means" for each lake and sampling date.
[e] Canfield et al., 1984. Ranges pertain to raw data.
[f] Wetzel (1983).
[g] Chimney et al. (1985). Ranges for temperature, dissolved oxygen conductivity, and pH pertain to raw values. Other ranges pertain to integrated means for each station and sampling date.
[h] Minimum values.

Source: Chimney et al. (1985)

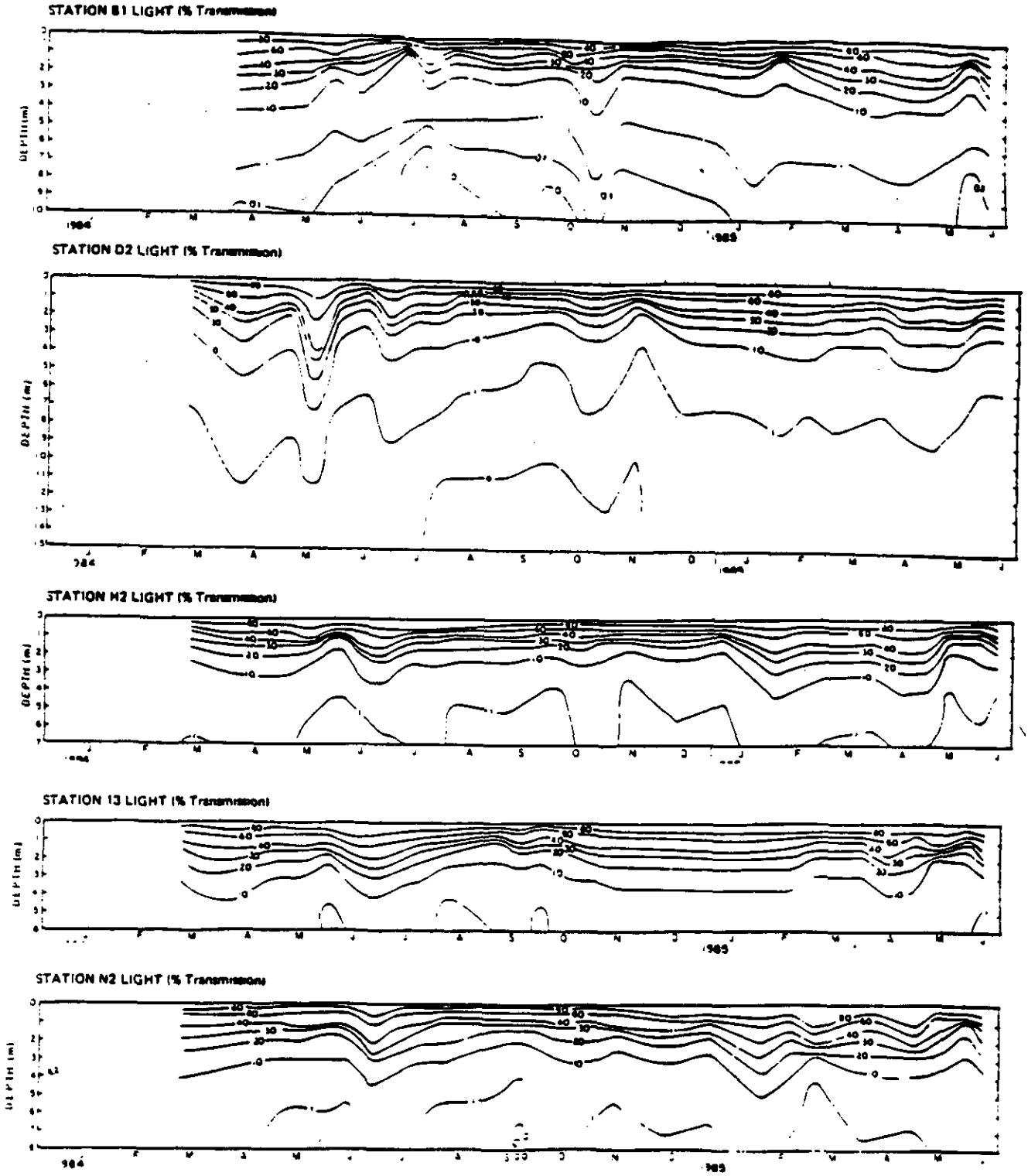

FIGURE 4-63. Time-Depth Diagrams of Percent Light Transmission for Par Pond and Pond B (January 1984 - June 1985) (source: Chimney et al., 1985; Wilde, 1985)

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Lower (1987) reports the results of the special study to determine levels of volatile, acid, and base/neutral organic compounds in SRS waters. Concentrations of all 88 tested organics never exceeded the lower limit of detection. Lower (1987) also reports the results of analyses for pesticides and PCB's in onsite streams and the Savannah River. The results for Par Pond/Lower Three Runs Creek can be found in Table A-10 of Appendix A. Results of the two-year water quality program instituted under the CCWS are also reported in Lower (1987). Sampling locations for this study are shown in Figure A-1 of Appendix A. The CCWS study monitored Par Pond and Lower Three Runs Creek for standard parameters and general water chemistry (Table 4-126, nutrients (Table 4-127), total and dissolved major cations (Table 4-128, 4-129), trace elements (Table 4-130), and organic carbon (Table 4-131).

Since the water quality of Par Pond has not changed significantly in the last decade (Wilde, 1985), and since the seepage and overflow of Par Pond water to Lower Three Runs Creek is only marginally related to P-Reactor operations, there is no reason to expect that continued operation of P Reactor would have any significant effects on the water chemistry of either system.

4.5.2 Phytoplankton

The phytoplankton community of Par Pond was quantitatively analyzed monthly from January 1984 through June 1985 (Chimney et al., 1985). Several less comprehensive studies of the phytoplankton in the Par Pond system were conducted before 1984. These earlier studies were summarized by Wilde and Tilly (1985).

4.5.2.1 Species Composition and Abundance

In the most recent study (Chimney et al., 1985), 337 phytoplankton taxa representing all of the major taxonomic groups characteristic of North American freshwaters (Smith, 1950; Prescott, 1962; Whitford and Schumacher, 1984) were collected from Par Pond (Table 4-132). Principal taxonomic groups listed in descending order of overall numerical importance (organisms per mL) were Bacillariophyta (diatoms), Chrysophyta (yellow-brown algae), Crytophyta (cryptomonads), Chlorophyta (green algae), and Cyanophyta (blue-green algae). The Chlorophyta contained the largest number of species observed (152) with Bacillariophyta containing the second largest number of species (69) (Chimney et al., 1985).

No significant differences were found between a station near the Hot Dam and other Par Pond stations for mean total phytoplankton density, mean density of each of the major taxonomic groups, mean species diversity, species richness or phytosynthetic efficiency (Chimney et al., 1985). The station near the Hot Dam did have significantly ($P < 0.05$) higher mean quantities of chlorophyll a and mean rates of primary productivity than the rest of Par Pond. Chimney et al. (1985) reported that overall mean primary productivity was 1.3 to 1.7 times greater and chlorophyll a was 1.4 to 1.5 times greater at the station near the Hot Dam than at stations elsewhere in Par Pond.

TABLE 4-126

General Water Chemistry and Standard Parameters: Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Temperature (°C)	pH	Total Alkalinity (mg/L as $CaCO_3$)	Dissolved Oxygen (mg O_2/L)	Dissolved Oxygen Saturation (%)	Specific Conductance (μmhos/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Chlorides (mg/L)	Sulfates (mg/L)
	Par Pond in western arm near pumphouse intake	21.5 (46) 5.3 - 33.0	7.32 (45) 6.14 - 8.83	14.5 (45) 11.0 - 17.8	8.20 (46) 5.60 - 11.2	91.7 (46) 67.7 - 117.8	62.9 (38) 55.2 - 74.4	3.65 (45) 0.25 - 15.7	3.4 (43) 0.9 - 17.5	6.05 (46) 5.00 - 7.60	4.90 (28) 1.55 - 7.67
1	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	31.0 (46) 14.8 - 43.0	7.33 (46) 6.75 - 8.23	15.6 (45) 12.7-19.0	6.44 (46) 3.50 - 10.4	80.7 (46) 51.4 - 120.1	66.4 (38) 57.0 - 77.0	2.05 (43) 0.25 - 14.1	2.8 (43) 0.55 - 23.3	6.28 (46) 5.00 - 7.60	5.12 (28) 1.34 - 7.55
	Lower Three Runs Creek at SRP Road B	19.3 (46) 7.0 - 31.0	6.94 (46) 5.50 - 8.00	21.8 (45) 12.1-63.7	7.06 (46) 2.40 - 10.2	74.6 (46) 25.5 - 91.9	74.1 (38) 56.9 - 134.8	4.11 (44) 0.25 - 28.4	6.1 (43) 1.2 - 37.0	6.17 (45) 4.90 - 7.40	3.51 (28) 0.25 - 7.20
2	Lower Three Runs Creek at Pattersons Mill	16.2 (46) 1.5 - 25.0	7.17 (46) 5.90 - 8.50	35.1 (45) 9.76-61.2	7.51 (46) 5.20 - 11.9	74.4 (46) 55.6 - 92.1	86.3 (38) 46.6 - 125.4	5.40 (44) 0.25 - 69.2	3.5 (43) 1.1 - 13.5	3.82 (45) 2.30 - 5.90	1.85 (26) 0.04 - 5.75
1	Lower Three Runs Creek at US Highway 125	16.0 (46) 1.5 - 24.7	7.17 (46) 6.10 - 8.40	33.6 (45) 11.9-53.6	7.30 (46) 4.60 - 13.0	71.9 (46) 51.9 - 94.4	82.5 (38) 38.9 - 119.2	4.43 (45) 0.25 - 27.2	6.3 (43) 1.4 - 50.0	3.71 (45) 2.40 - 6.20	0.78 (26) 0.20 - 3.34

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W890070

TABLE 4-127

Nutrient Concentrations (mg P/L or mg N/L): Par Pond and Lower Three Runs Creek Watershed

Station Number	Site	Total Phosphorus	Total Orthophosphates	Dissolved Orthophosphates	Nitrates	Nitrites	Ammonia	Total Kjeldahl Nitrogen
5	Par Pond in western arm near pumphouse intake	0.020 (45) <0.010 - 0.085	0.005 (39) <0.001 - 0.026	0.004 (40) <0.001 - 0.024	0.031 (43) <0.001 - 0.128	0.003 (44) <0.001 - 0.009	0.031 (46) <0.005 - 0.321	0.276 (46) 0.020 - 0.920
4	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	0.042 (45) <0.010 - 0.692	0.006 (40) <0.001 - 0.026	0.004 (40) <0.001 - 0.017	0.052 (43) 0.003 - 0.163	0.003 (44) <0.001 - 0.005	0.041 (46) 0.012 - 0.281	0.276 (46) 0.020 - 0.920
3	Lower Three Runs Creek at SRP Road B	0.045 (46) <0.010 - 0.174	0.018 (41) <0.001 - 0.118	0.007 (40) <0.001 - 0.044	0.041 (43) <0.001 - 0.157	0.003 (42) <0.001 - 0.010	0.086 (46) 0.012 - 0.620	0.264 (46) 0.050 - 0.900
2	Lower Three Runs Creek at Pattersons Mill	0.037 (46) <0.010 - 0.093	0.019 (41) 0.003 - 0.042	0.014 (41) 0.003 - 0.031	0.090 (42) 0.019 - 0.191	0.003 (43) <0.001 - 0.005	0.029 (46) <0.005 - 0.220	0.275 (46) 0.044 - 0.950
1	Lower Three Runs Creek at US Highway 125	0.053 (46) <0.010 - 0.229	0.024 (41) 0.005 - 0.039	0.018 (40) 0.005 - 0.039	0.124 (42) 0.021 - 0.257	0.004 (43) <0.001 - 0.035	0.040 (46) <0.005 - 0.245	0.257 (46) 0.052 - 0.980

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-128

Dissolved Major Cation Concentrations: Ca, Mg, Na, K (mg/L): Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Calcium	Magnesium	Sodium	Potassium
5	Par Pond in western arm near pumphouse intake	3.67 (38) 2.95 - 4.53	1.07 (38) 0.943 - 1.19	5.83 (38) 4.34 - 7.38	1.05 (38) <0.368 - 2.10
4	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	3.92 (39) 3.42 - 4.71	1.14 (39) 0.975 - 1.26	6.09 (39) 4.40 - 6.98	1.23 (39) <0.368 - 2.42
3	Lower Three Runs Creek at SRP Road B	6.16 (39) 3.20 - 18.6	1.07 (39) 0.699 - 1.20	5.71 (39) 1.78 - 7.36	1.02 (39) <0.368 - 2.30
2	Lower Three Runs Creek at Pattersons Mill	12.6 (39) 5.87 - 22.9	0.817 (39) 0.644 - 1.08	3.23 (39) 1.41 - 5.31	0.664 (39) <0.368 - 1.63
1	Lower Three Runs Creek at US Highway 125	11.9 (38) 3.78 - 17.9	0.791 (38) 0.527 - 1.14	2.96 (38) 1.80 - 8.13	1.68 (38) <0.368 - 4.66

All values reported as means with the number of analyses in parentheses.
Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

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TABLE 4-129

Total and Dissolved Major Cation Concentrations: Al, Fe, Mn (mg/L): Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Aluminum, Total	Aluminum, Dissolved	Iron, Total	Iron, Dissolved	Manganese, Total	Manganese, Dissolved
5	Par Pond in western arm near pumphouse intake	0.287 (38) <0.038 - 2.02	<0.038 (38) <0.038 - 0.038	0.382 (38) <0.003 - 2.61	0.029 (38) <0.003 - 0.097	0.041 (16) <0.0004 - 0.152	0.011 (17) <0.0004 - 0.033
4	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	0.280 (38) <0.038 - 2.38	<0.038 (39) <0.038 - 0.126	0.251 (38) 0.015 - 1.05	0.045 (39) <0.003 - 0.148	0.075 (16) <0.0004 - 0.210	0.035 (17) <0.0004 - 0.150
3	Lower Three Runs Creek at SRP Road B	0.255 (39) <0.038 - 1.50	<0.038 (39) <0.038 - 0.129	1.54 (39) 0.265 - 8.40	0.496 (39) <0.003 - 3.54	0.209 (16) <0.0004 - 0.760	0.138 (17) 0.040 - 0.429
2	Lower Three Runs Creek at Pattersons Mill	0.380 (39) 0.044 - 1.53	0.040 (39) <0.038 - 0.158	0.509 (39) 0.181 - 1.58	0.169 (39) <0.003 - 0.375	0.069 (16) <0.0004 - 0.188	0.041 (17) 0.021 - 0.083
1	Lower Three Runs Creek at US Highway 125	0.454 (39) 0.073 - 1.77	<0.038 (38) <0.038 - 0.153	0.713 (39) 0.283 - 2.66	0.272 (38) <0.003 - 0.819	0.100 (16) <0.0004 - 0.309	0.042 (15) <0.0004 - 0.077

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W8906070

TABLE 4-130

Total Trace Elemental Concentrations (μg/L): Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
5	Par Pond in western area near pumphouse intake	1.5 (16) <0.4 - 5.7	0.53 (16) <0.04 - 2.70	5.5 (16) <0.4 - 51.0	2.9 (16) <0.4 - 9.3	1.3 (16) <0.4 - 6.7	2.0 (16) <0.4 - 6.0	5.5 (16) <0.4 - 29.2
4	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	1.9 (16) <0.4 - 15.0	0.40 (16) <0.04 - 1.90	9.1 (16) <0.4 - 93.0	2.4 (16) <0.4 - 6.6	1.3 (16) <0.4 - 3.9	4.3 (16) <0.4 - 28.1	5.4 (16) <0.4 - 31.0
3	Lower Three Runs Creek at SRP Road B	2.4 (16) <0.4 - 10.5	0.67 (16) <0.04 - 4.70	7.3 (16) <0.4 - 47.0	3.0 (16) <0.4 - 5.5	1.5 (16) <0.4 - 4.3	6.8 (16) <0.4 - 59.9	9.7 (16) <0.4 - 60.0
2	Lower Three Runs Creek at Pattersons Mill	1.6 (16) <0.4 - 6.8	0.37 (16) <0.04 - 2.30	7.0 (16) <0.4 - 56.0	2.5 (16) <0.4 - 5.5	1.2 (16) <0.4 - 4.7	8.1 (16) <0.4 - 61.3	5.8 (16) <0.4 - 30.0
1	Lower Three Runs Creek at US Highway 125	2.0 (16) <0.4 - 7.8	0.45 (16) <0.04 - 3.1	4.6 (16) <0.4 - 30.0	2.5 (16) <0.4 - 5.2	1.4 (16) <0.4 - 5.7	3.0 (16) <0.4 - 8.2	4.8 (16) <0.4 - 21.5

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

W8906070

TABLE 4-131

Organic Carbon Concentrations (mg C/L): Par Pond/Lower Three Runs Creek Watershed

Station Number	Site	Total Organic Carbon	Dissolved Organic Carbon	Particulate Organic Carbon
5	Par Pond in western arm near pumphouse intake	6.23 (24) 1.07 - 13.1	3.53 (10) 3.10 - 4.10	1.50 (10) 0.280 - 4.50
4	Par Pond "bubble-up" at hot dam between Pond C and middle arm of Par Pond	5.73 (25) 2.27 - 12.1	3.71 (10) 2.92 - 4.50	1.20 (10) 0.300 - 3.10
3	Lower Three Runs Creek at SRP Road B	5.40 (25) 1.14 - 12.6	3.57 (10) 2.85 - 4.10	2.02 (10) 0.410 - 4.60
2	Lower Three Runs Creek at Pattersons Mill	6.89 (25) 1.49 - 13.3	6.66 (10) 1.83 - 11.3	2.30 (10) 0.220 - 7.10
1	Lower Three Runs Creek at US Highway 125	8.15 (25) 2.23 - 14.9	7.72 (10) 2.83 - 13.5	1.96 (10) 0.24 - 4.50

All values reported as means with the number of analyses in parentheses.
Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

There was no indication that Cyanophyta were dominant at the sampling station near the Hot Dam or anywhere else in Par Pond at times other than when they characteristically are dominant in nonthermal lakes and reservoirs in North America (i.e., late summer and early fall; Hutchinson, 1967; Smith, 1950; and Wetzel, 1983). It was concluded that the addition of heat from reactor operations increases productivity and has no significant adverse impact on the phytoplankton community of Par Pond (Wilde, 1985).

The species identified in the 1984-1985 study by Chimney et al. (1985) included most (128) of the 169 phytoplankters identified in a 1978 study by Wilde (1983) (Table 4-132). Data from the study by Chimney et al. (1985) also indicated that the phytoplankton community of Par Pond has maintained species composition, density levels, and species diversity similar to that reported for 1978 by Wilde (1983). In addition, primary productivity values for Par Pond reported in the study by Chimney et al. (1985) were similar to the values previously reported for Par Pond in studies conducted between 1965 and 1973 (Tilly, 1973; 1974a and b).

4.5.2.2 Comparisons with Regional Lakes

To aid in determining if the phytoplankton flora of Par Pond represented a "balanced indigenous biological community," as part of a Section 316(a) demonstration (Wilde, 1985), data from the study by Chimney et al. (1985) were compared to available values from the literature for other southeastern lakes and reservoirs (Table 4-133). These evaluations must be made cautiously since there is a great amount of variability in methodology and data presentation between studies.

Data on the phytoplankton taxa observed, the relative abundance of numerically important taxa, and the seasonal and year-round community composition of phytoplankton in Par Pond were quite similar to comparable data reported for numerous other southeastern lakes and reservoirs (Chimney et al., 1985). The phytoplankton community of Par Pond was as abundant (mean density = 4488 organisms per mL) and contained as many taxa (mean = 72 per sample) as any of these other lakes and reservoirs (Table 4-133). Data from Par Pond for the other parameters listed in Table 4-133 (i.e., primary productivity and chlorophyll a) were found to be consistently within the range of values given for other regional systems (Chimney et al., 1985).

The mean phytoplankton diversity (3.09) and productivity (444 mg $C/m^2/day$) of Par Pond was intermediate to other lakes and reservoirs of the southeastern United States where diversity and productivity values ranged from 1.82 to 3.91 and 101 to 2578 mg $C/m^2/day$, respectively (Table 4-133).

TABLE 4-132

Phytoplankton Taxa Collected from Par Pond During Monthly Sampling in 1984-1985 and Quarterly Sampling in 1978

Taxa	1984-1985[a]	1978[b]
Bacillariophyta		
Achnanthes linearis	x	x
A. minutissima	x	x
Achnanthes sp.	x	
Asterionella formosa	x	x
Atthea zachariasi	x	x
Caloneis bacillum	x	
C. ventricosa	x	
Caloneis sp.		x
Cyclotella stelligera	x	x
Cyclotella sp.	x	x
Cymbella lunata	x	
C. minuta	x	x
Diploneis elliptica	x	
Eunotia curvata	x	
E. dioden	x	
E. flexuosa	x	
E. pectinalis	x	x
E. zazumensis	x	
Eunotia sp.	x	
Fragilaria capucina	x	
F. crotonensis	x	x
F. vaucheriae	x	
Fragilaria sp.	x	
Frustrulla rhomboides	x	x
Gomphonema acuminatum	x	
G. clevei	x	
G. gracile	x	x
G. parvulum	x	x
Gyrosigma acuminatum	x	
Gyrosigma sp.	x	
Melosira ambigua	x	x
M. distans	x	
M. distans v. tenella	x	
M. herzogii	x	
M. granulata	x	x
M. granulata v. angustissima	x	x
M. italica	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Bacillariophyta, Contd		
M. varians	x	
Navicula capitata	x	
N. cryptocephala	x	
N. elginensis	x	
N. hustedtii		x
N. minima	x	
N. pupula	x	
N. radiosa	x	
N. radiosa v. tenella	x	
Navicula sp.	x	x
Nitzschia acicularis	x	x
N. amphibia	x	x
N. dissipata		x
N. holsetica	x	x
N. intermedia	x	
N. palea	x	x
N. sigmoidea	x	
Pinnularia biceps	x	
P. major	x	
Rhizosolenia eriensis	x	x
Rhizosolenia sp.		x
Stauroneis phoenicenteson	x	
Stauroneis sp.		x
Surirella linearis	x	
S. robusta	x	
Surirella sp.	x	
Synedra delicatissima	x	x
S. parasitica	x	
S. planktonica	x	x
S. radians	x	
S. rumpens	x	x
S. tenera	x	
S. ulna	x	x
S. vaucheriae		x
Synedra sp.	x	
Tabellaria flocculosa	x	
T. fenestrata		x
Chlorophyta		
Actinastrum hantzschii		x
Ankistrodesmus convolutus		
A. falcatus		x
A. falcatus v. mirabilis		x

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Chlorophyta, Contd		
A. spiralis	x	x
Arthrodesmus maximum	x	
A. octocornus	x	
A. validus	x	
Arthrodesmus sp. 1	x	x
Arthrodesmus sp. 2	x	
Botryococcus braunii		x
Carteria dissecta	x	
C. globosa	x	
Carteria sp. 1	x	x
Characium ambiguum	x	
Characium sp. 1	x	
Chlamydomonas sp. 1	x	x
Chalmydomonas sp. 2	x	
Chlorogonium sp.	x	
Closteriopsis longissima	x	x
Closteriopsis sp.	x	
Closterium abruptum	x	
C. acerosum	x	
C. acutum	x	
C. aciculare	x	
C. dianae	x	
C. gracile	x	
C. kuetzingii	x	
C. parvulum	x	
C. venus	x	
Closterium sp.	x	x
Coelastrum cambricum	x	x
C. microporum	x	
C. probascideum	x	x
C. reticulatum	x	
Cosmarium angulosum	x	
C. biretum v. trigibberum	x	
C. clepsydra	x	
C. contractum	x	
C. depressum	x	
C. granatum	x	
C. impressulum	x	
C. isthmium	x	
C. protractum	x	
C. pseudibroemei	x	
C. reniforme	x	
C. sexangulare	x	
C. tenue	x	
C. tenue v. minus	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Chlorophyta, Contd		
Cosmarium sp.	x	xx
Cosmarium spp.	x	
Crucigenia apiculata	x	
C. crucifera	x	
C. irregularis	x	
C. quadrata	x	xx
C. tetrapedia	x	xx
C. truncata	x	
Desmidium aptogonum	x	
D. baileyi	x	
D. grevellii	x	
Dictyosphaeium pulchellum	x	xx
Elakatothrix gelatinosa	x	xx
E. viridis	x	xx
Euastrum ciastonii	x	
Eudorina elegans	x	xx
Francia droescheri		x
F. ovalis	x	x
Gleocystis ampla	x	x
G. gigas	x	x
G. planktonica	x	x
G. vesiculosa		x
Golenkenia gigas	x	
G. paucispina	x	
G. radiata	x	x
Gonatozygon brebissonii		x
Gonium pectorale	x	x
Kirchneriella contorta	x	
K. lunata	x	
K. lunaris	x	
K. obesa	x	
K. subsolitaria		x
Lagerhemia chodatii	x	
L. quadradiseta		x
Micratinium pusillum	x	x
Micrasterias muricata	x	
M. radiata	x	
Mougeotia sp.	x	x
Nephrocytium acardhianum	x	
Oedogonium sp.	x	
Onychonema laeve v. micracanthum	x	
Oocystis borgei	x	x
O. lacustris	x	x
O. parva	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Chlorophyta, Contd		
O. pusilla	x	x
Pandorina morum	x	
Pediastrum boryanum		x
P. duplex	x	
P. tetras	x	
Pleutrotaenium subcornulatum	x	
P. tridentulum		x
Quadrigula closteriodes	x	
Scenedesmus abundans	x	
S. acuminatus	x	
S. bernardi	x	
S. bijuga	x	
S. brasiliensis	x	
S. brevispina	x	x
S. denticulatus		x
S. dimorphus	x	x
S. intermedius		x
S. longispina	x	
S. opoliensis	x	x
S. quadricauda	x	x
S. spinosus	x	
Scenedesmus sp.	x	
Schroderia judayi	x	
S. setigera	x	x
Scourfieldii cordiformis	x	
Selenastrum capricornutum	x	x
S. gracile	x	x
S. minutum	x	x
Sorastrum americanum	x	
Sphaerellopsis sp.	x	
Sphaerocystis planktonica	x	
Spirogyra sp.	x	
Spondylosium leutkemuelleri	x	
S. planum	x	
Staurastrum anatinum	x	
S. apiculatum	x	
S. chaetoceros	x	x
S. claviferum	x	
S. clevei	x	
S. curvatum	x	
S. gladiosum	x	
S. gracile	x	
S. hexacerum		
S. megacanthum	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Chlorophyta, Contd		
S. micron	x	
S. paradoxum	x	x
S. pentacerum	x	
S. ravenellii		x
S. rotula	x	
S. small	x	
S. smithii	x	
S. tetracerum	x	
Staurastrum sp. 1	x	x
Staurastrum sp. 2		x
Tetraedron caudatum	x	x
T. constrictum	x	
T. gracile	x	x
T. minimum	x	x
T. guadricuspidatum	x	
T. regulare	x	x
T. staurogeniaeforme		x
T. trigonum	x	x
Tetraedron sp.	x	x
Treubaria setigerum	x	
Ulothrix sp.	x	
Undetermined green flagellates		x
Vaucheria sp.	x	
Volvox aures	x	
Westella botryoides	x	x
W. linearis	x	
Xanthidium antilopaeum	x	
X. cristatum	x	x
Xanthidium sp.		x
Zygnema sp.	x	
Unid. coccoid unicells 5-10 μ	x	
Unid. coccoid unicells 11-15 μ	x	
Unid. coccoid colony	x	
Chrysophyta		
Bitrichia sp.	x	
Chromulina mikroplankton	x	
C. minima	x	
C. parvula	x	
Chromulina sp. 1	x	
Chrysosphaerella longispina	x	
Dinobryon bavaricum	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Chrysophyta, Contd		
D. divergens	x	x
D. sertularia	x	
Dinobryon sp.	x	
Kephyrion ovale	x	
Kephyrion sp.	x	
Mallomonas acaroides	x	
M. alpina		x
M. caudata	x	x
M. pseudocoronata	x	x
M. tonsurata	x	x
Mallomonas sp. 1	x	x
Mallomonas sp. 2	x	
Mallomonas spp.	x	
Ochromonas nannos	x	
Ochromonas sp.	x	
Ophiocytium capitantum v. longispinum		x
Synura caroliniana	x	
S. petersenii		x
S. uvella	x	x
Unid. chrysophyte sp. 1	x	
Unid. chrysophyte sp. 2	x	
Unid. chrysophyte spp	x	
Cryptophyta		
Cryptomonas caudata	x	
C. curvata	x	
C. erosa	x	x
C. marsonii	x	x
Cryptomonas sp.		x
Rhodomonas minuta	x	x
Rhodomonas sp.		x
Cyanophyta		
Anabaena circinalis	x	
A. planktonica	x	
A. wisconsinense	x	
Anabaena sp.	x	x
Anacystis sp.		x
Aphanizomenon flos-aquae	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Cyanophyta, Contd		
Aphanocapsa elachista	x	
A. elachista v. conferta	x	
A. elachista v. planktonica	x	
Aphanocapsa pulchra	x	
A. rivularis	x	
Aphanocapsa sp.	x	
A. nidulans	x	
Chroococcus dispersus	x	
C. lacustris	x	
C. limneticus	x	
Chroococcus sp.		x
Coelosphaerium kuetzingianum	x	
C. naegelianum	x	
Dactylococcopsis fascicularis		x
Gloeothece linearis v. composita	x	
Lyngbya limnetica	x	x
Lyngbya sp.	x	
Mastigocladus laminosus	x	x
Merismopedia tenuissima	x	x
Microcystis aeruginosa	x	
M. incerta	x	
M. stagnalis	x	
Oscillatoria amphibia	x	
O. formosa	x	
O. geminata	x	x
O. limosa	x	
O. nigra	x	
O. splendida	x	
O. tenuis	x	
Oscillatoria sp.	x	x
Phormidium sp. 1	x	x
Phormidium spp.	x	
Spirulina major	x	x
S. princeps	x	
Spirulina sp.	x	
Schizothrix sp.	x	x
Tolypothrix sp.	x	
Unid. cyanophyte	x	
Euglenophyta		
Euglena acus	x	
E. gracilis	x	
E. minuta	x	x

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Euglenophyta, Contd		
E. proxima	x	
Euglena sp. 1	x	x
Euglena sp. 2		x
Lepocinclis sp.	x	
Microglena cordiformis	x	
Phacus monilatus	x	
P. obicularis	x	
P. suecicus	x	
P. tortus	x	
Phacus sp.		x
Trachelomonas armata	x	
T. furcata	x	
T. hispida	x	
T. horrida		x
T. oblonga	x	
T. volvocina	x	
Trachelomonas sp.	x	
Phytoflagellates		
Unid. flagellate sp. 1	x	
Unid. flagellate sp. 2	x	
Unid. flagellate sp. 3	x	
Unid. flagellate sp. 5	x	
Unid. flagellate sp. 6	x	
Unid. flagellate sp. 7	x	
Unid. flagellate sp. 9	x	
Unid. phytobiflagellate sp. 1	x	
Unid. phytobiflagellate sp. 2	x	
Pyrrophyta		
Ceratium carolinianum	x	
C. hirundinella	x	
Glenodinium palustre	x	
G. guadridens	x	
Glenodinium sp.	x	x
Gymnodinium aeruginosum	x	
G. excavatum	x	
G. ordinatum	x	
G. palustre	x	

TABLE 4-132, Contd

Taxa	1984-1985[a]	1978[b]
Pyrrophyta, Contd		
Gymnodinium sp. 1	x	
Gymnodinium sp. 2	x	
Peridinium cinctum	x	
P. cinctum v. tuberosum	x	
P. inconspicuum	x	
P. pusillum	x	
P. umbonatum	x	
P. wisconsinense	x	
Peridinium sp.	x	x

[a] Source: Chimney et al. (1985)
[b] Source: Wilde (1983)

TABLE 4-133

Comparison of Phytoplankton Data from Par Pond and Pond B with Literature Values from Previous Studies and Other Southeastern Lakes and Reservoirs

Reservoir/Lake	Mean Total Density No./mL	Maximum Total Density No./mL	Mean Species Richness (taxa)	Total Number Taxa	Mean Species Diversity	Maximum Species Diversity	Mean Chl. a (µg/L)	Maximum Chl. a (µg/L)	Mean Primary Prod. (mg C/m^2/day)	Maximum Primary Prod. (mg C/m^2/day)
Par Pond, SC[a]	4488	32968	72	337	3.09	4.40	5.1	25.0	444	1579
Pond B, SC[a]	3058	11815	58	203	2.61	3.47	2.9	8.2	186	627
Previous Study:										
Par Pond, SC[b,c]	3379	8456	29	114	3.01	4.10	2.0	4.5	396	468
Pond B, SC[c]	1316	2281	21	81	2.70	3.20	-*	-	-	-
Southeastern Lakes/Reservoirs:										
Clarks Hill, SC[d]	3674	11369	-	206	-	-	5.2	12.7	-	-
Clarks Hill, SC[e]	-	-	-	-	-	-	6.3	6.3	239	426
Lake Robinson, SC[e]	4723	11305	-	-	-	-	-	-	240	342
Lake Robinson, SC[f]	-	-	-	-	-	-	11.9	36.0	385	3111
Clear Pond, SC[e]	-	-	-	-	-	-	5.3	6.2	285	651
Big Snooks, SC[e]	-	-	-	-	-	-	1.2	1.3	101	255
Lake Hartwell, SC[g]	8384	35100	14	194	-	-	7.8	24.9	-	-
Parr Reservoir, SC[h]	7274	115481	15	-	2.46	3.45	-	-	-	-
Monticello Reservoir, SC[h]	11434	159833	13	-	1.82	4.16	-	-	-	-
Lake Keowee, SC[i]	978	~1250	-	-	-	-	2.71	-	-	-
13 SC lakes[j,k]	4305	-	35	-	3.01	5.02	7.2	21.4	-	-
15 NC lakes[k,l]	3804	-	30	-	2.58	4.73	6.0	23.4	-	-
14 GA lakes[k,m]	6220	-	31	-	2.89	4.77	6.3	21.2	-	-
Lake Norman, NC[n]	1550	8367	34	200	3.39	4.00	-	-	792	1176
Mt. Island, NC[n]	1137	4263	32	236	3.54	4.51	-	-	828	1752
Lake Wylie, SC[n]	1590	17782	43	319	3.76	5.04	-	-	962	1727
Fishing Creek, SC[n]	1679	5087	47	171	3.91	4.54	-	-	-	-
Lake Wateree, SC[n]	6900	26664	48	216	3.54	4.58	-	-	2578	5291

Sources: * Data not available.
(a) Chimney et al., 1985; (b) Tilly, 1973; (c) Wilde, 1983; (d) Applied Biology, 1982; (d) Mallin, 1984; (f) Carolina Power and Light, 1976; (g) Carr, 1982; (h) Dames and Moore, 1985; (i) Duke Power Co., 1977; (j) Hern et al., 1977; (k) Taylor et al., 1978; (l) Morris et al., 1978a; (m) Morris et al., 1978b; and (n) Weiss et al., 1975.

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4.5.2.3 Entrainment

Studies to determine the impact of phytoplankton entrainment at the Par Pond pumphouse were conducted from January 1984 through June 1985 by Chimney et al. (1985). They estimated that 0.1×10^{15} to 36.8×10^{15} (mean = 4.6×10^{15}) phytoplankton organisms were lost per day to entrainment (Table 4-134). This estimate was based on measurements of mean daily withdrawal of water (m^3/day) at the Par Pond pumphouse (recorded by the SRS Power Engineering Department), mean total density of phytoplankton within the intake structure, and an assumption of 100% mortality after passage through the reactor cooling system. This represented a removal of between 0.1 and 2.7% (mean = 1.3%) of the total phytoplankton community in Par Pond per day (Table 4-134). Collections from various locations within Par Pond (Chimney et al., 1985) indicated that phytoplankton were distributed fairly evenly throughout the pond. It was further determined, that the fraction of the estimated whole-reservoir phytoplankton community lost per day did not differ significantly ($P < 0.05$) from the percent of the total reservoir volume withdrawn during the same period (Chimney et al., 1985). This indicated a lack of avoidance of or attraction to the intake structure by phytoplankton.

An assessment of the significance of phytoplankton entrainment, at the Par Pond pumphouse must be made on a community basis rather than simply the number of organisms lost from the system. In addition, the analysis presented in Table 4-134 was based on an assumption of 100% mortality after passage through the reactor cooling system. During periods in which the reactor was not operating (approximately 30% of the time), entrained phytoplankton were subjected only to mechanical and pressure stress and it is likely that many organisms survived passage through the cooling system during these periods. Thus, the phytoplankton loss estimates in Table 4-134 should be regarded as the upper limit; actual values may have been much lower, but survival rate during periods when the reactor was not operating are not known.

Under most natural environmental conditions, phytoplankton have a tremendous reproductive potential. Generation times can vary from several hours to a few days (Fogg, 1965; Wetzel, 1983). This is much shorter than the present turnover rate (71-542 days) for Par Pond (Table 4-134). Therefore, it seems highly improbable that pumphouse operations alone would result in the elimination of any taxa from this system (Chimney et al., 1985).

The most recent data (1984-1985) provided by Chimney et al. (1985) indicated that the phytoplankton community of Par Pond has maintained species composition, density levels and species diversity similar to values reported for 1978 by Wilde (1983). Thus, no depletion can be detected for this seven-year-period. It was not possible to ascertain what the characteristics of the community would be like if entrainment pressure was eliminated; however, despite entrainment losses, Par Pond had a significantly more diverse and species-rich phytoplankton community

TABLE 4-134

Entrainment of Par Pond Phytoplankton (January 1984 - June 1985)

Month	Pumping Rate (m^3/day)[a]	Percent Reservoir Volume Pumped/ day[b]	Reservoir Turnover Period (days)[c]	Whole Reservoir Population Estimate (no./m^3)	Phyto-plankton Lost/Day (no./m^3)[d]	Percent Par Pond Phyto-plankton Lost/Day[e]
1984						
January	8.1×10^5	1.3	76.2	2.2×10^{17}	3.6×10^{15}	1.6
February	8.0×10^5	1.3	77.4	2.6×10^{17}	4.8×10^{15}	1.9
March	7.5×10^5	1.2	83.0	1.0×10^{17}	1.0×10^{15}	1.0
April	6.2×10^5	1.0	99.9	1.6×10^{17}	1.0×10^{15}	0.6
May	7.8×10^5	1.2	79.3	1.5×10^{17}	2.1×10^{15}	1.4
June	7.6×10^5	1.2	81.7	1.0×10^{17}	1.7×10^{15}	1.6
July	7.8×10^5	1.3	79.7	2.1×10^{17}	2.9×10^{15}	1.4
August	7.8×10^5	1.3	79.3	5.3×10^{17}	8.2×10^{15}	1.6
September	8.7×10^5	1.4	71.0	2.0×10^{17}	4.0×10^{15}	2.0
October	7.9×10^5	1.3	78.2	2.4×10^{17}	2.2×10^{15}	0.9
November	6.0×10^5	1.0	103.0	0.9×10^{17}	1.0×10^{15}	1.1
December	7.6×10^5	1.2	82.0	2.2×10^{17}	1.8×10^{15}	0.8
1985						
January	7.9×10^5	1.3	78.9	1.6×10^{17}	2.5×10^{15}	1.6
February	7.7×10^5	1.2	80.5	2.4×10^{17}	3.5×10^{15}	1.4
March	8.5×10^5	1.4	72.9	1.6×10^{17}	2.2×10^{15}	1.4
April	1.1×10^5	0.2	542.4	1.2×10^{17}	0.1×10^{15}	0.1
May	5.3×10^5	0.8	117.5	3.8×10^{17}	3.5×10^{15}	0.9
June	8.3×10^5	1.3	74.7	13.4×10^{17}	36.8×10^{15}	2.7
Mean	7.2×10^5	1.2	108.8	2.7×10^{17}	4.6×10^{15}	1.3
(S.E.)	(0.4×10^5)	(0.1)	(25.7)	(0.7×10^{17})	(1.9×10^{15})	(0.1)

[a] Data supplied by SRS Power Engineering Department

[b] Percent of total reservoir volume pumped/day = (mean daily pumping rate for month divided by reservoir volume) x 100

[c] Reservoir turnover period = reservoir volume divided by mean daily pumping rate for month

[d] Phytoplankton lost/day = mean density of phytoplankton within the pump wells x mean daily pumping rate for month

[e] Percent Par Pond phytoplankton lost = (phytoplankton lost/day divided by whole-reservoir population estimate) x 100

Source: Chimney et al. (1985)

than did Pond B, a system not subject to entrainment. Since the Par Pond phytoplankton compares favorably to other South Carolina reservoirs in terms of community structure and primary productivity, it was concluded that entrainment losses have no adverse impact on the Par Pond phytoplankton community (Wilde, 1985).

4.5.2.4 Status of the Par Pond Phytoplankton Community

The phytoplankton community in Par Pond was not dominated by pollution-tolerant algae. Although some of the taxa identified in studies by Chimney et al. (1985) and Wilde (1983) are considered pollution-tolerant (see Taylor et al., 1980), the community was not dominated by these organisms. Cyanophyta, as a group, are often recognized as tolerant of high water temperatures (Fogg, 1965). However, the population pulse of Cyanophyta observed in Par Pond during August of 1984, that resulted in the highest blue-green algal densities (4.8×10^3 organisms/mL) of the 18-month study period by Chimney et al. (1985) was typical for a temperate North American lake (Reid, 1961). Furthermore, the dominant Cyanophyta taxa reported by Chimney et al. (1985) and Wilde (1985) were typically found in nonthermal lakes throughout North America (see Prescott, 1982; Smith, 1950; Taft and Taft, 1971; Whitford and Schumacher, 1984).

The Par Pond phytoplankton community had representatives of all the major taxonomic groups (Bacillariophyta, Chlorophyta, Cryptophyta, Chrysophyta, Cyanophyta, Pyrrophyta, and Euglenophyta) that would be expected to occur in temperate North American freshwater lakes (see Hutchinson, 1967; Smith, 1950; Wetzel, 1983) and have been found in other southeastern lakes and reservoirs (e.g., Applied Biology, 1982; Carr, 1982; Hern et al., 1977).

It has been concluded that the Par Pond phytoplankton community is self-sustaining since these organisms have short generation times (hours-days; Fogg, 1965; Wetzel, 1983), and have persisted there for several years with similar community composition reported in 1978 and in 1984/1985 (Wilde, 1983; Chimney et al., 1985).

4.5.2.5 Expected Impacts from Restarting P Reactor

Since Par Pond has historically maintained a balanced indigenous phytoplankton community throughout the past operation of P Reactor, the restart of this reactor should be inconsequential relative to phytoplankton. A restart of P Reactor should result in slightly enhanced phytoplankton primary production in the vicinity of the Hot Dam, based on previous observations (Wilde, 1985).

4.5.3 Periphyton

4.5.3.1 Status of the Par Pond Periphyton Community

Several studies of periphyton attached to glass slides placed at various locations in Par Pond were conducted by Tilly (see Wilde and Tilly, 1985). A species list containing the principal taxa observed in these studies appears in Table 4-135. These studies also showed that primary production (measured as ^{14}C uptake) and standing crop (measured as dry weight) generally were greater at a station near the Hot Dam than in other areas of Par Pond. This trend was attributed to higher temperature and greater availability of nutrients at the Hot Dam station. There was no apparent domination by pollution-tolerant species ,and periphyton species composition was similar at the station near the Hot Dam to that of stations elsewhere in the pond.

4.5.3.2 Expected Impacts from Restarting P Reactor

Since previous reactor operations caused no apparent adverse impact to the periphyton of Par Pond, the restart of P Reactor should cause no appreciable harm.

4.5.4 Zooplankton

4.5.4.1 Species Composition and Abundance

The zooplankton community of Par Pond is composed of four major taxonomic groups: Protozoa, Rotifera, Cladocera, and Copepoda (Chimney et al., 1985). A total of 164 individual taxa (79 Protozoa, 68 Rotifera, 11 Cladocera, and 6 Copepoda) were identified from monthly samples collected between January 1984 and June 1985 (Table 4-136). Many of these taxa had been reported in previous studies (Vigerstad, 1980; Wilde and Tilly, 1985) conducted during the 1970's (Table 4-136).

Mean species richness, mean species diversity, mean total density of zooplankton and mean densities of Protozoa and Rotifera at a station near the point where the thermal effluent first enters Par Pond, were not statistically different from the other Par Pond stations (Chimney et al., 1985). However, mean densities of macrozooplankton (Copepoda and Cladocera) were significantly higher at this station when compared to other Par Pond stations. Based on these results, thermal impact on the zooplankton community in Par Pond appeared limited to the immediate area of the Hot Dam, and thermal discharges were considered to be beneficial to the system because Copepoda and Cladocera are readily utilized by fish as a food source (Chimney et al., 1985).

TABLE 4-135

Principal Periphyton Species[a] Collected from Par Pond[b]

Bacillariophyta

Achnanthes affinis
Achnanthes lanceolata
Achnanthes minutissima
Anomoeoneis vitrea
Cyclotella pseudostelligera
Cyclotella stelligera
Cymbella delicatula
Cymbella microcephala
Cymbella minuta v. silesiaca
Fragilaria crotonensis
Fragilaria pinnata
Fragilaria vaucheriae
Gomphonema carolinense
Gomphonema grunowii
Gomphonema intricatum
Gomphonema parvuium
Gomphonema subccavatum
Melosira distans v. alpigena
Melosira granulata v. angustissima
Nitzschia frustulum
Nitzschia frustulum v. perminuta
Synedra delicatissima v. angustissima
Synedra minuscula
Synedra rumpens
Synedra tenera
Synedra ulna
Tabellaria fenestrata

Cylorophyta

Actinastrum hantschii
Ankistrodesmus falcatus
Arthrodesmus octocornis
Bulbochaete sp.
Chlamydomonas sp.
Closterium cornu
Closterium sp.
Closterium venus
Cosmarium angulosum
Cosmarium asphaerosparum
Cosmarium bireme
Cosmarium bisphaericum
Cosmarium blyttii
Cosmarium circulare

TABLE 4-135, Contd

Chlorophyta, Contd

Cosmarium comminsurale var crassum
Cosmarium dentatum
Cosmarium excavatum f. duplomajor
Cosmarium exiguum
Cosmarium goleritum
Cosmarium impressulum
Cosmarium margaritatum
Cosmarium pardalis
Cosmarium phaseolus
Cosmarium psuedoconnatum
Cosmarium schliephakeanum
Cosmarium spp.
Cosmarium subcrenatum
Cosmarium tenue
Cosmocladium saxonicum
Dictyosphaerium pulchellum
Euastrum ciastonii
Euastrum denticulatum
Gonatozygon aculeatum
Gonatozygon brebissonii
Gonatozygon monotaenium
Mougeotia sp.
Oedogonium sp.
Oocystis borgei
Oscillatoria lutea
Oscillatoria princeps
Pandorina morum
Pediastrum duplex var recticulata
Pediastrum tetras var tetraedron
Pedidinium cinctum
Peridinium excavatum
Peridinium sp.
Peridinium umbonatum
Scenedesmus armatus
Scenedesmus brasiliensis
Scenedesmus quadricanda
Sphaerocystis schroeteri
Spirogyra sp.
Spondylosium planium
Staurastrum chaetocero
Staurastrum clevei
Staurastrum dejectum
Staurastrum dickei
Staurastrum leptocladum
Staurastrum manfeldtii
Staurastrum margaritaceum
Staurastrum megacanthum

TABLE 4-135, Contd

Chlorophyta, Contd

Staurastrum perundulatum
Staurastrum protectum
Staurastrum sp.
Staurastrum tetracerum
Staurastrum turgescen
Stigeoclonium flagelliferum
Stigeoclonium sp.
Xanthidium subhastiferum
Zygnema sp.

Cyanophyta

Agmenellum elegans
Amphidinium sp.
Anabaena circinalis
Anabaena sp.
Anacystis cyanea
Calothrix sp.
Gleocapsa sp.
Microcoleus sp.
Microcoleus vaginatus
Nostoc macorum
Nostoc sp.
Schizothrix arenaria
Schizothrix calcicola
Schizothrix sp.

Pyrrhophyta

Ceratium hirundinella

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[a] Identifications made by the Academy of Natural Sciences of Philadelphia under subcontract to Du Pont.
[b] Collections made from artificial substrates.

Source: Wilde (1985)

TABLE 4-136

Zooplankton Collected from Par Pond During Monthly Sampling in 1984-1985 and in Previous Studies During the 1970's

	1984-1985[a]	1970's[b]
Cladocera		
Acroperus of. harpae		x
Alona affinis		x
A. globulosa		x
A. guttata tuberculata		x
A. intermedia		x
A. karua		x
A. rectangula		x
A. rustica		x
A. setulosa		x
A. verrucosa		x
A. sp.		x
Alonella hamulata		x
B. longirostris cornuta		x
Bosmina longirostris	x	x
Chydorus brevilabris		x
C. piger		x
C. sphaericus		x
Camptocercus cf. rectorpstris		x
Ceriodaphnia lacustris		x
C. quadrangula		x
C. sp.	x	
Daphnia parvula	x	
Disparalona acutirostris		x
Eubosmina hagmanni		x
Eurycercus lamellatus		x
Eurycercus (Bullatifrons) sp.		x
E. (Eurycercus) microdontus		x
E. tubicen	x	
Holopedium amazonicum		x
Holopedium cf. gibberum	x	
Ilyocryptus spinifer		x
Macrothrix laticornus	x	
Macrothrix rosea		x
Moina micrura	x	
M. sp.		x
Pleuroxus denticulatus		x
Pseudochydorus globosus		x

TABLE 4-136, Contd

	1984-1985[a]	1970's[b]
Cladocera, Contd		
Scapholebris kingi		x
Simocephalus serrulatus		x
S. vetulus		x
Copepoda		
Cyclops leucarti		x
Cyclops varicans	x	x
Diaptomus mississippiansis	x	
Diaptomus spp.		x
Macrocyclops albidus	x	
M. ater	x	
Mesocyclops edax	x	
Tropocyclops prasinus	x	
Unid. calanoids		x
Rotifera[c]		
Anuraeopsis fissa	x	
Anureaopsis sp.	x	
Ascomorpha ovalis	x	
A. saltans	x	
Asplanchna priodonta	x	x
Unid. bdelloid rotifer	x	
Brachionus angularis	x	
Brachionus patulus	x	
Cephalodella intuta	x	
Cephalodella sp.	x	
Collothea mutabulis	x	
Colurella obtusa	x	
Colurella sp.	x	
Conochiloides dossuarius	x	
Conochilus unicornis	x	
Epiphanes macrourus	x	
Euchlanis sp.	x	
Filinia longiseta	x	
Gastropus stylifer	x	
Hexarthra mira	x	
Kellicottia bostoniensis	x	x
Keratella cochlearis	x	x
K. cochlearis f. hispida	x	
K. cochlearis f. pusilla	x	
K. cochlearis f. tecta	x	

TABLE 4-136, Contd

	1984-1985[a]	1970's[b]
Rotifera, Contd		
K. crassa	x	
L. flexilis	x	
L. inermis	x	
L. luna	x	
Lecane patella	x	
Lecane sp. 1	x	
Lecane spp.	x	
Lepadella acuminata	x	
L. cristata	x	
Lepadella patella	x	
Lepadella sp. 2	x	
Monommata aequalis	x	
Monostyla bulla	x	
M. closterocerca	x	
M. copeis	x	
M. lunaris	x	
M. obtusa	x	
Monostyla sp. 1	x	
Monostyla sp. 2	x	
Monostyla spp.	x	
Ploesoma truncata	x	
Platyias patulus	x	
Polyarthra euryptera	x	x
P. remata	x	
P. vulgaris	x	
Unid. Rotifera sp. 2	x	
Unid. Rotifera sp. 3	x	
Unid. Rotifera sp. 4	x	
Unid. Rotifera sp. 5	x	
Unid. Rotifera	x	
Synchaeta stylata	x	
Synchaeta spp.	x	
Testudinella parva	x	
Trichocerca cylindrica	x	x
T. longiseta	x	
T. lophoessa	x	
T. multicrinis	x	
T. procellus	x	
T. rousseleti	x	
T. similus	x	
Trichocerca sp. 2	x	

TABLE 4-136, Contd

	1984-1985[a]	1970's[b]
Rotifera, Contd		
Trichocerca sp. 3	x	
Trichocerca sp. 4	x	
Trichocerca spp.	x	
Trichotria tetractis	x	
Protozoa[d]		
Actinophrys sp.	x	
Arcella vulgaris	x	
Askenasia sp. 1	x	
Askenasia sp. 2	x	
Askenasia spp.	x	
Astramoeba sp.	x	
Unid. ciliate sp. 1	x	
Unid. ciliate sp. 2	x	
Unid. ciliate sp. 3	x	
Unid. ciliate sp. 4	x	
Unid. ciliate sp. 5	x	
Unid. ciliate sp. 6	x	
Unid. ciliate sp. 7	x	
Unid. ciliate sp. 8	x	
Unid. ciliate sp. 10	x	
Unid. ciliate sp. 12	x	
Unid. ciliate sp. 13	x	
Unid. ciliate sp. 14	x	
Unid. ciliate sp. 15	x	
Unid. ciliate sp. 17	x	
Unid. ciliate sp. 19	x	
Unid. ciliate sp. 20	x	
Unid. ciliate sp. 21	x	
Unid. ciliate sp. 23	x	
Unid. ciliate sp. 24	x	
Unid. ciliate spp.	x	
Centropyxis aculeata	x	
Condonella cratera	x	
Condylostoma vorticella	x	
Cyclotrichium sp. 1	x	
Cyclotrichium sp. 2	x	
Cyphodera ampulla	x	
Cyphodera sp.	x	
Didinium balbanii	x	

TABLE 4-136, Contd

	1984-1985[a]	1970's[b]
Protozoa, Contd		
D. balbanii v. nanum	x	
D. nastum	x	
D. limnetica	x	
Dileptus anser	x	
D. bivacuolatus	x	
Dileptus sp. 1	x	
Dileptus sp. 2	x	
Dileptus spp.	x	
Epistylis lacustris	x	
Euglypha ciliata	x	
E. laevis	x	
Euglypha sp.	x	
Euplotes sp.	x	
Holophyra simplex	x	
Unid. Holophyrid ciliate	x	
Mesodinium acarus	x	
Nebella caudata	x	
Nuclearia simplex	x	
N. simplex v. 1	x	
Opisthostyla similis	x	
Unid. Oxyotrich ciliate	x	
Paramecium sp. 1	x	
Paramecium sp. 2	x	
Paramecium spp	x	
Podophyra sp.	x	
Rhabdostyla sp.	x	
Spathidium sp.	x	
Spirostomum sp.	x	
Staurophyra elegans	x	
Strichotricha sp.	x	
Stokesia vernalis	x	
Strobilidium gyrans	x	
Strombidinopsis setigera	x	
Strombidium delicatissium	x	
S. minutum	x	
Strombidium spp.	x	
Unid. Suctorian ciliate	x	
Tintinnopsis sp.	x	
T. cylindrica	x	
Trachelius subtilis	x	

TABLE 4-136, Contd

	1984-1985[a]	1970's[b]
Protozoa, Contd		
Urotrichia sp. 1	x	
Urotrichia sp. 2	x	
Vorticella sp. 1	x	
Vorticella sp. 2	x	
Vorticella sp. 3	x	

[a] Chimney et al. (1985)
[b] Wilde and Tilly (1985)
[c] Identified to genus only in studies prior to 1984-1985.
[d] Not identified in earlier studies

4.5.4.2 Comparisons with Regional Lakes

To aid in determining if the zooplankton fauna of Par Pond represented an "indigenous balanced biological community," data from the study by Chimney et al. (1985) were compared to available values from the literature for other southeastern lakes and reservoirs (Table 4-137). The comparisons are biased by the fact that in the studies other than by Chimney et al. (1985), zooplankton were collected using towed plankton nets with mesh openings of 64 to 80 µm. Mesh of this size does not retain Protozoa and results in a substantial underestimation of both the abundance and taxonomic diversity of Rotifera. Nevertheless, these data are useful in assessing the present ecological status of Par Pond with comparable aquatic habitats. Zooplankton community composition (including the important and dominant taxa) and its seasonal dynamics observed during the study by Chimney et al. (1985) were typical of other southeastern lakes and reservoirs (Chimney et al., 1985).

4.5.4.3 Entrainment

Studies to determine the impact of zooplankton entrainment at the Par Pond pumphouse were conducted from January 1984 through June 1985 by Chimney et al. (1985). They compared the total numbers of zooplankton removed from the reservoir per day with estimates of zooplankton density for the whole reservoir. Differences in zooplankton species richness, species diversity, and species composition were also evaluated in an attempt to identify possible entrainment influence on the community.

Chimney et al. (1985) calculated that 3.5×10^{11} to 23.5×10^{11} (mean = 10.7×10^{11}) zooplankton organisms were lost per day to entrainment (Table 4-138). This estimate was based on data for mean daily withdrawal of water (m^3/day) at the Par Pond pumphouse (recorded by the SRS Power Engineering Department), mean total density of zooplankton within the intake structure, and an assumption of 100% mortality after passage through the reactor cooling system. Estimates of removal by reactor operations ranged between 0.4 and 2.3% (mean = 1.3%) of the total zooplankton community in Par Pond per day (Table 4-138).

Based on the mean density data for all Par Pond locations, Chimney et al. (1985) concluded that zooplankton were fairly evenly distributed throughout Par Pond. Thus, in the absence of avoidance of or attraction to the intake structure, the fraction of the whole-reservoir zooplankton population lost per day would be expected to correspond closely with the percent of the reservoir volume withdrawn during the same period. A t-test comparison indicated that monthly entrainment losses of zooplankton from Par Pond were not significantly ($P < 0.05$) different from the pumping rates over an 18-month period (Chimney et al., 1985). Differences between the percentage of the total pond volume pumped per day and the percentage of the total zooplankton population lost per day on a monthly basis were attributed to variability associated with estimating whole-reservoir zooplankton densities (Chimney et al., 1985). Thus, no avoidance or attraction was indicated.

TABLE 4-137

Comparison of Zooplankton Data from Par Pond and Pond B with Literature Values from Other Southeastern Lakes and Reservoirs (modified from Chimney et al., 1985)

Reservoir/Lake	Mean Total Density No./L	Maximum Total Density No./L	Mean Species Diversity	Maximum Species Diversity	Mean Species Richness (no. taxa)	Number Cladocera Taxa	Number Copepoda Taxa	Number Rotifer Taxa	Number Protozoa Taxa	Number Total Taxa
Par Pond, SC[a]	1480.7	4054.2	3.73	3.80	42	11	6	68	79	164
Pond B, SC[a]	936.9	3102.9	2.74	3.38	37	4	9	44	58	115
Southeastern Lakes/Reservoirs										
Lake Robinson, SC[b,c]	20.3	409.1	-*	-	4-13	13	8	33	4	58
Clarks Hill, SC[d]	64.8	310.8	-	-	-	19	7	31	2	59
Lake Hartwell, SC[e]	143.3	548.0	-	-	14	10	6	13	-	29
Lake Keowee, SC[f]	-	95.0	-	-	-	22	10	53	-	85
Lake Norman, NC[g]	39.6	190.5	-	-	-	-	-	-	-	-
Mt. Island, NC[h]	46.8	160.5	-	-	-	-	-	-	-	-
Lake Wylie, SC[g,h]	37.5	185.9	1.84	2.74	-	34	12	33	-	79
Fishing Creek, SC[g]	14.9	48.6	-	-	-	-	-	-	-	-
Lake Wateree, SC[g]	57.1	419.6	-	-	-	-	-	-	-	-
Parr Reservoir, SC[i]	93.4	231.0	2.87	3.17	17	-	-	-	-	-
Monticello Reservoir, SC[i]	96.1	384.0	2.78	3.18	16	-	-	-	-	-
Other Cooling Impoundments										
Sutherland Reservoir, NE[j]	675.4	1416.0	-	-	-	20	12	28	-	60
Dresden Cooling Pond, IL[k]	122.0	520.3	-	-	15	14	12	29	-	55
Lake Sangchris, IL[l]	-	-	2.08	3.00	-	28	10	29	-	67

Sources: * Data not available.
(a) Chimney et al., 1985; (b) Carolina Power and Light, 1976; (c) Mallin, 1984; (d) Applied Biology, 1982; (e) Carr and Assoc., 1982; (f) Duke Power Co., 1977; (g) Weiss et al., 1975; (h) Industrial Bio-Test, 1974; (i) Dames and Moore, 1985; (j) Nalco Environmental Sciences, 1976; (k) Ecological Analysts, 1982; (l) Lewis, 1984; and (m) Waite, 1981.

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TABLE 4-138

Entrainment of Par Pond Zooplankton (January 1984 - June 1985)

Month	Pumping Rate (m^3/day)[a]	Percent Reservoir Volume Pumped/ Day[b]	Reservoir Turnover Period (days)[c]	Whole Reservoir Population Estimate (no./m^3)	Zooplankton Lost/Day (no./m^3)[d]	Percent Par Pond Zooplankton Lost/Day[e]
1984						
January	8.1×10^5	1.3	76.2	690.0×10^{11}	5.2×10^{11}	0.8
February	8.0×10^5	1.3	77.4	860.0×10^{11}	11.8×10^{11}	1.4
March	7.5×10^5	1.2	83.0	1390.0×10^{11}	13.9×10^{11}	1.0
April	6.2×10^5	1.0	99.[illegible]	540.0×10^{11}	3.8×10^{11}	0.7
May	7.8×10^5	1.2	79.3	1560.0×10^{11}	23.5×10^{11}	1.5
June	7.6×10^5	1.2	81.7	400.0×10^{11}	9.3×10^{11}	2.3
July	7.8×10^5	1.3	79.7	300.0×10^{11}	5.1×10^{11}	1.7
August	7.8×10^5	1.3	79.3	390.0×10^{11}	7.9×10^{11}	2.0
September	8.7×10^5	1.4	71.0	700.0×10^{11}	9.6×10^{11}	1.4
October	7.9×10^5	1.3	78.2	1000.0×10^{11}	16.3×10^{11}	1.6
November	6.0×10^5	1.0	103.0	920.0×10^{11}	8.6×10^{11}	0.9
December	7.6×10^5	1.2	82.0	2220.0×10^{11}	18.7×10^{11}	0.8
1985						
January	7.9×10^5	1.3	78.9	850.0×10^{11}	11.1×10^{11}	1.3
February	7.7×10^5	1.2	80.5	1260.0×10^{11}	7.5×10^{11}	0.6
March	8.5×10^5	1.4	72.9	710.0×10^{11}	9.1×10^{11}	1.3
April	1.1×10^5	0.2	542.4	960.0×10^{11}	3.5×10^{11}	0.4
May	5.3×10^5	0.8	117.5	640.0×10^{11}	6.9×10^{11}	1.1
June	8.3×10^5	1.3	74.7	1130.0×10^{11}	21.1×10^{11}	1.9
Mean	7.2×10^5	1.2	108.8	920.0×10^{11}	10.7×10^{11}	1.3
(S.E.)	(0.4×10^5)	(0.1)	(25.7)	110.0×10^{11}	(1.4×10^{11})	(0.1)

[a] Data supplied by SRS Power Department

[b] Percent of total reservoir volume pumped/day = (mean daily pumping rate for month divided by reservoir volume) x 100.

[c] Reservoir turnover period = reservoir volume divided by mean daily pumping rate for month.

[d] Zooplankton lost/day = mean density of zooplankton within the pump wells x mean daily pumping rate for month.

[e] Percent Par Pond zooplankton lost = (zooplankton lost/day divided by whole-reservoir population estimate) x 100.

Source: Chimney et al. (1985)

Under normal environmental conditions, zooplankton have a tremendous reproductive potential (Allen, 1976). Generation times vary from several days to a few weeks (Wetzel, 1983; Pennak, 1978). This is much shorter than the present turnover rate (71-542 days) for Par Pond (Table 4-138). Organisms removed from the immediate vicinity of the pumphouse are rapidly replaced by in situ reproduction and by individuals reproduced elsewhere in Par Pond and transported into the Intake Arm. During the study by Chimney et al. (1985), average entrainment accounted for the removal of 1.3% of the total zooplankton community in Par Pond per day. In comparison, natural mortality rates of zooplankton caused by predation have shown losses to exceed 10% of the entire population on a daily basis (Dodson, 1972; Fedorenko, 1975; Kajak and Ranke-Rybicka, 1970). Natural mortality rates would be even higher if other sources of mortality, such as disease and starvation, were considered. Entrainment rates in Par Pond were considered to be well within the limits that could be sustained without adverse impact to the zooplankton community (Chimney et al., 1985).

The entrainment estimates by Chimney et al. (1985) were based on an assumption of 100% zooplankton entrainment mortality throughout the year. During periods when P Reactor was shutdown (about 30% of the time), entrained organisms were subjected only to the mechanical and pressure stresses associated with passage through the reactor cooling system. It can be assumed that some of the organisms survived the journey. However, data are not available to permit valid estimates of survival during periods when the reactor was not operating. It is also not possible to accurately predict what the zooplankton community in Par Pond would be like in the absence of entrainment. However, in spite of entrainment losses, Par Pond had a substantially more abundant and diverse zooplankton community than did Pond B, a system not subject to entrainment (Chimney et al., 1985).

It was concluded that because of the tremendous reproductive potential of zooplankton, the stability of the Par Pond zooplankton community inferred from previous data, and the favorable comparisons between the zooplankton community of Par Pond with those of other southeastern lakes and reservoirs, entrainment at the Par Pond pumphouse causes no significant adverse effects on the zooplankton community of Par Pond.

4.5.4.4 Status of Par Pond Zooplankton Community

The Par Pond zooplankton community was not dominated by any species or taxonomic group considered to be pollution tolerant. Comparisons with other lakes and reservoirs showed that the zooplankton community in Par Pond was equal to or greater than those of other lakes in terms of diversity and standing crop. All major taxonomic groups typical of the region were well represented, and based on the historical presence of zooplankton in Par Pond, it is evident that the community is successfully reproducing and self-sustaining.

4.5.4.5 Expected Impacts from P-Reactor Operation

Since a balanced indigenous zooplankton community has been maintained during previous operations of P Reactor, operation of this reactor is not expected to cause any appreciable harm to the existing community.

4.5.5 Par Pond Macroinvertebrates

Benthic macroinvertebrates and meroplankton were collected in the North Arm, Intake Arm, Hot Arm and Cold Dam areas of Par Pond (Figure 4-64) from February 1984 - May 1985 (Kondratieff et al., 1985). Triplicate quantitative benthic samples were collected with a petite ponar grab sampler on a quarterly basis in each area at four sites that included shallow, intermediate, and deep water habitats. Qualitative benthic samples were collected quarterly from representative littoral habitats (emergent vegetation, submerged vegetation, mud substrate, and sand substrate) with a D-frame dip net. Quantitative duplicate macroinvertebrate meroplankton samples were collected biweekly using 505-μm mesh plankton nets at eight transects in Par Pond and at the Par Pond pumphouse (Figure 4-65). Sampling and processing methods are detailed in Kondratieff et al. (1985).

For all sampling methods combined, a total of 160 macroinvertebrate taxa were collected from Par Pond (Table 4-139). Of these, 47 taxa were collected by ponars, 97 were collected by dip-nets, and 109 were collected in the plankton nets.

4.5.5.1 Benthic Macroinvertebrates

The benthic macroinvertebrate community of Par Pond in the four sampling areas was dominated by dipterans (29.0 to 58.6%) and oligochaetes (segmented worms; 20.9 to 25.8%; Table 4-140). Chironomid midges and phantom midges (Chaoborus punctipennis) were by far the most common dipterans in the benthos (Kondratieff et al., 1985). Other common macroinvertebrate taxa included pelecypods (clams; 3.5 to 12.7%), turbellarians (flatworms; 0.7 to 13.0%), amphipods (1.1 to 3.8%) and gastropods (snails; 0.7 to 7.1%; Table 4-140). Mean species richness (number of taxa collected at a sampling location on a sampling date) ranged from 11.5 at the Cold Dam to 12.5 in the North Arm (Table 4-141). No differences in species richness were found among sampling locations.

Densities of benthic macroinvertebrates ranged from 2410.0 organisms/m^2 in the Intake Arm to 7224.8/m^2 in the Hot Arm (Table 4-141). Densities in the Hot Arm were significantly higher than in the other three regions of Par Pond due to greater abundance of chironomids and oligochaetes (Table 4-140) and are probably related to thermal inputs to the Hot Arm (Kondratieff et al., 1985).

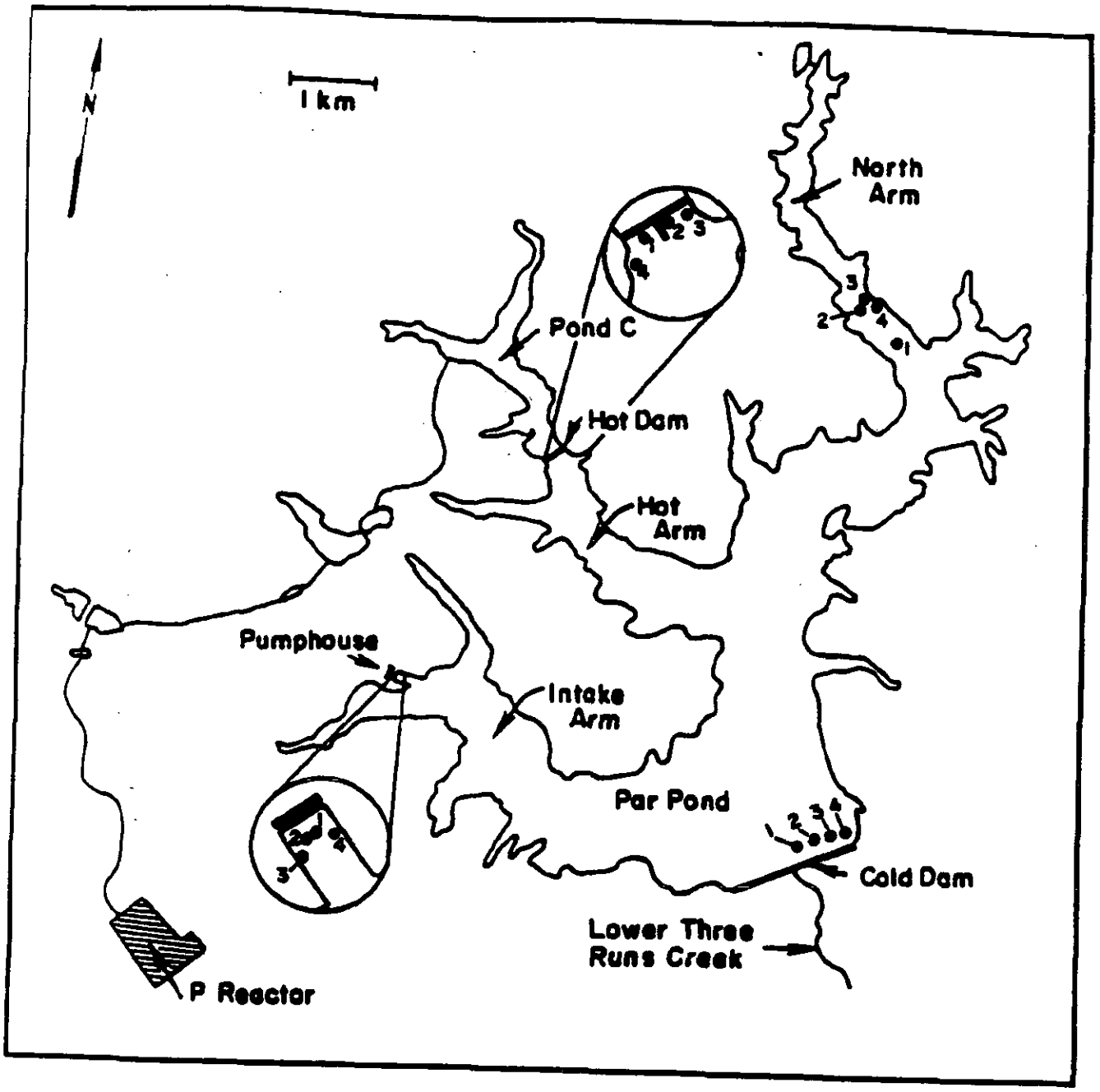

FIGURE 4-64. *Sampling Stations for Benthic Macroinvertebrates in Par Pond (1984-1985)* (source: Kondratieff et al., 1985)

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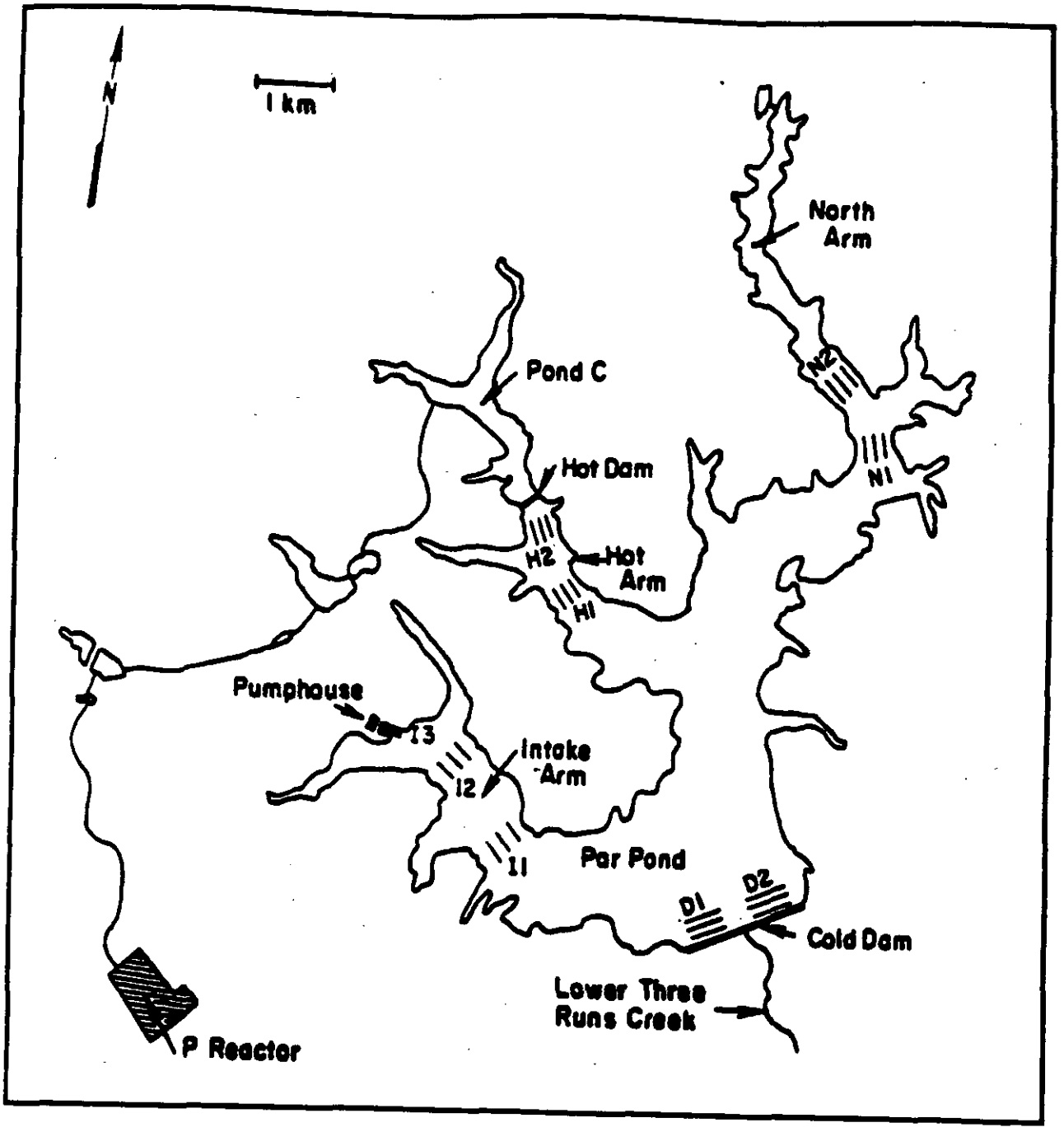

FIGURE 4-65. Sampling Stations for Macroinvertebrate Meroplankton in Par Pond (1984-1985) (source: Paller and Saul, 1985)

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TABLE 4-139

Par Pond and Pond B Macroinvertebrate Taxa (1984-1985)

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Coelenterata			
Cordylophora lacustris		4	M
Craspedacusta sowerbyi		4	M
Hydra sp.	Hydra	4	M
Phylum Platyhelminthes	Flat worms		
Class Turbellaria			
Dugesia tigrina		4	D,N,M
Phylum Aschelminthes	Round worms		
Class Nematoda			
Unid. spp.		1	D,M
Phylum Annelida			
Class Oligochaeta	Segmented worms		
Nais sp.		1	M
Stylaria lacustris		1	D,M
Unid. Naididae		1	D,M
Class Hirudinea	Leeches		
Unid. spp.		4	D,M
Phylum Mollusca			
Class Gastropoda	Snails		
Amnicola limosa		3	D,N,M
Ancylidae			
Unid. Ancyclidae		3	M
Campeloma decisum		3	D,M
Ferrisia rivularis		3	N,M
Gyraulus parvus		3	N,M
Helisoma anceps		3	D,N,M
H. trivolvis		3	D,N,M
Menetus dilitatus		3	D,N,M
Physella heterostropha		3	D,N,M
Pseudosuccinea columella		3	N

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Mollusca, contd			
Class Pelecypoda	Clams		
Anodonta imbecillus		2	N
Corbicula fluminea		2	D,N,M
Elliptio complanata		2	M
Sphaeriidae			
Unid. sphaeriidae		2	D,N,M
Phylum Arthropoda			
Class Arachnoidea			
Order Hydracarine	Water mites		
Albia sp.		7	D,M
Arrenurus sp.		7	M
Frontipoda americana		7	M
Hydrodroma despiciens		7	M
Koenikea sp.		7	M
Limnesia sp.		7	D,M
Neumania sp.		7	M
Piona sp.		7	M
Unionicola sp.		7	D,M
Unid. sp. A		7	M
Unid. sp. C		7	M
Unid. sp. D		7	M
Unid. spp.		7	M
Class Crustacea			
Order Amphipoda	Scuds		
Hyalella azteca		1	D,N,M
Order Isopoda	Isopods		
Asellus sp.		1	D,M
Order Ostracoda	Seed shrimp		
Unid. sp. A		2	M
Unid. sp. B		2	M
Order Decapoda	Crayfish		
Procambarus sp.		6	N,M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Anthropoda, contd			
Class Insecta			
Order Collembola	Springtails		
Isotomurus palustris		1	M
Unid. spp.		1	D,M
Order Ephemeroptera	Mayflies		
Baetis spp.		1	D,N,M
Caenis diminuta		1	N
Caenis spp.		1	D,N,M
Callibaetis floridanus		1	N
Callibaetis sp.		1	D,N,M
Stenonema sp.		1	
Order Odonata	Dragonflies & damselflies		
Anax longipes		4	N
Aphylla williamsoni		4	D,N,M
Argia fumipennis		4	M
Argia spp.		4	N
Basiaeschna janata		4	N
Brachymesia gravida		4	N
Celithemis fasciata		4	D,N
C. ornata		4	D,N
Celithemis sp.		4	N,M
Coryphaeschna ingens		4	N,M
Didymops transversa		4	N
Dromogamphus spinosus		4	N
Enallagma divagans		4	N,M
E. vesperum		4	N,M
E. hageni		4	N,M
Enallagma sp.		4	D,N,M
Epiaeschna heros		4	N
Epicordulia princeps		4	M
E. regina		4	N
Erythemis simplicicollis		4	N
Ischnura spp.		4	M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Arthropoda, contd			
Gomphidae			
Gomphus exilis		4	N
Lestes vigilax		4	D,N
Lestes sp.		4	N,M
Libellula auripennis		4	N
L. axilena		4	N
L. cyanea		4	N
L. incesta		4	N
Libellula sp.		4	N
Nehalennia sp.		4	N
Pachydiplax longipennis		4	D,N,M
Perithemis tenera		4	N,M
Progamphus prob. *obscurus*		4	N
Tetragoneuria cynosura		4	D,N
Tetragoneuria sp.		4	N,M
Unid. spp.		4	N
Order Hemiptera	True bugs		
Belostoma flumineum		7	N
Belostoma sp.		7	D,N,M
Merragata brunnea		7	N
Mesovelia mulsanti		7	D,N,M
Neoplea striola		7	N,M
Felocoris femoratus		7	N
Ranatra sp.		7	N
Trichocorixa macroceps		7	N
Trichocorixa sp.		7	N
Order Plecoptera	Stone flies		
Unid. sp.		4	M
Order Coleoptera	Beetles		
Agabus		7	N
Bagous sp.		6	N,M
Berosus sp.		5	N
Celina sp.		7	D,N,M
Curculionidae			
Cybister fimoriolatus		7	N
Disonycha sp.		6	D,M
Donacia sp.		6	N,M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Arthropoda, contd			
Dubiraphia bivattata		1	M
Haliplus prob. americanus		6	N,M
H. triopsis		6	N
H. fasciatus		6	N
Haliplus sp.		6	N,M
Hydroporus prob. hybridus		6	D,N,M
Hydroporus spp.		6	D,N,M
Hydrovatus pustulatus		6	N
Macronychus glabratus		1	M
Peltodytes dietrichi		6	N
P. sexmaculatus		6	N
Peltodytes sp.		6	N,M
Pyrrhalta nymphaeae		4	N
Thermonectus basillaris		7	M
Noteridae			
Hydrocanthus sp.		4	N
Unid. sp.		4	D
Order Trichoptera	Caddisflies		
Ceraclea maculata		1	M
Cernotina spicata		4	D,N,M
Cheumatopsyche sp.		2	M
Cyrnellus fraternus		4	M
Hydropsyche sp.		2	M
Hydroptila sp.		5	M
Leptocerus americanus		6	D,M
Oecetis inconspicua		4	N
Oecetis sp. 2		4	M
Orthotrichia sp.		5	D,N,M
Oxyethira spp.		5	D,N,M
Polycentropus sp.		4	N
Ptilostomis sp.		4	N
Triaenodes spp.		6	N,M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Arthropoda, contd			
Order Lepidoptera	Moths		
Eoparargyractis sp.		6	N,M
Langessa nomophilalis		6	N,M
Munroessa gyralis		6	M
Munroessa sp.		6	N
Parapoynx spp.		6	D,N,M
Pyralidae			
Synclita sp.		6	N,M
Unid. sp.		6	N
Order Diptera	True flies		
Chaoboridae			
Chaoborus punctipennis		4	D,N,M
Culicidae			
Mansonia perturbans		1	N
Ceratopogonidae			
Bezzia sp.		4	M
Unid. spp.		4	D,M
Emphididae			
Unid. spp.		4	M
Ephydridae			
Unid. spp.		1	M
Tipulidae			
Limonia sp.		6	N
Pilaria sp.		2	N
Unid. spp.		6	N
Psychodidae			
Psychoda alternata		1	M
Telamatoscopus sp.		1	M
Unid. spp.		1	D,M
Simuliidae			
Simulium sp.		2	M
Chironomidae			
Chironominae			
Glyptotendipes sp.		1	M
Parachironomus sp.		1	M
Unid. spp.		1	D,N,M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

TABLE 4-139, Contd

Scientific Name	Common Name	Group[a]	Sampling Method[b]
Phylum Arthropoda, contd			
Orthocladiinae			
Unid. spp.		1	D,N,M
Tanypodinae			
Ablabesmyia sp.		4	M
Clinotanypus sp.		4	M
Labrundinia sp.		4	M
Procladius sp.		4	M
Thienemannimyia sp.		4	M
Unid. spp.		4	D,N,M

[a] Functional groups: 1 = collector-gatherer; 2 = collector-filterer; 3 = scraper; 4 = predator-engulfer; 5 = herbivore-piercer; 6 = shredder; 7 = piercer-carnivore.

[b] D = dredge (quantitative benthic) sample; N = net (qualitative benthic) sample; M = meroplankton sample.

Source: Kondratieff et al. (1985)

TABLE 4-140

Percent Abundance of Benthic Macroinvertebrates in Par Pond (1984-1985)

Taxa	Sampling Area[a] H	N	D	I
Coelenterata	0.0	0.0	0.3	0.4
Turbellaria	13.0	2.8	0.7	5.0
Nemotoda	16.0	1.0	1.7	2.0
Annelida				
Oligochaeta	21.6	20.39	25.8	23.6
Hirudinea	2.6	0.6	0.3	0.2
Ostracoda	0.0	0.0	0.1	0.0
Crustacea				
Isopoda	0.0	0.0	<0.1	0.0
Amphipoda	3.6	3.8	1.1	1.4
Decapoda	0.0	0.0	0.0	0.0
Hydracarina	0.4	0.5	0.2	0.3
Insecta				
Collembola	0.0	0.0	0.0	0.0
Odonata	<0.1	0.3	0.3	0.7
Ephemeroptera	<0.1	0.7	<0.1	<0.1
Plecoptera	0.0	0.0	0.0	0.0
Hemiptera	0.0	<0.1	0.0	0.0
Neuroptera	0.0	0.0	0.0	0.0
Trichoptera	0.3	1.2	0.9	1.4
Lepidoptera	0.0	<0.1	<0.1	0.1
Coleoptera	<0.1	0.2	0.1	<0.1
Diptera	29.0	58.6	58.0	47.1
Gastropoda	0.7	5.8	3.6	7.1
Pelecypoda	12.7	3.5	7.0	10.6
Total[b]	99.9	99.9	100.1	99.9

[a] H = Hot Arm, N = North Arm, D = Cold Dam, and I = Intake Arm
[b] Some columns may not total 100.0% due to rounding.

Source: Kondratieff et al. (1985).

TABLE 4-141

Mean Species Richness, Mean Density, and Mean Species Diversity for Benthic Macroinvertebrates from Par Pond (1984-1985)

Sampling Area	Mean Species Richness (S.E.)[a]	Mean Density as No./m^2 (S.E.)	Mean Species Diversity (S.E.)	Mean Biomass (AFDW, g/m^2) (S.E.)
Hot Arm	11.6 (0.6)	7224.8 (1272.3)	1.97 (0.07)	41.77 (9.53)
North Arm	12.5 (1.3)	3814.8 (357.2)	1.96 (0.09)	6.76 (10.85)
Cold Dam	11.5 (1.1)	4090.2 (448.2)	1.90 (0.09)	8.12 (8.26)
Intake Arm	12.2 (1.0)	2416.0 (207.4)	2.07 (0.06)	26.76 (11.16)

[a] S.E. = standard error

Source: Kondratieff et al., 1985

Mean species diversity, as calculated by the Shannon-Weaver function (Weber, 1973), ranged from 1.90 at the Cold Dam to 2.07 in the Intake Arm (Table 4-141). Diversity at all stations generally decreased with increasing depth; this pattern has been commonly reported for lakes and reservoirs (Thut, 1969). There were no significant differences in diversity among stations. The species diversity values for Par Pond are generally lower than those reported for other reservoirs in the United States. This difference is probably is due to differences in the levels of taxonomic resolution among studies and is not believed to be related to thermal impacts (Kondratieff et al., 1985).

Macroinvertebrates were separated into functional feeding groups, based on their mode of feeding. Functional groups included collector-gatherers, collector-filterers, scrapers, shredders, piercer-herbivores, engulfer-predators, and piercer-carnivores (Merritt and Cummins, 1984). The relative abundances of these trophic groups are illustrated in Figure 4-66. Collector-gatherers (37.4 to 61.9%) and engulfer-predators (24.2 to 51.4%) were the dominant functional groups at all stations. Collector-gatherers were primarily composed of oligochaetes, midges and nematodes, whereas engulfer-predators consisted primarily of Turbellaria (flatworms), phantom midges, and leeches (Hirudinea). The collector-filterer functional group (3.6 to 12.9%) was represented almost exclusively by clams [mostly the Asiatic clam (Corbicula fluminea) and fingernail clams (Sphaeriidae)]. Scrapers (0.7 to 7.3%) consisted mostly of snails. The remaining functional groups each accounted for less than one percent of the organisms collected.

Mean benthic biomass (ash-free dry weight) ranged from 6.76 g/m^2 in the North Arm to 41.77 g/m^2 in the Hot Arm (Table 4-141). The Hot Arm had a significantly higher mean biomass than all sampling areas due primarily to higher densities of the Asiatic clam (Table 4-140).

4.5.5.2 Macroinvertebrate Meroplankton

The meroplankton macroinvertebrate community at most sampling locations in Par Pond was dominated by dipterans (composed mostly of Chaoborus punctipennis and midges; 28.9 to 90.6%) and oligochaetes (2.7 to 41.7%: Table 4-142). Other abundant taxa in the meroplankton samples included Trichoptera (1.2 to 45.5%), pelecypods (0.8 to 15.8%), Hydracarina (water mites; 1.2 to 13.8%), gastropods (0.1 to 8.7%), and amphipods (0.1 to 3.5%). Some of these taxa (e.g., pelecypods and gastropods) are typically associated with benthic habitats and/or aquatic vegetation. These taxa were probably collected when the meroplankton net inadvertently bumped the lake bottom or brushed against aquatic vegetation. Samples collected from the pumphouse intakes often contained a relatively high percentage of caddisflies (Trichoptera; Table 4-142). The caddisflies collected from the pumphouse were solely Cyrenella fraternus, a river species that undoubtedly found suitable habitat in the flowing water of the pump wells. This species was not collected at other locations in Par Pond.

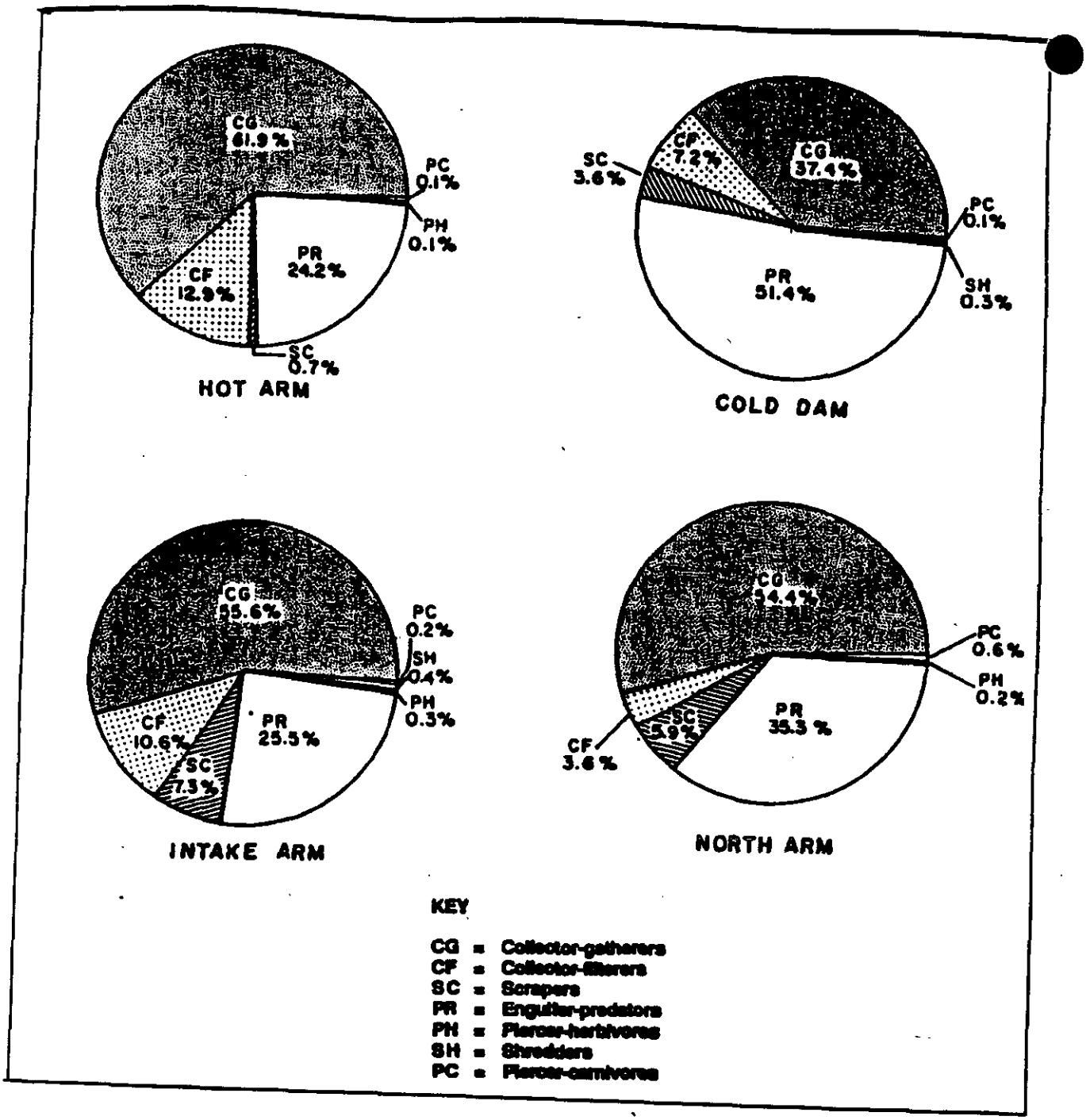

FIGURE 4-66. Percent Abundance of Benthic Macroinvertebrate Functional Feeding Groups in Par Pond (1984-1985) (source: Kondratieff et al. (1985)

TABLE 4-142

Percentage Abundance of Major Macroinvertebrate Meroplankton Taxa Collected from Par Pond (1984-1985)

Taxa	Sampling Locations H1[a]	H2	N1	N2	D1	D2	I1	I2	P
Diptera	63.4	58.0	53.0	35.9	60.2	90.6	41.1	28.9	32.4
Trichoptera	3.6	5.9	2.3	1.6	1.3	1.2	2.2	4.3	45.5
Odonata	0.3	0.3	0.5	0.3	0.3	0.1	0.9	1.2	0.1
Ephemeroptera	0.2	0.1	0.2	0.2	0.4	0.1	0.5	0.8	0.2
Amphipoda	0.7	0.3	1.3	2.0	0.7	0.1	2.5	3.5	0.9
Gastropoda	0.5	2.8	0.3	0.3	0.8	0.1	0.9	8.7	0.8
Pelecypoda	2.5	1.6	0.8	2.6	3.2	0.2	15.8	0.9	0.5
Oligochaeta	22.6	25.7	26.9	41.3	28.5	2.7	25.2	41.7	8.6
Turbellaria	0.2	0.9	0.2	0.7	0.2	0.0	0.6	2.5	1.5
Nematoda	1.8	1.0	0.1	0.2	0.0	0.0	0.2	0.2	0.2
Hydracarina	2.8	1.2	13.8	12.8	4.5	3.6	6.4	3.8	8.8
Ostracoda	1.3	1.6	0.3	0.2	0.5	0.9	0.9	2.2	0.2
Other	0.1	0.6	0.3	2.0	0.5	0.2	2.8	1.3	0.2
Total[b]	100.0	100.0	100.0	100.0	100.1	99.8	100.0	100.0	99.9

[a] H = Hot Arm; N = North Arm; D = Cold Dam; I = Intake Arm; P = Pumphouse
[b] Some columns may not equal 100.0% due to rounding.

Source: Kondratieff et al. (1985)

Meroplankton samples collected from near the surface of the lake typically contained fewer taxa and much lower densities of organisms than those samples collected near the bottom (Table 4-143). The mean number of taxa collected per 50 m^3 meroplankton sample ranged from 2.2 to 4.8 taxa for near-surface samples and from 3.0 to 7.2 taxa for near-bottom samples. No obvious differences in species richness were noted between the Hot Arm and the remainder of the lake. Meroplankton densities ranged from 47.4 to 265.6 organisms/1000 m^3 in the near-surface samples, while near-bottom densities were usually several times higher, ranging from 241.6 to 1026.4 organisms/1000 m^3 (Table 4-143). Meroplankton densities were highly variable, as evidenced by the large standard errors reported in Table 4-143.

Macroinvertebrate meroplankton in Par Pond exhibited distinct diel activity patterns, with most species having higher nocturnal densities (Kondratieff et al., 1985). Mean daytime meroplankton densities ranged from 407.9 organisms/1000 m^3 in the North Arm to 820.2 organisms/1000 m^3 at the Cold Dam (Table 4-144). Nighttime densities were often one to five orders of magnitude greater than daytime densities, with mean densities ranging from 17,072.6 organisms/1000 m^3 in the Intake Arm to 55,286.6 organisms/1000 m^3 in the North Arm. Peak nighttime densities as high as 276,023 organisms/1000 m^3 were reported during the study (Table 4-144). These high meroplankton densities were due almost exclusively to nocturnal migrations of the phantom midge, Chaoborus punctipennis, from the sediments into the water column. This behavior pattern has been reported in many other lakes and reservoirs (LaRow, 1969; LaRow and Marzolf, 1970; Lewis, 1975). The meroplankton community of the Hot Arm of Par Pond was similar to the remaining portions of the reservoir with respect to all of the parameters that were measured.

4.5.5.3 Impact Evaluation

Par Pond supports a diverse and productive macroinvertebrate community. The Hot Arm of Par Pond, which is subject to an elevated temperature regime during reactor operation, was similar to the remainder of the lake with respect to species richness, species diversity, or overall species composition. However, the Hot Arm supported higher densities of macroinvertebrates than did the rest of the lake, particularly nematodes, oligochaetes, flatworms, amphipods, and clams. These higher densities probably reflect overall higher levels of productivity in the Hot Arm, which have resulted in increased food sources for these macroinvertebrate taxa. The high macroinvertebrate densities are not considered to be deleterious, but rather, provide a more abundant food supply for higher trophic levels in the lake, particularly for centrarchids, such as sunfish and juvenile largemouth bass. Following the restart of P Reactor, it is anticipated that the macroinvertebrate community of Par Pond will be similar to the community that existed in 1984-1985 when the data discussed in this section (Section 4.5.5) were collected.

TABLE 4-143

Mean Species Richness and Mean Density of Macroinvertebrate Meroplankton Samples Collected from the Top and Bottom of the Water Column at Sample Locations in Par Pond (1984-1985)

Sampling Location	Mean Species Richness (no. of taxa)		Mean Density (organisms/1000 m^3)	
	Top (S.E.)[a]	Bottom (S.E.)	Top (S.E.)	Bottom (S.E.)
Station				
Hot Arm 1	2.6 (0.4)	3.0 (0.4)	57.7 (9.7)	324.9 (99.1)
Hot Arm 2	3.1 (0.3)	4.3 (0.6)	139.4 (42.6)	445.9 (135.1)
North Arm 1	3.8 (0.3)	4.4 (0.5)	207.4 (53.9)	528.5 (170.1)
North Arm 2	2.6 (0.4)	4.9 (0.7)	121.0 (35.2)	1026.4 (572.8)
Cold Dam 1	3.4 (0.5)	3.5 (0.5)	166.1 (61.8)	456.7 (160.5)
Cold Dam 2	2.7 (0.3)	3.1 (0.3)	133.8 (41.7)	770.3 (453.5)
Intake Arm 1	2.2 (0.2)	4.1 (0.4)	47.4 (9.2)	241.6 (100.9)
Intake Arm 2	4.8 (0.6)	7.2 (0.7)	265.6 (127.8)	416.2 (81.6)
Mean	3.2 (0.3)	4.3 (0.5)	142.3 (25.6)	526.3 (90.1)

[a] S.E. = standard error

Source: Kondratieff et al. (1985)

TABLE 4-144

Diel Differences in Mean Density (organisms/1000 m^3) of Macroinvertebrate Meroplankton in Par Pond (1984-1985)

	Day		Night	
	Mean	Range	Mean	Range
Hot Arm	559.3	0 - 4,599	50,828.0	837 - 170,261
North Arm	407.9	23 - 2,016	55,286.8	1,570 - 231,578
Dam	820.2	20 - 3,967	37,178.7	373 - 276,023
Intake Arm	767.1	167 - 3,907	17,072.6	763 - 53,707

Source: Kondratieff et al. (1985)

4.5.6 Fish Communities

Par Pond is a 1,102-ha reactor cooling reservoir created in 1958 by constructing an earthen dam on Lower Three Runs Creek (Figure 4-67). Par Pond functions as a recirculating cooling reservoir for P Reactor. Water used to cool P Reactor is withdrawn from the south (Intake) arm of Par Pond, passes through the P-Reactor heat exchangers, and is discharged into Pond C, a 67-ha precooling reservoir for Par Pond. Heated water from Pond C enters the middle (Hot) arm of Par Pond through a culvert beneath the dam that separates the two reservoirs.

Paller and Saul (1985) conducted fisheries survies in Par Pond from January 1984 through June 1985. They collected both adult/juvenile fish (monthly) and ichthyoplankton (biweekly) at sample stations in the North Arm, Intake Arm, Hot Arm, and Cold Dam areas of Par Pond (Figure 4-67). Four techniques (electrofishing, gill netting, hoop netting, and angling) were used to collect juvenile and adult fish from each sample area; effort was apportioned equally among sample areas. Ichthyoplankton were collected by towing paired 0.5-m diameter 505 µm mesh plankton nets near the top and bottom of the water column in each sample area. Ichthyoplankton were also collected from the intake wells in the Par Pond pumphouse to estimate entrainment rates. In addition to Paller and Saul (1985), a number of other researchers have studied the fishes of Par Pond. These studies are cited at various places in this report.

Abundance and Distribution

Paller and Saul collected at least 23 species of fish from Par Pond. The dominant species (based on total weight, all methods combined) were lake chubsucker, largemouth bass, bluegill, and black crappie (Table 4-145). Brook silverside was important numerically but constituted only a small proportion of the biomass. Mean electrofishing, angling, and gill netting catch rates in the Hot Arm of Par Pond were as high or higher than in the other Par Pond sampling areas (Tables 4-146 and 4-148). Largemouth bass and black crappie were particularly abundant in the Hot Arm relative to the other sampling areas (Table 4-149). Mean species number was lower in the Hot Arm (7.9) than in the other sample areas (9.9 to 10.6), as was mean Shannon-Weaver diversity (1.1 compared with 1.81 to 2.24). A localized area of somewhat depressed species richness and diversity in the Hot Arm had previously been reported by Hogan (1978).

Other researchers have also reported high densities of some species of fish in the Hot Arm of Par Pond. Gibbons et al. (1972) and Martin (1980) indicated that largemouth bass were more abundant in the Hot Arm than elsewhere in Par Pond. Largemouth bass, black crappie, and bluegill may be attracted to the relatively warm waters in the Hot Arm during the winter because temperatures are closer to preferred levels than in cooler parts of the lake. However, these species have also been collected in large numbers in the Hot Arm during the summer when water temperatures exceeded preferred levels, possibly as a result of greater food availability in the Hot Arm. Cove rotenone samples collected by Hogan (1978)

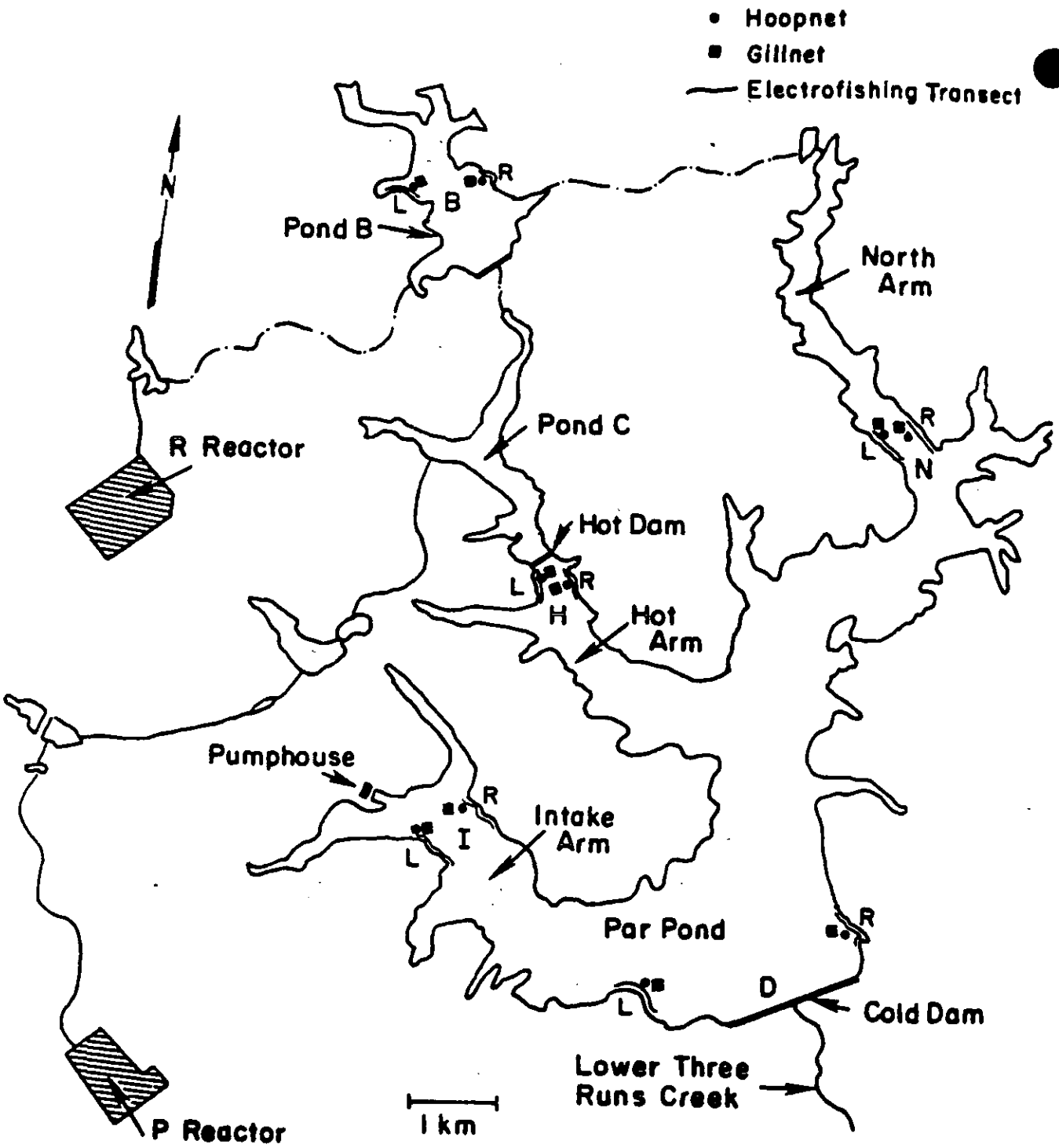

FIGURE 4-67. Map of Par Pond Showing Location of Monthly Adult and Juvenile Fish Sampling Stations in Par Pond (January 1984 - June 1985) (source: Paller and Saul, 1985)

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TABLE 4-145

Number of Individuals and Total Weight of All Adult Fish Species Collected in Par Pond (January 1984 - June 1985)

Species	Collecting Method: Electrofishing No.	Electrofishing Wt.(kg)	Gill Netting No.	Gill Netting Wt.(kg)	Hoop Netting No.	Hoop Netting Wt.(kg)	Angling No.	Angling Wt.(kg)	All Methods Combined No.	All Methods Combined Wt.(kg)
Game Fish										
Largemouth bass	1530	312.6	651	333.9	4	1.7	166	142.0	2351	790.2
Black crappie	38	7.3	69	30.0	5	1.4	85	45.2	197	83.9
White crappie	2	0.5	0	0.0	0	0.0	0	0.0	2	0.5
Bluegill	1758	42.8	52	14.2	6	0.8	35	11.2	1851	69.0
Redbreast sunfish	67	2.3	3	0.8	1	0.2	0	0.0	71	3.3
Pumpkinseed	1	<0.1	0	0.0	0	0.0	0	0.0	1	<0.1
Dollar sunfish	8	<0.1	0	0.0	0	0.0	0	0.0	8	<0.1
Spotted sunfish	13	0.4	0	0.0	0	0.0	0	0.0	13	0.4
Warmouth	37	2.8	9	0.9	1	0.1	0	0.0	47	3.8
Unid. sunfish	1	<0.1	0	0.0	0	0.0	0	0.0	1	<0.1
Yellow perch	87	1.4	22	6.8	0	0.0	0	0.0	109	8.2
Forage Fish										
Lake chubsucker	601	138.5	1727	964.0	44	21.8	0	0.0	2372	1124.3
Brook silverside	4971	4.6	0	0.0	0	0.0	0	0.0	4971	4.6
Blueback herring	4	<0.1	2	0.2	0	0.0	0	0.0	6	0.2
Gizzard shad	1	1.2	113	157.3	2	2.1	0	0.0	116	160.6
Golden shiner	180	1.7	137	15.5	1	<0.1	0	0.0	318	17.2
Shiners (*Notropis* spp.)	336	0.3	0	0.0	0	0.0	0	0.0	336	0.3
Mosquitofish[a]										
Swamp darter (*Etheostoma* spp.)[b]										
Rough Fish										
Bowfin	24	40.2	16	28.9	1	3.6	0	0.0	41	72.7
Chain pickerel	128	18.5	33	15.0	0	0.0	0	0.0	161	33.5
Redfin pickerel	4	0.4	0	0.0	0	0.0	0	0.0	4	0.4
Yellow bullhead	9	7.4	36	23.9	1	<0.1	0	0.0	46	31.3
Brown bullhead	0	0.0	21	14.8	0	0.0	0	0.0	21	14.8
Flat bullhead	1	1.1	120	70.1	0	0.0	0	0.0	121	71.2
White catfish	0	0.0	2	1.3	0	0.0	0	0.0	2	1.3

[a] Observed but not collected.
[b] Taken in ECS ichthyoplankton collections.

Source: Paller and Saul (1985)

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TABLE 4-146

Mean Number of Adult Fish Captured Monthly per 100 m of Shoreline by Electrofishing at Sampling Locations in Par Pond (January 1984 - June 1985)[a]

Month	Sampling Areas: Cold Dam	Hot Arm	Intake Arm	North Arm
1984				
January	19.7	275.0	7.7	38.2
February	1.2	23.5	38.7	98.0
March	8.5	10.8	6.3	9.7
April	13.5	31.7	2.5	21.0
May	6.7	2.3	6.3	9.0
June	14.3	1.2	5.7	2.3
July	20.5	11.7	4.7	6.2
August	6.3	13.3	3.5	2.8
September	12.0	5.7	48.8	5.8
October	29.5	10.7	17.5	20.3
November	20.0	25.5	32.7	40.5
December	24.0	7.7	94.3	21.7
1985				
January	3.5	10.3	4.2	9.0
February	7.8	89.7	21.8	86.3
March	10.0	21.7	9.0	52.7
April	15.2	21.2	64.2	28.8
May	12.0	2.3	10.8	7.7
June	2.3	0.7	2.8	0.3
Mean for all months	12.6	31.4	21.2	25.6

[a] Each value is the mean number of fish collected from six 100-m transects paralleling the shoreline.

Source: Paller and Saul (1985)

TABLE 4-147

Angling Catch (no./100 casts) at Sampling Areas in Par Pond (January 1984 - June 1985)

Month	Sampling Areas: Cold Dam	Hot Arm	Intake Arm	North Arm
1984				
January	12	13	1	1
February	10	10	12	9
March	1	1	1	1
April	5	7	7	2
May	0	61	9	1
June	10	12	0	0
July	1	17	1	0
August	1	36	3	1
September	1	15	1	0
October	1	1	1	1
November	0	9	3	3
December	0	12	0	2
1985				
January	1	1	0	2
February	1	0	0	1
March	0	1	4	0
April	0	0	0	0
May	0	0	0	2
June	1	0	0	0
Mean for all months	2.5	10.9	2.4	1.4

Source: Paller and Saul (1985)

TABLE 4-148

Number of Adult Fish Captured per Gill Net Day at Sampling Areas in Par Pond[a]

Month	Sampling Areas: Cold Dam	Hot Arm	Intake Arm	North Arm
1984				
January	18.5	53.0	26.0	27.0
February	26.5	23.0	12.5	22.0
March	26.5	10.5	19.0	35.5
April	26.0	20.0	18.0	19.0
May	17.5	35.5	26.5	22.0
June	10.5	29.0	14.5	11.0
July	19.0	53.5	15.0	17.0
August	18.0	38.0	14.0	15.0
September	11.0	1.5	14.5	11.5
October	19.0	27.0	11.0	24.0
November	15.0	24.5	12.0	18.5
December	12.0	14.5	19.0	11.0
1985				
January	23.0	2.0	26.0	8.5
February	29.5	0.5	10.5	6.5
March	14.0	9.0	16.0	36.0
April	39.5	25.0	31.0	17.0
May	41.5	6.5	24.5	22.5
June	18.0	43.0	21.5	51.0
Mean for all months	21.4	23.1	18.4	20.8

[a] Two gill nets were set for 24 hr in each sampling area each month.

Source: Paller and Saul (1985)

TABLE 4-149

Mean Monthly Numbers of Fish Collected by All Methods Combined at Sampling Areas in Par Pond (January 1984 - June 1985)

Species	Par Pond Cold Dam	Hot Arm	Intake Arm	North Arm
Largemouth bass	24.3	40.5	19.9	19.4
Black crappie	2.0	6.8	1.2	0.9
Bluegill	25.7	35.7	14.1	27.3
Lake chubsucker	36.7	28.0	28.1	38.4
Brook silverside	4.9	113.6	68.4	89.3
All species combined	121.9	245.4	166.6	197.5

Source: Paller and Saul (1985)

indicated that the standing crop of small fishes (the preferred forage of largemouth bass and large crappie, Carlander, 1977) was approximately twice as high in the Hot Arm as in other areas of Par Pond. Janssen and Geisy (1984) suggested that largemouth bass may be attracted to the Hot Arm by the presence of moribund forage fish flushed into Par Pond from Pond C following reactor starts. Macroinvertebrates (the preferred forage of bluegill and smaller crappie, Carlander, 1977) were more abundant in the Hot Arm than elsewhere in Par Pond (Chimney et al., 1985; Kondratieff et al., 1985). The turbulent flow associated with the discharge area may also serve to attract some fishes. Thus, a combination of factors may attract some species of fish to the discharge area in the Hot Arm.

Comparisons with Other Reservoirs

Fish community structure in Par Pond as a whole compares favorably to that in other lakes and reservoirs in the United States. A comparison of cove rotenone samples collected from Par Pond (Clugston, 1973; Hogan, 1978; and Martin, 1980) with cove rotenone samples collected from other South Carolina reservoirs indicated that total standing crop, species number (with the exception of 1972), and Shannon Weaver diversity in Par Pond was within the range exhibited by other reservoirs (Paller and Saul, 1985; Table 4-150). The percentage of gamefish in Par Pond was generally higher than in the other reservoirs. Lake chubsuckers, which composed a relatively large percentage of the standing crop in all of the Par Pond collections, were absent from the other reservoirs. Lake chubsuckers, however, often occur in natural lakes in the coastal plain of the Carolinas (Carlander, 1975).

Data from cove rotenone sampling in 1969 and 1978 (Clugston, 1973; and Martin, 1978) suggested that largemouth bass constituted a higher percentage of the standing crop in Par Pond than in most other reservoirs. Largemouth bass standing crop during these years (24 and 21 kg/ha, respectively) was approximately twice as high as the average in United States reservoirs as reported by Jenkins (1975). During 1972 and 1977, however, largemouth bass standing crop in Par Pond was only 5.6 and 8.8 kg/ha. Clugston (1973) suggested that the reduction in 1972 may have been partly a sampling artifact caused by the movement of largemouth bass into open water where they were not susceptible to collection by cove rotenone sampling (Clugston, 1973). Relatively recent mark-recapture studies in 1978-1979 (Martin, 1980) and 1980-1981 (Gilbert and Hightower, 1981) indicated standing crops of approximately 40 to 100 "catchable size" fish/ha, suggesting the occurrence of a dense population of largemouth bass in Par Pond, probably due to the lack of fishing in this reservoir. Lack of fishing mortality is probably also responsible for the preponderance of large bass in Par Pond. Proportional stock density (PSD, Anderson, 1980) values reflect the proportions of large and small fish in a population. Desirable PSDs for largemouth bass generally range from 40 to 60%, with higher values reflecting proportionally more large bass. The PSD for largemouth bass in Par Pond, as reported by Paller and

TABLE 4-150

Relative Abundance (Percentage Composition) of Fishes Collected from Par Pond and Other Reservoirs by Cove Rotenone Sampling

Taxa	Par Pond, SC (1969)	Par Pond, SC (1972)	Par Pond, SC (1975-76)	Par Pond, SC (1978)	Non-heated South Carolina Reservoirs: Greenwood (1968)	Hartwell (1968)	Secession (1968)	Clarks Hill (1968)	Heated Reservoirs, Texas Reservoirs: Striker Creek (1968)	Eagle Mountain (1974)	Colorado City (1976)	Colorado City (1968)	Lake Sangchris, IL (1974-76)
Blueback herring	0.1	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bluegill	25.3	13.7	25.1	30.5	9.1	24.9	30.0	34.1	4.9	1.8	4.8	19.6	6.3
Other sunfishes	13.1[a]	13.7[a]	10.8	15.0	2.4	5.5	5.0	4.1	46.5[b]	4.4	11.9	10.1	2.4
Bullheads	0.8	2.3	2.4	0.5	2.0	2.9	2.8	2.1	0.3	1.0	0.1	1.4	0.9
Bowfin	2.5	1.8	2.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	2.8	3.5	0.0	0.0
Carp	0.0	0.0	0.0	0.0	0.0	16.9	9.2	13.9	9.4	12.6	5.6	18.4	7.5
Catfishes	0.0	0.0	0.0	0.0	0.7	0.4	1.8	9.6	5.8	9.2	4.4	7.0	2.6
Chain pickerel	4.5	12.9	7.5	5.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crappie	2.6	1.7	1.1	2.5	0.3	4.7	0.5	0.8	0.3	0.3	0.6	1.4	0.1
Lake chubsucker	15.4	42.3	33.8	19.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buffaloes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.5	22.7	0.0	0.0
Other suckers	2.2	0.0	0.0	0.0	1.4	0.4	0.0	0.6	0.0	1.9	0.8	3.0	0.0
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.7	27.2	0.0	0.9
Gizzard shad	0.0	0.0	0.0	0.0	76.9	17.5	28.6	19.1	14.1	12.1	7.2	27.4	76.3
Threadfin shad	0.0	0.0	0.0	0.0	0.0	6.3	3.2	4.7	0.1	0.1	3.9	0.0	0.0
Golden shiner	0.4	5.2	5.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Largemouth bass	22.8	5.6	8.0	17.4	5.0	6.1	10.3	6.0	17.8	7.4	6.4	6.6	1.0
White bass	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.5	0.3	0.7	0.5	0.3
Yellow perch	5.8	0.9	3.4	1.2	2.2	13.1	7.3	4.2	0.0	0.0	0.0	0.0	0.0
Other Species	4.6	0.0	0.2	0.1	0.4	0.9	1.3	0.8	0.4	0.0	0.1	4.5	2.6
Total percent	100.1	100.1	100.0	100.0	101.0	100.0	100.0	100.0	100.1	100.1	99.9	99.9	101.7[c]
Total kg/ha	105.2	176.8	262.5	136.1	346.2	112.0	197.3	96.7	89.4	265.1	189.0	159.4	360.9
Number of species	19	14	-	20	17	21	17	19	19	22	22	19	19
Diversity	0.93	0.79	-	-	0.42	0.94	0.84	0.89	0.84	0.96	1.00	0.93	0.44
Percent game fish	69.6	35.6	48.4	66.6	20.3	55.1	54.9	58.8	75.8	23.4	28.8	45.2	12.7
Percent rough and forage fish	30.4	64.4	51.6	33.4	79.7	44.9	45.1	41.2	24.2	76.6	71.2	54.8	87.3

[a] Primarily warmouth.
[b] Primarily redear.
[c] Percent as reported as Tranquilli et al. (1979) totaled 101.7.

Source: Paller and Saul (1985); adapted from Clugston (1973), Tranquilli et al. (1979), and Becker et al. (1979).

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Saul (1985) was 68%. While the percentage of large bass in Par Pond was unusually high, small and intermediate fishes were also present in substantial proportions (Figure 4-68) indicating continuous recruitment and growth.

Condition and Disease

The condition factor (K) is a weight-to-length ratio indicating the robustness of a fish. High condition factors indicate food intake in excess of maintenance requirements (Bennett, 1970). Paller and Saul (1985) reported that the mean condition factor of largemouth bass from Par Pond (1.15) was lower than the average for other U.S. reservoirs (1.41, Carlander, 1977) (Table 4-151). Large (450 to 550 mm) bass exhibited the lowest condition factors (Table 4-152). Gibbons et al. (1978) suggested that low condition factor of fish in heated areas of Par Pond might be attributable to the mobilization of tissue reserves as a result of increased metabolic requirements. However, studies by Hogan (1978) suggest that the supply of forage fishes in Par Pond may be insufficient, particularly for large bass which require larger forage fish for adequate nutrition (Pitcher and Hart, 1982). This conclusion was supported by stomach analysis data (Paller and Saul, 1985) which indicated relatively few fish in the stomachs of bass over 500 mm (Table 4-153). Fish usually constitute the predominant food of large largemouth bass (Pflieger, 1975; Saike and Tash, 1978; Lewis, 1968). Fish and insects were the primary foods of 100 to 500 mm largemouth bass in Par Pond. Unlike largemouth bass, the condition of bluegill and black crappie from Par Pond was comparable to that in other U.S. reservoirs (Paller and Saul, 1985) (Table 4-151). The feeding habits of bluegill from Par Pond were also similar to those of bluegill in other U.S. reservoirs (Paller and Saul, 1985).

There have been several studies of disease and parasitism among Par Pond fishes. Esch and Hazen (1978) documented the occurrence of red-sore disease among largemouth bass in Par Pond. Hazen et al. (1978) reported the Aeromonas hydrophila was the primary etiologic agent of red-sore disease in Par Pond, and that the probable route of infection was the surface epithelium of the fish. Largemouth bass from the warmest areas in Par Pond exhibited a significantly higher incidence of infection than fish from cooler areas (Hazen, 1978). Between 1976 and 1977, from 5 to 40% of the largemouth bass collected from Par Pond had infections associated with red-sore disease (Hazen, 1979). The prevalence of red-sore disease was much lower (under 1%) in 1984 and 1985 (Paller and Saul, 1985, Table 4-154.

Reproduction

Temperature can influence gonadal development in fish and affect the time of reproduction. The gonadosomatic index (GSI), a gonad weight to body weight ratio (Kaya and Hasler, 1972), was used to evaluate the reproductive status of largemouth bass from Par Pond. These data indicated that largemouth bass in Par Pond begin to reproduce at approximately the same size (270 to 280 mm for females and slightly smaller for males) as largemouth bass in other lakes and reservoirs (Heidinger, 1975). Seasonal

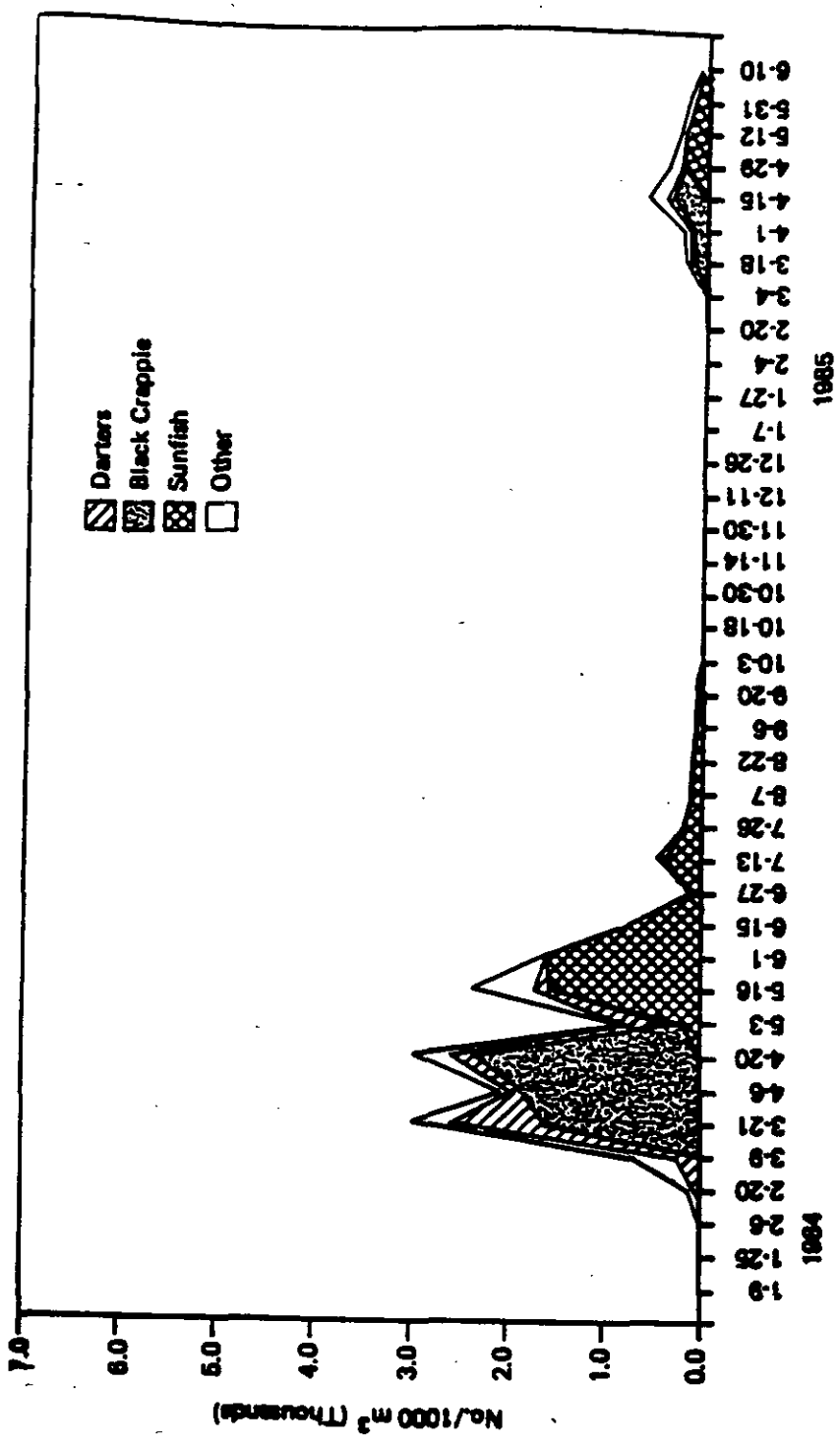

FIGURE 4-68. **Size Distribution of Largemouth Bass Collected by Electrofishing in Par Pond (January 1984 - June 1985)** (source: Paller and Saul, 1985)

TABLE 4-151

Mean Condition Factors (K) of Selected Species from Par Pond Compared with the Mean Condition Factors from Other Lakes, Reservoirs, Ponds, and Rivers in the United States[a] (June 1985)

Species	Other Bodies of Water			
	Par Pond	Range of Means	Mean of Means	Number
Largemouth bass	1.15	1.08 - 1.95	1.41	50
Bluegill	1.72	1.11 - 3.27	1.89	51
Black crappie	1.33	0.79 - 1.71	1.41	24

[a] Means for other bodies of water from Carlander (1977)

Source: Paller and Saul (1985)

TABLE 4-152

Mean Condition Factor (K) of Largemouth Bass of Different Sizes from Par Pond (January 1984 - June 1985)

Length Class (mm)	Cold Dam		Hot Arm		Intake Arm		North Arm		All Stations	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
51-100	1.09	13	1.25	4	1.30	13	1.09	16	1.16	46
101-150	1.06	43	1.03	14	1.02	27	1.08	27	1.05	111
151-200	1.12	34	1.10	77	1.10	20	1.07	33	1.10	164
201-250	1.15	28	1.12	140	1.26	27	1.23	27	1.15	222
251-300	1.11	21	1.17	67	1.28	17	1.19	15	1.18	120
301-350	1.22	71	1.19	126	1.22	63	1.21	59	1.20	319
351-400	1.24	102	1.16	115	1.26	74	1.25	46	1.22	337
401-450	1.16	125	1.10	164	1.17	88	1.17	73	1.14	450
451-500	1.04	28	1.01	47	1.06	22	1.09	14	1.04	111
501-550	1.16	6	0.90	5	1.11	7	0.83	2	1.04	20

Source: Paller and Saul (1985)

TABLE 4-153

Percentage Composition by Weight of the Stomach Contents of Largemouth Bass of Different Sizes from Par Pond and Pond B (January 1984 - June 1985)

Total Length (mm)	No.	Percent Empty Stomachs[a]	Average Percent Fullness[b]	Average Percent Fish[c]	Insect[c]	Crayfish[c]	Mollusk[c]	Annelid[c]	Other[d]
Par Pond									
101-200	26	34.6	0.44	58.8	17.6	0.0	0.0	0.0	23.5
201-300	157	28.7	0.64	66.2	16.1	0.0	0.9	0.1	16.6
301-400	388	44.1	0.37	66.2	13.4	1.8	1.0	0.1	16.5
401-500	396	44.7	0.27	57.0	19.5	2.5	0.6	1.4	19.6
501-600	14	42.9	0.38	25.0	25.0	12.5	0.0	0.0	37.5
Pond B									
201-300	109	35.8	0.35	57.8	29.6	0.0	0.0	0.0	12.6
301-400	75	53.3	0.34	73.8	20.9	0.0	0.0	0.0	5.3

[a] Number of fish with empty stomachs divided by number in column 2 times 100.
[b] Weight of stomach contents divided by body weight times 100.
[c] Weight of material in each category (fish, insect, etc.) divided by total weight of stomach contents times 100.
[d] Principally small vertebrates, including turtles and amphibians, or plant material.

Source: Paller and Saul (1985)

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TABLE 4-154

Prevalence of Red-Sore Disease in Par Pond Fish (January 1984 - June 1985)

Species	Location	Month	Number of Fish
Lake chubsucker	Intake Arm	March 1984	1
	North Arm	March 1984	1
	Hot Arm	April 1984	4
	Cold Dam	May 1984	2
Bluegill	Hot Arm	August 1984	2
Largemouth bass	Hot Arm	August 1984	1
		April 1985	1

Totals

Species	No. of Fish with Red Sore	Number Captured	Red Sore Prevalence (%)
Lake chubsucker	8	2,372	0.34
Bluegill	2	1,851	0.11
Largemouth bass	2	2,351	0.09

Source: Paller and Saul, 1985

trends in the GSI of female bass from Par Pond suggested that spawning began earlier in the Hot Arm than in a nearby unheated reservoir (Pond B) or in cooler areas within Par Pond (Paller and Saul, 1985).

Paller and Saul (1985) collected the ichthyoplankton (drifting larvae and eggs) of at least 11 species of fish from Par Pond during 1984 and 1985 (Table 4-155). Black crappie, sunfishes, and darters together constituted 83.6% of the larvae collected from Par Pond. With the exception of darters, mean ichthyoplankton densities in the Hot Arm were within the range of the mean densities in the other Par Pond sample areas. Ichthyoplankton (all taxa summed) densities were approximately seven times higher during 1984 than during 1985 (Figure 4-64; Paller and Saul, 1985); however, approximately 10 times more blueback herring larvae were collected during 1985 than during 1984 (Paller and Saul, 1985). There were no obvious reasons for these differences between years. Ichthyoplankton densities generally peaked several weeks earlier in Par Pond than in Pond B, a nearby unheated reservoir, suggesting (as did the GSI data) that the elevated temperatures in Par Pond may result in early spawning (Figures 4-69 and 4-70).

Entrainment and Impingement

Because P Reactor operates in a recirculation mode, ichthyoplankton in Par Pond are subject to entrainment within the P-Reactor cooling system. All ichthyoplankton entrained into the P-Reactor cooling system when the reactor is operating are assumed to be killed due to high temperatures in the heat exchangers. Based on samples taken during daylight hours, Paller and Saul (1985) estimated that 1975.2×10^5 ichthyoplankton were entrained into the Par Pond water intakes during January - June 1985 (Table 4-157). Entrainment rates were 15 times higher during January to mid-June 1984 than during January to mid-June 1985. This was the result of higher larval densities near the intakes during 1984 and higher pumping rates during April 1984. Diel samples (Table 4-158) suggested that entrainment rates may have been as much as ten times higher during the night than during the day. While avoidance of the ichthyoplankton nets during the day may have exagerated the day/night differences in Table 4-158, fish larvae are known to enter the water column at night resulting in real increases in density. If the relationships between night and day entrainment was consistent over most of the sample period, total entrainment in Par Pond may have been as much as five times greater than the preceding estimate, which was based only on daytime samples. Ichthyoplankton densities in Par Pond were much higher in 1984 this than in 1985 despite the fact that pumping rates (and therefore entrainment) were higher during 1984. This suggested that factors other than entrainment control ichthyoplankton abundance in Par Pond.

Instead of being entrained into cooling systems, larger fish can be impinged on the trash racks and screens that protect intake structures. The stationary screens at the Par Pond water intakes are inspected once a year and the trash racks are inspected approximately once every five years (Wilde, 1985b). Dead fish have never been observed on either the trash racks or the screens during these inspections. Mean current velocities

TABLE 4-155

Number (total number collected) and Percentage Composition of Ichthyoplankton Collected During Biweekly Sampling Areas in Par Pond (January 1984 - June 1985)

Species	Cold Dam		Hot Arm		Intake Arm		North Arm		All Areas	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Brook silverside	277	2.1	185	1.2	479	1.3	222	0.8	1163	1.2
Blueback herring	95	0.7	178	1.1	913	2.5	234	0.8	1420	1.5
Gizzard shad	74	0.6	498	3.1	366	1.0	413	1.5	1351	1.4
Unid. clupeid	107	0.8	599	3.8	433	1.2	258	0.9	1397	1.5
Largemouth bass	86	0.6	2147	13.6	7	<0.1	2	<0.1	2242	2.4
Bluegill	0	0.0	0	0.0	2	<0.1	0	0.0	2	<0.1
Black crappie	3845	28.5	4384	27.7	11074	30.2	14263	51.4	33566	35.8
Yellow perch	18	0.1	1	<0.1	34	0.1	30	0.1	83	0.1
Darters (*Etheostoma* spp.)	5231	38.8	880	5.6	3369	9.2	4472	16.1	13952	14.9
Unid. pickerel	0	0.0	0	0.0	3	<0.1	0	0.0	3	<0.1
Suckers	0	0.0	0	0.0	1	<0.1	2	<0.1	3	<0.1
Minnows (Cyprinidae)	16	0.1	0	0.0	10	<0.1	1	<0.1	27	<0.1
Sunfish (*Lepomis* spp.)	3099	23.0	5721	36.2	15940	43.5	6098	22.0	30858	32.9
Unid. sunfish	389	2.9	765	4.8	3124	8.5	1349	4.9	5627	6.0
Unid. fishes	242	1.8	466	2.9	926	2.5	396	1.4	2030	2.2
Total percent		100.0		100.0		100.0		99.9		99.9
Total number	13479		15824		36681		27740		93724	

Source: Paller and Saul (1985)

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TABLE 4-156

Mean Ichthyoplankton Densities at Sampling Areas in Par Pond and Pond B (January 1984 - June 1985)

Taxa	Densities (No./1,000 m^3)			
	Cold Dam	Hot Arm	Intake Arm	North Arm
Darters	103.5	18.8	54.9	92.3
Crappie	84.2	97.8	180.4	333.2
Sunfishes (*Lepomis* spp.)	60.9	118.1	240.9	123.1
All taxa	275.5	349.0	577.5	612.3

Source: Paller and Saul (1985)

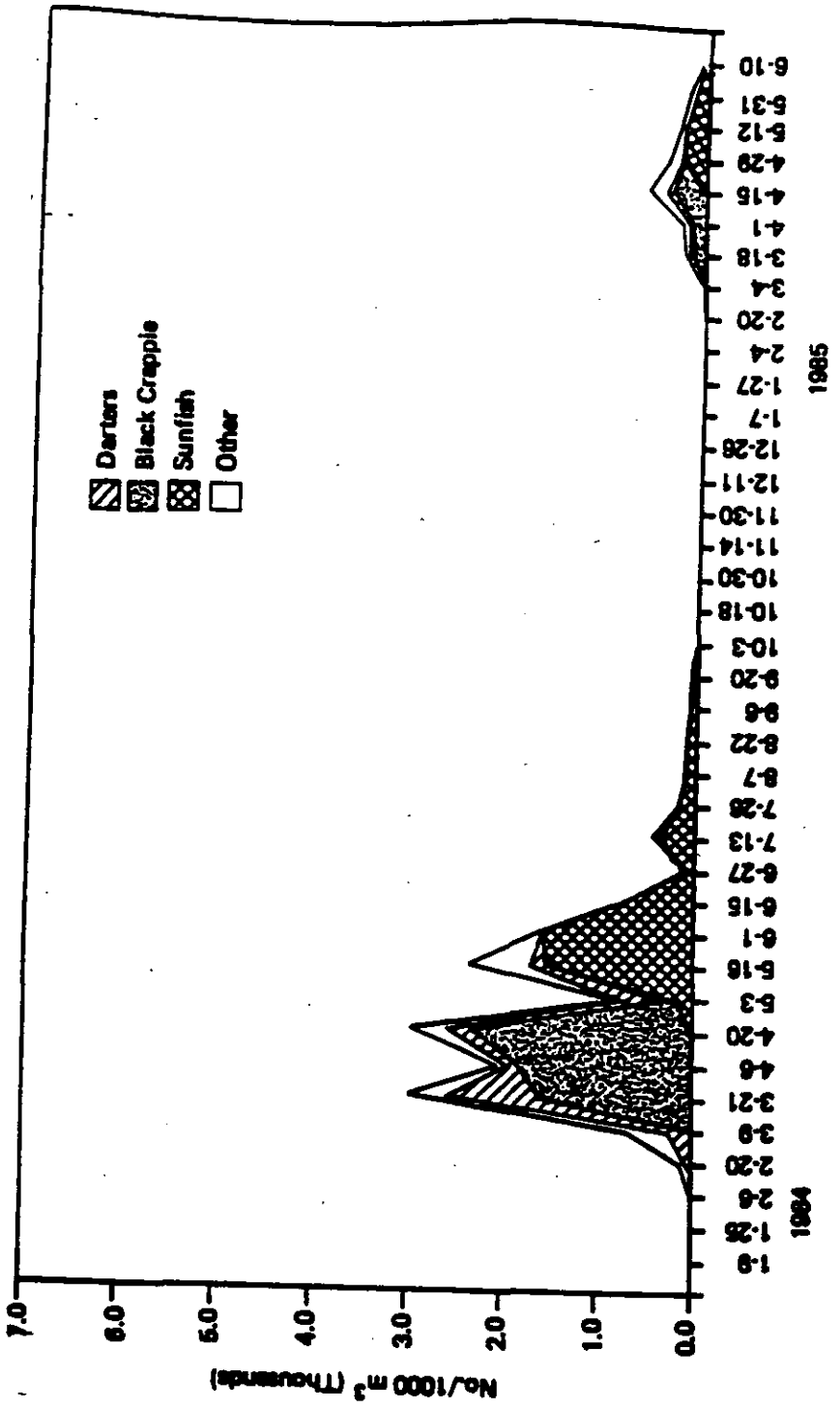

FIGURE 4-69. Total Ichthyoplankton in Par Pond, January 1984 - June 1985 (source: Paller and Saul, 1985)

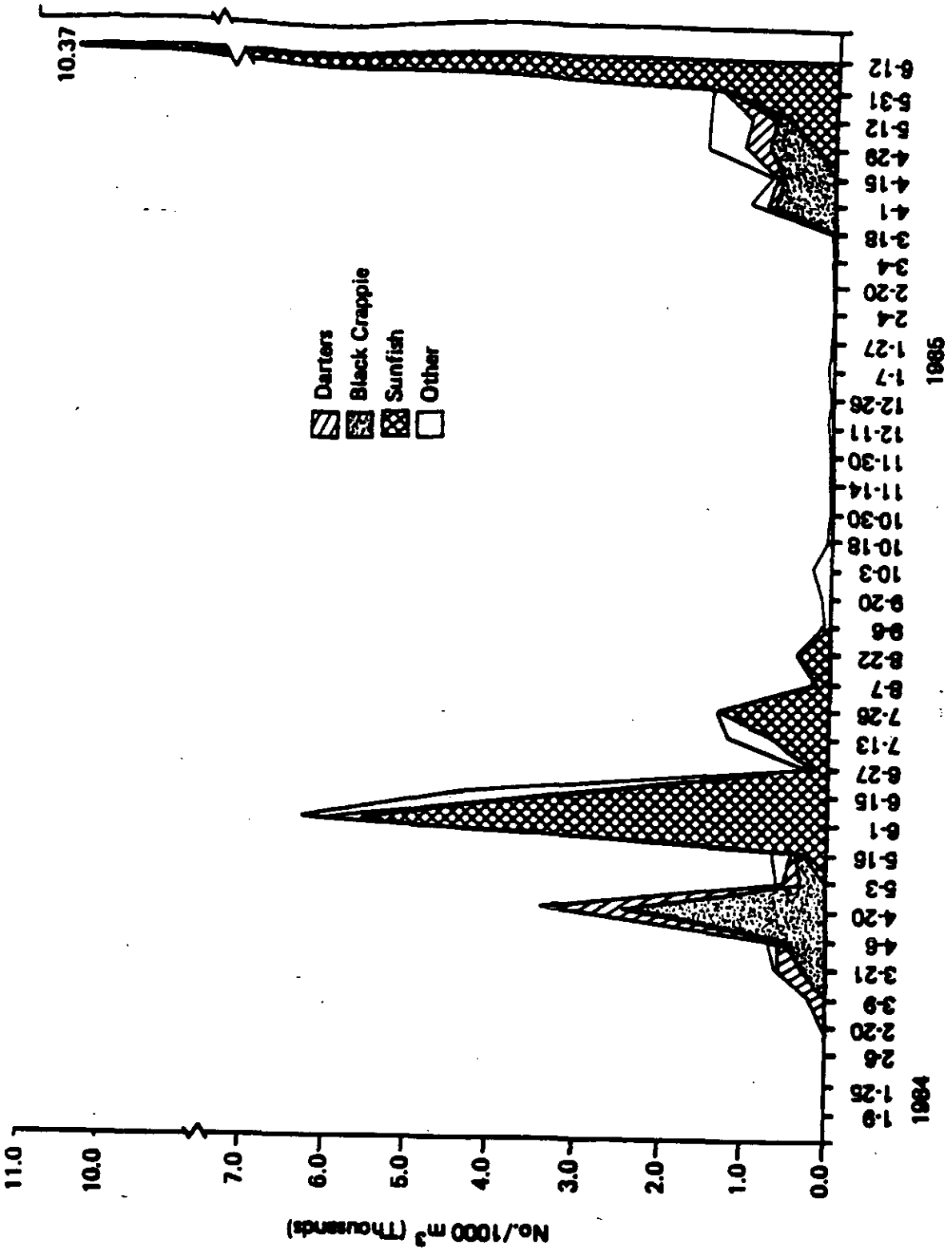

FIGURE 4-70. Total Ichthyoplankton in Pond B, January 1984 - June 1985 (source: Paller and Saul, 1985)

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TABLE 4-157

Entrainment of Ichthyoplankton into the Par Pond Pumphouse Calculated on the Basis of Biweekly Ichthyoplankton Samples Taken During Daylight Hours (January 1984 - June 1985)

Interval	Days in Interval	Mean Daily Pumping Rate[a] ($m^3 \times 10^5$)	Mean Density (No./1,000 m^3)	Number Entrained/ day x 10^5	Number Entrained Over Entire Interval x 10^5
01/09/84-01/24/84	16	8.6	0.0	0.0	0.0
01/25/84-02/05/84	12	7.2	13.3	0.1	1.2
02/06/84-02/19/84	14	8.4	26.7	0.2	2.8
02/20/84-03/08/84	18	7.5	601.7	4.5	81.0
03/09/84-03/20/84	12	7.4	3511.7	26.0	312.0
03/21/84-04/05/84	16	8.6	4388.3	37.7	603.2
04/06/84-04/19/84	14	7.0	1855.0	13.0	182.0
04/20/84-05/02/84	13	4.8	581.7	2.8	36.4
05/03/84-05/15/84	13	8.6	1698.3	14.6	189.8
05/16/83-05/31/84	16	4.8	1906.7	9.2	147.2
06/01/84-06/14/84	14	6.5	488.3	3.2	44.8
06/15/84-06/26/84	12	8.6	175.0	1.5	18.0
06/27/84-07/12/84	16	7.1	805.8	5.7	91.2
07/13/84-07/25/84	13	8.6	762.5	6.6	85.8
07/26/84-08/06/84	12	8.6	205.0	1.8	21.6
08/07/84-08/21/84	15	8.6	171.7	1.5	22.5
08/22/84-09/05/84	15	6.6	20.0	0.1	1.5
09/06/84-09/19/84	14	8.6	58.3	0.5	7.0
09/20/84-10/02/84	13	9.1	68.3	0.6	7.8
10/03/84-10/17/84	15	7.9	58.3	0.5	7.5
10/18/84-10/29/84	12	7.8	43.3	0.3	3.6
10/30/84-11/13/84	15	6.9	5.0	<0.1	0.5
11/14/84-11/30/84	17	5.5	0.0	0.0	0.0
12/01/84-11/12/84	11	8.3	0.0	0.0	0.0
12/12/84-12/26/84	15	6.7	5.0	<0.1	0.5
12/27/84-01/07/85	12	8.5	10.0	0.1	1.2
01/08/85-01/26/85	19	7.4	11.7	0.1	1.9
01/27/85-02/04/85	9	8.5	13.3	0.1	0.9
02/05/85-02/20/85	16	8.5	16.7	0.1	1.6
02/21/85-03/04/85	23	6.7	16.7	0.1	1.2
03/05/85-03/18/85	14	8.5	13.3	0.1	1.4
03/19/85-04/01/85	14	7.9	13.3	0.1	1.4
04/02/85-04/15/85	14	1.1	150.0	0.2	2.8
04/16/85-04/29/85	14	1.2	343.3	0.4	5.6
04/30/85-05/12/85	13	2.2	556.7	1.2	15.6
05/13/85-05/31/85	19	7.2	461.7	3.3	62.7
06/01/85-06/10/85	10	8.3	138.3	1.1	11.0
Total					1975.2

[a] Pumping rates obtained from Savannah River Plant records.

Source: Paller and Saul (1985)

TABLE 4-158

Diel Ichthyoplankton Entrainment into the Par Pond Pumphouse on Specific Sampling Dates (January 1984 - June 1985)

Date	Diurnal Period	Ichthyoplankton Density (No./1,000 m^3)	Volume Pumped ($m^3 \times 10^5$)	Number Ichthyoplankton Entrained
1984				
February 20	06-10	86.7	1.431	12407
	10-14	26.7	1.431	3821
	14-18	0.0	1.431	0
	18-22	26.7	1.431	3821
	22-02	46.7	1.431	6683
	02-06	73.3	1.431	10489
	Day (06-18)			16228
	Night (18-06)			20993
May 16	06-10	2756.7	0.613	168,986
	10-14	3013.3	0.613	184,715
	14-18	2706.7	0.613	165,921
	18-22	29523.3	0.613	1,809,778
	22-02	32506.7	0.613	1,992,661
	02-06	20390.7	0.613	1,249,950
	Day (06-18)			519,622
	Night (18-06)			5,052,389
August 22	06-10	150.0	0.409	6135
	10-14	20.0	0.409	818
	14-18	13.3	0.409	544
	18-22	136.7	0.409	5591
	22-02	93.3	0.409	3816
	02-06	80.0	0.409	3272
	Day (06-18)			7497
	Night (18-06)			12679
November 30	06-10	0.0	1.417	0
	10-14	0.0	1.417	0
	14-18	3.3	1.417	468
	18-22	0.0	1.417	0
	22-02	0.0	1.417	0
	02-06	0.0	1.417	0
	Day (06-18)			468
	Night (18-06)			0

Source: Paller and Saul (1985)

TABLE 4-158, Contd

Date	Diurnal Period	Ichthyoplankton Density (No./1,000 m^3)	Volume Pumped ($m^3 \times 10^5$)	Number Ichthyoplankton Entrained
1985				
February 4	06-10	3.3	1.431	472
	10-14	13.3	1.431	1903
	14-18	20.0	1.431	2862
	18-22	16.7	1.431	2390
	22-02	20.0	1.431	2862
	02-06	6.7	1.431	959
	Day (06-18)			5237
	Night (18-06)			6211
May 12	06-10	2213.3	0.204	45151
	10-14	713.3	0.204	14551
	14-18	560.0	0.204	11424
	18-22	3810.0	0.204	77724
	22-02	5106.7	0.204	104177
	02-06	7023.3	0.204	143275
	Day (06-18)			71126
	Night (18-06)			325176

Source: Paller and Saul (1985)

are approximately 23 cm/sec at the trash racks and 11 cm/sec at the stationary screens (Wilde, 1985b). These current velocities are considerably less than the maximum swimming speeds of healthy adult specimens of the common Par Pond species. Consequently impingement is believed to occur rarely at the Par Pond water intakes.

In summary, there are several features of the Par Pond fish community that may be attributable to thermal effects, including localized reductions in species richness in the Hot Arm and early spawning of some species. Elevated temperatures may also contribute to the relatively low condition of large largemouth bass in Par Pond although forage deficiencies are probably a more important cause. In most respects, however, the Par Pond fish community is comparable to fish communities in other reservoirs except that Par Pond has more largemouth bass and fewer gizzard shad. Based upon indications of successful reproduction in most or all major species, the continued presence of diverse and abundant fish populations in Par Pond, and favorable comparisons between the fish community in Par Pond and other U.S. reservoirs, it can be concluded that P-Reactor operations have not adversely affected the fish community of Par Pond.

Fish Kills Associated with P-Reactor Restart

Pond C is separated from the main body of Par Pond by a causeway referred to as the Hot Dam. A large culvert underneath the Hot Dam connects the two systems. Water temperatures at the discharge site in Pond C typically exceed 40°C and are often over 50°C during summer months. In contrast, water temperatures in Par Pond remain relatively cool, reaching a maximum of approximately 36°C near the culvert from Pond C (Paller and Saul, 1985).

In spite of the extreme temperatures in Pond C, several species of fish (mosquitofish, bluegill, redbreast sunfish, and largemouth bass) have established reproducing populations (Clugston, 1973; Aho et al., 1986b). Several small areas of relatively cool water provide refugia for these fish during reactor operation. Recruitment occurs during winter months and during relatively long periods of reactor shutdown.

Fish kills were routinely monitored in Pond C from January 1984 through December 1985 concurrently with fisheries monitoring studies in Par Pond (Aho et al., 1986b; Paller and Saul, 1985). A fish kill that occurred in August 1988 following an extended (nearly 6 month) outage of P Reactor was also monitored. Fish kills occurred sporadically in Pond C in response to reactor cycling (Aho et al., 1986b). Major kills, (10,000 or more fish) were often associated with P-Reactor restarts during late spring and early summer, and restarts that followed reactor shutdowns of unusually long duration. The largest single kill, conservatively estimating at over 200,000 fish, occurred during May 1985 after a six-week reactor outage (Table 4-159). Juvenile bluegill and largemouth bass composed the majority of this kill (Aho et al., 1986b). The August 1988 fish kill included approximately 150,000 fish, most of which were young-of-year sunfish (Lepomis spp., J. H. Heuer, pers. comm.).

TABLE 4-159

Number of Fish Killed in Pond C (by species and reactor cycle) Based on Shoreline Transects Counts (December 1983 through December 1985)

Reactor Cycle	N[a]	Redbreast Sunfish	Bluegill	Mosquitofish	Largemouth Bass	Yellow Bullhead	Lake Chubsucker	Others[c]	Totals
1	14	245.0 ±96.1[b]	297.5 ±74.7	430.5 ±194.2	7.0 ±8.0	0.0	3.5 ±5.8	7.0 ±8.04	990.5 ±110.5
2	14	220.5 ±186.9	1011.5 ±424.9	584.5 ±176.7	38.5 ±21.5	7.0 ±8.0	35.0 ±52.1	7.0 ±8.04	1904.0 ±235.9
3	11	63.0 ±25.2	1816.5 ±718.0	196.0 ±126.0	17.5 ±14.3	0.0	0.0	0.0	2093.0 ±380.94
4	13	56.0 ±35.3	1109.5 ±543.2	105.0 ±68.2	14.0 ±16.1	7.0 ±8.0	17.5 ±23.6	0.0	1309.0 ±265.3
5	15	70.0 ±37.6	14343.0 ±3217.1	108.5 ±32.9	14.0 ±13.5	14.0 ±13.5	7.0 ±8.0	0.0	14556.5 ±2347.9
6	13	45.5 ±28.3	10255.0 ±5738.8	815.5 ±498.1	21.0 ±18.93	10.5 ±17.4	3.5 ±5.8	0.0	11131.0 ±2694.6
7	13	7.0 ±8.0	49.0 ±18.9	10.5 ±9.6	7.0 ±8.0	0.0	0.0	0.0	73.5 ±11.4
8	14	0.0	63.0 ±45.9	126.0 ±86.1	3.5 ±5.8	0.0	3.5 ±5.8	0.0	196.0 ±43.0
9	13	10.5 ±12.7	42.0 ±19.5	1214.5 ±507.9	0.0	7.0 ±8.0	0.0	0.0	1274.0 ±262.9
10	9	73.5 ±60.9	112.0 ±49.5	987.0 ±633.7	3.5 ±5.8	0.0	3.5 ±5.8	0.0	1179.5 ±287.6
11	11	14.0 ±10.6	745.5 ±263.2	9912.0 ±4248.4	3.5 ±5.8	0.0	0.0	0.0	10675.0 ±2175.5
12	11	17.5 ±14.3	549.5 ±337.4	3444.0 ±1584.3	17.5 ±11.4	3.5 ±5.8	0.0	0.0	4032.0 ±798.1
13	24	21.0 ±14.8	2576.0 ±1375.3	731.5 ±289.6	0.0	3.5 ±5.9	0.0	0.0	3332.0 ±651.9
14	9	2816.0 ±941	185190.0 ±61209.4	7521.5 ±11549.7	11238.5 ±3621.7	77.0 ±92.8	7.0 ±11.04	3.5 ±5.8	206853.5 ±35791.5
15	10	0.0	33404.0 ±31380.7	14.0 ±17.9	0.0	0.0	0.0	7.0 ±8.0	33425.0 ±13258.5
16	11	0.0	647.5 ±733.8	14.0 ±17.9	0.0	0.0	0.0	7.0 ±11.04	668.5 ±305.5
17	9	10.5 ±12.7	59.5 ±44.9	7.0 ±8.0	0.0	0.0	0.0	0.0	77.0 ±20.5
18	8	0.0	7.0 ±8.0	105.0 ±54.9	0.0	0.0	0.0	7.0 ±8.0	119.0 ±26.2
19	14	0.0	31.5 ±28.3	136.5 ±79.9	3.5 ±5.8	0.0	0.0	0.0	171.5 ±38.4
20	2	10.5 ±12.7	7.0 ±8.0	10.5 ±12.7	0.0	0.0	0.0	0.0	28.0 ±8.0
Grand total		3680.5 ±1409.3	250566.5 ±67597.8	26474.0 ±2884.2	11389.0 ±1235.5	129.5 ±22.0	80.5 ±13.5	38.5 ±21.5	292358.5 ±81117.4

[a] N is the number of observations in the reactor cycle.

[b] Mean ±95% confidence interval.

[c] Others includes the following species: yellow bullhead, lake chubsucker, redfin pickerel, banded pygmy sunfish, golden shiners, and swamp darter.

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Paller and Saul (1985) never observed temperature related fish kills in Par Pond during 18 months of study; nor, with one exception, have other researchers. Clugston (1973) reported the loss of several thousand blueback herring in March 1972. He speculated that these fish may have died when they swam from 16°C water to 25°C water near the Pond C discharge.

4.6 SAVANNAH RIVER

4.6.1 Water Quality

Water quality in the Savannah River near SRS has been monitored monthly since the establishment of sampling stations upstream and downstream of SRS in 1959. The upstream sampling point has been located near Jackson, South Carolina, upstream from all SRS stream mouths. The downstream sampling point is located at the US 301 crossing of the Savannah River, 16.6 km downstream of the mouth of Lower Three Runs Creek. A third routine river sampling location adjacent to the 681-3G SRS pumphouse intake canal was maintained from 1973 through 1981 to determine the physiochemical characteristics of the river water adjacent to its second introduction to the SRS cooling canal intakes. A summary of historical trends in water quality in the Savannah River from 1959 to 1982 (Gladden et al., 1985a) follows.

Historically, the Savannah River has been subjected to many factors that affected its water quality. Completion of the Clarks Hill Dam and the filling of the reservoir resulted in decreased silt loading and turbidity. From 1951 until 1956, downstream reaches of the Savannah River were dredged in order to improve channel alignment and maintain a 2.7 to 4.9 m depth for navigability. This dredging temporarily increased suspended solids, turbidity, and dissolved nutrients. Improved waste water treatment by municipalities at upstream Augusta, Georgia sources since the mid-1960s has reduced the nitrate-nitrogen concentrations from 0.57 mg/L during 1965 through 1969 (Marter, 1970) to 0.43 mg/L in 1982 (Du Pont, 1983).

Variability of data for all water chemistry parameters has diminished over the last 20 years, primarily due to flow stabilization by upstream dams. The pH of the river generally is slightly acid at a pH range of 5.3 to 7.6. The river water is relatively soft (alkalinity hardness of about 14 mg/L), well oxygenated (>9 mg/L) and low in biochemical oxygen demand (typically <2 mg/L). Water temperatures vary seasonally, ranging from a low of 8°C to more than 24°C. The net increase in water temperature of the Savannah River from upstream to downstream of the SRS is approximately 1.2°C (Jacobsen et al., 1972), and is attributed to the discharge of thermal effluents to Beaver Dam Creek, Four Mile Creek, and Pen Branch/Steel Creek as a consequence of SRS operations and natural warming of colder hypolimnetic release water from Lake Thurmond (Clarks Hill) upstream.

Tables 4-160 through 4-162 present the mean concentrations recorded from the three Savannah River monitoring stations during the period 1973 to 1982 for a wide variety of water chemistry constituents. In addition to meeting South Carolina Class B water quality standards, the results indicated the overwhelming similarity in water chemistry between the

TABLE 4-160

Savannah River Water Quality, 1973 to 1982 at River Mile 158.5 Upstream of the SRS

Parameter		Mean Concentration, mg/L[a] 1973-1982	Number of Analyses
Temperature (°C)		17.7	111
pH (units) (range)		5.3-7.6	110
Dissolved oxygen		9.6	112
Alkalinity		13.8	112
Conductivity (μmhos/cm)		66.8	112
Suspended solids		17.1	112
Volatile solids		23.4	112
Total dissolved solids		47.9	112
Total solids		65.2	112
Biochemical oxygen demand		1.6	111
Chemical oxygen demand		NA	-
Chlorides		5.3	112
Kjeldahl nitrogen	(N)	NA	-
Nitrates + nitrites	(N)	0.693	112
Sulfates	(SO_4)	5.17	112
Total phosphates	(PO_4)	0.464	112
Aluminum	(Al)	0.382	112
Ammonia	(N)	0.108	112
Calcium	(Ca)	2.24	112
Sodium	(Na)	7.66	112
Iron, total	(Fe)	0.34	112
Lead	(Pb)	NA	-
Manganese	(Mn)	NA	-
Mercury	(Hg)	<0.002	19

[a] Except as noted.
NA = no analysis

Source: Gladden et al. (1985a)

TABLE 4-161

Savannah River Water Quality, 1973 to 1982 Adjacent to SRS Pumphouse (681-3G; RM 155.5)

Parameter		Mean Concentration, mg/L[a] 1973-1982	Number of Analyses
Temperature (°C)		19.0	100
pH (units) (range)		5.3-8.0	101
Dissolved oxygen		9.7	101
Alkalinity		17.7	100
Conductivity (µmhos/cm)		NA	-
Suspended solids		24.1	101
Volatile solids		22.1	101
Total dissolved solids		58.6	101
Total solids		83.0	101
Biochemical oxygen demand		0.73	40
Chemical oxygen demand		10.7	82
Chlorides		6.2	101
Kjeldahl nitrogen	(N)	<1.0	26
Nitrates + nitrites	(N)	0.294	101
Sulfates	(SO_4)	4.34	100
Total phosphates	(PO_4)	0.098	98
Aluminum	(Al)	0.97	99
Ammonia	(N)	0.147	98
Calcium	(Ca)	3.66	99
Sodium	(Na)	9.33	99
Iron, total	(Fe)	0.90	99
Lead	(Pb)	0.42	99
Manganese	(Mn)	<0.01	7
Mercury	(Hg)	<0.001	19

NA = no analysis

[a] Except as noted

Source: Gladden et al. (1985a)

TABLE 4-162

Savannah River Water Quality, 1973 to 1982 at the US Highway 301 Bridge (RM 118.7)

Parameter		Mean Concentration, mg/L[a] 1973-1982	Number of Analyses
Temperature (°C)		18.1	112
pH (units) (range)		5.5-7.3	111
Dissolved oxygen		9.5	112
Alkalinity		13.9	111
Conductivity (µmhos/cm)		67.9	111
Suspended solids		16.2	111
Volatile solids		23.3	111
Total dissolved solids		48.2	111
Total solids		65.7	111
Biochemical oxygen demand		1.5	110
Chemical oxygen demand		NA	-
Chlorides		5.1	-
Kjeldahl nitrogen	(N)	NA	-
Nitrates + nitrites	(N)	0.637	111
Sulfates	(SO_4)	5.14	111
Total phosphates	(PO_4)	0.421	111
Aluminum	(Al)	0.443	111
Ammonia	(N)	0.090	111
Calcium	(Ca)	2.23	111
Sodium	(Na)	7.24	110
Iron, total	(Fe)	0.32	111
Lead	(Pb)	NA	-
Manganese	(Mn)	NA	-
Mercury	(Hg)	<0.002	19

[a] Except as noted

Source: Gladden et al. (1985a)

upstream and downstream SRS monitoring sites. More specifically, a previous report (Lower, 1983) documented that no statistically significant changes were evidenced for all tested parameters between the Savannah River water quality stations upstream and downstream of the SRS. Since statistically-significant variability between these sites did not occur, it may be concluded that SRS operations have had no measurable impact on the water quality of the Savannah River. For details of the statistical analysis see Lower (1983).

Analyses of weekly fecal coliform samples collected from the Savannah River in 1983 indicated higher concentrations upriver (maximum 4600 colonies/100 mL) than downriver (maximum 1200 colonies/100 mL) (Table 4-163) from the SRS.

Additional Savannah River water samples collected near the 681-5G river pumphouse intake have been routinely sent to the Georgia Department of Natural Resources (GDNR) for water chemistry analysis since the early 1970's. Results of 1983 and previous year GDNR analyses have historically shown good agreement with the SRS results (Du Pont, 1984). A comparison of 1983 GDNR and SRS river water quality analyses is shown in Table 4-164.

Sampling of the upstream and downstream stations continued beyond 1982, and a comparison of previous data and expanded sampling results from 1983 through 1985 appear in Tables 4-165 and 4-166.

Radiological monitoring of the Savannah River has been conducted since prior to plant startup (Gladden et al., 1985a), and continues under the direction of the Environmental Monitoring (EM) Section. A summary of radioactivity in Savannah River water from 1953 to 1981 (Table 4-167) can be found in Gladden et al. (1985), and a more detailed summary for 1978 through 1984 (Table 4-168) appears in Lower (1987). Results of the monitoring program for all SRS surface waters for 1987 and 1988 can be found in Appendix A of this document.

Lower (1987) reports the results of a special study to determine levels of volatile, acid, and base/neutral organic compounds in the Savannah River. The study found that all 88 tested compounds were below detection limits. This report also summarizes the results of analyses for pesticides and PCB's in onsite streams and the Savannah River. Concentrations in the Savannah River were near or below detectable limits and can be found in Table A-10 of Appendix A. Results of the 1983-1985 two-year water quality program instituted under the CCWS are also reported in Lower (1987). Sampling locations for this study are shown in Figure A-1 of Appendix A. The CCWS study monitored standard parameters and general water chemistry (Table 4-169), nutrients (Table 4-170), total and dissolved major cations (Table 4-171, 4-172), trace elements (Table 4-173), and organic carbon (Table 4-174).

TABLE 4-163

1983 Savannah River Fecal Coliform Bacteria Monitoring Results

Station	Fecal Counts, No. Colonies/100 mL			
	Maximum Weekly Value	Minimum Weekly Value	Average of Monthly Geometric Means	Number of Analyses
Jackson, SC	4600	62	362	52
US Hwy 301	1200	22	146	52

Source: Gladden et al. (1985a)

TABLE 4-164

1983 Savannah River Water Quality (all data represent arithmetic mean concentration (mg/L) except as noted)

Parameter		River Mile 158.5 Upstream of SRS	681-5G[a]	River Mile 118.7 Downstream of SRS
Temperature (°C)		17	17.3	18
pH (units) (range)		6.4-7.7	6.8-7.3	6.3-7.8
Dissolved oxygen		9.3	7.9	8.9
Alkalinity		20	17.3	19
Conductivity (µmhos/cm)		78	74	76
Turbidity (JTU[b])		3.8	15.2	3.4
Suspended solids		9.8	NA[c]	9.4
Volatile solids		3	NA	3
Total volatile solids		16	NA	17
Total dissolved solids		59	NA	62
Chemical oxygen demand		10	NA	11
Chloride	(Cl)	6.3	NA	6.7
$NO_3 + NO_2$	(N)	0.34	0.25	0.30
Sulfates	(SO_4)	5.0	NA	4.7
Total phosphate	(P)	0.11	0.09	0.16
Aluminum	(Al)	0.23	NA	0.17
Ammonia	(NH_4-N)	0.12	0.22	0.05
Magnesium	(Mg)	1.1	NA	1.0
Manganese	(Mn)	0.12	NA	0.06
Sodium	(Na)	7.8	NA	8
Iron, total	(Fe)	0.46	NA	0.43
Chromium	(Cr)	0.01	NA	<0.01
Zinc	(Zn)	0.01	NA	0.01

[a] Analyzed by the Georgia Department of Natural Resources
[b] Jackson Turbidity Units
[c] No analysis for these parameters by the Georgia Department of Natural Resources

Source: Gladden et al. (1985a)

TABLE 4-165

Savannah River Water Quality, 1973 Through 1985, at River Mile 158.5 Upriver of SRS

Parameter	Units	Mean Concentration,[a] 1973-1982[b]		Mean Concentration,[a] 1983-1985[c]	
Temperature	°C	17.7	(111)	17.0	(36)
pH (range)	-	5.3 - 7.6	(110)	6.2 - 7.7	(36)
Dissolved oxygen	mg/L	9.6	(112)	9.6	(36)
Alkalinity	mg/L	13.8	(112)	19.0	(36)
Conductivity	µmhos/cm	66.8	(112)	77.7	(35)
Turbidity	NTU	NA		5.0	(35)
Suspended solids	mg/L	17.1	(112)	8.9	(36)
Volatile solids	mg/L	23.4	(112)	3.0	(33)
Total dissolved solids	mg/L	47.9	(112)	59.7	(36)
Total solids	mg/L	65.2	(112)	68.7	(36)
Biochemical oxygen demand	mg/L	1.6	(111)	NA	
Chemical oxygen demand	mg/L	NA		10.1	(35)
Chlorides	mg/L	5.3	(112)	6.2	(36)
Kjeldahl nitrogen (N)	mg/L	NA		NA	
Nitrates + nitrites (N)	mg/L	0.693	(112)	0.42	(36)
Sulfates (SO_4)	mg/L	5.17	(112)	5.5	(36)
Total phosphates (P)	mg/L	0.151	(112)	0.09	(36)
Aluminum, total (Al)	mg/L	0.382	(112)	0.22	(35)
Ammonia (N)	mg/L	0.108	(112)	0.12	(23)
Calcium, total (Ca)	mg/L	2.24	(112)	5.0	(12)
Copper, total (Cu)	mg/L	NA		0.01	(24)
Cadmium, total (Cd)	mg/L	NA		0.01	(24)
Magnesium, total (Mg)	mg/L	NA		1.24	(35)
Manganese, total (Mn)	mg/L	NA		0.15	(35)
Mercury, total (Hg)	mg/L	<0.002	(19)	0.00017	(20)
Nickel, total (Ni)	mg/L	NA		0.06	(24)
Sodium, total (Na)	mg/L	7.66	(112)	7.8	(35)
Iron, total (Fe)	mg/L	0.34	(112)	0.48	(35)
Lead, total (Pb)	mg/L	NA		0.01	(24)
Chromium, total (Cr)	mg/L	NA		<0.01	(35)
Zinc, total (Zn)	mg/L	NA		<0.03	(35)

[a] Except as noted; number of analyses in parentheses
[b] Gladden et al., 1985a
[c] Du Pont, 1984; 1985; 1986

NA = no analysis conducted

Source: Lower (1987)

TABLE 4-166

Savannah River Water Quality, 1973 Through 1985, at River Mile 118.7 (US Highway 301 Bridge) Downriver of SRS

Parameter	Units	Mean Concentration,[a] 1973-1982[b]		Mean Concentration,[a] 1983-1985[c]	
Temperature	°C	18.1	(112)	18.0	(36)
pH (range)	-	5.5 - 7.3	(111)	6.1 - 7.8	(36)
Dissolved oxygen	mg/L	9.5	(112)	9.3	(36)
Alkalinity	mg/L	13.9	(111)	18.7	(36)
Conductivity	µmhos/cm	67.9	(111)	77.0	(35)
Turbidity	NTU	NA		4.6	(34)
Suspended solids	mg/L	16.2	(111)	9.7	(36)
Volatile solids	mg/L	23.3	(111)	3.0	(33)
Total dissolved solids	mg/L	48.2	(111)	60.7	(36)
Total solids	mg/L	65.7	(111)	70.7	(36)
Biochemical oxygen demand	mg/L	1.5	(110)	NA	
Chemical oxygen demand	mg/L	NA		10.2	(35)
Chlorides	mg/L	5.1	(112)	6.4	(36)
Kjeldahl nitrogen (N)	mg/L	NA		NA	
Nitrates + nitrites (N)	mg/L	0.64	(111)	0.37	(24)
Sulfates (SO_4)	mg/L	5.1	(111)	5.7	(36)
Total phosphates (P)	mg/L	0.16	(111)	0.11	(36)
Aluminum, total (Al)	mg/L	0.44	(111)	0.19	(35)
Ammonia (N)	mg/L	0.09	(111)	0.066	(23)
Calcium, total (Ca)	mg/L	2.23	(111)	5.1	(12)
Copper, total (Cu)	mg/L	NA		0.01	(24)
Cadmium, total (Cd)	mg/L	NA		0.01	(24)
Magnesium, total (Mg)	mg/L	NA		1.21	(35)
Manganese, total (Mn)	mg/L	NA		0.10	(35)
Mercury, total (Hg)	mg/L	<0.002	(19)	0.00018	(20)
Nickel, total (Ni)	mg/L	NA		0.06	(24)
Sodium, total (Na)	mg/L	7.24	(110)	7.66	(35)
Iron, total (Fe)	mg/L	0.32	(111)	0.61	(35)
Lead, total (Pb)	mg/L	NA		0.01	(24)
Chromium, total (Cr)	mg/L	NA		<0.01	(35)
Zinc, total (Zn)	mg/L	NA		0.024	(35)

[a] Except as noted; number of analyses in parentheses
[b] Gladden et al., 1985a
[c] Du Pont, 1984; 1985; 1986

NA = no analysis conducted

Source: Lower (1987)

TABLE 4-167

Average Radionuclide Concentrations Measured in Savannah River Water in pCi/L (except tritium in pCi/mL from 1953-1981)

Year	Loc[a]	Alpha	Beta	Tritium	Ce-141	Cs-134	Zr-Nb	Ru-106	Cs-137	Zn-65	Sr-990	Sr-90	Mn-34	I-131	BaLa-141	Np-239	Cr-31	S-35	Co
1953	2	0.20	5.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1953	10	0.10	5.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1954	2	0.90	8.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1954	10	0.80	8.30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1955	2	0.90	20.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1955	10	0.90	16.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1956	2	0.70	13.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1956	10	0.50	14.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1957	2	0.50	17.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1957	10	0.50	34.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1958	2	0.50	14.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1958	10	0.50	26.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1959	2	0.70	17.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1959	10	0.50	22.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1960	2	0.20	19.00	5.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1960	10	0.20	19.00	9.00	.	.	.	.	5.000	.	.	.	.	10.00	.	.	.	.	.
1961	2	0.20	7.00	3.00	.	.	.	.	.	.	.	2.00	.	.	.	.	.	.	.
1961	10	0.20	28.00	14.00	.	.	.	.	4.000	.	.	6.00	.	6.00	.	.	.	.	.
1962	2	0.20	25.00	2.00	.	.	.	.	2.000	.	.	2.00	.	.	.	.	.	.	.
1962	10	0.20	44.00	12.00	.	.	.	.	7.000	.	.	9.00	.	9.00	.	.	.	.	.
1963	2	0.20	21.00	0.90	5.80	.	8.00	7.0	2.800	1.7	3.20	0.90	0.70	.	.	.	.	.	.
1963	10	0.20	29.00	14.00	5.70	.	7.90	7.0	3.300	1.9	4.60	1.40	1.00	2.40	4.4	19.00	28.00	.	.
1964	2	0.30	11.00	1.40	4.00	.	0.70	6.1	0.800	.	.	1.20	.	.	.	.	.	.	.
1964	10	0.30	18.00	10.00	5.00	.	0.80	5.1	5.500	1.2	1.70	1.90	.	1.90	3.2	11.00	17.70	.	.
1965	2	0.25	7.00	1.10	0.00	.	0.00	0.0	0.000	0.0	0.00	1.30	0.00	0.00	0.0	0.00	0.00	.	0.00
1965	10	0.20	10.00	10.90	0.00	.	0.00	0.0	2.050	0.0	0.00	2.10	0.00	0.60	0.0	0.00	7.10	.	0.00
1966	2	0.30	4.50	1.05	1.45	.	0.00	0.0	0.000	0.0	0.00	1.00	0.00	0.30	0.0	1.00	0.00	.	0.00
1966	10	0.20	13.00	11.30	2.70	.	0.60	0.0	2.700	0.0	0.90	1.65	0.00	0.40	1.7	3.60	24.20	.	0.00
1967	2	.	5.00	1.00	0.00	.	0.00	0.0	0.000	0.0	0.00	0.70	0.00	0.00	0.0	0.00	0.00	.	0.00
1967	10	.	7.50	9.80	0.00	.	0.00	0.0	2.050	0.0	0.90	1.15	0.00	0.60	0.0	1.95	5.95	.	0.00
1968	2	.	4.00	0.75	0.00	.	0.00	0.0	0.000	0.0	.	0.60	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1968	10	.	10.00	9.35	0.00	.	0.00	0.0	1.150	0.0	2.60	1.00	0.00	0.00	0.0	0.00	[illegible]	26.00	0.00

TABLE 4-167, Contd

Year	Loc[a]	Alpha	Beta	Tritium	Ce-141	Cs-134	Zr-Nb	Ru-106	Cs-137	Zn-65	Sr-990	Sr-90	Mn-34	I-131	BaLa-141	Np-239	Cr-31	S-35	Co
1969	2	·	4.00	0.90	0.00	·	0.00	0.0	0.000	0.0	0.00	0.75	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1969	10	·	6.00	7.85	0.00	·	0.00	0.0	0.650	0.0	0.40	1.05	0.00	0.30	0.0	0.00	0.00	5.05	0.00
1970	2	·	4.00	0.75	0.00	·	0.00	0.0	0.000	0.0	0.00	0.45	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1970	10	·	6.50	5.85	0.00	·	0.00	0.0	1.200	0.0	1.40	1.05	0.00	0.00	0.0	0.00	0.00	4.05	0.00
1971	2	·	4.00	8.57	0.00	·	0.00	0.0	0.000	0.0	0.00	0.60	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1971	10	0.20	5.50	5.55	0.00	·	0.00	0.0	0.200	0.0	0.55	0.90	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1972	2	·	·	0.75	0.00	·	0.00	0.0	0.000	0.0	0.00	0.60	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1972	10	0.20	·	6.05	0.00	·	0.00	0.0	0.050	0.0	0.50	0.75	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1973	2	0.40	0.00	0.43	0.00	·	0.00	0.0	0.000	0.0	0.00	0.40	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1973	10	0.40	0.00	6.62	0.00	·	0.00	0.0	0.020	0.0	0.20	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1974	2	0.36	3.52	0.47	0.00	·	0.00	0.0	0.000	0.0	0.55	0.40	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1974	10	0.27	3.92	5.90	0.00	·	0.00	0.0	0.010	0.0	0.64	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1975	2	0.38	2.50	0.49	0.00	·	0.00	0.0	0.000	0.0	0.47	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1975	10	0.34	2.55	4.02	0.00	·	0.00	0.0	0.015	0.0	0.50	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1976	2	0.41	2.99	0.46	0.00	·	0.00	0.0	0.000	0.0	0.75	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1976	10	0.53	3.05	4.75	0.00	·	0.00	0.0	0.015	0.0	0.87	0.50	0.00	0.00	0.0	0.00	0.00	0.00	0.00
1977	2	0.33	3.20	0.50	0.71	1.2	0.04	1.8	0.320	1.0	0.28	0.34	0.06	0.31	·	·	1.20	0.00	0.00
1977	10	0.29	2.11	4.80	0.49	1.1	0.05	0.9	0.140	1.1	0.36	0.29	0.02	0.14	·	·	0.56	0.00	0.00
1978	2	0.33	1.74	0.39	3.00	0.0	0.00	0.0	0.000	0.0	0.14	0.40	0.00	0.00	·	·	0.00	0.00	0.00
1978	10	0.21	0.3	3.9	0	0.015	0	0	0.00	0	0.51	0.30	0	0	·	·	0	0	·
1979	2	0.22	1.8	0.4	0	·	0	0	0.00	0	0.00	0.43	0	0	0	0	0	0	·
1979	10	0.24	3.1	3.1	0	·	0	0	0.02	0	0.00	0.32	0	0	0	0	0	0	·
1980	2	0.01	1.6	0.4	0	·	0	0	0.00	0	0.00	0.10	0	0	0	0	0	0	·
1980	10	0.14	1.6	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
1981	2	0.14	1.6	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
1981	10	0.11	2.0	4.1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

[a] Location 2 - upstream of SRS.
Location 10 - downstream of SRS at Highway 301
· Less than detection limit.

Source: Gladden et al. (1985a)

WB9060170

TABLE 4-168

Radioactivity in Savannah River Water, 1978-1984[a]

Parameter	Savannah River Upriver of SRS[b]	Savannah River Downriver of SRS[c]
Gross alpha, dissolved	0.109 (356) -0.27 - 4.70	0.078 (359) -2.20 - 1.40
Gross alpha, suspended	0.062 (332) -5.30 - 1.30	0.053 (320) -0.34 - 0.56
Nonvolatile beta, dissolved	0.927 (352) -6.80 - 11.0	1.08 (354) -6.30 - 9.90
Nonvolatile beta, suspended	0.477 (328) -8.30 - 5.90	0.401 (322) -9.10 - 6.00
Tritium	0.338 (359) -0.53 - 3.8	3.60 (359) 0.86 - 11.0
$^{89,90}Sr$	0.101 (152) -2.90 - 4.00	0.330 (162) -2.30 - 8.40
^{90}Sr	0.286 (87) -1.20 - 2.20	0.231 (92) -0.28 - 0.73
^{35}Sr	0.882 (66) -14.0 - 2.8	0.715 (47) -16.0 - 5.0
^{51}Cr	1.045 (285) 0.00 - 15.0	1.003 (306) 0.00 - 19.0
^{54}Mn	0.187 (286) 0.00 - 3.1	0.070 (306) 0.00 - 0.72
^{60}Co	0.572 (286) 0.00 - 14.0	0.303 (306) 0.00 - 3.30

[a] All values mean pCi/L concentrations (except tritium, pCi/mL), with number of analyses conducted during 1978-1984 in parentheses. Range of minimum and maximum values during 1978-1984 indicated below mean value.

[b] Near Jackson, SC; Health Protection Department Station SR-2.

[c] At US Highway 301 crossing; Health Protection Department Station SR-10.

NA = no analysis conducted.

Source: Lower (1987)

TABLE 4-168, Contd

Parameter	Savannah River Upriver of SRS[b]	Savannah River Downriver of SRS[c]
^{65}Zn	0.581 (286) 0.00 - 3.90	0.428 (306) 0.00 - 6.70
^{95}Zr-^{95}Nb	0.163 (286) 0.00 - 2.20	0.108 (306) 0.00 - 1.00
$^{103,106}Ru$	3.19 (286) 0.00 - 53.0	2.30 (306) 0.00 - 55.0
^{131}I	0.458 (284) 0.00 - 7.80	0.377 (306) 0.00 - 4.40
^{134}Cs	0.590 (286) 0.00 - 6.70	0.464 (306) 0.00 - 11.0
^{137}Cs	0.264 (289) 0.00 - 2.20	0.217 (306) 0.00 - 9.20
$^{141,144}Ce$	0.682 (286) 0.00 - 15.0	0.472 (302) 0.00 - 9.20

[a] All values mean pCi/L concentrations (except tritium, pCi/mL), with number of analyses conducted during 1978-1984 in parentheses. Range of minimum and maximum values during 1978-1984 indicated below mean value.

[b] Near Jackson, SC; Health Protection Department Station SR-2.

[c] At US Highway 301 crossing; Health Protection Department Station SR-10.

NA = no analysis conducted.

Source: Lower (1987)

TABLE 4-169

General Water Chemistry and Standard Parameters: Savannah River

Station Number	Site	Temperature (°C)	pH	Total Alkalinity (mg/L as $CaCO_3$)	Dissolved Oxygen (mg O_2/L)	Dissolved Oxygen Saturation (%)	Specific Conductance (μmhos/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Chlorides (mg/L)	Sulfates (mg/L)
14	Savannah River upriver of SRP near Jackson, SC	15.9 (46) 4.3 - 24.0	6.88 (46) 5.90 - 7.80	19.6 (45) 12.3 - 28.5	7.60 (46) 5.20 - 11.4	74.8 (46) 55.4 - 93.4	79.4 (38) 47.3 - 98.3	10.1 (45) 0.25 - 54.0	20.2 (43) 5.1 - 80.2	6.29 (46) 2.90 - 8.90	6.00 (28) 2.90 - 9.17
19	Savannah River at pumphouse 1G intake canal	15.8 (46) 3.8 - 23.5	6.98 (46) 5.90 - 8.05	16.5 (45) 5.63 - 24.0	7.38 (46) 3.80 - 11.3	72.6 (46) 41.9 - 90.2	68.2 (38) 36.7 - 90.3	9.47 (45) 0.25 - 43.9	18.3 (43) 4.9 - 81.0	5.53 (46) 2.60 - 8.40	5.26 (28) 2.13 - 8.99
6	Savannah River downriver of Steel Creek Landing	17.1 (45) 4.6 - 26.0	6.94 (45) 6.30 - 7.90	18.7 (45) 11.6 - 24.5	7.19 (46) 4.70 - 10.9	72.0 (45) 53.1 - 91.6	77.0 (38) 50.9 - 93.7	12.6 (45) 2.00 - 70.0	21.0 (43) 1.4 - 90.9	6.00 (45) 2.70 - 8.20	5.26 (28) 1.77 - 8.48

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

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TABLE 4-170

Nutrient Concentrations (mg P/L or mg N/L): Savannah River

Station Number	Site	Phosphorus	Total Orthophosphates	Total Orthophosphates	Dissolved Nitrates	Nitrites	Ammonia	Total Kjeldahl Nitrogen
34	Savannah River upriver of SRP near Jackson, SC	0.109 (44) 0.037 - 0.224	0.081 (41) 0.035 - 0.167	0.061 (42) 0.018 - 0.147	0.289 (43) 0.129 - 0.424	0.014 (44) <0.001 - 0.046	0.183 (46) 0.015 - 0.480	0.306 (46) 0.110 - 0.750
29	Savannah River at pumphouse 3G intake canal	0.104 (45) 0.040 - 0.200	0.068 (41) 0.021 - 0.154	0.050 (42) 0.003 - 0.136	0.262 (41) 0.067 - 0.485	0.012 (44) 0.002 - 0.041	0.155 (46) 0.019 - 0.360	0.277 (46) 0.073 - 0.900
6	Savannah River downriver of Steel Creek Landing	0.107 (45) 0.040 - 0.184	0.075 (41) 0.023 - 0.181	0.058 (42) 0.011 - 0.157	0.293 (42) 0.090 - 0.439	0.012 (44) <0.001 - 0.047	0.138 (46) 0.011 - 0.440	0.282 (46) 0.087 - 0.970

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-171

Dissolved Major Cation Concentrations: Ca, Mg, Na, K (mg/L): Savannah River

Station Number	Site	Calcium	Magnesium	Sodium	Potassium
34	Savannah River upriver of SRP near Jackson, SC	3.42 (38) 2.64 - 4.61	1.35 (38) 1.13 - 1.89	8.56 (38) 3.99 - 12.2	1.41 (38) <0.368 - 2.40
29	Savannah River at pumphouse 3G intake canal	3.10 (39) 2.48 - 3.60	1.19 (39) 0.833 - 1.44	7.37 (39) 3.14 - 11.2	1.20 (39) <0.368 - 1.72
6	Savannah River downriver of Steel Creek Landing	3.46 (39) 2.85 - 4.49	1.33 (39) 1.06 - 1.79	8.22 (39) 3.94 - 12.0	1.41 (39) <0.368 - 2.10

All values reported as means with the number of analyses in parentheses.
Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

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TABLE 4-172

Total and Dissolved Major Cation Concentrations: Al, Fe, Mn (mg/L): Savannah River

Station Number	Site	Aluminum, Total	Aluminum, Dissolved	Iron, Total	Iron, Dissolved	Manganese, Total	Manganese, Dissolved
34	Savannah River upriver of SRP near Jackson, SC	0.983 (39) 0.208 - 2.92	0.061 (38) <0.038 - 0.229	0.956 (39) 0.274 - 3.27	0.133 (38) <0.003 - 0.397	0.108 (17) <0.0004 - 0.356	0.057 (18) <0.0004 - 0.115
29	Savannah River at pumphouse 3G intake canal	0.996 (39) 0.290 - 5.41	0.063 (39) <0.038 - 0.298	0.915 (39) 0.140 - 3.27	0.136 (39) <0.003 - 0.516	0.096 (17) <0.004 - 0.349	0.059 (18) <0.0004 - 0.126
6	Savannah River downriver of Steel Creek Landing	1.06 (39) 0.115 - 3.99	0.079 (39) <0.038 - 0.607	1.08 (39) 0.477 - 4.01	0.161 (39) <0.003 - 0.678	0.085 (17) <0.0004 - 0.210	0.040 (18) <0.0004 - 0.085

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-173

Total Trace Elemental Concentrations (?g/L): Savannah River

Station Number	Site	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
34	Savannah River upriver of SRP near Jackson, SC	2.6 (17) <0.4 - 16.2	0.51 (17) <0.04 - 2.90	7.1 (17) <0.4 - 52.0	2.3 (17) <0.4 - 5.7	1.9 (17) <0.4 - 9.0	3.7 (17) <0.4 - 13.6	4.6 (17) <0.4 - 17.8
29	Savannah River at pumphouse 3G intake canal	2.5 (17) <0.4 - 21.1	0.36 (17) <0.04 - 1.70	9.3 (17) 0.4 - 57.0	2.5 (17) <0.4 - 5.6	1.7 (17) <0.4 - 5.3	3.1 (17) <0.4 - 12.0	4.8 (17) <0.4 - 14.0
6	Savannah River downriver of Steel Creek Landing	2.5 (17) <0.4 - 19.2	0.21 (17) <0.04 - 1.38	10.5 (17) <0.4 - 67.0	2.5 (17) <0.4 - 8.3	2.0 (17) <0.4 - 6.3	2.4 (17) <0.4 - 9.8	8.0 (17) <0.4 - 58.0

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

TABLE 4-174

Organic Carbon Concentrations (mg C/L): Savannah River

Station Number	Site	Total Organic Carbon	Dissolved Organic Carbon	Particulate Organic Carbon
34	Savannah River upriver of SRP near Jackson, SC	6.10 (25) 1.72-11.8	5.25 (11) 3.71-8.30	2.34 (11) 0.670-4.60
29	Savannah River at pumphouse 3G intake canal	6.23 (25) 0.420-10.5	5.13 (11) 3.90-6.90	2.16 (11) 0.690-5.40
6	Savannah River downriver of Steel Creek Landing	6.45 (24) 2.50-10.5	4.98 (11) 3.61-6.63	2.06 (11) 0.610-5.30

All values reported as means with the number of analyses in parentheses. Ranges of values are presented in the line below the mean value.

Source: Lower (1987)

Since South Carolina Class B stream water classification standards have been met in the Savannah River in the vicinity of the SRS during past operations, continued operation would not be expected to have a negative impact on the water quality of the river.

4.6.2 Savannah River Macroinvertebrates

Macroinvertebrates were sampled from October 1983 through September 1985 at nine locations in the Savannah River (Chimney and Cody, 1986; O'Hop et al., 1985). Stations were located upriver and downriver from SRS streams that received thermal effluents and at River Mile 137.7, located between Steel Creek and Lower Three Runs Creek (Figure 4-71). Sampling was conducted monthly using triplicate Hester-Dendy multiplate samplers and quarterly by collecting duplicate drift samples. Detailed sampling methods are presented in Chimney and Cody (1986) and O'Hop et al. (1985).

A total of 142 macroinvertebrate taxa were collected from the Savannah River during the two-year study. Ninety taxa were collected on the multiplate samplers and 128 were collected in the drift. Table 4-175 lists all of the taxa collected during the study. Since most dipterans, including chironomids were identified only to family or subfamily, and most other taxa were identified to genus, it is likely that the total number of species collected from the Savannah River was far in excess of 142.

4.6.2.1 Hester-Dendy Multiplate Data

On the multiplate samplers, the mean number of taxa collected per multiplate sampler ranged from 12.0 to 21.5 (Table 4-176). In general, fewer taxa were collected at the downstream stations than at the upstream stations in 1983-1984, but this pattern was much less pronounced in 1984-1985. These differences are probably due to localized differences in current velocity and river substrate composition. There is no evidence that they are due to SRS operations, since the number of taxa was reduced both upstream and downstream from SRS creeks.

Mean densities of organisms ranged from 2751.2 to 7986.0 organisms/m^2 of substrate (Table 4-176). Densities were highly variable from month to month, but were usually lowest during the winter and highest during the summer (O'Hop et al., 1985; Chimney and Cody, 1986). In 1983-1984, densities were higher at all of the upstream stations (RM 152.2 to RM 150.4) than at the stations located farther downstream, while in 1984-1985 densities were higher at RM 152.2 to 141.7 than at the downstream stations (Table 4-176). In 1984-1985, densities just downstream from Four Mile Creek were also found to be significantly higher on the South Carolina side of the river, while just below Steel Creek, densities were significantly higher along the Georgia side of the river (Chimney and Cody, 1986). No obvious explanation for the differences in densities was found by O'Hop et al. (1985) or Chimney and Cody (1986). However, both studies suggested that the difference was more likely due to differences in current velocity or the extent of macrophyte bed development than to thermal influences.

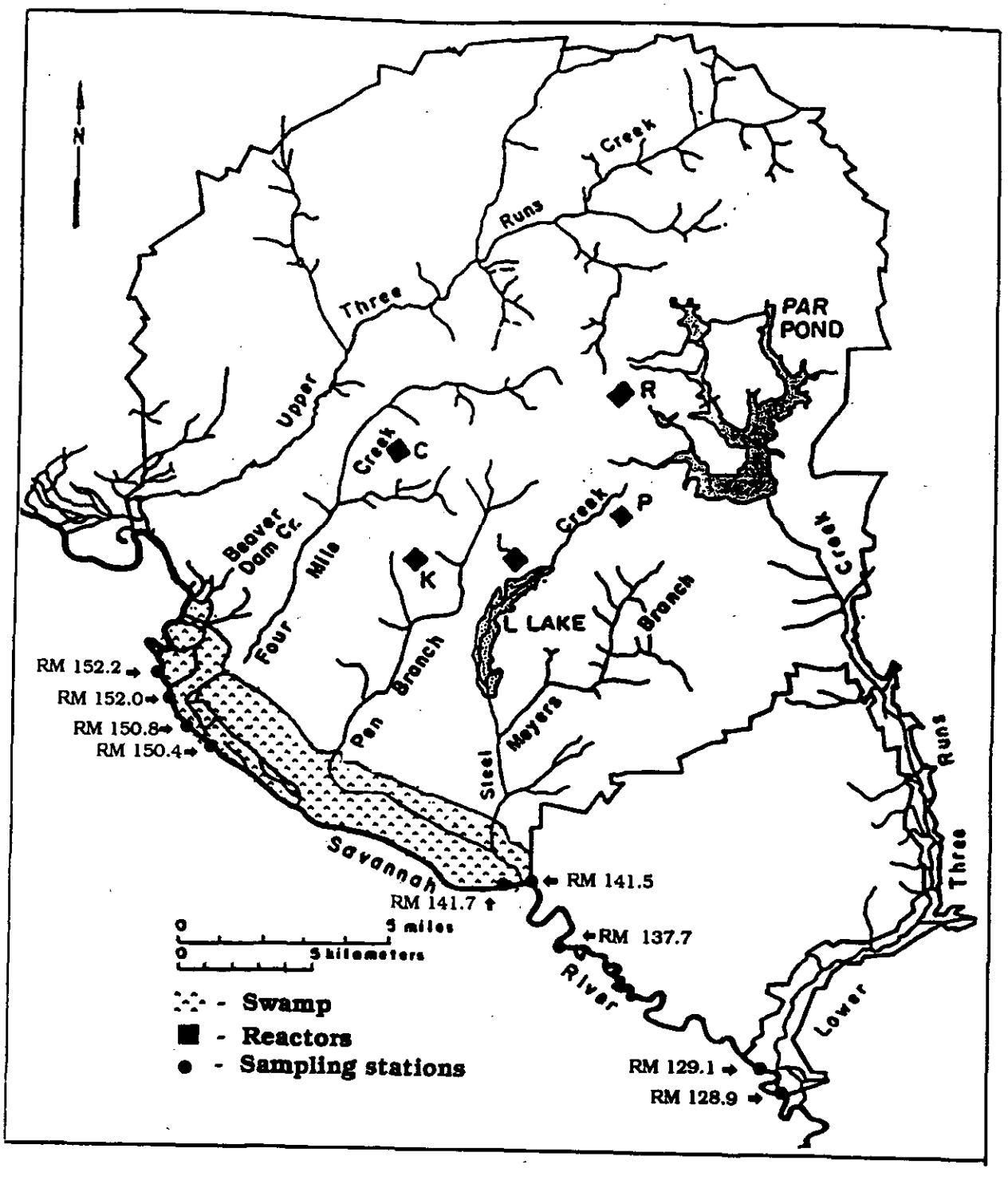

FIGURE 4-71. Macroinvertebrate Sampling Stations in the Savannah River (1983-1985) (source: Gladden et al., 1985)

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TABLE 4-175

Macroinvertebrate Taxa Collected from Hester-Dendy Multiplate Samplers and Drift Samples in the Savannah River (October 1983 - September 1985)

Scientific Name	Common Name	Group[a]	Sampling[b] Method
Phylum Platyhelminthes	Flat worms		
Class Turbellaria		P	H,D
Phylum Aschelminthes	Round worms		
Class Nematoda		CG	H,D
Phylum Annelida			
Class Oligochaeta	Segmented worms	CG	H,D
Class Hirudinea	Leeches	P	H,D
Phylum Mollusca			
Class Gastropoda	Snails		
Ferrissia rivularis		Sc	H,D
Laevapex fuscus		Sc	H,D
Amnicola		Sc	H,D
Pseudosuccinea columnella		Sc	D
Physella heterostropha		Sc	H,D
Gyraulus parvus		Sc	H,D
Helisoma trivolvis		Sc	H,D
Menetus dilatatus		Sc	H,D
Campeloma decisum		Sc	H
Class Pelecypoda	Clams		
Corbicula fluminea		CF	H,D
Sphaeriidae		CF	H,D
Phylum Arthropoda			
Class Arachnoidea			
Order Hydracarina	Water mites	P	H,D
Class Crustacea			
Order Isopoda	Isopods		
Asellus		CG	D
Order Amphipoda	Scuds		
Gammarus fasciatus		CG	H,D
Hyalella azteca		CG	H,D
Order Decapoda			
Palaemonetes paludosus		Sh	H,D
Procambarus		Sh	D
Class Insecta			
Order Collembola	Springtails	CG	D

TABLE 4-175, Contd

Scientific Name	Common Name	Group[a]	Sampling[b] Method
Order Ephemeroptera	Mayflies		
Baetis		CG	H,D
Callibaetis		CG	D
Baetisca sp.		CG	D
Heterocloeon		CG	D
Pseudocloeon parvulum		Sc	H,D
Caenis		CG	H,D
Danella simplex		CG	H,D
Ephemerella invaria		CG	H,D
Eurylophella temporalis		CG	H,D
Heptagenia		Sc	H,D
Pseudiron		P	H,D
Spinadis		P	D
Stenocron interpunctatum		CG	H,D
Stenonema modestum		CG	H,D
Paraleptophlebia		CG	D
Neoephemera youngi		CG	H,D
Isonychia		CF	H,D
Tricorythodes		CG	H,D
Leptohyphes		CG	H
Order Odonata	Dragonflies & damselflies		
Boyeria vinosa		P	H,D
Neurocordulia molesta		P	H,D
Macromia spp.		P	H,D
Calyopteryx spp.		P	D
Hetaerina		P	H,D
Argia		P	H,D
Enallagma		P	H,D
Libellula spp.		P	D
Lestes		P	D
Order Plecoptera	Stoneflies		
Nemocapnia carolina		Sh	H,D
Alloperla furcula		P	H,D
Shipsa		Sh	D
Acroneuria abnormis		P	H,D
Acroneuria sp.		P	H
Agnetina annulipes		P	H
Paragnetina fumosa		P	H
Perlesta placida		P	H,D
Perlinella		P	H
Clioperla clio		P	H
Helopicus bogaloosa		P	H

TABLE 4-175, Contd

Scientific Name	Common Name	Group[a]	Sampling[b] Method
Hydroperla		P	H
Isoperla		P	H,D
Pteronarcys dorsata		Sh	H,D
Taeniopteryx longicera		Sh	H
T. robinae		Sh	H,D
Order Hemiptera			
Belostoma		P	D
Palmacorixa		PH	D
Sigara		PH	D
Trichocorixa		PH	D
Gerridae		P	D
Hydrometra		P	D
Mesovelia mulsanti		P	D
Nepidae		P	D
Neoplea		P	D
Order Coleoptera	Beetles		
Ancyronyx variegatus		CG	H,D
Dubiraphia		CG	H,D
Macronychus glabratus		CG	H,D
Microcylloepus pusillus		CG	H,D
Stenelmis		Sc	H,D
Dineutes		P	H,D
Gyrinus		P	H,D
Haliplus		Sh	D
Peltodytes		Sh	D
Hydrochus		Sh	D
Berosus		PH	H,D
Tropisternus		P	D
Noteridae		P	D
Curculionidae		P	D
Coptatomus		P	D
Dytiscus		P	D
Hygrotus		P	D
Liodessus		P	D
Order Megaloptera	Fishflies & Dobsonflies		
Chauliodes		P	H,D
Corydalus cornutus		P	H,D
Nigronia		P	H
Sialis		P	D
Order Neuroptera	Spongilla flies		
Climacia areolaris		P	D
Sisyra		P	D

TABLE 4-175, Contd

Scientific Name	Common Name	Group[a]	Sampling[b] Method
Order Trichoptera	Caddisflies		
Brachycentrus		CF	H,D
Micrasema		Sh	D
Cheumatopsyche spp.		CF	H,D
Hydropsyche		CF	H,D
Macrostemum carolina		CF	H,D
Hydroptila		PH	H,D
Ochrotrichia		CG	D
Orthotrichia		PH	H
Oxythira		PH	H,D
Lepidostoma		Sh	D
Ceraclea		Sh	H,D
Leptocerus americanus		Sh	D
Nectopsyche candida		Sh	H,D
Nectopsyche sp.		Sh	H,D
Oecetis		P	H,D
Trianodes		Sh	D
Limnephilidae		Sh	H,D
Ironoquia		Sh	D
Pycnopsyche		Sh	D
Cernotina		P	D
Chimarra		CF	H,D
Neureclipsis		CF	H,D
Cyrnellus		CF	H,D
Nyctiophylax		P	D
Phylocentropus		CF	H
Polycentropus		P	H,D
Lype diversa		CG	H,D
Order Lepidoptera	Moths & butterflies		
Neargyractis		Sc	D
Parapoynx		Sh	H,D
Synclita		Sh	H,D
Petrophila sp.		Sh	H
Order Diptera	True flies		
Ceratopogonidae	Biting midges		
Ceratopogoninae		P	H,D
Forcipomyiinae		P	H,D
Chaoboridae	Phantom midges		
Chaoborus punctipennis		P	H,D
Chironomidae	Midges	CG[c]	H,D
Tanytarsini		CF	H,D
Tanypodinae		P	H,D
Empididae	Dance flies	P	H,D
Simuliidae	Blackflies	CF	H
Simulium		CF	H,D

TABLE 4-175, Contd

Scientific Name	Common Name	Group[a]	Sampling[b] Method
Tipulidae	Craneflies		
Tipula		Sh	H,D
Culicidae	Mosquitoes		
Culex		CF	D
Aedes		CF	D
Anopheles		CF	D
Uranotaenia		CF	D
Ephydridae	Shore flies	CG	D
Psychodidae	Moth flies	CG	D
Ptychopteridae	Phantom crane flies		
Bittacomorpha		CG	D

[a] Functional feeding group: CG = Collector-Gatherer; CF = Collector-Filterer; P = Predator; Sh = Shredder; Sc = Scraper; PH = Piercer-Herbivore

[b] Sampling method: H = Hester-Dendy multiplate sampler; D = drift sample

[c] Taxon included more than one functional group; the most common functional group was listed.

Source: O'Hop et al. (1985); Chimney and Cody (1986)

TABLE 4-176

Macroinvertebrate Data Collected on Multiplate Samplers from the Savannah River: Average Number of Taxa per Sampler, Average Density of Macroinvertebrates (no./m^2 of sampler), and Average Biomass (g AFDW/m^2 of sampler) (October 1983 - September 1985)

Station[a]	Average No. Taxa/Sampler	Average Density	Average Biomass
October 1983 - September 1984			
RM 152.2 (above BDC)	17.0	4968.5	0.403
RM 152.0 (below BDC)	16.8	5242.4	0.735
RM 150.8 (above FMC)	17.6	6174.0	0.753
RM 150.4 (below FMC)	17.2	5868.9	0.755
RM 141.7 (above SC)	14.6	2922.5	0.390
RM 141.5 (below SC)	15.7	3171.4	0.387
RM 137.7	13.5	4542.7	0.511
RM 129.1 (above LTRC)	14.5	3892.7	0.496
RM 128.9 (below LTRC)	12.0	3736.9	0.398
October 1984 - September 1985			
RM 152.2 (above BDC)	20.2	6218.7	0.628
RM 152.0 (below BDC)	20.3	5823.6	0.586
RM 150.8 (above FMC)	20.9	7083.5	0.706
RM 150.4 (below FMC)	21.4	7986.0	0.805
RM 141.7 (above SC)	17.2	5046.6	0.708
RM 141.5 (below SC)	21.5	2751.2	0.419
RM 137.7	20.7	3270.8	0.518
RM 129.1 (above LTRC)	18.9	3665.1	0.679
RM 128.9 (below LTRC)	18.2	3420.5	0.533

[a] RM = River Mile; BDC = Beaver Dam Creek; FMC = Four Mile Creek; SC = Steel Creek; LTRC = Lower Three Runs Creek

Source: O'Hop et al. (1985); Chimney and Cody (1986)

Mean macroinvertebrate biomass (ash-free dry weight) ranged from 0.387 to 0.805 g AFDW/m^2 at the nine sampling stations (Table 4-176). At most stations (and particularly those located downriver of RM 150.8), biomass was somewhat higher in 1984-1985 than in 1983-1984. There were no obvious trends observed between stations located upstream and downstream of SRS creek mouths.

The most abundant groups collected from the multiplate samplers belonged to the insect orders Diptera (46.5 to 86.3%), Ephemeroptera (3.3 to 17.3%), Trichoptera (7.9 to 39.0%), and Plecoptera (0.1 to 3.1%) and the oligochaete worms (0.0 to 4.3%; Tables 4-177 and 4-178). The Diptera was dominated by the Chironomidae (midges) and Simuliidae (blackflies); Ephemeroptera by Stenonema, Baetis, Heptagenia, Tricorythodes, Ephemerella, and Euryophella; Trichoptera by hydropsychid caddisflies, especially Cheumatopsyche; and Plecoptera by Taeniopteryx (winter) and Perlesta (O'Hop et al., 1985).

With respect to functional feeding groups, collector-gatherers (mostly dipterans and mayflies) were numerically dominant on the multiplate samplers at all stations in 1983-1984 (43.1 to 70.0%), while collector-filterers were dominant at all stations in 1984-1985 (48.2 to 63.1%; Table 4-179). The most commonly collected collector-filterers included net-spinning caddisflies (Hydropsychidae), blackflies (Simuliidae) and tanytarsine midges. Together, collector-gatherers and collector-filterers consistently accounted for more than 80% of the organisms collected. Predators comprised 1.2 to 6.1% of the organisms on the multiplates over the two-year period. Scrapers were locally abundant near Lower Three Runs Creek (7.8 to 13.5%), but less abundant at the other river stations (1.3 to 6.6%). Shredders were collected infrequently, comprising less than 1% of the organisms collected at all stations (Table 4-179).

With respect to biomass, collectors (collector-gatherers and filterers combined) accounted for 55.4 to 83.9% of macroinvertebrate biomass on the multiplate samplers at the nine sampling stations over the two-year period; scrapers accounted for 8.3 to 30.5%, predators for 5.7 to 21.5% and shredders for 0.0 to 4.2% (Table 4-180). Scrapers and predators comprised a larger proportion of biomass at most stations than suggested by their numerical abundance, due to the relatively large size of some species (e.g., large stonefly or megalopteran predators, or snails, which are scrapers). No consistent longitudinal trends were observed in either year with respect to functional groups numerical abundance or biomass, nor were any consistent differences apparent above and below SRS streams.

4.6.2.2 Macroinvertebrate Drift

The taxonomic composition of the drift samples differed substantially from that of the multiplate samples. In general, dipterans were relatively less abundant in the drift, while Hydracarina, Oligochaeta, Ephemeroptera, and Trichoptera constituted higher percentages of the organisms collected from the drift than on the multiplates (Tables 4-181 and 4-182). There

TABLE 4-177

Percent Abundance of Major Groups of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers in the Savannah River (October 1983 - September 1984)

Taxon	RM[a] 152.2		RM 152.0		RM 150.8	RM 150.4		RM 141.7	RM 141.5		RM 137.7	RM 129.1	RM 128.9	
	E[b]	W[c]	E	W	E	E	W	E	E	W	E	E	E	W
Turbellaria	0.1	0.1	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
Nematoda	0.1	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0
Oligochaeta	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0
Hirudinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Gastropoda	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Pelecypoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Hydracarina	0.5	0.3	0.3	0.4	0.6	0.3	0.2	0.4	0.2	0.3	0.1	0.2	0.1	0.
Isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.
Decapoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Collembola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Ephemeroptera	4.9	6.1	3.9	4.2	4.5	3.7	3.3	6.5	4.3	7.2	5.2	7.1	5.1	7
Odonata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Plecoptera	0.3	0.3	0.2	0.2	0.3	0.4	0.1	0.4	0.3	0.3	0.3	0.4	0.3	0.
Coleoptera	0.2	0.1	0.6	0.2	0.2	0.3	0.1	0.3	1.3	1.2	0.2	0.2	0.2	0.
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.
Trichoptera	22.9	20.8	25.7	13.7	32.3	37.6	12.4	20.8	15.5	39.0	18.9	20.0	7.9	12.
Diptera	70.6	71.9	68.5	81.2	61.9	57.3	83.8	71.2	77.9	51.8	75.2	71.9	86.3	79.
Total[d]	99.9	99.9	100.0	100.0	100.0	99.8	100.0	99.9	99.9	99.9	99.9	99.9	99.9	100.

[a] River Mile
[b] East Bank
[c] West Bank
[d] Some columns may not total 100.0% due to rounding.

Source: O'Hop et al. (1985)

TABLE 4-178

Percent Abundance of Major Groups of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers in the Savannah River (October 1984 - September 1985)

Taxon	RM[a] 152.2		RM 152.0		RM 150.8	RM 150.4		RM 141.7	RM 141.5		RM 137.7	RM 129.1	RM 128.9	
	E[b]	W[c]	E	W	E	E	W	E	E	W	E	E	E	W
Turbellaria	0.2	0.5	<0.1	0.3	<0.1	0.1	<0.1	<0.1	0.2	<0.1	0.3	<0.1	<0.1	0.0
Nematoda	0.3	0.2	0.2	0.4	0.2	0.2	0.2	0.1	0.1	0.2	0.3	<0.1	<0.1	<0.1
Oligochaeta	4.3	0.5	0.4	3.5	0.4	0.4	<0.1	<0.1	0.4	0.1	4.2	0.8	0.2	0.6
Hirudinea	<0.1	0.1	<0.1	<0.1	0.0	0.0	<0.1	0.0	<0.1	<0.1	0.0	<0.1	<0.1	<0.1
Gastropoda	0.1	0.1	<0.1	1.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.1	0.1	<0.1	<0.1
Pelecypoda	<0.1	<0.1	0.0	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	<0.1	0.0	0.0	<0.1
Hydracarina	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.5	0.3	0.3	0.3	0.2	0.4
Amphipoda	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	<0.1	2.8	<0.1	0.2	<0.1	<0.1	<0.1
Decapoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	5.7	6.2	5.6	5.6	6.1	4.0	6.5	8.5	8.5	11.9	13.4	17.3	16.5	16.1
Odonota	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Plecoptera	1.2	1.3	1.1	1.9	1.3	1.0	1.4	1.2	1.4	1.9	3.1	1.9	1.4	2.6
Hemiptera	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	0.3	0.2	0.9	0.4	0.3	0.3	0.2	0.2	0.7	0.2	0.8	0.6	0.6	0.4
Megaloptera	<0.1	<0.1	0.2	<0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.2	0.2	0.3	<0.1
Trichoptera	22.1	29.1	23.3	21.5	27.5	26.2	10.8	29.8	30.2	30.4	29.6	30.0	26.4	17.8
Lepidoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	<0.1	0.0	0.0	0.0
Diptera	65.2	61.3	67.9	64.7	63.6	67.4	80.3	59.5	54.7	54.8	46.5	48.7	54.3	61.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] River Mile
[b] East Bank
[c] West Bank

Source: Chimney and Cody (1986)

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TABLE 4-179

Average Percent of Total Density (no./m^2 of sampler) of Macroinvertebrate Functional Groups Collected from Multiplate Samplers in the Savannah River (October 1983 - September 1985)

October 1983 - September 1984

Station[a]	Collectors				
	Gatherers	Filterers	Scrapers	Shredders	Predators
RM 152.2 (above BDC)	70.0	22.6	2.0	0.2	5.2
RM 152.0 (below BDC)	63.1	31.7	1.6	0.0	3.6
RM 150.8 (above FMC)	57.4	38.0	1.8	0.1	2.7
RM 150.4 (below FMC)	62.4	33.6	1.3	0.0	2.7
RM 141.7 (above SC)	58.7	34.2	4.8	0.1	2.1
RM 141.5 (below SC)	54.9	38.0	3.4	0.0	3.7
RM 137.7	48.4	44.2	5.8	0.2	1.4
RM 129.1 (above LTRC)	48.7	41.9	7.8	0.4	1.2
RM 128.9 (below LTRC)	43.1	41.4	13.5	0.2	1.8

October 1984 - September 1985

RM 152.2 (above BDC)	42.0	52.0	1.7	0.2	4.1
RM 152.0 (below BDC)	34.3	59.7	1.9	<0.1	3.9
RM 150.8 (above FMC)	34.8	59.3	2.7	0.1	3.0
RM 150.4 (below FMC)	32.7	63.1	1.3	<0.1	2.8
RM 141.7 (above SC	31.4	61.3	4.7	0.1	2.5
RM 141.5 (below SC)	38.8	54.3	1.9	0.2	4.8
RM 137.7	38.8	48.2	6.6	0.3	6.1
RM 129.1 (above LTRC)	31.1	54.0	10.7	0.3	3.9
RM 128.9 (below LTRC)	29.8	56.0	10.8	0.2	3.2

[a] RM = River Mile; BDC = Beaver Dam Creek; FMC = Four Mile Creek; SC = Steel Creek; LTRC = Lower Three Runs Creek

Source: O'Hop et al. (1985); Chimney and Cody (1986)

TABLE 4-180

Average Percent of Total Biomass (g AFDW/m^2 of sampler) of Macroinvertebrate Functional Groups Collected from Multiplate Samplers in the Savannah River (October 1983 - September 1985)

October 1983 - September 1984

Station[a]	Collectors	Scrapers	Shredders	Predators
RM 152.2 (above BDC)	80.1	13.7	0.5	5.7
RM 152.0 (below BDC)	83.9	9.5	0.0	6.6
RM 150.8 (above FMC)	78.6	12.5	0.4	8.5
RM 150.4 (below FMC)	82.8	10.9	0.1	6.2
RM 141.7 (above SC)	60.6	22.1	0.7	16.6
RM 141.5 (below SC)	67.3	15.0	0.2	17.6
RM 137.7	74.2	19.7	0.3	5.8
RM 129.1 (above LTRC)	61.0	20.6	4.2	14.2
RM 128.9 (below LTRC)	57.2	30.5	0.5	11.8

October 1984 - September 1985

RM 152.2 (above BDC)	78.5	9.2	0.5	11.8
RM 152.0 (below BDC)	75.2	12.5	0.1	12.1
RM 150.8 (above FMC)	76.3	14.3	0.2	9.2
RM 150.4 (below FMC)	77.5	9.7	0.2	12.6
RM 141.7 (above SC)	66.0	19.9	0.3	13.8
RM 141.5 (below SC)	75.3	8.3	1.2	15.2
RM 137.7	61.7	18.1	1.2	19.0
RM 129.1 (above LTRC)	59.6	15.9	3.0	21.5
RM 128.9 (below LTRC)	55.4	19.6	3.8	21.2

[a] RM = River Mile; BDC = Beaver Dam Creek; FMC = Four Mile Creek; SC = Steel Creek; LTRC = Lower Three Runs Creek

Source: O'Hop et al. (1985); Chimney and Cody (1986)

were substantial differences in the taxonomic composition of the drift samples between the two sampling years, which suggests high temporal variability in the species composition of the drift. This variability is to be expected, since many taxa become more prevalent in the drift during emergence or during spates (Waters, 1972).

Macroinvertebrate drift densities also varied temporally. Average drift densities at the nine sampling stations in 1983-1984 ranged from 927.1 to 1303.6 organisms/1000 m^3, while in 1984-1985 drift densities were substantially higher at all stations, ranging from 1354.2 to 3235.6 organisms/1000 m^3 (Table 4-183). However, much of the increase in drift densities in 1984-1985 can be attributed to very high densities during May 1985 (Table 4-183).

Collector-gatherers were the numerically dominant functional feeding group in the drift samples in both years, comprising 53.1 to 67.4% of the drift organisms in 1983-1984 and 73.8 to 86.9% in 1984-1985 (Table 4-184). Predators or collector-filterers were usually the second most abundant functional group (5.7 to 22.8%), followed by shredders (0.3 to 4.0%), piercer-herbivores (0.1 to 1.9%) and scrapers (0.3 to 1.8%; Table 4-184).

4.6.2.3 Impact Evaluation

The Savannah River supports a diverse and productive macroinvertebrate community similar to those found in other blackwater rivers of the southeast. Sampling stations in the Savannah River located above and below the confluences of the creeks that drain the SRS showed both seasonal and annual differences in taxonomic composition, invertebrate densities, biomass and functional feeding group composition, but location above and below the creek confluences was usually not significant and the few differences that were significant appear to be related to differences in water velocity and habitat, rather than to SRS operations. No evidence was found which indicates that SRS operations have had any adverse effects on the macroinvertebrate community of the Savannah River in the past, and no impacts are anticipated when reactor operations are resumed.

4.6.3 Fish Communities

4.6.3.1 Impingement and Entrainment

The Savannah River Site (SRS) is located on the middle reaches of the Savannah River and withdraws cooling water from the river for nuclear production reactors, fossil fuel steam and electric generators, and other facilities. Flow in the Savannah River is regulated by the operation of a series of dams upstream of the SRS, particularly the Strom Thurmond (formerly Clarks Hill) Dam and reservoir that is operated by the U.S. Army Corps of Engineers. The intake of river water at the SRS results in the impingement and entrainment of some resident and migratory fishes at the SRS pumping facilities (DOE, 1984, McFarlane et al., 1978).

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TABLE 4-181

Percent Abundance of Major Groups of Macroinvertebrates Collected in Drift Samples from the Savannah River (October 1983 - July 1984)

Taxon	RM 157.3[a]	RM 157.0	RM 152.2	RM 152.0	RM 150.8	RM 150.4	RM 141.7	RM 141.5	RM 137.7	RM 127.1	RM 128.9
Turbellaria	0.4	0.0	0.6	0.7	0.6	0.3	0.2	0.9	0.4	0.4	0.1
Nematoda	1.6	0.0	1.4	0.9	1.9	1.8	2.2	1.3	1.4	1.5	1.3
Hirudinea	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Gastropoda	0.4	0.0	0.7	0.2	0.4	0.3	0.2	0.3	0.2	0.1	0.0
Pelecypoda	0.3	3.5	0.4	0.3	0.7	0.3	0.2	0.2	0.3	0.3	0.0
Hydracarina	10.0	18.1	7.3	10.0	10.2	7.0	4.6	7.6	6.2	7.9	5.9
Isopoda	0.2	0.0	0.1	0.1	0.4	0.1	0.4	0.2	0.2	0.2	0.1
Amphipoda	1.0	1.2	0.9	0.8	0.9	1.1	1.1	1.9	1.5	1.0	1.4
Decapoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Collembola	1.3	0.0	0.9	0.7	0.8	0.9	0.6	0.5	0.4	0.5	0.4
Ephemeroptera	9.5	9.2	8.7	11.0	9.9	10.3	14.8	12.5	12.0	11.4	12.6
Odonata	0.7	0.7	0.6	1.0	0.7	0.9	1.2	1.3	1.1	1.8	0.6
Plecoptera	0.4	0.3	0.4	0.7	0.7	0.5	1.1	0.7	0.6	1.2	0.8
Hemiptera	0.3	4.2	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.3	0.2
Coleoptera	1.2	7.0	1.9	1.9	2.3	1.8	2.9	2.4	2.6	2.5	3.2
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0.3
Neuroptera	0.0	1.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.0
Trichoptera	10.3	5.1	15.7	15.0	14.6	14.1	20.9	18.9	20.6	20.2	17.2
Lepidoptera	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.4	0.0	0.3	0.3
Diptera	62.4	49.6	59.9	56.3	55.6	60.0	48.7	50.4	52.3	50.1	55.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] RM = River Mile

Source: O'Hop et al. (1985)

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TABLE 4-182

Percent Abundance of Major Groups of Macroinvertebrates Collected in Drift Samples from the Savannah River (November 1984 - July 1985)

Taxon	RM 157.3[a]	RM 152.2	RM 152.0	RM 150.8	RM 150.4	RM 141.7	RM 141.5	RM 137.7	RM 129.1	RM 128.9
Turbellaria	0.7	0.2	0.6	0.3	0.3	0.1	0.3	0.4	0.1	0.2
Nematoda	3.1	3.3	4.5	3.7	4.2	2.2	2.5	2.2	2.6	2.6
Oligochaeta	44.6	48.2	44.5	46.3	47.5	51.9	42.3	37.6	33.7	34.7
Hirudinea	<0.1	0.0	0.1	<0.1	0.1	<0.1	<0.1	0.1	0.0	<0.1
Gastropoda	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.2
Pelecypoda	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.0
Hydracarin[aa]	2.0	2.5	2.9	3.8	3.5	2.2	2.8	3.8	4.9	4.8
Isopoda	0.0	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1
Amphipoda	0.1	0.1	0.1	<0.1	0.1	0.1	0.3	0.4	0.4	0.2
Decapoda	<0.1	0.0	0.0	0.0	<0.1	<0.1	0.0	<0.1	<0.1	0.0
Collembola	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	<0.1	0.1
Ephemeroptera	2.9	2.8	2.9	2.7	3.0	3.9	5.1	5.1	8.3	7.6
Odonata	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.5	0.3
Plecoptera	0.3	0.4	0.4	0.3	0.3	1.1	1.0	1.2	1.7	1.4
Hemiptera	<0.1	<0.1	<0.1	0.0	<0.1	<0.1	<0.1	0.0	0.0	<0.1
Coleoptera	0.6	0.6	0.7	0.7	0.7	1.0	1.1	0.8	1.3	0.8
Megaloptera	0.0	<0.1	0.0	0.0	0.0	<0.1	<0.1	<0.1	<0.1	0.0
Neuroptera	<0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.2
Trichoptera	4.3	3.7	4.7	4.1	3.5	4.5	5.2	7.9	7.4	7.1
Lepidoptera	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.1	<0.1	0.2
Diptera	40.8	37.6	37.8	37.3	36.0	32.3	38.6	39.6	38.5	39.6
Other	0.1	<0.1	0.1	0.1	<0.1	<0.1	0.0	<0.1	<0.1	0.0
Total[a]	100.2	100.1	100.0	100.0	100.0	100.0	100.1	99.9	99.8	100.1

[a] Some columns may not total 100.0% due to rounding.
[b] RM = River Mile

Source: Chimney and Cody (1986)

TABLE 4-183

Invertebrate Drift Density (no./1000 m^3) at Stations in the Savannah River (October 1983 - July 1985)

1983-1984

River Mile	1983 October	1984 February	May	July	Average
152.2	2216.3	938.8	985.2	705.2	1186.4
152.0	1997.5	833.1	864.2	453.2	1037.0
150.8	1423.9	734.7	881.8	668.1	927.1
150.4	1579.4	876.6	1478.7	345.3	1070.0
141.7	1711.5	1078.4	1316.7	623.5	1182.5
141.5	1667.6	1069.5	1296.0	936.2	1242.3
137.7	1908.9	1092.1	1497.2	865.0	1340.8
129.1	1777.2	1186.7	791.7	525.3	1070.2
128.9	2317.7	1189.7	1397.6	327.3	1303.6

1984-1985

River Mile	1984 November	1985 February	May	July	Average
152.2	893.1	1446.8	5032.6	440.8	1953.3
152.0	773.7	1842.0	4286.9	702.2	1901.2
150.8	931.0	1492.6	4594.8	714.9	1933.3
150.4	843.3	2018.9	5159.4	596.4	2154.5
141.7	1027.1	2471.3	8930.1	513.8	3235.6
141.5	808.8	1951.2	3437.1	720.9	1729.5
137.7	1325.2	2351.6	3540.4	549.7	1941.7
129.1	717.5	2038.5	2299.7	361.2	1354.2
128.9	892.6	2010.4	2776.3	405.4	1521.2

Source: O'Hop et al. (1985); Chimney and Cody (1986)

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TABLE 4-184

Percent Abundance of Macroinvertebrate Functional Feeding Groups in Drift Samples Collected from the Savannah River (October 1983 - July 1985)

Functional Group	RM 157.3	RM 152.2	RM 152.0	RM 150.8	RM 150.4	RM 141.7	RM 141.5	RM 137.7	RM 129.1	RM 128.9
1983-1984										
Collector-Gatherers	66.4	66.2	61.9	62.6	67.4	58.2	59.3	58.4	53.1	63.6
Collector-Filterers	9.7	15.1	15.3	14.5	15.1	21.0	17.9	22.8	22.6	18.6
Scrapers	1.1	1.8	1.8	1.5	1.0	1.5	1.0	0.9	1.5	1.3
Predators	20.7	14.9	19.0	19.4	15.1	16.6	17.8	15.2	17.6	12.9
Piercer-Herbivores	0.7	0.5	0.6	0.6	0.4	1.0	1.9	0.6	1.2	0.9
Shredders	1.3	1.4	1.4	1.4	1.0	1.7	2.0	2.1	4.0	2.8
Total[a]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Functional Group	RM 157.3	RM 152.2	RM 152.0	RM 150.8	RM 150.4	RM 141.7	RM 141.5	RM 137.7	RM 129.1	RM 128.9
1984-1985										
Collector-Gatherers	84.9	86.9	85.1	84.7	86.1	85.9	81.9	73.8	76.6	76.8
Collector-Filterers	7.4	6.6	6.6	6.7	5.7	6.0	8.6	15.0	10.0	10.3
Scrapers	0.6	0.5	0.4	0.3	0.4	0.4	0.8	0.8	0.8	0.9
Predators	6.6	5.4	7.0	7.6	7.3	6.9	7.9	9.0	11.4	10.4
Piercer-Herbivores	0.3	0.1	0.3	0.2	0.1	0.2	0.3	0.1	0.3	0.2
Shredders	0.3	0.4	0.6	0.5	0.3	0.7	0.4	1.4	0.9	1.3
Total[a]	100.1	99.9	100.0	100.0	99.9	100.1	99.9	100.1	100.0	99.9

[a] Some columns may not total 100.0% due to rounding.

RM = River Mile

Source: O'Hop et al. (1985); Chimney and Cody (1986)

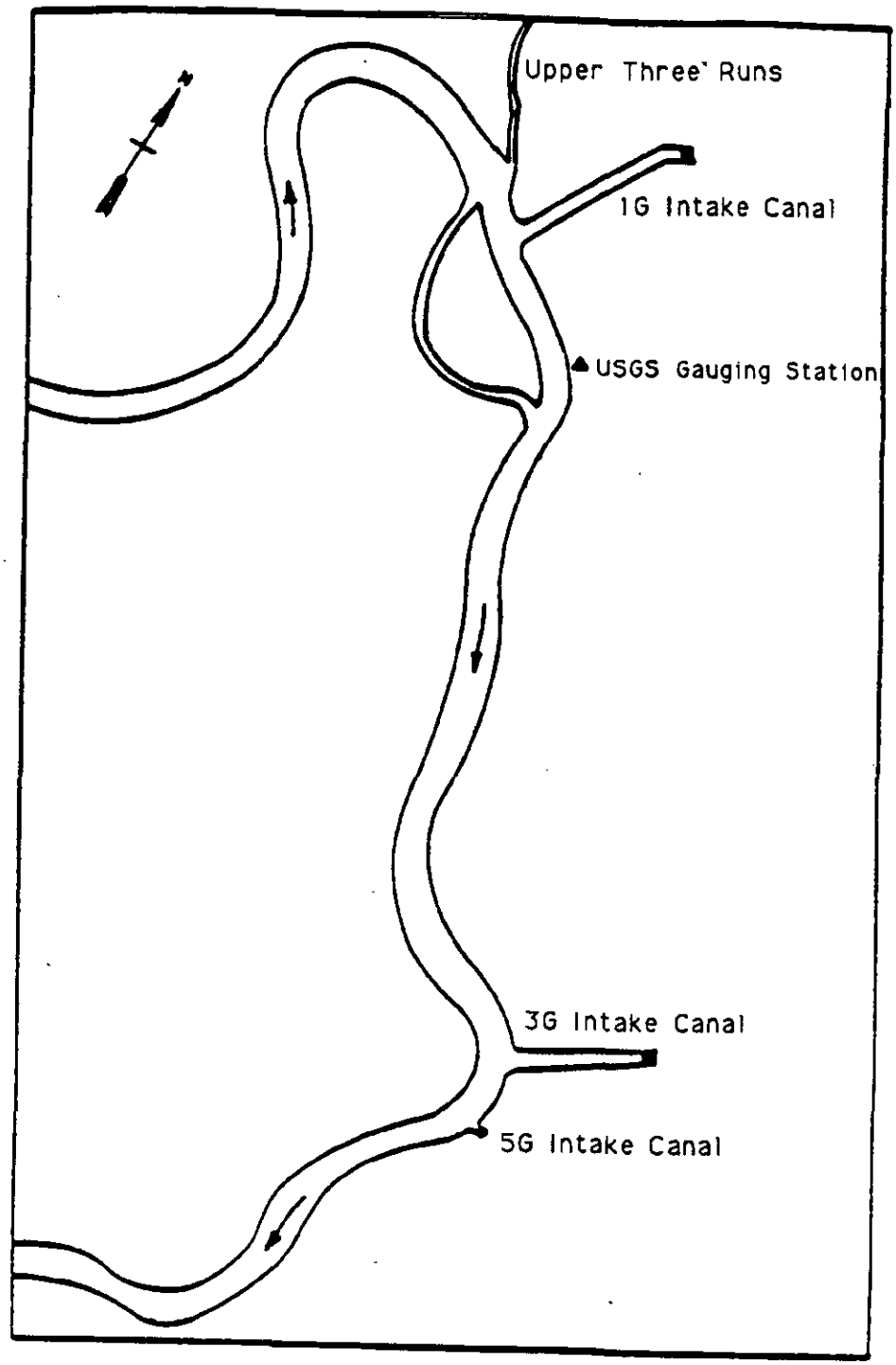

FIGURE 4-72. SRS Pumping Station Locations

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The Savannah River Site operates three pumping stations on the Savannah River (Figure 4-72). Two of these, designated 1G and 3G, are identical ten-pump units, each located at the terminus of a long intake canal. The third station, 5G, operates six smaller pumps on a small inlet cove of the river, just downriver from Station 36. The monthly average volume of Savannah River water withdrawn at the 1G and 3G intakes combined ranged from 14.4 m^3/sec to 25.3 m^3/sec during 1983-1985 (Table 4-185). Intake volume at the 5G pumphouse was relatively constant at approximately 2.2 m^3/sec. The percentage of Savannah River water withdrawn at the 1G and 3G intake was 4.1% to 14.4% of the river volume in 1983, 4.1% to 13.1% in 1984, and 6.7% to 14.6% in 1985 (Table 4-185).

4.6.3.1.1 Adult and Juvenile Fish

Streams of the southeastern Atlantic Coastal Plain generally contain a diverse fish fauna. Dahlberg and Scott (1971) reported 106 fish species from the Savannah River drainage basin. Bennett and McFarlane (1983) have summarized available literature and found that 71 species of anadromous and fresh water fishes were reported from the Savannah River in the vicinity of the SRS.

The Savannah River supports both recreational and commercial fisheries. Bream and largemouth bass are the species most sought after by sport fishermen in freshwater sections of the river (Schmitt and Hornsby, 1985). Channel catfish are taken by both sport and commercial fishermen. Anadromous species of importance in the Savannah River include American shad (Alosa sapidissima), hickory shad (Alosa mediocris), Atlantic sturgeon (Acipenser oxyrhynchus), shortnose sturgeon (Acipenser brevirostrum), and striped bass (Morone saxatilis). Both shortnose sturgeon and striped bass are protected from commercial harvest, and the shortnose sturgeon is listed as an endangered species. The catadromous American eel (Anguilla rostrata) is harvested commercially in some sections of the river.

The species composition and relative abundance of Savannah River fish in the vicinity of the SRS were examined during 1982-1985 (ECS, 1983; Paller et al., 1984; Paller and Osteen, 1985; Paller and Saul, 1986). Quarterly collections were made along transects in the Savannah River and in the 1G and 3G intake canals using electrofishing and hoop-netting techniques. The dominant species collected in the Savannah River and the SRS intake canals during 1982-1985 are presented in Table 4-186. Other species comprising less than one percent of reported catches for either location or sampling gear are presented in Table 4-187.

Several factors have been identified as potentially affecting the productivity of Savannah River fish populations. Schmitt and Hornsby (1985) identified two areas of the lower Savannah River where water quality is substantially degraded as a result of wastewater input: below the New Savannah Bluff Lock and Dam from Butler Creek to downstream of Spirit Creek and the Savannah Harbor area. Rulifson et al. (1982) cited

TABLE 4-185

Monthly Volume and Percent of Savannah River Water Withdrawn at the 1G and 3G Intakes at the SRS, 1983-85

		1983	1984	1985
January	Volume(m^3/sec)	23.7	25.3	23.0
	Percent of River[a]	5.8	5.6	12.9
February	Volume(m^3/sec)	22.5	15.2	22.8
	Percent of River	4.6	4.1	6.7
March	Volume(m^3/sec)	22.6	18.0	21.6
	Percent of River	4.4	4.4	10.5
April	Volume(m^3/sec)	22.8	23.7	21.8
	Percent of River	4.1	6.3	12.4
May	Volume(m^3/sec)	22.8	23.6	22.8
	Percent of River	9.3	6.4	14.6
June	Volume(m^3/sec)	16.9	22.0	18.7
	Percent of River	6.4	9.2	12.6
July	Volume(m^3/sec)	19.5	22.2	15.7
	Percent of River	10.2	9.8	9.5
August	Volume(m^3/sec)	23.4	23.1	15.3
	Percent of River	12.7	7.8	9.5
September	Volume(m^3/sec)	22.6	23.8	16.4
	Percent of River	12.1	11.3	10.7
October	Volume(m^3/sec)	23.1	18.8	19.9
	Percent of River	13.5	10.5	-[b]
November	Volume(m^3/sec)	22.9	14.4	21.3
	Percent of River	14.4	7.9	-
December	Volume(m^3/sec)	23.6	22.0	18.2
	Percent of River	9.8	13.1	-

[a] Percentage over-estimated during months of high river discharge.
[b] River discharge volume not available.

TABLE 4-186

Percent Composition of Abundant[a] Fish Species Collected in the Savannah River and SRS Intake Canals, 1982-85

	Savannah River		Intake Canals	
Taxa	Electro-Fishing Percent	Hoop-Netting Percent	Electro-Fishing Percent	Hoop-Netting Percent
Flier	0.30	1.21	0.09	1.55
Redbreast sunfish	26.73	7.09	10.04	12.69
Bluegill	8.44	4.32	24.07	19.95
Spotted sunfish	5.22	0.86	1.83	1.55
Warmouth	1.25	1.04	0.85	0.26
Pumpkinseed	0.17	0.35	2.30	1.04
Redear sunfish	1.63	0.95	4.13	1.81
Dollar sunfish	2.74	0.00	8.38	0.26
Bluespotted sunfish	0.98	0.00	2.34	0.00
Largemouth bass	7.69	0.00	6.04	0.00
Black crappie	2.07	4.75	0.89	27.20
Yellow perch	1.08	0.00	6.47	0.78
Bowfin	3.83	1.04	1.91	1.04
Blueback herring	1.73	0.17	0.51	0.00
American shad	1.25	0.26	0.00	0.00
Gizzard shad	2.44	0.86	2.76	2.59
Threadfin shad	1.96	0.00	0.94	0.00
Spotted sucker	11.21	0.78	5.23	3.37
Lined topminnow	0.00	0.00	1.20	0.00
Pirate perch	1.49	0.00	0.47	0.00
Chain pickerel	3.29	0.00	10.97	0.26
Grass pickerel	1.08	0.00	1.70	0.00
Longnose gar	0.81	2.51	0.26	0.52
White catfish	0.07	8.47	0.00	0.26
Flat bullhead	0.24	31.98	0.04	11.92
Brown bullhead	0.00	1.47	0.00	0.00
Channel catfish	0.41	24.29	0.09	8.55
Brook silverside	1.29	0.00	0.94	0.00
Striped mullet	1.42	0.00	2.00	0.00
American eel	3.32	3.11	0.13	2.33
Other species	5.86	4.49	3.42	2.07

[a] Species comprising greater than one percent of all collections for either sampling method or location.

TABLE 4-187

Fish Species Collected in Low Abundance[a] in the Savannah River or SRS Intake Canals, 1982-85

Mud sunfish	Eastern silvery minnow
Redeye bass	Ohoopee shiner
White crappie	*Notropis* spp.
Striped bass	Unidentified minnow
White bass	Golden shiner
Hybrid bass	Hogchoker
Tesselated darter	Redfin pickerel
Logperch	*Esox* spp.
Blackbanded darter	Spotted gar
Lake chubsucker	Florida gar
Chubsucker	Snail bullhead
Highfin carpsucker	Speckled madtom
Silver redhorse	Eastern mudminnow
Quillback carpsucker	Mosquitofish

[a] Less than one percent of collections for any sampling method or location identified in Table 4-186.

dams and impoundments, inadequate fishway facilities, reduction in spawning habitat, reduction in nursery areas, dredge and fill projects, poor food availability, and the location, type, and magnitude of effluents into the Savannah River as potential contributors to declining anadromous fish stocks.

4.6.3.1.2 Impingement

The impingement of adult and juvenile fish on the intake screens at the SRS pumping stations was monitored during 1982-1985 (ECS, 1983; Paller et al., 1984; Paller and Osteen, 1985; and Paller and Saul, 1986). Collections of impinged fish were made on approximately 100 randomly selected dates yearly during 1983-1985. Impingement at the 1G and 5G intakes varied substantially among years. The largest annual impingement collection occurred at the 1G intake in 1983 (1462 fish, Table 4-188). Extrapolating the estimated daily impingement for this period to an entire year provides an estimate of 5336 fish per year impinged at the 1G intake during 1983. The highest annual impingement collections at the 3G (1150 fish) and 5G (1282 fish) intakes also occurred in 1983 with an estimated annual impingement of 4198 and 4679 fish per year, respectively. Although the sampling effort remained constant from 1983 through 1985, both the actual (measured) impingement and the estimated annual impingement declined through time at both the 1G and 3G intakes. The minimum estimated annual impingement occurred in 1985 at the 1G (1670 fish) and 3G (1316 fish) intakes; minimum annual impingement occurred in 1984 at the 5G intake (213 fish). Average estimated annual impingement for the three year period was 3124 fish (8.56 fish/day) at the 1G intake, 2761 fish (7.56 fish/day) at the 3G intake, and 1718 fish (4.70 fish/day) at the 5G intake.

Impingement at the SRS intakes is strongly seasonal. Approximately 60% of the fish impingement at 1G and 3G during 1983-1985 occurred from March through May (63.3% at 1G; 58.4% at 3G, Figure 4-73). Almost 93% of impingement at the 5G intake occurred during these months. Overall, the largest number of impinged fish were collected in May, when approximately 25% of the annual impingement occurred at 1G and 3G, while 65% of annual impingement at the 5G intake occurred during April. No month other than March, April, and May exhibited greater than 12% of the annual average impingement at the 1G intake. Substantial impingement occurred during January (approximately 18%) and December (approximately 12%) at the 3G intake, however. Impingement was low during the late summer and fall months at all intakes.

Bluespotted sunfish (23.29%) and threadfin shad (11.39%) were the most abundant species in impingement samples at all intakes over the three year period from 1982-1985 (Table 4-189). Among the remaining species only gizzard shad (6.31), redbreast sunfish (5.49%), and warmouth (5.30%) exceeded five percent of the total collection (Table 4-189). Thus, overall impingement losses from the Savannah River were concentrated among fish identified as forage species [see categories of Schmitt and Hornsby (1985)] that have little commercial or recreational value.

TABLE 4-188

Total Annual Impingement at 1G, 3G and 5G Intakes

Year		Intake 1G	3G	5G
1982	Total fish collected	73	284	84
	Number of days sampled	43	43	43
	Average impingement/day	1.70	6.60	1.95
	Estimated annual impingement	619.7	2410.7	713.0
1983	Total fish collected	1462	1150	1282
	Number of days sampled	100	100	100
	Average impingement/day	14.62	11.50	12.82
	Estimated annual impingement	5336.3	4197.5	4679.3
1984	Total fish collected	655	766	59
	Number of days sampled	101	101	101
	Average impingement/day	6.48	7.58	0.58
	Estimated annual impingement	2367.0	2768.2	213.2
1985[a]	Total fish collected	430	339	67
	Number of days sampled	94	94	94
	Average impingement/day	4.57	3.61	0.71
	Estimated annual impingement	1669.7	1316.3	260.2
1983-85[b] average	Total fish collected	849.0	751.7	469.3
	Number of days sampled	98.3	98.3	98.3
	Average impingement/day	8.56	7.56	4.70
	Estimated annual impingement	3124.3	2760.7	1717.6

[a] Includes unpublished data from October-December 1985.
[b] Only 1983-85 data were used for these calculations because sampling was limited in 1982.

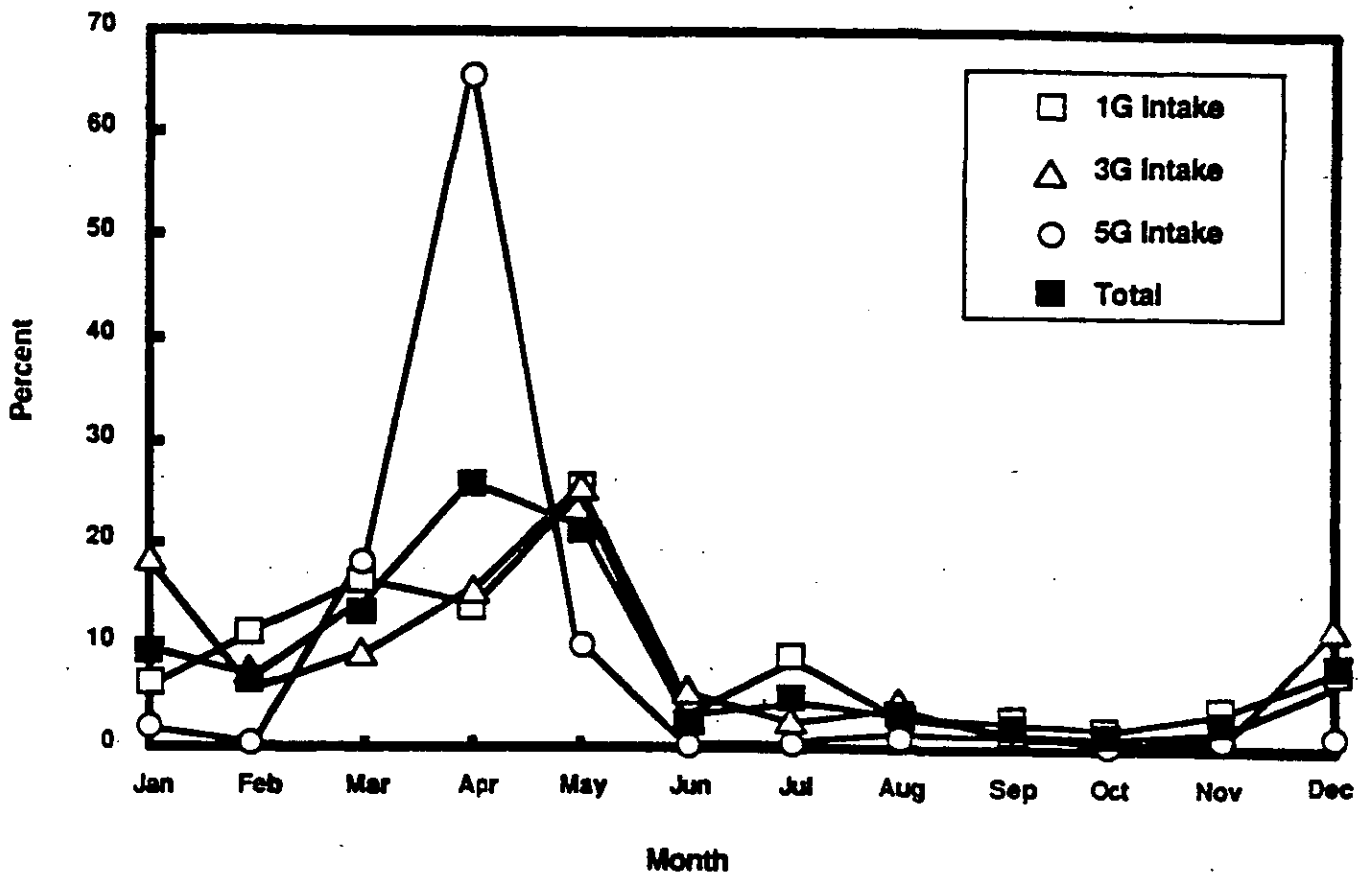

FIGURE 4-73. Monthly Percentage of Total Annual Impingement at 1G, 3G, and 5G Intakes. Average Values for 1983-1985.

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TABLE 4-189

Count and Percentages of Fish Species Representing Greater Than One Percent of Impingement Collections at the 1G, 3G, and 5G Intakes (September 1982 - September 1985)

Species	Number	Percent
Bluespotted sunfish	1465	23.29
Threadfin shad	716	11.39
Gizzard shad	397	6.31
Redbreast sunfish	345	5.49
Warmouth	333	5.30
Flier	313	4.98
Hogchoker	252	4.01
Spotted sunfish	218	3.47
Bluegill	179	2.85
Black crappie	171	2.72
Bowfin	162	2.58
Blueback herring	141	2.24
Spottail shiner	122	1.94
Pirate perch	119	1.89
Dollar sunfish	112	1.78
Pumpkinseed	85	1.35
White catfish	82	1.30
Redfin pickerel	77	1.22
Flat bullhead	70	1.11
Mud sunfish	69	1.10
Total of minor species	860	13.68
Total	6288	100.00

The impingement of fish at the SRS intakes appear to be strongly selective relative to the abundance of fish in the intake canals. Quarterly electrofishing collections from the intake canals were dominated by bluegill, redbreast and dollar sunfish at all intake areas, although not during all years (Figures 4-74, 4-75, and 4-76). Chain pickerel were collected routinely, while yellow perch, suckers, largemouth bass, and spotted sunfish appeared less routinely in collections, but occasionally in substantial numbers. The most notable exception to this pattern is the dominance of flat bullhead, white catfish, and channel catfish in collections near the 5G intake during September 1984 through September 1985. Generally, those species that were dominant in electrofishing collections were not species that were most abundant in impingement collections.

Freeman and Sharma (1977) summarized impingement data from power plants in the United States. Information for ten of these facilities in the southeastern United States is summarized in Table 4-190. Although the pumping capacity at the SRS intakes is near the middle range for the facilities considered, the annual impingement rate is the lowest (eight thousand fish per year). Only the Widows Creek (15 thousand) and Bull Run (11 thousand) Steam Plants had comparably low annual impingement rates. Three of the facilities considered (Arkansas Nuclear One, Browns Ferry and Wateree) had reported impingement rates in excess of three million fish per year.

The species composition of impingement at the SRS intakes was somewhat unique among the facilities considered, however. Whereas, impingement at most of these facilities was strongly dominated by clupeids (primarily threadfin and/or gizzard shad), bluespotted sunfish were most abundant in collections at the SRS (Table 4-189). Bluespotted sunfish and most of the other fishes impinged at the SRS intakes have little or no recreational and commercial value.

4.6.3.1.2 Ichthyoplankton

Recent studies on ichthyoplankton of the mid- and lower reaches of the Savannah River (including ichthyoplankton entrainment) began in 1982 and ended in 1985 (ECS, 1983; Paller et al., 1984; Paller et al., 1985; and Paller et al., 1986). These studies indicated that gizzard and/or threadfin shad, American shad, blueback herring, sunfishes, crappie, minnows and suckers were among the most abundant ichthyoplankton taxa in the Savannah River (Table 4-191). Generally, the cluepids (including anadromous American shad and blueback herring, and resident gizzard and threadfin shad) dominated collections in the Savannah River during 1983-1985. Some species, such as the largemouth bass and other centrarchids, were comparatively abundant as adults in the Savannah River but scarce in the ichthyoplankton collections. Eggs and larvae of these taxa reside in sheltered areas where they are unlikely to become entrained in currents and carried into open water. Such species are less susceptible to SRS entrainment impacts than those that produce drifting eggs and larvae.

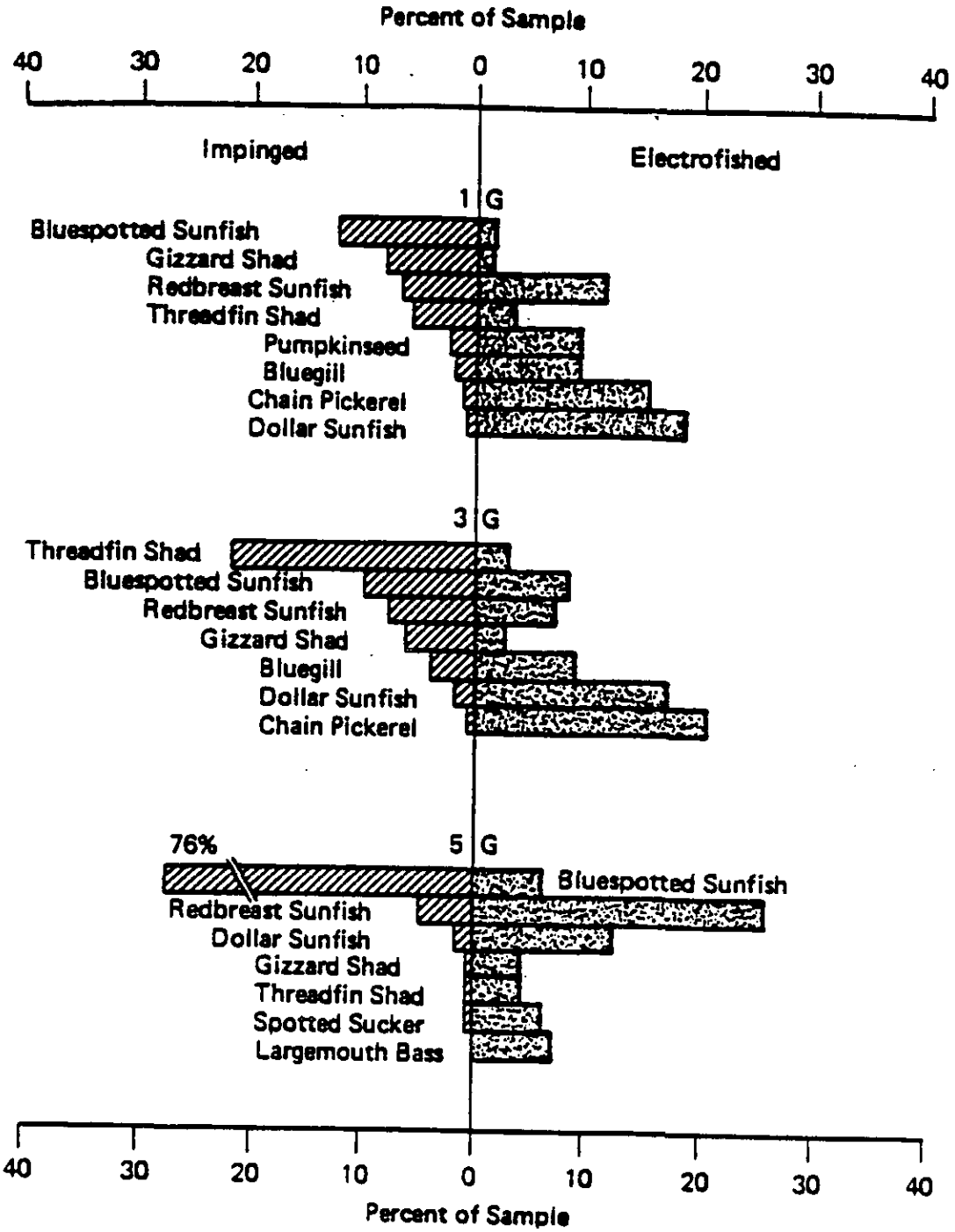

FIGURE 4-74. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouse by Electrofishing, September 1982 - August 1983 (source: Paller et al., 1984)

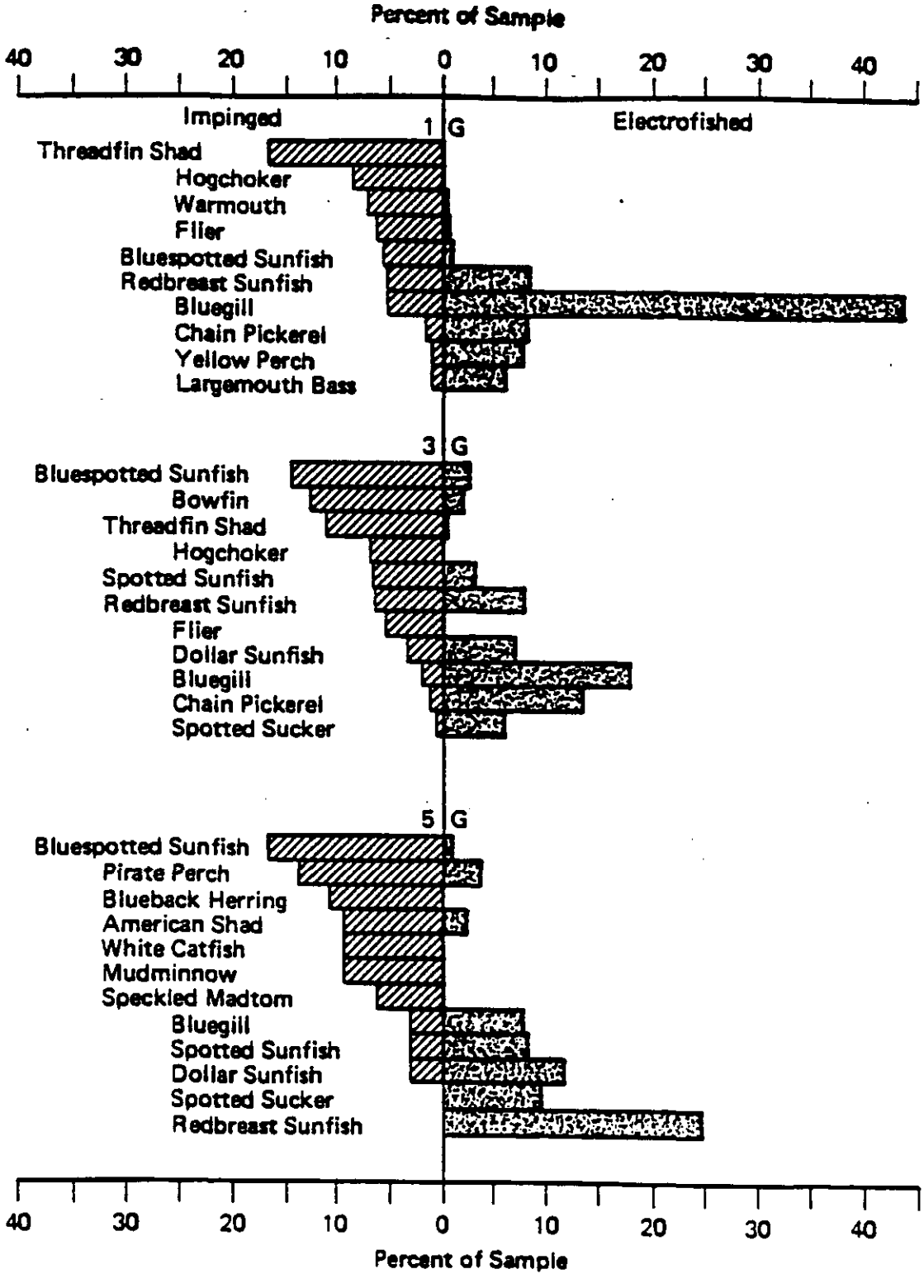

FIGURE 4-75. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouses by Electrofishing, September 1983 - August 1984 (source: Paller and Osteen, 1985)

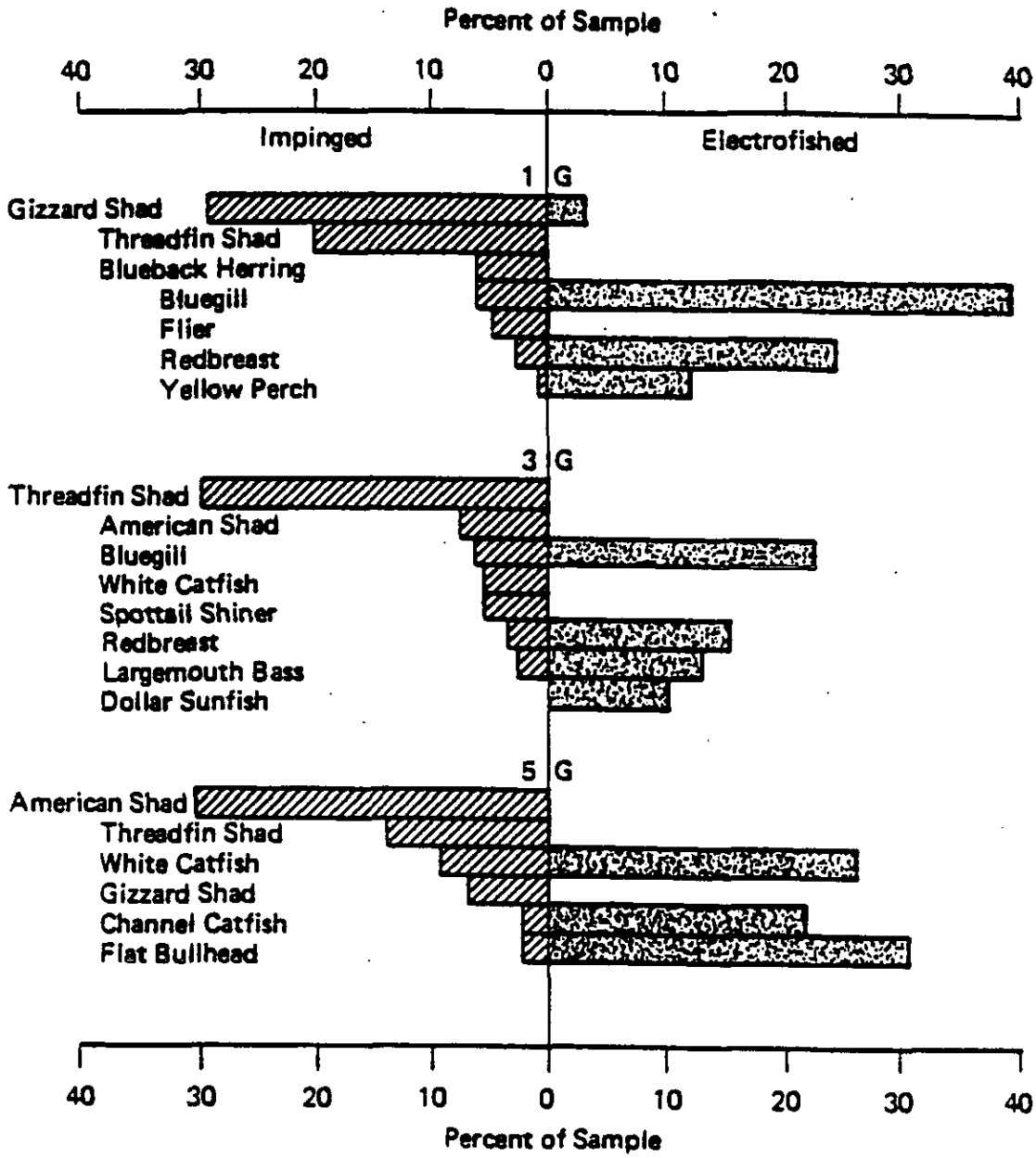

FIGURE 4-76. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected in the Vicinity of the Pumphouses by Electrofishing, September 1984 - September 1985 (source: Paller and Saul, 1986)

Summary of Fish Impingement Rates at Electrical Generating Facilities in the Southeastern United States[a] and the Savannah River Site

Facility	Location (water source)	Intake Capacity (m^3/sec)	Estimated Annual Impingement (thousands)	Abundant Species
Arkansas Nuclear One	Lake Dardanelle	49.2	15,949	Threadfin shad Gizzard shad Freshwater drum
Allen Station	Catawba River	37.8	450	Threadfin shad Gizzard shad Bluegill
Browns Ferry Nuclear Plant	Wheeler Reservoir	83.3	3,111	Shad and herring Freshwater drum Catfish
Colbert Steam Plant	Pickwick Reservoir	NA	101	Threadfin shad Skipjack herring Gizzard shad
Watts Bar Steam Plant	Watts Bar Reservoir	17.7	50	Threadfin shad Freshwater drum Bluegill
Widows Creek Steam Plant	Guntersville Reservoir	68.9	15	Threadfin shad Freshwater drum Gizzard shad
Bull Run Steam Plant	Melton Hill Reservoir	26.3	11	Threadfin shad Gizzard shad Logperch
Kingston Steam Plant	Watts Bar Reservoir	61.0	221	Threadfin shad Freshwater drum Bluegill
Wateree Station	Wateree River	21.5	3,059	Threadfin shad Channel catfish Yellow perch
John Sevier Steam Plant	Holston River	28.7	76	Gizzard shad Threadfin shad Channel catfish
Savannah River Plant	Savannah River	41.6	8	Bluespotted sunfish Threadfin shad Gizzard shad

[a] Adapted from Freeman and Sharma (1977)

TABLE 4-191

Percent Composition of Fish Eggs and Larvae Collected in the Savannah River, 1983-85

Taxa	1983[a]	1984[a,b]	1985[b,c]
American shad	1.4	14.0	50.7
Blueback herring	12.1	4.5	2.2
Gizzard and/or threadfin shad	19.9	10.8	9.9
Unid. clupeid	6.7	7.6	3.3
Striped bass	0.2	3.0	5.4
Spotted sucker	5.0	4.3	8.1
Unid. sucker	0.8	0.7	0.4
Pirate perch	8.0	0.3	0.1
Yellow perch	3.5	1.1	0.2
Darter	2.6	2.7	0.7
Sunfish (*Lepomis*)	2.1	6.9	0.7
Unid. sunfish	1.1	4.0	0.3
Crappie	16.6	13.5	0.3
Mudminnow	<0.1	<0.1	0.0
Swampfish	<0.1	<0.1	<0.1
Minnow (Cyprinid)	14.0	13.5	3.7
Carp	3.6	3.2	4.6
Mosquitofish	<0.1	<0.1	<0.1
Topminnow		<0.1	<0.1
Needlefish	<0.1	0.1	<0.1
Silverside	0.2	0.2	0.1
Catfish and/or bullhead	0.1	<0.1	0.1
Pickerel	0.3	0.1	<0.1
Sturgeon	<0.1	<0.1	<0.1
Gar	<0.1	<0.1	0.0
Unidentified	1.7	9.8	9.2
Total numbers	36,941	18,267	22,698

[a] Based on 26 transects between RM 29.6 and 187.1.
[b] Does not include intake canals.
[c] Based on 21 transects between RM 89.3 and 187.1.

Source: Paller et al. (1984); Paller et al. (1985); Paller et al. (1986)

All clupeid taxa exhibited considerable variations in abundance among years. American shad eggs and larvae increased in relative abundance from 1.4% to 50.7% of collections between 1983 and 1985. Concurrently, blueback herring eggs and larvae decreased from 12.1% (1983) to 2.2% (1985). Gizzard and/or threadfin shad relative abundance paralleled the decline in blueback herring.

Some of the decline in the relative abundance of blueback herring from 1984 to 1985 could be attributable to a reduction of sampling effort in the lower reaches of the Savannah River (Paller and Osteen, 1985; Paller and Saul, 1986), because this section of the river appears to be a major spawning area for the species during some years (Table 4-192, 4-193, and 4-194). However, the decrease in density from 1983 through 1985 was also observed in the mid-reaches of the river, and is likely more closely related to variations in spawning stock abundance or the availability of spawning sites. Low river water levels, especially during the 1985 spawning season, likely reduced access to swamp and backwater spawning sites utilized by blueback herring (Paller et al., 1986). The sharp increase in American shad ichthyoplankton abundance from 1983 to 1985 may also be related to increases in spawning stock abundance.

Striped bass spawning in the upper reaches of the Savannah River had not been documented prior to 1982 (ECS, 1982). Dudley et al. (1977) reported that striped bass spawning was restricted to the lower reaches of the river and McFarlane et al. (1978) collected no striped bass ichthyoplankton during their sampling in 1977. However, striped bass eggs and/or larvae were collected during each year of this survey (Tables 4-192, 4-193, and 4-194) and, the highest densities occurred between approximately RM 166 to RM 120 during 1983-1985. Although striped bass ichthyoplankton abundance was substantially lower than found for American shad, similar trends of increasing abundance were observed from 1983 to 1985.

Sturgeon larvae were collected from the Savannah River in the vicinity of the SRS during 1982. Both Atlantic sturgeon and the endangered shortnose sturgeon were represented (D. Snyder, pers. comm.). Larvae of both sturgeon species were collected in small numbers in all subsequent years. Total number of specimens was highest in 1982, although sampling intensity was lowest during that year (Paller et al., 1986). Generally, it appears that both species spawn upstream or near the SRS and that shortnose sturgeon spawn earlier and at cooler water temperature than Atlantic sturgeon.

4.6.3.1.3 Entrainment

Larvae

A minimum of 17 taxa of fish larvae were entrained at the three intake structures at the SRS during 1983 (Table 4-195). Clupeidae, the herring family, comprised 59.3% of the total ichthyoplankton entrainment. The single most abundant taxon was the genus Dorosoma (gizzard shad and

TABLE 4-192

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February - July 1983

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad[a]	Minnows	Sunfish	Crappie	Total Ichthyo-plankton[b]
			Lower Farfield					
29.6	5.3	11.7	2.7	8.3	4.8	1.5	13.6	67.8
40.0	4.5	16.1	1.4	17.2	6.1	1.1	15.6	89.2
50.2	6.4	20.8	0.5	21.3	12.1	1.9	21.0	118.1
60.0	7.1	32.4	5.1	18.7	11.8	3.4	26.8	144.0
69.9	4.7	19.7	0.5	20.1	6.1	2.0	12.1	87.2
79.9	4.5	26.9	0.8	40.7	6.3	2.0	16.9	124.9
89.3	7.6	32.7	2.3	59.2	9.0	2.4	25.4	171.5
97.5	12.3	39.2	1.1	54.1	10.9	2.6	29.8	191.1
110.0	18.3	13.4	1.3	15.7	17.7	2.5	21.7	136.6
120.0	8.2	8.6	11.3	7.7	12.8	3.0	16.4	98.7
			Nearfield					
128.9	5.4	5.9	0.7	5.4	14.9	4.7	16.3	84.4
129.1	6.9	5.8	4.1	5.3	18.1	4.2	16.2	95.2
137.7	10.0	3.8	0.1	3.7	22.3	7.5	15.5	105.1
141.5	6.8	4.2	0.0	4.2	14.7	9.7	13.7	102.2
141.7	12.1	4.0	0.0	4.9	12.2	10.1	14.9	110.2
150.4	8.7	2.5	1.3	4.3	12.9	1.7	5.5	54.0
150.8	8.9	3.6	0.1	4.9	11.1	0.9	7.8	53.2
152.0	7.8	1.9	2.4	6.9	12.1	1.7	5.9	62.1
152.2	10.5	2.5	10.2	8.0	14.7	1.1	6.1	90.3
155.2	11.9	1.9	5.1	9.5	12.2	0.3	4.3	65.4
155.3[c]	0.8	6.5	0.0	33.1	5.9	1.1	9.3	76.8
155.4	10.5	2.6	5.9	11.9	19.2	0.2	6.0	82.3
157.0	12.9	2.9	0.0	8.7	8.3	0.5	6.1	61.5
157.1[c]	1.0	7.9	0.1	23.7	4.4	1.9	11.9	71.5
157.3	17.8	1.7	0.0	9.6	12.1	1.0	5.4	73.6
			Upper Farfield					
166.6	25.6	2.4	6.3	24.7	11.8	2.0	3.7	96.6
176.0	8.9	1.3	0.1	12.8	11.7	1.0	2.9	52.5
187.1	1.6	0.3	0.0	25.2	4.9	0.9	0.7	47.7

[a] Gizzard and/or threadfin shad.
[b] Totals include taxa shown plus taxa not shown.
[c] Intake canals.

Source: Paller et al. (1984)

TABLE 4-193

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February-July 1984

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad[a]	Minnows	Sunfish	Crappie	Total Ichthyo-plankton[b]
				Lower Farfield				
29.6	1.2	0.7	0.0	2.1	1.0	8.3	5.5	24.5
40.0	1.3	0.8	0.0	2.8	0.9	9.1	8.4	30.8
50.2	1.7	0.9	0.0	3.2	2.7	12.6	4.8	32.5
60.0	1.3	2.4	0.0	4.4	1.9	6.1	10.3	33.0
69.9	0.8	0.9	0.0	3.9	3.1	3.2	5.3	24.2
79.9	1.5	2.6	0.0	4.2	2.3	1.8	4.1	25.2
89.3	3.8	1.6	0.6	4.7	4.3	2.5	3.9	30.2
97.5	6.2	4.1	0.7	11.3	3.1	4.0	5.1	44.8
110.0	10.5	1.3	1.6	1.1	5.2	4.6	3.9	35.8
120.0	5.6	1.7	4.1	2.5	5.8	3.2	3.6	34.9
				Nearfield				
128.9	3.6	0.9	3.7	2.1	6.6	3.4	3.1	32.3
129.1	5.2	0.9	3.1	1.3	7.8	5.1	2.8	34.3
137.7	8.0	1.1	6.4	1.7	9.6	6.4	4.1	49.0
141.5	7.4	2.2	3.4	2.1	13.6	10.0	6.7	57.1
141.7	11.2	1.0	14.3	2.5	12.1	10.4	6.4	67.6
150.4	2.8	3.1	6.7	3.8	5.2	2.7	6.0	41.4
150.8	5.8	2.9	5.2	4.5	4.8	1.7	5.8	39.7
152.0	5.8	1.6	2.1	4.8	4.4	1.5	6.4	34.7
152.2	9.8	1.1	2.8	3.5	5.1	0.9	4.5	38.6
155.2	5.6	1.9	6.1	3.7	3.8	0.6	4.9	35.5
155.3[c]	0.2	6.6	1.6	4.9	3.0	0.8	10.9	43.1
155.4	4.0	1.1	6.1	3.8	4.2	1.0	5.9	36.8
157.0	9.9	1.5	4.0	3.5	4.6	1.9	6.1	45.3
157.1[c]	0.2	4.6	1.4	5.2	2.4	1.9	10.1	42.5
157.3	11.8	2.6	3.2	4.0	6.5	1.7	4.6	47.4
				Upper Farfield				
166.6	3.3	2.5	0.0	8.2	5.6	0.4	1.1	28.7
176.0	4.0	0.8	0.0	7.0	6.1	1.1	0.3	26.2
187.1	3.6	0.2	0.1	4.0	5.7	0.9	0.4	23.6

[a] Gizzard and/or threadfin shad.
[b] Totals include taxa shown plus taxa not shown.
[c] Intake canals.

Source: Paller et al. (1985)

TABLE 4-194

Mean Ichthyoplankton Densities (No./1000 m^3) at Savannah River Transects During February-July 1985

River Mile	American Shad	Blueback Herring	Striped Bass	Other Shad[a]	Minnows	Sunfish	Crappie	Total Ichthyo-plankton[b]
				Lower Farfield				
89.3	47.4	0.9	2.0	2.2	2.5	1.4	0.1	67.8
97.5	26.6	1.7	1.2	4.7	1.6	0.2	0.1	44.1
110.0	39.6	0.6	1.5	1.2	3.2	0.2	0.1	55.6
120.0	35.3	0.8	1.3	1.7	2.2	0.7	0.4	51.7
					Nearfield			
128.9	41.7	1.4	5.3	2.2	4.1	1.0	0.2	64.2
129.1	31.3	0.8	6.3	1.9	2.9	1.4	0.2	54.7
137.7	34.1	1.8	0.4	2.9	1.9	1.4	0.1	55.2
141.5	30.0	1.4	0.1	3.4	1.5	1.1	0.1	50.9
141.7	54.6	0.9	0.5	3.7	1.8	1.8	0.3	83.2
145.7	63.2	0.7	0.6	3.0	1.6	1.5	0.5	84.3
150.4	22.0	1.0	2.4	2.1	0.8	0.2	0.3	44.7
150.8	12.6	1.9	0.3	3.0	1.0	0.1	0.0	31.8
152.0	10.6	1.4	3.7	3.2	1.6	0.1	0.1	28.7
152.2	14.2	2.2	3.3	3.6	2.0	0.1	0.1	43.1
155.2	18.2	2.6	16.0	3.1	1.0	0.0	0.2	67.1
155.3[c]	0.3	0.9	2.5	7.0	1.0	0.1	0.2	30.7
155.4	19.3	0.8	13.6	4.8	1.6	0.1	0.0	57.0
157.0	24.6	0.4	0.5	3.8	1.7	0.2	0.1	47.5
157.1[c]	0.8	1.1	0.1	3.0	0.7	0.2	0.1	22.2
157.3	36.0	0.5	2.1	3.8	1.6	0.2	0.2	81.6
				Upper Farfield				
166.6	59.4	3.2	10.7	22.3	2.5	0.2	0.1	149.3
176.0	15.7	2.4	0.1	27.2	4.5	0.4	0.2	70.9
187.1	3.3	2.8	0.1	22.7	5.4	0.6	0.4	58.6

[a] Gizzard and/or threadfin shad.
[b] Totals include taxa shown plus taxa not shown.
[c] Intake Canals.

Source: Paller et al. (1986)

threadfin shad), with 10.5 x 10^6 larvae (37.4%). Other abundant taxa were crappie, blueback herring and minnows, which represented 14.1, 9.5, and 9.0%, respectively.

Total larval fish entrainment for the SRS from February through July 1983 (the spawning period for most Savannah River fishes) was calculated to be 27.9 x 10^6, of which 12.9 x 10^6 larvae (46.2%) were from the 1G pumphouse, 13.2 x 10^6 larvae (47.3%) were from the 3G pumphouse and 1.8 x 10^6 (6.5%) were from the 5G pumphouse (Table 4-196).

At least 17 taxa of larval fish were entrained at the SRS pumphouses during the 1984 spawning season (Table 4-197). As in 1983, the most common family in the entrainment samples was Clupeidae (the herring and shad family) which comprised 50% of the larval fish that were entrained. The single most abundant taxon was crappie with 4.3 x 10^6 larvae (24.5%). Other abundant taxa were unidentified clupeids, blueback herring, and other shad (gizzard and/or threadfin shad), which comprised 23.9, 13.2, and 12.7% of the total larvae entrained, respectively. Generally, there were no differences in the species composition among the three pumphouses.

Total larval fish entrainment for the SRS from February through July 1984 was calculated to be 17.6 x 10^6. The 1G pumphouse entrained 7.7 x 10^6 larvae (44%), 8.8 x 10^6 larvae (50.3%) were entrained at the 3G pumphouse and 1.0 x 10^6 larvae (5.6%) at the 5G pumphouse (Table 4-196).

At least six taxa of larvae were entrained at the SRS pumphouses in 1985 (Table 4-198). The most common larval fish entrained were suckers, which comprised 43% of the larval fish entrained. The single most abundant taxon was spotted sucker with a total of 4.6 x 10^6 larvae (42.7%) entrained at the three pumphouses. Other abundant taxa were gizzard and/or threadfin shad (22.0%), unidentified Clupeidae (11.4%), and carp (10.3%). Generally, there were no substantive differences in the species composition between three pumphouses.

Total larval fish entrained due to SRS activities from February through July 1985 was calculated to be 10.9 x 10^6 (Table 4-196). The 1G pumphouse entrained 3.8 x 10^6 larvae (35%); 6.4 x 10^6 larvae (59%) were entrained at the 3G pumphouse and 0.7 x 10^6 larvae (6%) at the 5G pumphouse.

The highest percentage of larval entrainment during 1983-1985 occurred at the 3G intake (9.5 x 10^6 larvae, 50.3% of the total; Table 4-196). Larval entrainment was substantially lower at the 1G intake (8.1 x 10^6 larvae, 43.4% of the total). Larval entrainment at the 5G intake was consistently low (1.2 x 10^6 larvae, 6.3% of the total), and never exceeded 6.5% of the annual total entrainment at the SRS river water intakes during 1983-1985. Thus, the magnitude of larval entrainment at the SRS is primarily determined by losses at the 1G and 3G intakes.

TABLE 4-195

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses (February - July 1983)

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	90	80	4	174	0.6
Blueback herring	1434	1146	68	2648	9.5
Other shad (Dorosoma spp.)	4315	5782	365	10,462	37.4
Unident. clupeids	1641	1572	90	3303	11.8
Esocidae					
Unident. pickerel	129	53	9	191	0.7
Cyprinidae					
Carp	26	80	17	123	0.4
Unident. cyprinids	814	1026	690	2530	9.0
Catostomidae					
Spotted sucker	853	573	237	1663	5.9
Other suckers		13	20	33	0.1
Ictaluridae					
Unident. catfish		13		13	<0.1
Aphredoderidae					
Pirate perch	388	400	28	816	2.9
Atherinidae					
Brook silverside			7	7	<0.1
Percichthyidae					
Striped bass	13		2	15	<0.1
Centrarchidae					
Unident. crappie	2170	1599	184	3953	14.1
Unident. sunfish	233	40	2	275	1.0
Other centrarchids	129	133	7	269	1.0
Percidae					
Yellow perch	142	320	33	495	1.8
Other percids	388	187	52	627	2.2
Other	129	213	26	368	1.3
Total	12,894	13,230	1,841	27,965	100.0

Source: Paller et al. (1984)

TABLE 4-196

Estimated Entrainment of Larval Fish at SRS Intakes

		1G	3G	5G	Total
1977[a]	Number ($x10^6$)	7.1	11.9	0.6	19.6
	Percent	36.2	60.7	3.1	
1982[b]	Number ($x10^6$)	5.2	12.0	0.7	17.9
	Percent	28.8	67.1	4.0	
1983[c]	Number ($x10^6$)	12.9	13.2	1.8	28.0
	Percent	46.2	47.3	6.5	
1984[d]	Number ($x10^6$)	7.7	8.8	1.0	17.6
	Percent	44.0	50.3	5.6	
1985[e]	Number ($x10^6$)	3.8	6.4	0.7	10.9
	Percent	34.9	58.7	6.4	
Average number ($x\ 10^6$)		8.1	9.5	1.2	18.8
(1983-85) percent		43.4	50.3	6.3	

[a] April-June, McFarlane et al. (1978).
[b] March-August, ECS (1983).
[c] February-July, Paller et al. (1984).
[d] February-July, Paller et al. (1985).
[e] February-July, Paller et al. (1986).

TABLE 4-197

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses (February - July 1984)

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	36	26	-	62	0.4
Blueback herring	891	1398	39	2328	13.2
Other shad	1010	1085	139	2234	12.7
Unident. clupeids	2102	1975	116	4193	23.9
Esocidae					
Unident. pickerel	23	7	-	30	0.2
Cyprinidae					
Carp	175	203	46	424	2.4
Unident. cyprinids	449	679	167	1295	7.4
Catostomidae					
Spotted sucker	495	506	118	1119	6.4
Other suckers	-	23	12	35	0.2
Aphredoderidae					
Pirate perch	-	-	3	3	<0.1
Percichthyidae					
Striped bass	33	73	17	123	0.7
Centrarchidae					
Unident. crappie	1908	2181	233	4322	24.5
Unident. sunfish	147	100	22	269	1.5
Other centrarchids	200	59	16	275	1.6
Percidae					
Yellow perch	77	218	5	300	1.7
Other percids	84	219	39	342	1.9
Lepisosteidae					
Gar	19	-	-	19	0.1
Other	99	87	19	205	1.2
Total	7,748	8,839	991	17,578	100.0

Source: Paller et al. (1985)

TABLE 4-198

Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses (February - July 1985)

Taxa	Pumphouse 1G (x1000)	G (x1000)	5G (x1000)	Total (x1000)	Percent Compo-sition
Clupeidae					
American shad	46	9	5	60	0.6
Blueback herring	195	198	21	414	3.8
Other shad	563	1660	171	2394	22.0
Unident. clupeids	379	797	69	1245	11.4
Cyprinidae					
Carp	341	687	89	1117	10.3
Unident. cyprinids	122	225	61	408	3.8
Catostomidae					
Spotted sucker	1835	2585	223	4643	42.7
Unident. sucker	0	24	6	30	0.4
Others	341	195	39	575	5.1
Total	3,822	6,380	684	10,886	100.1

Source: Paller et al. (1986)

Eggs

The total egg entrainment during February through July 1983 was calculated to be 9.2 x 10^6 eggs of which 4.3 x 10^6 eggs (46.7%) were entrained at 1G, 4.2 x 10^6 eggs (45.7%) at 3G and 0.7 x 10^6 eggs (0.7%) at 5G (Table 4-199). The most abundant species was American shad which represented 55.0% of the total eggs entrained (Table 4-200). The other abundant groups were "other" eggs and striped bass eggs, which represent 28.0 and 14.2% of the total egg entrainment, respectively.

The total fish egg entrainment during February through July 1984 was estimated to be 5.8 x 10^6 eggs, of which 2.7 x 10^6 eggs (46.6%) were entrained at the 1G pumphouse, 2.6 x 10^6 eggs (44.8%) at the 3G pumphouse and 0.5 x 10^6 eggs (8.6%) at the 5G pumphouse (Table 4-199). The most abundant egg species was American shad, which represented 50.3% of the total eggs entrained (Table 4-200). The other abundant groups of eggs entrained were striped bass and "other" eggs which represented 30.6 and 15.2% of the total eggs entrained, respectively.

The total fish egg entrainment during February through July 1985 was estimated to be 15.1 x 10^6, of which 7.8 x 10^6 eggs (51.7%) were entrained at the 1G pumphouse, 6.2 x 10^6 (41.4%) at the 3G pumphouse, 1.1 x 10^6 eggs (7.3%) at the 5G pumphouse (Table 4-199). American shad eggs were again most abundant in the entrainment samples and represented 46.7% of the total eggs entrained (Table 4-200). The other abundant groups of eggs entrained were striped bass and "other" eggs which represented 26.2% and 24.8% of the total entrained, respectively.

American shad eggs dominated entrainment collections from 1983 to 1985 and the percentage of total egg entrainment attributable to this species was relatively constant (Table 4-200). American shad eggs averaged 50.0% of egg entrainment and ranged from 46.7% (1985) to 55.0% (1983) of all eggs entrained. The number of American shad eggs entrained annually varied substantially, however. The highest number of American shad eggs entrained was 7.1 x 10^6 in 1985.

Striped bass eggs were less than half as abundant as American shad eggs in entrainment, averaging 23.4% (2.4 x 10^6 eggs/year) from 1983 to 1985 (Table 4-200). Striped bass eggs varied widely among years both as a percentage of total egg entrainment (14.2 to 30.6%) and as numbers of eggs entrained annually (1.3 x 10^6 to 4.0 x 10^6 eggs/year). Eggs of blueback herring, Dorosoma spp. (gizzard and/or threadfin shad) and percids were relatively minor components in entrainment. The undifferentiated component of "other" eggs represented a substantial component of egg entrainment, but likely included a wide variety of taxa, few of which represented substantial individual contributions to total egg entrainment.

Overall entrainment losses of eggs and larvae averaged approximately 10% of the ichthyoplankton passing the SRS intakes (Table 4-201), with egg losses concentrated among the anadromous American shad and striped bass. This is somewhat higher than the estimated 4% entrainment at the Connecticut Yankee Nuclear Plant on the Connecticut River (Marcy, 1976)

TABLE 4-199

Estimated Egg Entrainment at SRS Intakes

		Pumphouse			
		1G	3G	5G	Total
1977[a]	Number ($x10^6$)	2.4	4.0	0.5	6.9
	Percent	34.8	58.0	7.2	
1982[b]	Number ($x10^6$)	8.7	8.2	1.2	18.1
	Percent	48.3	45.1	6.6	
1983[c]	Number ($x10^6$)	4.3	4.2	0.7	9.2
	Percent	46.7	45.7	7.6	
1984[d]	Number ($x10^6$)	2.7	2.6	0.5	5.8
	Percent	46.6	44.8	8.6	
1985[e]	Number ($x10^6$)	7.8	6.2	1.1	15.1
	Percent	51.7	41.1	7.3	
Average number ($x10^6$)		4.9	4.3	0.8	10.0
(1983-85) percent		48.3	43.8	7.8	

[a] April-June, McFarlane et al. (1978).
[b] March-August, ECS (1983).
[c] February-July, Paller et al. (1984).
[d] February-July, Paller et al. (1985).
[e] February-July, Paller et al. (1986).

TABLE 4-200

Estimated Entrainment and Taxonomic Composition of Fish Eggs at SRS Intakes, 1983-85

Taxa		1983[a]	1984[b]	1985[c]	Average
American shad	Number ($x10^6$)	5.07	2.91	7.06	5.01
	Percent	55.0	50.3	46.7	50.0
Blueback herring	Number ($x10^6$)	0.09	0.07	0.14	0.10
	Percent	1.0	1.2	0.9	1.0
Dorosoma spp.	Number ($x10^6$	-[d]	0.13	0.21	-[e]
	Percent	-[d]	2.2	1.4	-[e]
Striped bass	Number ($x10^6$)	1.31	1.77	3.96	2.35
	Percent	14.2	30.6	26.2	23.4
Unident. percids	Number ($x10^6$)	0.16	0.02	-[d]	-[e]
	Percent	1.7	0.3	-[d]	-[e]
Other eggs	Number ($x10^6$)	2.58	0.88	3.74	2.4[f]
	Percent	28.0	15.2	24.8	25.6[f]
Total number ($x10^6$)		9.21	5.78	15.11	10.03

[a] Paller et al. (1984).
[b] Paller et al. (1985).
[c] Paller et al. (1986).
[d] Not provided in source document.
[e] Not calculated because of partial data.
[f] Includes *Dorosoma* spp. and unident. percids.

and 3.2% entrainment at the Fort Calhoun Station on the Missouri River (Hergenrader et al., 1982). However, it is noteworthy that there was no evidence of decreasing numbers of American shad or striped bass ichthyoplankton during 1982-1985, when intensive studies were conducted on the Savannah River (Tables 4-192, 4-193, and 4-194). In fact, American shad egg and larvae densities were higher during 1985 than during previous years of the study suggesting that the anadromous fish populations using the mid reaches of the Savannah River are not declining.

TABLE 4-201

Percentage of Savannah River Ichthyoplankton Entrained at SRP Intakes, 1983-85

		1983[a]	1984[b]	1985[c]
Number entrained ($x10^6$)	1G	17.2	10.4	11.6
	3G	17.4	11.4	12.6
	5G	2.5	1.5	1.8
	Total	37.1	23.3	26.0
Number transported in river ($x10^6$)	RM 157.3	388	282	212
	RM 155.4	405	216	133
Percent entrained (i.e., no. entrained divided by no. transported x 100)	1G	4.4	3.7	5.5
	3G	4.3	5.3	9.5
	5G	0.6	0.7	1.4
	Total[d]	9.6	8.3	12.3
Percent river withdrawn[e]		7.7	7.0	12.2

[a] Paller et al. (1984).
[b] Paller et al. (1985).
[c] Paller et al. (1986).
[d] Based on transport at RM 157.3.
[e] All intakes combined, February-July.

4.7 COMMERCIALLY AND RECREATIONALLY VALUABLE BIOTA

Although aquatic and semi-aquatic species of commercial or recreational importance exist in the waters of the SRS, public exploitation is not allowed on site. In addition to potentially valuable fisheries resources, the SRS also supports populations of alligator, bullfrog, and several species of turtles (slider, Florida cooter, and snapping turtle) that may have some commercial or recreational value.

The Savannah River supports both commercial and sports fisheries. Table 4-202 lists the species and catches of fish taken commercially from the river between 1970 and 1979. Many of these fisheries are confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia. Table 4-203 lists the total weight of shellfish caught in the lower Savannah River and adjacent coastal waters between 1972 and 1979.

The commercial fishes of significance near the SRS are American shad (Alosa sapidissima), channel catfish (Ictalurus punctatus), and Atlantic sturgeon (Acipenser oxyrhnchus). These species, except for sturgeon, are exploited to a limited degree by nonprofessional local fishermen. Commercial and recreational fisheries for blueback herring (Alosa aestivalis) exist in South Carolina (Ulrich et al., 1978), but none are taken commercially in Georgia because of state netting restrictions.

American shad stocks appear to be healthy and productive in the Savannah River. Music (1981) reported that commercial catches by Georgia shad fishermen in 1980 in the Savannah River represented 51% of Georgia shad landings in that year, while only 13% of Georgia's commercial shad fishermen operated in the Savannah River. Thus, American shad stocks in the Savannah River may be less heavily exploited and relatively more abundant than stocks in other Georgia rivers. Additionally, Schmitt and Hornsby (1985) reported the development of a previously undocumented sport fishery for American shad in the vicinity of the New Savannah Bluff Lock and Dam, and recommended that the magnitude of this fishery be evaluated.

Less is known concerning the status of striped bass in the Savannah River. Only recently has spawning upstream of tidally influenced regions of the river been documented (ECS, 1983; Paller et al., 1984; Paller et al., 1985; Paller et al., 1986). Nevertheless, Gilbert et al. (1986) suggested that striped bass spawning occurs primarily in the tidally influenced portions of the river. It is not clear whether the current spawning of striped bass in upstream regions of the river represents a re-establishment of a spawning stock in this area, or is a result of the increased intensity of sampling efforts during 1982-1985 relative to prior sampling programs.

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

TABLE 4-202

Commercial Landing Data for Fish Taken From Savannah River, 1970-1979[a]

Species	Combined Catches in Georgia and South Carolina (kg)									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Carp	0	250	252	1,503	590	998	136	453	136	363
Catfish	544	157	222	518	726	1,814	1,043	1,043	363	1,043
Black drum	0	0	0	0	0	227	272	0	0	0
Red drum	0	0	0	0	45	0	181	499	136	0
Hickory shad	318	384	291	725	91	227	91	136	181	91
Spotted sea trout	0	0	0	324	227	2,500	1,800	181	181	0
American shad	43,591	25,568	25,439	33,912	26,263	20,412	8,618	20,820	54,432	57,607
Sturgeon	726	23	1,967	551	136	45	363	862	454	227
Suckers	0	0	0	0	0	0	91	0	0	0
Common eels	0	0	0	0	0	91	0	45	0	45
Mullet	0	0	0	0	0	227	0	91	0	0
Striped bass	816	735	1,013	1,071	0	0	0	0	0	0

[a] Adapted from Du Pont (1983)

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TABLE 4-203

Commercial Landing Data for Shellfish Taken from Coastal Regions of Savannah River, 1972-1979[a]

	Shellfish Catch (kg)			
Year	Clams	Blue Crabs	Oysters	Shrimp
1972	-	419,489[b]	1,451[c]	115,940[c]
1973	862[d]	543,957[b]	2,858[c]	222,128[c]
1974	-	1,252,072[e]	6,804[e]	1,141,530[e]
1975	-	17,237[b]	3,447[e]	1,264,818[e]
1976	-	-	-	-
1977	-	63,504[b]	19,051[e]	626,286[e]
1978	1,860[d]	68,040[b]	-	731,475[e]
1979	454[d]	104,781[b]	9,072[b]	-

[a] Adapted from Du Pont (1982)
[b] Wassaw Sound plus Ossabaw Sound
[c] DOE (1982)
[d] Savannah River landings
[e] Northern District, Georgia

Source: DOE (1984)

Schmitt and Hornsby (1985) evaluated the sport fishery resources in the Savannah River downstream of the New Savannah Bluff Lock and Dam during 1980-1982. Average annual sport fishing harvest from the freshwater portions of the river (approximately RM 21-187) was estimated to range from 171,561 fish/yr in 1982 to 550,282 fish/yr in 1980 (3 yr average = 305,778 fish/yr). Dominant species in the sport harvest were redbreast sunfish (27.2%) and bluegill (24.1%, Table 4-204). The composite category of "bream" accounted for 64% of the total angler catch. The composite category of "catfish" also represented a substantial portion of the sport harvest (14.6%), with bullhead spp. (8.2%) the major reported taxon within this category. Crappie (8%) represented a substantial component of the sport harvest and was comparable to warmouth (7.3%). No other species (or species group) represented greater than 5% of the sport harvest. Notably, anadromous species (striped bass, 0.2%; American shad, 1.7%) did not contribute substantially to the angler's harvest. However, the authors noted that American shad harvest may be underestimated because of the development of a fishery for this species near the New Savannah Bluff Lock and Dam, while the assessment for this species emphasized downstream areas of the river.

Anglers in the freshwater section of the Savannah River fish predominantly for bream and largemouth bass (Schmitt and Hornsby, 1985). Based upon electrofishing studies, the relative abundance of bream in the freshwater section of the river is high, as is the actual angler success rate. The lower abundance of largemouth bass in the freshwater section results in a relatively low angler harvest of this species (Figure 4-77). Anglers in the estuarine section of the Savannah River fish predominantly for sea trout and striped bass, but success rates for these species are low (Figure 4-78).

The proportions of fish species caught by anglers were frequently in sharp contrast to angler preferences. Approximately 35% of angler fishing effort was directed toward bream (composite reporting category plus individual species), while 64% of the harvest was from this category (Table 4-204). The relationship between effort and harvest was even more disparate for largemouth bass; 25.7% of fishing effort was targeted toward this species, while it constituted only 3.2% of the catch. Overall, catfish were not highly desired (approximately 7% of effort), but were caught in slightly greater proportion (14.6%). American shad (7.8% of effort) and striped bass (4.7% of effort) were caught in substantially lower abundances than desired by sport fishermen, the disparity being comparable to that exhibited for largemouth bass.

Impacts to commercial and recreational fisheries by SRS operations are determined by river water intake and the resulting impingement and entrainment. In a previous report (Specht, 1987), relative abundance of fish in the Savannah River near the SRS intakes, and in impingement collections were analyzed relative to angler catches from creel survey data (Schmitt and Hornsby, 1985) in freshwater sections of the Savannah River. Fish relative abundance data collected concurrently with creel survey data by Schmitt and Hornsby (1985) was also analyzed because of its direct spatial and temporal comparability.

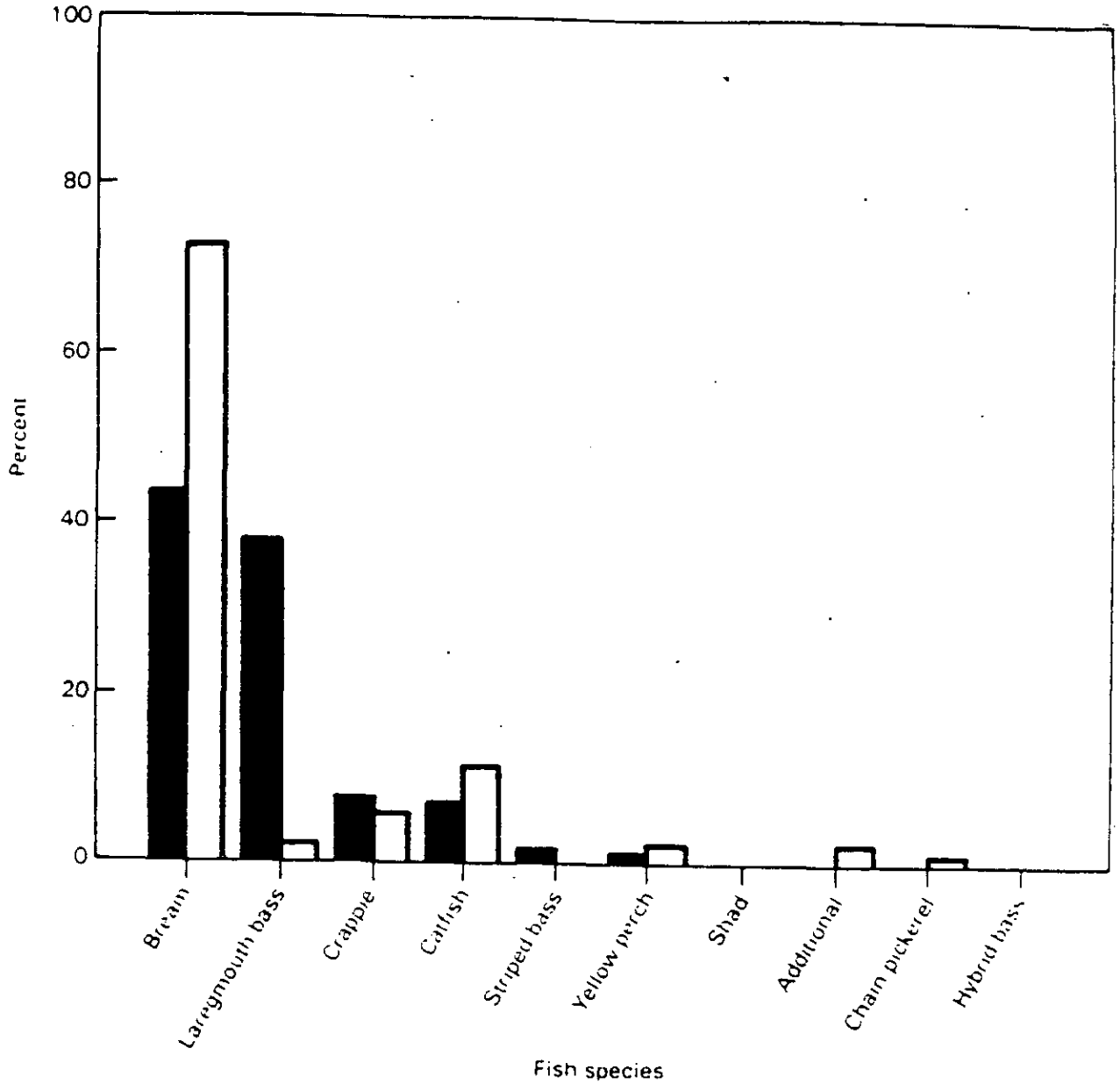
TABLE 4-204

Fish Species Preferred and Caught by Savannah River Sport Fishermen[a]

Taxon	Percent Angler Effort	Percent Angler Catch
Bream	24.9	64.0[b]
Redbreast sunfish	8.7	27.2
Bluegill	1.0	24.1
Warmouth	0.1	7.3
Redear sunfish	0.4	4.4
Largemouth bass	25.7	3.2
Crappie	10.7	8.0
Yellow perch	1.3	3.0
Catfish	7.0	14.6[b]
Bullhead spp.	0.4	8.2
Channel catfish	<0.1	4.2
White catfish	0.5	2.1
Chain pickerel	0.5	0.9
American shad	7.8	1.7
Striped bass	4.7	0.2
Hybrid bass	4.4	0.3
Other	1.9	4.1
Total	100.0	100.0

[a] Adapted from Schmitt and Hornsby (1985)
[b] Sum of taxa within category

Source: DOE (1988)



Legend

Effort

Catch

FIGURE 4-77. Comparison of Freshwater Angler Relative Fishing Effort and Fish Harvest by Species
(source: Mackey et al., 1983)

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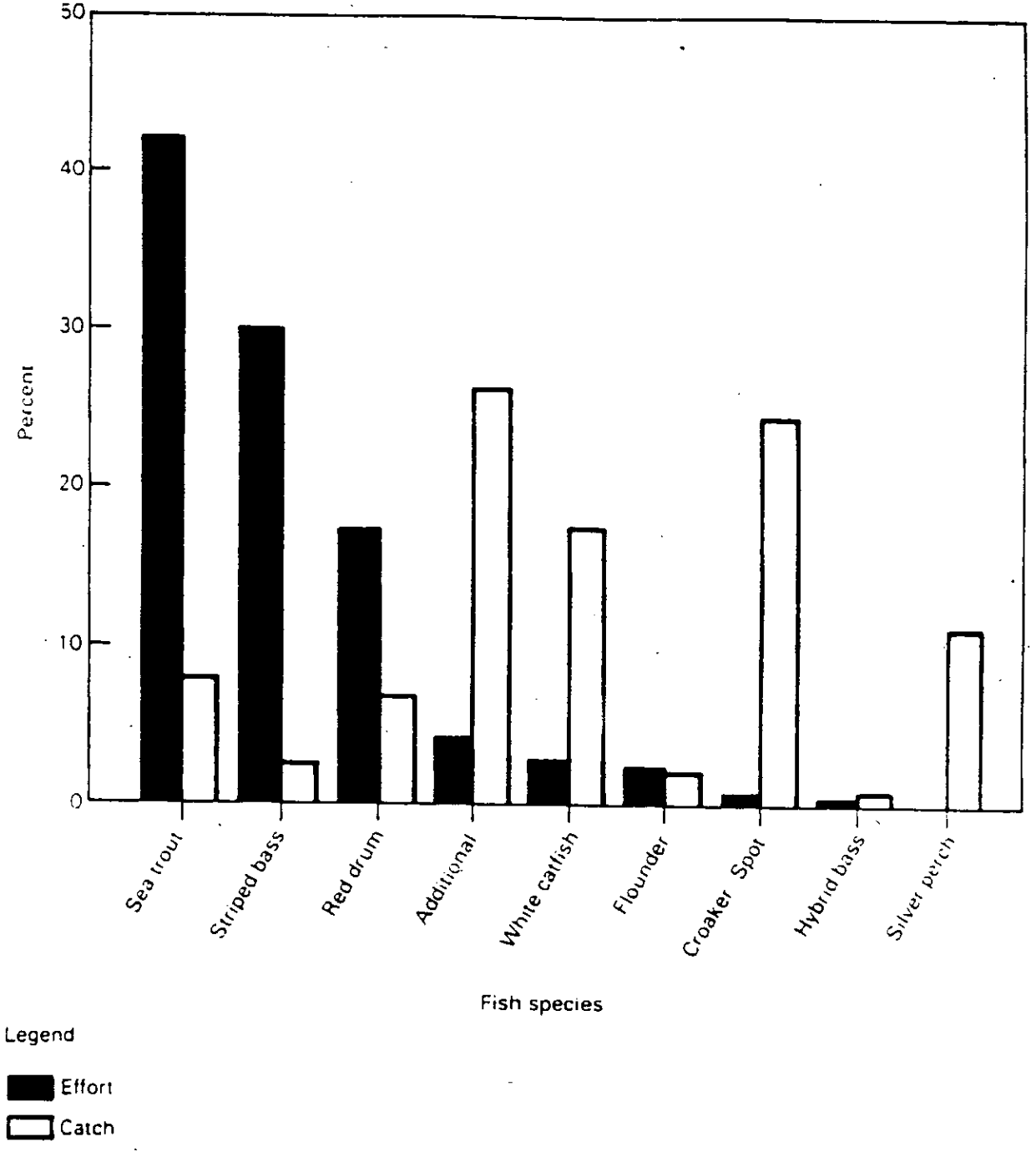

FIGURE 4-78. Comparison of Estuarine Angler Relative Fishing Effort and Fish Harvest by Species
(source: Mackey et al., 1983)

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Fish species caught by anglers in the Savannah River represent an extremely limited set of those species that are available. Electrofishing collections by Schmitt and Hornsby (1985) throughout the freshwater sections of the lower Savannah River indicated that the taxa caught by anglers represented only 33.1% of the relative abundance (numerical) collected in their electrofishing effort. Similarly, those species that constitute 95.8% of the angler catch constitute only 27.8% of total impingement at the SRS intakes. The species caught by anglers represent 59.8% of the numbers of fish caught by electrofishing and 86.9% of hoop-net sampling from the Savannah River near the SRS intakes. However, Paller and Osteen (1985) noted that the electrofishing collections near the SRS do not accurately reflect the abundance of minnows and other small species and the same caution undoubtedly applies to hoop-net collections because the hoop nets used for the SRS collections had a maximum mesh size of 37 mm.

"Bream" represent the largest component of the anglers' catch in the Savannah River. Although centrarchids were a substantial component of SRS impingement collections, the species impinged were not predominantly those caught by anglers (Figure 4-79). Although redbreast sunfish are abundant in the creel (27.1%) and in the river near the intakes (26.7%), they represented only 5.5% of impingement. Bluegill also show much higher relative abundance in the anglers' catch than in the river (all methods) and impingement samples. Among the "bream" caught by anglers, only the spotted sunfish represents a higher relative abundance in impingement (3.5%) than in the creel (1.1%), but the species relative abundance in impingement is less than the relative abundance in electrofishing collections (5.2%).

Crappie, yellow perch, and largemouth bass all exhibit higher relative abundances in the creel (8.0%, 3.0%, and 3.2%, respectively) than in impingement (2.9%, 0.8%, and 0.5%, respectively, Figure 4-79). All three species exhibit higher relative abundance in the river (by at least one collection method) than in impingement, and largemouth bass exhibited higher relative abundance in the river than in the creel. Chain pickerel is a minor component of the creel (0.9%) and has comparable abundance in impingement (0.7%).

Impingement relative abundances for all taxa of catfish [bullhead spp. (2.1%), channel catfish (0.8%), and white catfish (1.3%)] were lower than relative abundances for those taxa in the creel (8.2%, 4.2%, and 2.1%, respectively, Figure 4-79). However, the relative abundances of these taxa in hoop-net collections from the river were substantially higher than for either impingement or angler catches. The disparity between relative abundances of catfish taxa in electrofishing and hoop-net collections suggests that catfish are a substantial component of the Savannah River ichthyofauna, and that electrofishing provides poor estimates of the abundance of these taxa.

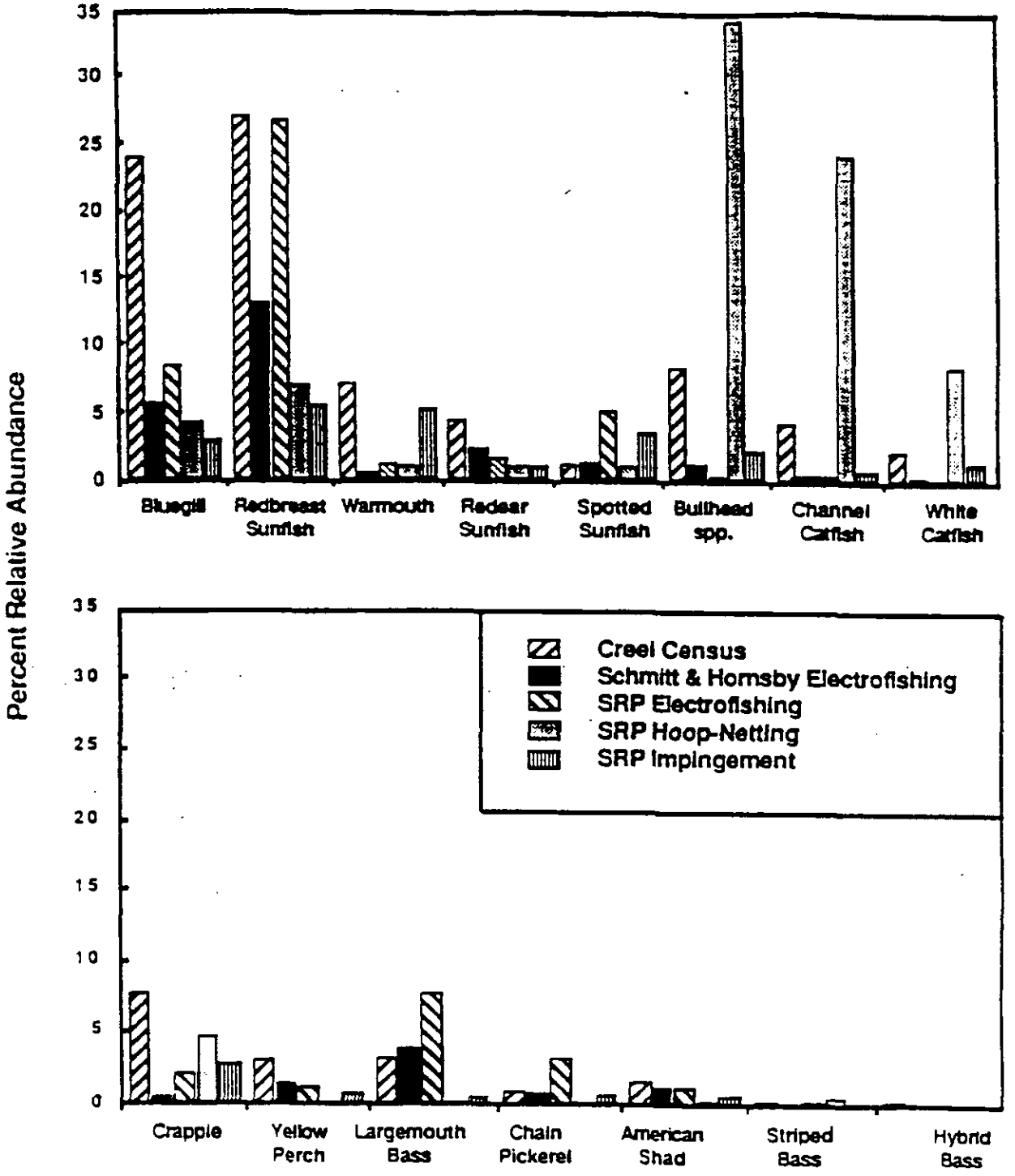

FIGURE 4-79. Relative Abundance of Fish Taxa in Creel, Electrofishing and Hoop-Net Collections, and SRP Impingement (source: DOE, 1988)

American shad, striped bass, and hybrid bass were minor components in all of the collection methods (angling, electrofishing, hoop-netting, impingement, Figure 4-79). The abundance of the migratory American shad and striped bass in the Savannah River near the SRS was undoubtedly underestimated during the quarterly sampling program. Nevertheless, the low frequency of these species in impingement collections (approximately 100 collections throughout the year) is highly encouraging because it indicates that adults and juveniles of these species are minimally influenced by impingement mortality associated with SRS operations.

Impacts

Impacts to the populations of commercially and recreationally important fish species come primarily from impingement and entrainment during the intake of cooling water. The taxonomic composition of impingement is variable, but centrarchids are the dominant group in collections at the SRS intakes. The overall rates of impingement at the SRS intakes are low relative to other cooling water intake facilities in the southeastern region, and impingement losses are concentrated among species of low commercial or recreational value (DOE, 1988).

Entrainment losses of fish eggs were primarily from the anadromous species, American shad and striped bass. Although estimated numbers of American shad eggs varied widely, among years during 1983-1985, the percent of American shad eggs in fish egg collections remained relatively constant. Numbers and percent composition of striped bass in egg collections varied somewhat more than for American shad. The highest entrainment of eggs of these species occurred in 1985 when densities were high and river discharge rates were low. Entrainment losses of fish larvae were concentrated among clupeids, predominantly gizzard and/or threadfin shad. Blueback herring were entrained in moderate abundance while few larvae of American shad occurred in the intake canals (DOE, 1988).

There is currently no basis for concluding that stocks of commercially and recreationally important fishes in the Savannah River are adversely affected by SRS operations. Although direct assessment of recent changes in fish stocks is currently not feasible, the losses of fish resulting from SRS operations are small and localized. Such small losses should not result in a significant risk to the abundance or persistence of fish stocks in the lower Savannah River (DOE, 1988).

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5.0 THREATENED AND ENDANGERED SPECIES

5.1 INTRODUCTION

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) is intended to prevent the further decline of endangered and threatened species and to bring about the restoration of these species and their habitat. The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) jointly administer this Act. The Act affords protection to some 300 species of native American plants and animals. A species can be listed federally under either of two categories, "endangered" or "threatened," depending on its status and the degree of the threat. Endangered refers to a species or subspecies that is in danger of extinction throughout all or a significant portion of its range. Threatened characterizes any species or subspecies that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. In addition, species may also be classified as "threatened due to similarity of appearance." This classification is afforded various species to ensure against excessive taking and to continue necessary protection to similar appearing species which are still classified as threatened. When a species is proposed for either the endangered or the threatened status, areas essential to its survival or conservation are proposed as "critical habitat," when appropriate. The SRS contains no areas that have been designated as critical habitat for any species.

Compliance with the Endangered Species Act requires federal agencies to consult with FWS and/or the NMFS regarding the implementation of a proposed action. If FWS or NMFS indicate that an endangered or threatened species (or one proposed as such) or critical habitat could be present in the area of the proposed action, a biological assessment must be prepared. This assessment is used as a basis for evaluating the effects on federally protected species through the formal consultation process.

The State of South Carolina has a Nongame and Endangered Species Conservation Act (Section 50-15, 1976, S.C. Code of Laws). Rules established to implement the act protect federally listed endangered and threatened wildlife that occur in South Carolina (R.123-150), as well as sea turtles (R.123-150.1), and predatory birds of the orders Falconiformes and Strigiformes (R.123-160). The state does not afford protection to flora other than federally protected species. Additions to the state protection listings can be made by the South Carolina Wildlife and Marine Resources Commission.

Table 5-1 lists species of concern that have been documented on or near the SRS. The following sections specifically address the endangered, threatened, and rare flora of the SRS, and the animal species protected by state or federal law that are known to occur on or near the Savannah River Site. State or federal protection is afforded the following faunal species: brother spike mussel (*Elliptio fraterna*), American sand burrowing mayfly (*Dolania americana*), shortnose sturgeon (*Acipenser brevirostrum*), Carolina crawfish frog (*Rana areolata capito*) American

TABLE 5-1

Species Listed by the Federal Government, State of South Carolina, or the South Carolina Heritage Trust as Endangered, Threatened, or Of Special Concern Known to Currently or Previously Occur on the Savannah River Site[a]

Species	Status[b]	Observation on or Near SRS
Mammals		
Ursus a. americana (black bear)	HT	No resident population on SRS, observation infrequent in past.
Condylura cristata parva (star-nosed mole)	HT	Collected infrequently near Risher Pond, Ellenton Bay, Rainbow Bay, and Steel Creek floodplain.
Plecotus rafinesquii (Rafinesque's big-eared bat)	FC2	Rare on SRS.
Birds		
Mycteria americana (wood stork)	FE, SCE	Individuals have been observed foraging in the Savannah River swamp.
Ictinia mississippiensis (Mississippi kite)	HT	Uncommon.
Elanoides forficatus (swallow-tailed kite)	SCE	Common in area at the turn of the century, no recent sightings.
Accipiter cooperii (Cooper's hawk)	ST	A few individuals have been observed near Sun Bay and Rainbow Bay.
Haliaeetus l. leucocephalus (bald eagle)	FE	Thirty-six birds have been observed on the SRS, most of which have occurred on Par Pond and L Lake. A single active nest containing two juveniles was located below Par Pond Dam in the Lower Three Runs Creek drainage area in 1986.

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TABLE 5-1, Contd

Species	Status[b]	Observation on or Near SRS
Aquila chrysaetos (golden eagle)	SCE	Rare winter sightings.
Pandion haliaetus (American osprey)	ST	A few individuals have been observed as migrants over SRS.
Falco peregrinns (peregrine falcon)	FE,SCE	Rare winter visitor, near Par Pond.
Picoides borealis (red-cockaded woodpecker)	FE, SCE	A few scattered colonies in pine stands of SRS.
Thyromanes bewickii altus (Bewick's wren)	FC1, SCT	Formerly common in the SRS area.
Lanius ludovicianus (loggerhead shrike)	FC2	Infrequently observed on SRS.
Dendroica kirtlandii (Kirtland's warbler)	FE, SCE	Rare visitor.
Passerculus sandwhichensis princeps (Savannah sparrow)	SCE	Abundant winter resident in the past.
Aimophila aestivalis (Bachman's sparrow)	FE, SCE	Common on SRS in the past.
Reptiles		
Alligator mississippiensis (American alligator)	FT (S/A)	Common on Par Pond, Beaver Dam Creek, and in the SRS Savannah River swamp.

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TABLE 5-1, Contd

Species	Status[b]	Observation on or Near SRS
Clemmys guttata (spotted turtle)	HT	Uncommon.
Seminatrix pygaea (Carolina swamp snake)	HT	Uncommon; collected from Ellenton Bay.
Micrurus f. fulvius (eastern coral snake)	HT	Uncommon.
Amphibians		
Ambystoma t. tigrinum (eastern tiger salamander)	HT	Found throughout SRS.
Pseudacris trisceriata feriaru (upland chorus frog)	HT	Locally uncommon.
Hyla avivoca ogechiensis (bird-voiced treefrog)	HT	Locally uncommon in the Savannah River swamp.
Rana palustris (pickerel frog)	HT	Rare; a few have been captured from Risher's Pond.
Rana areolata capito (Carolina crawfish frog)	FC2	Uncommon on SRS.
Fish		
Acipenser brevirostrum (shortnose sturgeon)	FE, SCE	Rare; larvae have been collected in the Savannah River near the SRS pumphouses.

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TABLE 5-1, Contd

Species	Status[b]	Observation on or Near SRS
Invertebrates		
Elliptio fraterna (brother spike mussel)	SCE	Collected from Savannah River below Lower Three Runs Creek.
Dolania americana (American sand burrowing mayfly)	FC2	Common in Upper Three Runs Creek.
Plants		
Echinacea laevigata (smooth coneflower)	FC2	Along Burma Road.
Nestronia umbellula (North American sandlewood)	FC2	Dry wood bluffs along Upper Three Runs Creek.
Rhexia aristosa (awned-meadow beauty)	FC2	Craig Pond.
Lindera subcoriacea (bog spice bush)	FC2	Seepage bogs on SRS
Carex decomposita (cypress stump sedge)	FC2	Steel Creek Delta.
Croton elliottii (Elliott's croton)	FC2	Karst ponds and bays.

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TABLE 5-1, Contd

Species	Status[b]	Observation on or Near SRS
Myriophyllum laxum (loose water millfoil)	FC2	Freshwater ponds.
Lobelia boykinii (swamp lobelia)	FC2	Carolina Bays on east side of SRS.

[a] Sources: 50 CFR 17.11 and 17.12 (January 1989); *Federal Register* 54:554-579. *South Carolina Code of Laws of 1976*, 1988 Cumulative Supplement, R. 123-150. South Carolina Wildlife and Marine Resources Department, Heritage Trust Data base, 1989.

[b] FE: Listed as an Endangered Species by the federal government.
FT: Listed as a Threatened Species by the federal government.
FC1: Under review (a candidate species) for listing as a Threatened or Endangered Species by the federal government; information is on hand to warrant listing.
FC2: Under review (a candidate species) for listing as a Threatened or Endangered Species by the federal government; not enough information is currently available to warrant listing.
SCE: Listed as an Endangered Species by the State of South Carolina.
SCT: Listed as a Threatened Species by the State of South Carolina.
FT(S/A): Threatened by similarity of appearance.
HT: Listed as a species of concern by the South Carolina Heritage Trust.

M890070

alligator (Alligator mississippiensis), wood stork (Mycteria americana), Mississippi kite (Ictinia mississippiensis), swallow-tailed kite (Elanoides forficatus), Cooper's hawk (Accipiter cooperii), bald eagle (Haliaeetus leucocephalus), golden eagle (Aquila chrysaetos), American osprey (Pandion haliaetus), peregrine falcon (Falco peregrinus), red-cockaded woodpecker (Picoides borealis), Bewick's wren (Thyromanes bewickii), Savannah sparrow (Passerculus sandwhichensis princeps), Bachman's sparrow (Aimophila aestivalis), and the Rafinesque's or southeastern big-eared bat (Plecotus rafenesquii).

Rafinesque's big-eared bat, one of three mammal species of concern inhabiting the SRS (Table 5-1) is the only species whose listing carries legal status. The black bear, a rarely seen visitor to the SRS, and the star-nosed mole, infrequently collected onsite, are listed by the South Carolina Heritage Trust data base as species of special concern; the Rafinesque's big-eared bat, however, is listed by the federal government as a candidate species for protection. This medium sized bat with large ears, white venter and gray dorsal pelage, has not been studied at the SRS. It has, however, been collected on the site and two specimens taken at SRS are in the mammal collection at the University of Georgia (Cothran et al., 1989).

The Carolina crawfish frog, also known as the Carolina gopher frog, is a subspecies of Rana aerolata. This amphibian, listed as a candidate species for federal protection, is the only one of five amphibian species of concern found on the SRS to enjoy such status. The Carolina crawfish frog is a member of the group of stubby appearing frogs whose habits of nocturnal activity and daytime utilization of crawfish and gopher tortoise holes, or other hiding places conceals them from casual observation. The Carolina subspecies is distinguished by its small closely packed warts and heavy ventral marking that gives a marbled appearance (Conant, 1975). The Carolina crawfish frog has been heard calling and collected infrequently from areas on the SRS (Gibbons and Patterson, 1978).

5.2 FLORA

The SRS is populated by a diverse flora (Batson et al., 1985). Within this flora exist many unusual and rare species, seven of which are considered appropriate for proposed federal listing as threatened or endangered. Table 5-2, compiled from Knox and Sharitz (1989), lists the names and the state and federal status of rare and unusual plants found on the SRS. In addition, Table 5-3, also compiled from Knox and Sharitz (1989), lists plant species of concern that might be found on the SRS. This listing includes four federally endangered species, one plant proposed for listing, one plant appropriate for proposed listing, and six species possibly appropriate for proposed listing.

A site boundary map (Figure 5-1) illustrating the locations of rare or threatened plant populations on the SRS was produced from site use permit documents (Knox and Sharitz; 1987a, 1987b, 1988a, 1988b).

Two endangered species, the bunched arrowhead (Saggitaria fasiculata) and the persistent trillium (Trillium persistens), and one proposed endangered species, the small whorled pogonia (Isotria medeoloides) are listed for the state of South Carolina by the U.S. Department of Interior and have been mentioned in the L-Reactor Operation Final Environmental Impact Statement (DOE, 1984). None of these species has been reported from the SRS.

Due to the long-term past operations at the SRS, continued operations of the reactor facilities are not expected to have any effects on the populations of floral species of concern.

TABLE 5-2

Names and Status of Plant Species of Concern Found on the Savannah River Site

Common Name	Scientific Name	Federal Status	State Status
Awned meadow-beauty	Rhexia aristosa	C2	SUR
Beak-rush	Rhynchospora inundata	NL	SUR
Bog spice bush	Lindera subcoriacea	C2	NL
Cypress stump sedge	Carex decomposita	C2	SUR
Dwarf bladderwort	Utricularia olivacea	NL	SCT
Durand's white oak or bastard white oak	Quercus durandii	NL	SCT
Elliott's croton	Croton elliottii	C2	SUR
Few-fruited sedge	Carex oligocarpa	NL	SUR
Florida bladderwort	Utricularia floridana	NL	SCT
Florida false loosestrife or Spathulate seedbox	Ludwigia spathulata	NL	SUR
Gaura	Gaura biennis	NL	SUR
Green fringed orchid	Platanthera lacera	NL	SCT
Loose water-milfoil	Myriophyllum laxum	C2	RCT
Milk-pea	Astragalus villosus	NL	SUR
Nailwort	Paronychia americana	NL	SUR
Nestronia	Nestronia umbellula	C2	NL
(None given)	Rhynchospora tracyi	NL	SUR
Nutmeg hickory	Carya myristiciformis	NL	RCT
Oconee azalea	Rhododendron flammeum	NL	SCT
Pink tickweek	Coreopsis rosea	NL	RCT
Pondweed	Potamogeton foliosus	NL	SUR
Quill-leaved swamp potato	Sagittaria isoetiformis	NL	SCT
Sandhill lily	Nolina georgiana	NL	SUR
Smooth purple cone-flower	Echinacea laevigata	C2	NCT
Swamp lobelia	Lobelia boykinii	C2	NL
Trepocarpus	Trepocarpus aethusae	NL	SUR
Wild water-celery	Vallisneria americana	NL	SUR
Woolly bumelia	Bumelia lanuginosa	NL	NL
Yellow cress	Rorippa sessiliflora	NL	SUR
Yellow porilla	Menispermum canadense	NL	SUR
Yellow wild indigo	Baptisia lanceolata	NL	SUR

E = Endandered
PE = Proposed as endangered
C1 = Appropriate for proposed listing
C2 = Possibly appropriate for proposed listing
C3 = No longer considered for proposed listing
NCE = National concern, endangered
NCT = National concern, threatened
RCE = Regional concern, endangered
RCT = Regional concern, threatened
SCE = Statewide concern, endangered
SCT = Statewide concern, threatened
SUR = Status unresolved, considered rare
NL = Not listed
ESC = Extirpated from South Carolina

Source: Knox and Sharitz (1989)

TABLE 5-3

Names and Status of Plant Species of Concern that May Occur on the Savannah River Site

Common Name	Scientific Name	Federal Status	State Status
Baldwin's nut-rush	Scleria baldwinii	NL	SCT
Blue maiden-cane	Amphicarpum muhlenbergianum	NL	SUR
Canby's cowbane	Oxypolis canbyi	E	NCE
Carolina larkspur	Delphinium carolinianum	NL	SUR
Chapman's sedge	Carex chapmanii	C2	NCT
Dwarf or Carolina trillium	Trillium pusillum var. pusillum	C2	NCE
Giant spiral-orchid	Spiranthes longilabris	NL	SCT
Georgia plume	Elliottia racemosa	C3	ESC
Mock bishop's-weed	Ptilimnium nodosum	PE	NCE
Oglethorpe oak	Quercus oglethorpensis	C2	SUR
Pickering's brewaria	Stylisma pickeringii	C2	SCT
Pondberry	Lindera melissifolia	E	NCE
Pond spice	Litsea aestivalis	C3	SUR
Queen's root	Stillingia aquatica	NL	SCE
Relict trillium	Trillium reliquum	E	NCE
Rocky shoals spider lily	Hymenocallis coronaria	C2	NCT
Rockrose	Helianthemum georgianum	NL	SUR
Rough-leaved loosestrife	Lysimachia asperulaefolia	E	NCE
Ruellia	Ruellia caroliniensis spp. ciliosa	NL	SUR
Sarvis holly	Ilex amelanchier	C2	NL
Scale leaf gerardia	Agalinis aphylla	NL	SUR
Small-flowered silverbell	Halesia parviflora	NL	SUR
Sneezeweed	Helenium brevifolium	NL	RCE
Sneezeweed	Helenium pinnatifidum	NL	SUR
Stagger-bush	Lyonia ferruginea	NL	SCT
Water-hyssop	Bacopa cyclophylla	NL	SCT
White wicky	Kalmia cuneata	C1	NCE
Wooly Dutchman's pipe	Aristolochia tomentosa	NL	SUR

E = Endandered
PE = Proposed as endangered
C1 = Appropriate for proposed listing
C2 = Possibly appropriate for proposed listing
C3 = No longer considered for proposed listing
NCE = National concern, endangered
NCT = National concern, threatened
RCE = Regional concern, endangered
RCT = Regional concern, threatened
SCE = Statewide concern, endangered
SCT = Statewide concern, threatened
SUR = Status unresolved, considered rare
NL = Not listed
ESC = Extirpated from South Carolina

Source: Knox and Sharitz (1989)

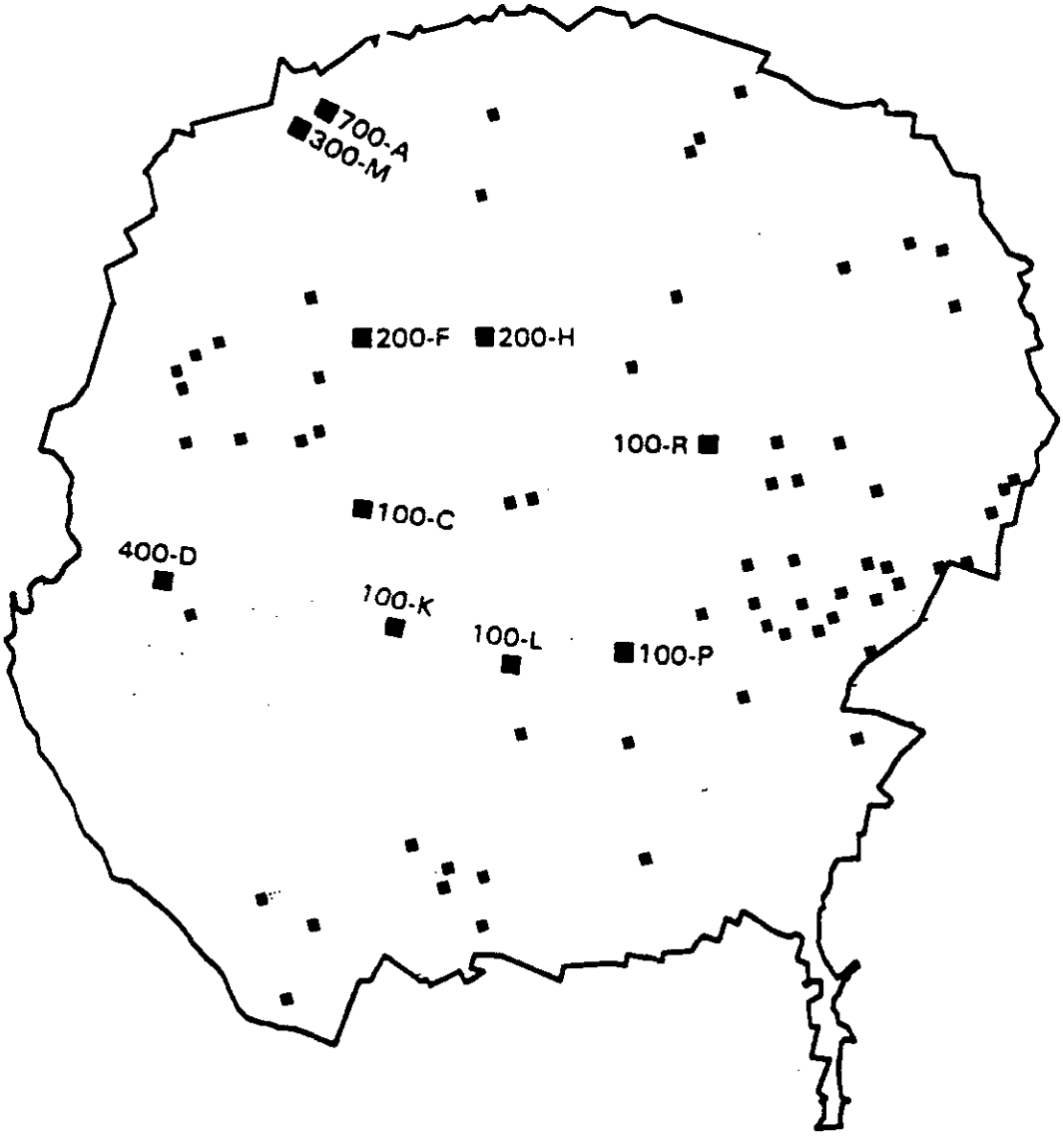

FIGURE 5-1. Location of Plant Species of Concern on the Savannah River Site

5.3 INVERTEBRATES

The brother spike mussel (Elliptio fraterna), listed as endangered by the state of South Carolina, has been identified only in the Chattahoochee and Savannah Rivers. Aspects of the natural history and distribution of this organism are poorly known. The 1972 collection of a single Elliptio fraterna from the Savannah River near SRS was the first such collection of a living individual since its description in 1852 (Britton and Fuller, 1980).

Loss of habitat is the only apparent possible consequence of operations at SRS. The magnitude of modification to the Savannah River necessary to affect habitat loss would be large, and even though little is known of the ecology and life history of this organism, operations at SRS would not be expected to have impacts of the magnitude sufficient to produce adverse effects on the habitat available to the mussels in question.

The American sandburrowing mayfly (Dolania americana), a relatively common organism in Upper Three Runs Creek on the SRS, is listed by the federal government as a candidate species for federal protection. This mayfly's habitat is clean shifting sand substrate (Peters and Peters, 1977). Based on its distribution it appears to prefer soft, slightly acidic, clear waters containing very small amounts of organic and inorganic pollution. This species would be sensitive to any situation involving increased siltation, organic loading, or toxic releases. Since Upper Three Runs Creek is not directly affected by reactor operation, no negative effects on the population would be expected from continuing reactor operation.

5.4 SHORTNOSE STURGEON

Two species of sturgeon, the Atlantic (Acipenser oxyrhynchus) and the shortnose (Acipenser brevirostrum), occur in the Savannah River (Paller et al., 1986). The shortnose sturgeon is rare and considered as an endangered species in the United States by the National Marine Fisheries Service (NMFS) (50 CFR 17.11 and 17.12).

The biology of the smaller (0.9 m) shortnose sturgeon has been reviewed by Specht (1987). The shortnose sturgeon is restricted to the east coast of North America. Breeding populations are normally associated with estuary-river complexes having a strong flow of freshwater. The shortnose sturgeon's endangered species status has stimulated recent investigations which have shown it to be more abundant in some drainage systems than had been previously known (Brundage and Meadows, 1982). Reproducing populations have recently been studied from Canada to Georgia (Marchette and Smiley, 1982; Heidt and Gilbert, 1978, Brundage and Meadows, 1982; Dadswell, 1979a, 1979b; Dovel, 1978; McCleave et al., 1977; Squiers and Smith, 1978; Taubert, 1980a, 1980b; Taubert and Reed, 1978).

Shortnose sturgeon have been found in rivers, estuaries, and the ocean with their greatest abundance occurring in the estuary of their respective river (Dadswell et al., 1982). The few fish that have been captured at sea were found within a few miles of land near the mouth of an estuarine system. The species is primarily anadromous, but access to the sea is apparently not a requirement for reproductive success. Landlocked populations have been reported in the Holyoke Pool section of the Connecticut River (Taubert, 1980a, 1980b), and the Lake Marion-Moultrie system in South Carolina (Marchette and Smiley, 1982).

Spawning of shortnose sturgeon occurs between February and May, depending on the latitude. Ripe and spent females have been collected in the Altamaha River, Georgia, during February (Heidt and Gilbert, 1978), and from January to April in the Savannah, Santee, and Pee Dee Rivers, South Carolina (Marchette and Smiley, 1982).

The major factor governing spawning appears to be temperature, although other factors include the occurrence of freshets and substrate character (Dadswell et al., 1982). Several investigators have reported shortnose sturgeon spawning to occur between 9 to 12°C (Heidt and Gilbert, 1978; Dadswell, 1979a; 1979b; Taubert, 1980a, 1980b; Buckley and Kynard, 1981). In South Carolina waters, the spawning season is earlier than in northern rivers; however, the range of spawning temperatures is similar (Marchette and Smiley, 1982).

In northern rivers, the spawning grounds are located in regions of fast flow (40 to 60 cm/s) with gravel or rubble bottoms (Taubert, 1980a, 1980b; Buckley, 1982; Pekovitch, 1979). Specific spawning grounds for populations in southeastern rivers have not been described.

Shortnose sturgeon eggs are dark brown to black with a light gray polar body (Dadswell, 1979a, 1979b; Meehan, 1910). Ripe eggs have a diameter of 3.0 to 3.2 mm and size does not change after fertilization or water hardening (Dadswell, 1979a, 1979b; Buckley and Kynard, 1981). Eggs are fertilized immediately after extrusion. When released, the eggs sink to the bottom (Pottle and Dadswell, 1979). The fertilized eggs are demersal and become adhesive within 20 min after fertilization (Meehan, 1910). Meehan reported that eggs hatched in 13 days after fertilization in water temperatures between 8 to 12°C. Buckley and Kynard (1981) found that hatching occurred in 8 days at 17°C, which agrees with Meehan's observations when both are converted to temperature units (one temperature unit equals 1°C for 24 hr).

Shortnose sturgeon larval development and behavior are not well known. Ichthyoplankton sampling efforts to collect shortnose sturgeon eggs and larvae indicate that the larvae are probably benthic in habit and that they may occupy interstitial spaces in the gravel during early larval stages (Pottle and Dadswell, 1979).

Little is known about the life history of juvenile shortnose sturgeon, particularly in southeastern rivers. In northern rivers, juveniles are benthic and feed primarily in deep channels over sandy-mud or gravel-mud bottoms (Dadswell, 1979a, 1979b; Taubert, 1980a; 1980b).

Growth data indicate that shortnose sturgeon grow faster in the southern portion of their range (Dadswell, 1979a, 1979b), where they may attain a length of approximately 50 cm after only two to four years (Taubert, 1980a, 1980b). The maximum size reported for a shortnose sturgeon is 122 cm (fork length, FL), a 23.6-kg female from the Saint John estuary. The largest male on record is 97 cm (FL), a 9.4-kg individual from the Saint John estuary (Dadswell, 1979a, 1979b). Maximum size varies from north to south with the largest maximum sizes reported from northern populations. Of 135 specimens collected by Marchette and Smiley (1982) from South Carolina rivers, the largest was 92.7 cm (fork length, FL) and weighed 4.3 kg.

The oldest female and male shortnose sturgeon collected to date, both from the Saint John River, were determined to be 67 and 32 years old, respectively (Dadswell, 1979a, 1979b). In general, shortnose sturgeon from northern populations have a longer life span than southern populations. Marchette and Smiley (1982) determined a maximum age of 20 yr based on 93 shortnose sturgeon collected from South Carolina waters.

Although shortnose sturgeon populations spawn once a year, spawning apparently is not a yearly event for each individual. Dadswell (1979a, 1979b) reported that females probably spawn a maximum of once every three years and males every other year in the Saint John River. Marchette and Smiley (1982) noted that male shortnose sturgeon in the Pee Dee River, South Carolina require two to three years between spawning periods while females require a three to four year ripening period.

Feeding by shortnose sturgeon seems to be either benthic or from plant surfaces. Dadswell et al. (1982) found them to be most active during the night or on windy days when water turbidity was high. Fish were more readily captured at night and stomach analyses showed full gastrointestinal tracts. Marchette and Smiley (1982) observed shortnose sturgeon grazing at night on molluscs attached to the underside of yellow pond lily pads.

5.4.1 Potential Impacts and Effects of SRS Operation

Loss of habitat, entrainment, impingement, and thermal effects are all possible consequences of current and future SRS operations.

Important life history habits, spawning grounds, larval, juvenile, and adult foraging areas are not known or have not been specifically described in the vicinity of SRS. Collection of larval sturgeon (Table 5-4) suggests that spawning occurs both upstream and downstream of SRS. This would indicate that spawning sites are not limited to a specific reach of the river and that a sufficient zone of passage around thermal plumes is available.

Although sturgeon spawn upstream of the SRS intake canals, entrainment of eggs is unlikely due to their negative bouyancy and adhesive nature which tends to limit downstream transport or dispersion through the water column (Specht, 1987, or Pottle and Dadswell, 1979). Collection of 43 sturgeon larvae during 1982-1985 (12 shortnose, 31 Atlantic; Table 5-4), four in or near the intake canals, suggest the possibility of larval entrainment. The low density of sturgeon larvae in the vicinity of the intakes and the reported or assumed preference for benthic habitats, makes it unlikely that entrainment would be a significant impact (Specht, 1987).

During several impingement studies (Paller et al., 1984; McFarlane et al., 1978) only one sturgeon (Atlantic, 147 mm total length, January 1983) was documented. It is therefore possible for sturgeon to be impinged. However, the lack of evidence for occupation of the intake canals by sturgeon and the attainable swimming speeds of healthy individuals, predicates against any substantial impingement losses (Mackey, 1987).

Adult sturgeon are capable of avoiding thermal plumes, thus avoiding any direct thermal impact. The localized nature of the thermal plumes minimizes the potential effect on eggs and larvae. There is no evidence of sturgeon overwintering in the thermal plumes, which precludes the potential for cold shock during rapid reactor shutdown.

The NMFS (National Marine Fisheries Service) had previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah River would not be adversely affected by SRS operations (Oravetz, 1983).

TABLE 5-4

Larval Sturgeon Collected from the Savannah River by ECS During 1982, 1983, 1984, and 1985

1982

Collection Date	River Mile	Sample Location[a]	Identity[b]	River Temp. (°C)	River Elev. (ft)
3/12	157.3	CT	Sh	12.5	85.9
3/26	157.3	CB	Sh	13.2	84.2
4/21	150.8	CB	Atl	17.8	83.5
4/22	155.2	EB	Atl	15.2	86.3
4/22	155.2	ET	Atl	15.2	86.3
4/22	155.2	EB	Atl	15.2	86.3
4/22	157.0	WB	Atl	15.2	86.3
4/22	157.0	EB	Atl	15.3	86.3
5/21	155.4	CB	Atl	20.3	83.2
5/21	155.4	CB	Atl	20.3	83.2
5/21	157.0	CB	Atl	20.2	83.2
5/21	157.3	CT	Atl	20.2	83.2
5/21	157.3	CB	Atl	20.2	83.2
8/12	157.3	CT	Atl	21.0	84.7

1983

Collection Date	River Mile	Sample Location[a]	Identity[b]	River Temp. (°C)	River Elev. (ft)
3/09	79.9	WB	Sh	16.0	94.9
3/22	155.4	CB	Sh	12.5	91.9
3/22	157.1	WT	Sh	11.5	92.5
3/22	155.3	ET	Sh	11.5	92.5
3/22	155.2	ET	Sh	11.3	92.5
3/23	97.5	WT	Sh	12.6	92.5
3/29	155.2	CT	Atl	12.5	90.6
4/26	129.1	CB	Atl	14.4	94.0
5/03	157.0	WB	Atl	18.1	86.5
5/10	155.4	CB	Atl	17.5	84.5
5/17	150.4	EB	Atl	22.5	84.3
5/18	69.9	EB	Atl	21.5	84.6
6/14	150.8	CB	Atl	20.5	83.8

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TABLE 5-4, Contd

1984						1985					
Collection Date	River Mile	Sample Location[a]	Identity[b]	River Temp. (°C)	River Elev. (ft)	Collection Date	River Mile	Sample Location[a]	Identity[b]	River Temp. (°C)	River Elev. (ft)
3/28	120.0	EB	Sh	15.0	89.3	3/19	155.4	WB	Sh	12.0	83.6
4/04	110.0	CB	Sh	15.5	88.6	3/26	166.6	EB	Sh	12.8	83.3
4/23	176.0	WB	Atl	14.0	92.9	4/09	157.3	EB	Atl	14.1	83.3
4/24	152.0	CB	Atl	14.5	93.3	4/16	141.7	EB	Atl	16.5	83.3
5/02	176.0	WB	Atl	15.8	94.5	4/16	157.0	WB	Atl	16.0	83.3
5/23	110.0	WB	Atl	20.5	86.6	4/24	120.0	CB	Atl	20.5	84.1
5/29	157.0	WB	Atl	20.4	86.1	4/30	176.0	WT	Atl	18.6	82.8
5/29	152.2	WB	Atl	20.5	86.1						
5/29	152.2	EB	Atl	20.5	86.1						

[a] Samples were taken in mid-channel (C), near the South Carolina bank (E) and near the Georgia bank (W). Samples were also taken near the top (T) and near the bottom (B) of the water column.

[b] Sh = shortnose sturgeon. Atl = Atlantic sturgeon.

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5.5 ALLIGATOR

The American alligator (Alligator mississippiensis), has been studied extensively on the SRS (Murphy, 1977, 1981; Smith et al., 1981, 1982a, 1982b; Seigel et al., 1986). These earlier studies are summarized in Volume VI of the Comprehensive Cooling Water Study Final Report (CCWS) (Du Pont, 1987). Recent work with the alligators of the SRS is documented in works by Seigel (1989) and Brandt (1989). The following summary information is taken from the CCWS (Du Pont, 1987), Seigel (1989), and Brandt (1989) and the reader is referred to those documents for a detailed treatment of the information.

The American alligator is the largest reptile of the SRS, reaching a length in excess of 3.7 m (10 to 12 ft) and a weight of 150 kg (325 lb) (Murphy, 1981). Although abundant as late as 1890, populations of alligators in the United States dwindled by the mid-20th century to less than 100,000 primarily as a result of intense hunting and habitat destruction (King, 1972). State game laws restricting the harvest of alligators were moderately useful in stabilizing populations, but it was not until federal protection was enacted in the 1960's and 1970's that populations began to recover. Recovery of this species has proceeded to the point where the FWS has reclassified the species from endangered/ threatened to threatened by similarity of appearance (DOI, 1987).

The general life history of the American alligator is well known. Courtship occurs in the late spring and females lay about 20 to 50 eggs in late June and July. Hatching occurs in late summer, and females have been reported to guard both the nest and the newly-hatched young. Hatchlings remain together for up to one or two years, then gradually disperse into the surrounding environment. Growth rates and ages at maturity are not fully known, but estimates from Florida and Louisiana suggest it may take as long as 10 to 12 years for alligators to reach sexual maturity. Maturation may occur more slowly in the northern portion of the range, such as in South Carolina (Murphy, 1981). Alligators will feed on most aquatic and semi-aquatic vertebrates and some terrestrial animals as well. American alligators have relatively broad temperature tolerances; the critical thermal maximum is estimated to be 38°C and animals have survived exposure to temperatures as low as 2 to 4°C (Colbert et al., 1946; Brisbin et al., 1982; Smith et al., 1982b; Hagan et al., 1983).

The two major types of aquatic habitats of importance to alligators on the SRS include both riverine (flowing water) and lacustrine (lake) systems (Figures 5-2 and 5-3). The riverine systems include Upper Three Runs Creek, Lower Three Runs Creek (below Par Pond), Steel Creek, Pen Branch, Four Mile Creek, Beaver Dam Creek, and the SRS section of the Savannah River along with its associated swamp. The lacustrine system includes the Par Pond reservoir, Pond B, Pond C, and the newly constructed L Lake, as well as numerous Carolina Bays, abandoned farm ponds, and beaver ponds.

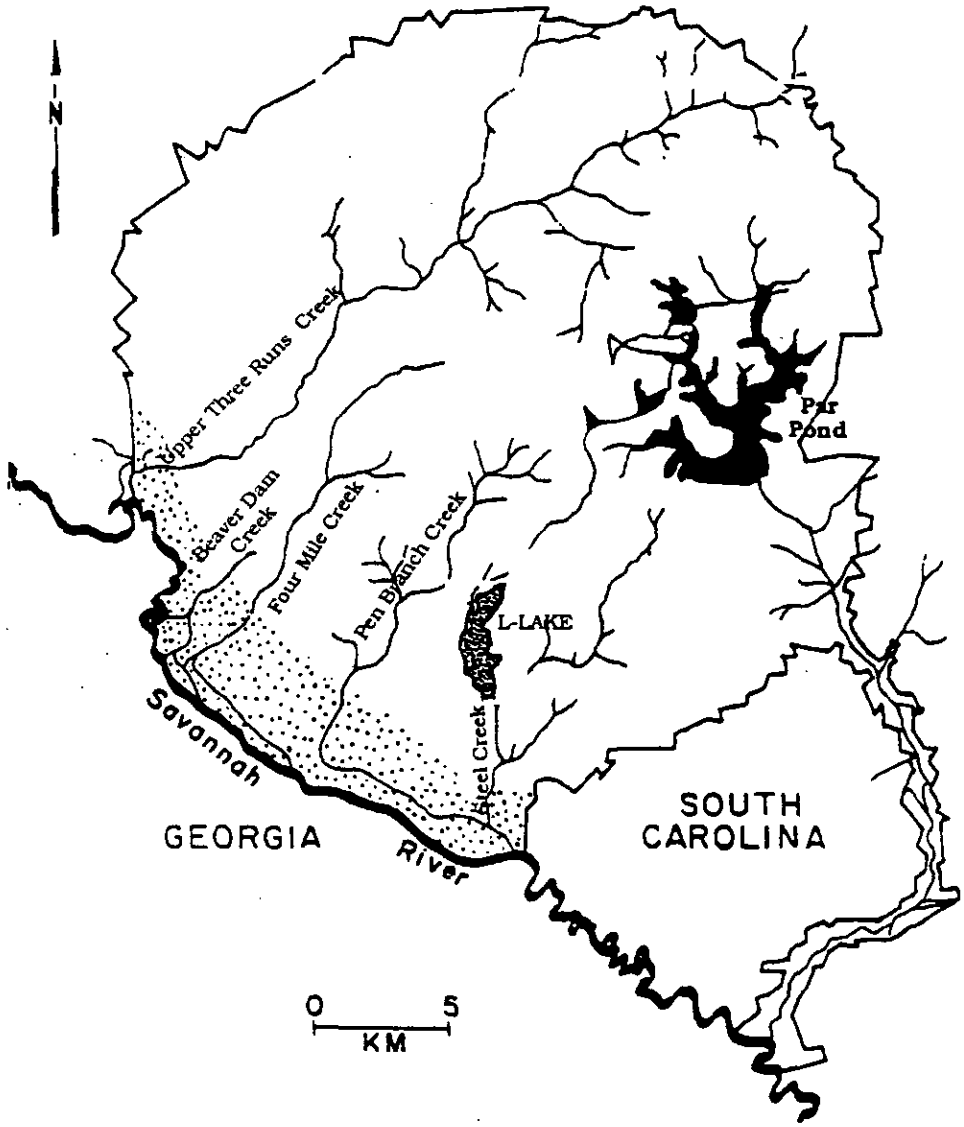

FIGURE 5-2. Map of Major Aquatic Habitats at the Savannah River Site

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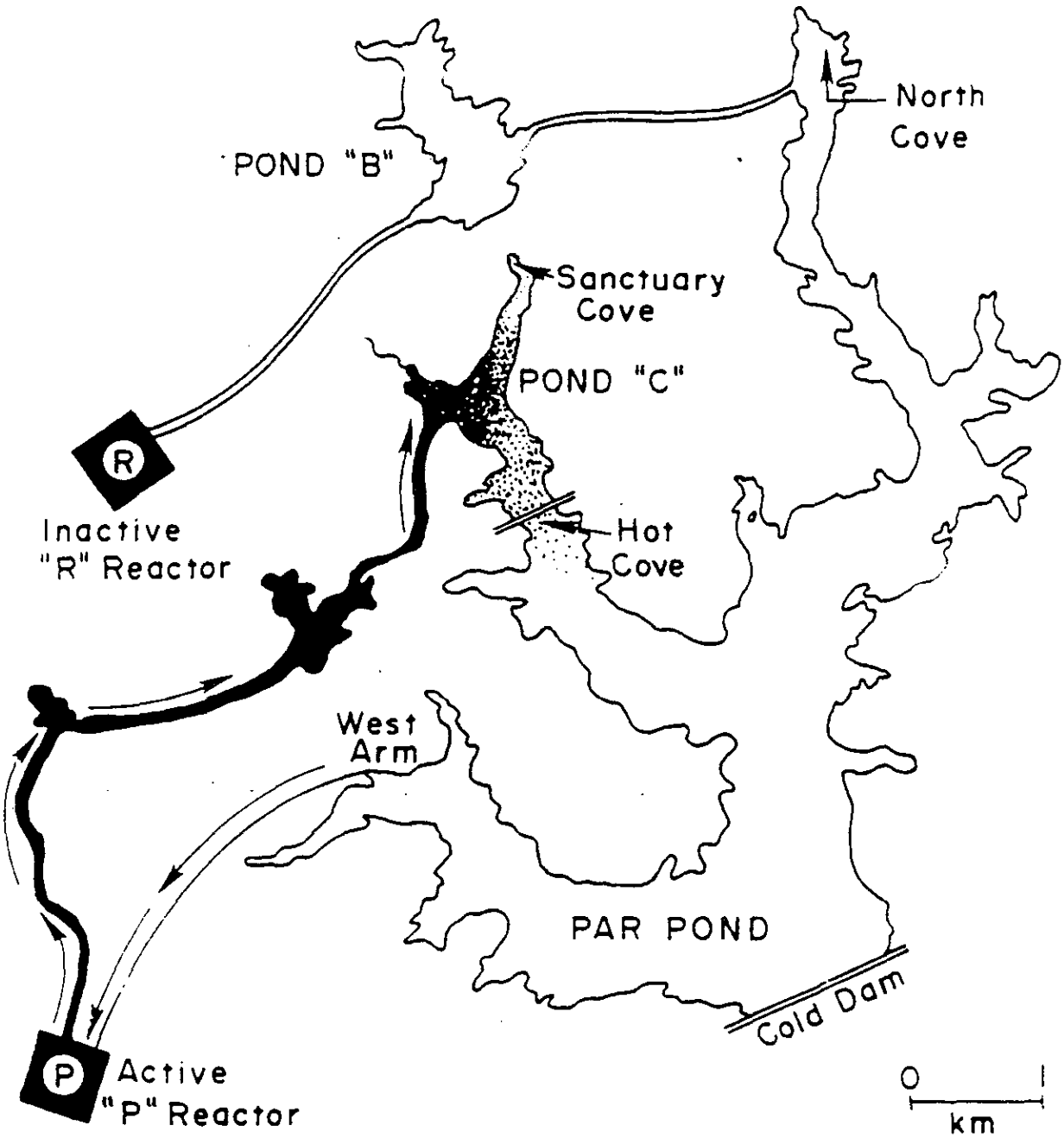

FIGURE 5-3. Map of the Par Pond Reservoir System at the Savannah River Site. Heated reactor effluents from the "P" Reactor enter the reservoir system at Pond "C" and pass southward through the Hot Arm to the main body of the lake. Ambient temperature water is then pumped back through the reactor from the West Arm of the reservoir forming a closed cooling loop (source: Murphy, 1981)

5.5.1 Summary of Ecological Studies on SRS Alligators, 1968-1981

Studies on the ecology of alligators on the SRS prior to 1981 focused primarily on Par Pond, which harbors the largest population of A. mississippiensis on the site. Research on the Par Pond population was initiated by T. Murphy and I. L. Brisbin in 1968, and was summarized by Murphy and Brisbin (1974) and Murphy (1981). A brief review of the major findings of this research is given below.

- Mark-recapture data suggested that approximately 66 adults and 40 juvenile alligators were present in Par Pond as of 1976. This was a much lower density of alligators than seen in other parts of the species' range, especially Louisiana.

- The size structure of the Par Pond population favored large adults (i.e., >2.4 m). The ratio of adults to juveniles in the Par Pond population was 59:41, compared to 31:69 for populations from coastal South Carolina.

- The sex ratio of adult alligators in Par Pond was 79:21 in favor of males, which was significantly different from data reported from Louisiana.

- Murphy found low levels of reproduction at Par Pond, estimating only 2.3 nests/year.

- Growth rates of juvenile alligators from Par Pond were found to be slower than those of juveniles from Louisiana.

- Distributions of alligators in Par Pond changed seasonally, with adult males utilizing thermally-affected areas during the winter. The use of these thermally-altered sites may have permitted a longer yearly activity period for adult males, with subsequent alteration of the timing of reproduction.

Murphy (1981) suggested that many of the unusual characteristics of the Par Pond population (low reproductive rate, low density, adult-biased population structure) was the result of "reproductive asynchrony," i.e., males coming into breeding condition earlier than females, resulting in a low frequency of mating, and therefore, fewer nests. However, two alternative explanations might also apply: first, as Murphy (1981) noted, the SRS is located near the northwestern edge of the range of A. mississipiensis. Data from other reptiles suggests that northern populations frequently have lower reproductive and growth rates than southern populations (e.g., Tinkle, 1961; Fitch, 1985), probably the result of shorter growing seasons. Second, most previous studies of alligators have been conducted in marsh habitats, which are better quality habitat for alligators than are the open waters of Par Pond.

5.5.2 Recent Population Status

The Par Pond system, including ponds B and C (Figure 5-3), harbors the largest and most extensively studied alligator population on the SRS. Recent work comparing previous study results with estimates current population has shown an increase and change in distribution by size class. The estimated population size has gone from 110 adults and juveniles in 1974 to 197 total in 1988 (Table 5-5). Although the sex ratio has changed from 3.2 to 1 (male to female) to 2.6 to 1 between 1977 and 1988 (Table 5-5, Figure 5-4), this is not considered a statistically significant change. Size distribution has shown a change from a population dominated by large individuals to one of smaller animals (Figure 5-5). Reproductive success within the Par Pond alligator population is sufficient to have almost doubled the population in the last 14 years. The average annual population exponential rate of increase was calculated as 0.06 (Figure 5-6) and would result in a projected population of over 320 individuals by the turn of the century (Brandt, 1989).

Beaver Dam Creek has had the highest frequency of alligator sightings in recent studies. This high density of alligators may be the result of the availability of relatively undisturbed, high-quality habitat and the moderate thermal effluent discharged into the creek. This thermal regime is not extreme enough to exceed the critical thermal maximum of the species and may contribute to alligator success by enhancing growth and survival by allowing year-round foraging and decreased mortality from freezing temperatures. Size distribution of the Beaver Dam Creek population (Figure 5-7) shows high representation of juveniles and sub-adults suggesting successful recruitment into the population (Seigel, 1989).

Steel Creek below L Lake supports a small population of alligators in all areas of the drainage, with most animals concentrated in the delta area. There has been evidence of nesting activity (Seigel, 1989). Although alligators are known to exist in L Lake and have been collected there, no quantitative data on population size are currently available (Gladden et al., 1988).

During the operation of C Reactor Four Mile Creek was not suitable alligator habitat and supported no population. Although Four Mile Creek Delta did contain some suitable habitat, no alligators were observed (Murphy, 1981). More recent observations showed a relatively high frequency of alligator sightings in Four Mile Creek and although the population is small, it utilized the delta and lower stream channel even during reactor operation. The population is probably not self-sustaining and no signs of reproduction have been documented. The source of individuals for the Four Mile Creek population is most likely Beaver Dam Creek due to its close proximity and large alligator population. The continued shutdown of C Reactor since 1984 may lead to sufficient habitat recovery to support an alligator population (Seigel, 1989).

TABLE 5-5

Estimated Population Size and Sex Ratios for Alligators Inhabiting Par Pond in 1972-1974 and 1986-1988. 1974 data from Murphy (1977). 1988 total population size includes 6 animals 1.25-1.5 m that were captured but not represented in earlier estimate

Year		Population Estimate and Confidence Interval (method)		Sex Ratio
1974	Adults	70	29-143 (Lincoln)	3.7:1
1974	Juveniles	40	19-72 (Lincoln)	1.8:1
1974	Total	110	48-215 (Lincoln)	3.2:1
1988	Adults	108	97-120 (Lincoln)	2.5:1
1988	Juveniles	83	45-121 (Jolly)	3.1:1
1988	Total	197		2.6:1

Source: Brandt (1989)

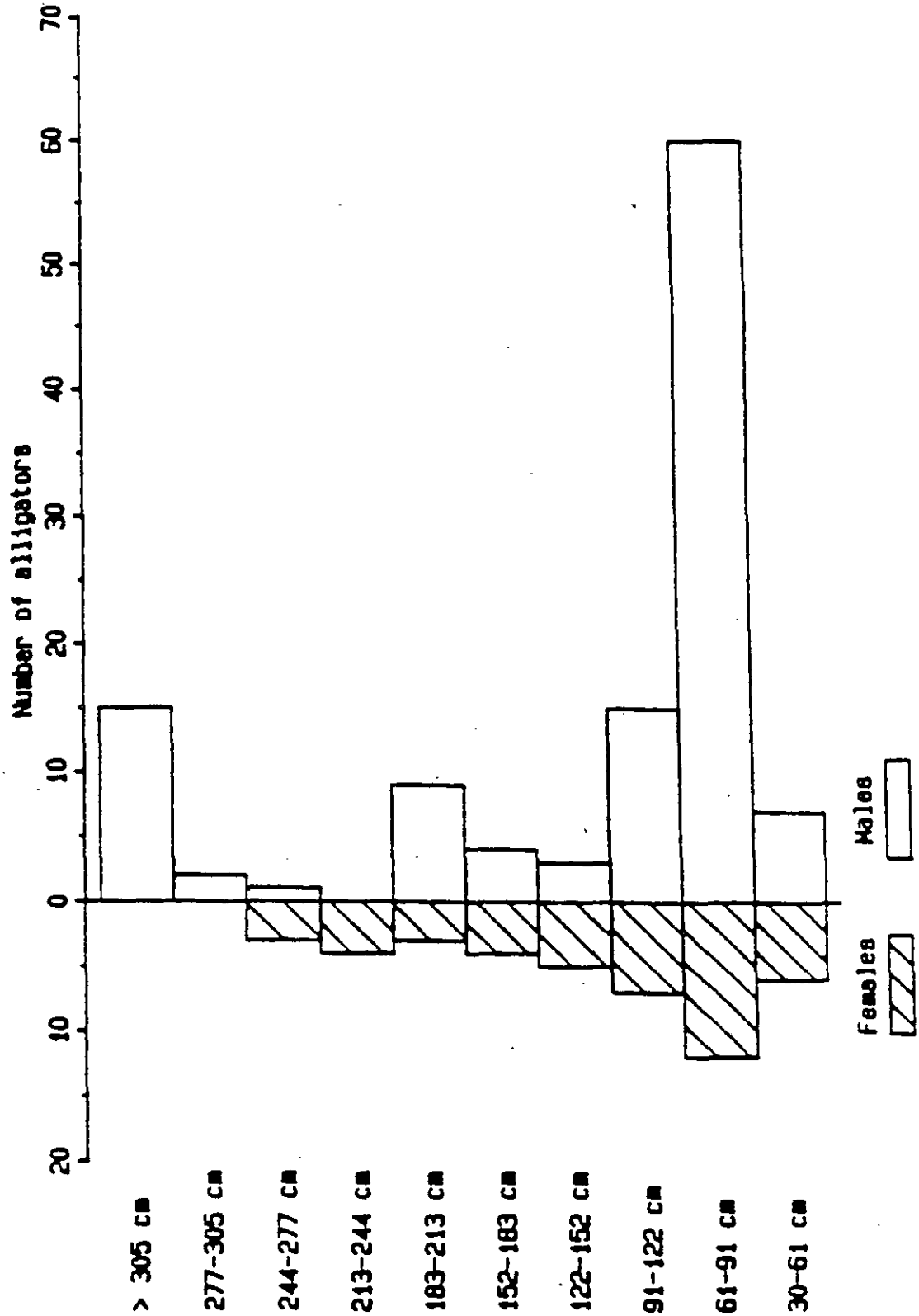

FIGURE 5-4. Size and Sex Structure of Alligators Captured in Par Pond, 1986-1988 (source: Brandt, 1989)

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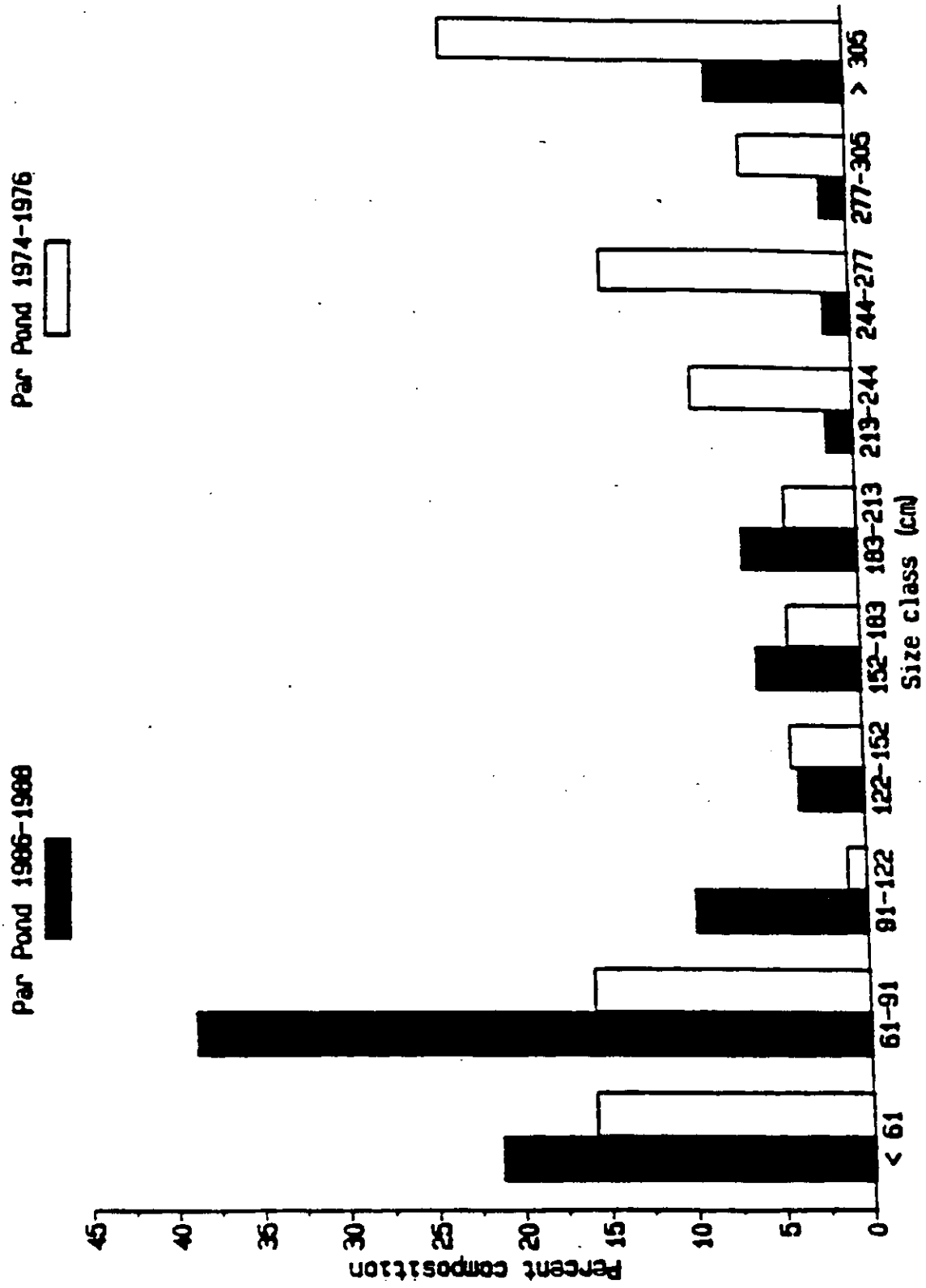

FIGURE 5-5. Alligator Size Distribution in Par Pond, 1974-1976 and 1986-1988 (source: Brandt, 1989)

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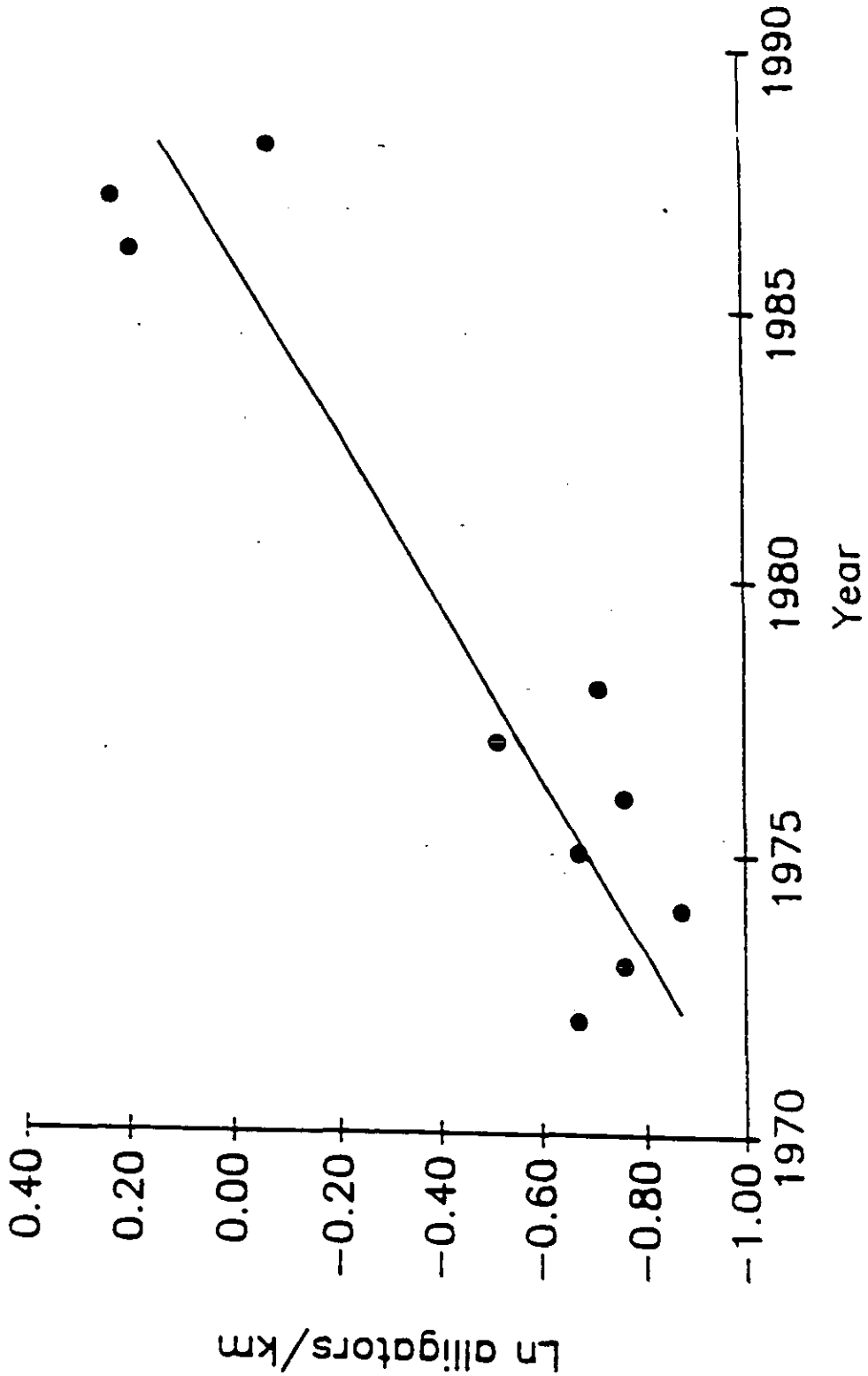

FIGURE 5-6. Alligator Population Growth in Par Pond, 1972-1988 (source: Brandt, 1989)

Pen Branch receives thermal effluent from K Reactor, and high flows and temperatures during reactor operation almost certainly preclude use of the drainage by alligators. Even though individuals have been reported moving upstream during reactor outages and alligators are sighted on occasion in Pen Branch, no large or self-sustaining population exists there. Thermal mitigation may provide suitable habitat, but the distance of Pen Branch from a pool of immigrants (Seigel, 1989) may slow the rate at which the Pen Branch population would develop.

There are other areas on the SRS that provide potential alligator habitat, but there is little information on the populations that exist there. Although Lower Three Runs Creek, dammed in 1959 to form Par Pond, supports a self-sustaining population directly below the dam, the remainder of the creek has not been surveyed for alligator use (Murphy, 1981). Upper Three Runs Creek provides a minimum of suitable habitat (Murphy, 1981) and few alligators have been sighted there (Seigel, 1989). Except for Steed's Pond, which supported a moderate population of alligators until it was drained in 1984, there is no evidence that any of the ponds and Carolina Bays on the SRS support alligator populations (Seigel, 1989). The Savannah River Swamp System (SRSS) appears to contain suitable habitat for alligators (Murphy, 1981), and although alligators are seen there regularly, difficulty in sampling makes it impossible to estimate the size of the population existing there at this time (Seigel, 1989).

5.5.3 Impact of Reactor Operation

Effects of reactor operation on the alligator populations of SRS are related to variations in temperature and flow in receiving bodies of water. Since existing alligator populations developed during operations at the SRS, continued reactor operation should have a minimal effect. There is evidence that alligators can actively avoid temperatures above their critical thermal maximum (Seigel, 1989); therefore, any individuals that have occupied areas of Pen Branch, L Lake, or Par Pond directly affected by high temperatures should successfully relocate. Increased flows will have the effect of reducing suitable habitat in Pen Branch and Steel Creeks and may possibly flood active nests in those drainages.

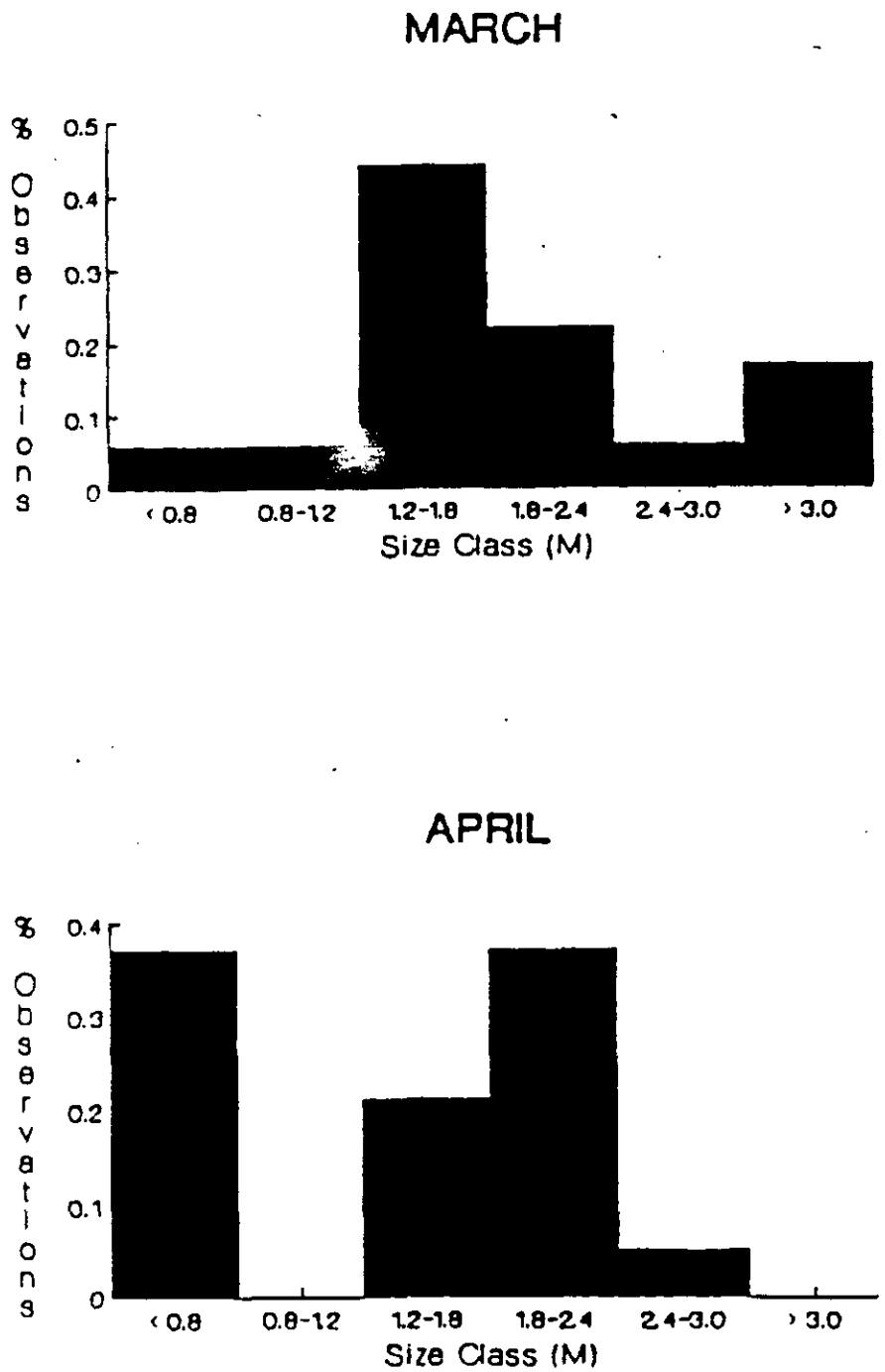

FIGURE 5-7. Size Structure of the Beaver Dam Creek Alligator Population as Assessed by Aerial Surveys in 1984 (source: Seigel, 1989)

5.6 AVIFAUNA

Thirteen species of birds listed as threatened or endangered by the federal or state government are known current or past residents of the SRS. This group includes the federally endangered red-cockaded woodpecker (Picoides borealis), bald eagle (Haliaeetus leucocephalus), peregrine falcon (Falco peregrinus), Kirtland's warbler (Dendroica kirtlandii), and wood stork (Mycteria americana); the federal candidate species, Benwick's wren (Thyromanes bewickii), loggerhead shrike (Lanius ludovicianus), and Bachman's sparrow (Aimophila aestivalis); and the State of South Carolina listed golden eagle (Aquila chrysaetos), American osprey (Pandion haliaetus), Cooper's hawk (Accipiter cooperii), swallow-tailed kite (Elanoides forficatus), and the Savannah sparrow (Passerculus sandwhichensis princeps).

The peregrine falcon has been reported in the past as a rare winter visitor to the SRS near Par Pond (Langley and Marter, 1973). Kirtland's warbler is also listed as a rare temporary visitor. Although the golden eagle has historically occurred on the SRS, there have been no recent sightings (Mayer et al., 1986). The federal candidate species, Bewick's wren, Bachman's sparrow, and the loggerhead shrike were common in the past (Langley and Marter, 1973). The osprey has been observed on the SRS but is considered an occasional migrant (Du Pont, 1982; DOE, 1984). Cooper's hawk has been documented on the SRS (DOE, 1984), and the swallow-tailed kite was common early in the 1900's in this area, but has not been recorded from the SRS (Sprunt and Chamberlain, 1970). The Savannah sparrow was reported as an abundant winter resident on the SRS in 1973 (Langley and Marter, 1973). There is no evidence that any of these birds are residents of, or nest on, the SRS (DOE, 1984).

5.6.1 Bald Eagle

A summary of the bald eagle's presence in South Carolina and historic use of the SRS has been extracted from Mackey (1987) and relies primarily on information supplied by Mayer et al. (1986).

The bald eagle (Haliaeetus leucocephalus) is a permanent breeding resident in South Carolina and is most abundant in the coastal region (Sprunt and Chamberlain, 1970). The bald eagle population in South Carolina has been increasing since 1981. As the numbers of nesting pairs and mating success of bald eagles along the coast have increased, greater numbers of fledglings have dispersed to inland areas (Mayer et al., 1986). Colonization of more inland areas is primarily the result of the construction of large inland impoundments on the Santee-Cooper and Savannah River drainages. These impoundments provide new foraging habitat for this species (Mayer et al., 1986).

The SRS includes four large impoundments (the Par Pond system and L Lake) and extensive wetland habitats along the Savannah River that potentially constitute inland bald eagle foraging and roosting habitat. With the increase in density of bald eagles sighted inland, the potential exists

for an overall increase in the use of the SRS by the bald eagle. This section reviews the history of bald eagle use of the SRS and provides an assessment of recent observations of this species onsite (Mayer et al., 1986).

Records of bald eagles in the SRS area date back to 1904 (Murphy, 1937). The presence of this species on the SRS was documented as early as May 1959 (Norris, 1963) when three eagles were observed on Par Pond. At least one of these birds, seen in September, was an immature (Norris, 1963). Par Pond has been, and still is, the location where the majority of eagle sightings on the SRS have taken place (Figure 5-8). Jenkins and Provost (1964) reported that two bald eagles had been recorded for the SRS, neither being permanent residents, nor breeders. Langley and Marter (1973) also noted that three bald eagles were observed as "transient visitants" near Par Pond. During a study of American alligators on Par Pond in the early 1970s, T. M. Murphy sighted bald eagles on that impoundment "once or twice a week" during the winter of 1971-1972 (Mayer et al., 1986). Between 1971 and 1975, Murphy noted that bald eagles were regularly seen on Par Pond from late September or early October to mid-March. Since 1978, a survey of most of the Par Pond system has been conducted as part of the annual SRS Christmas Bird Count. The sightings of bald eagles on Par Pond during this annual, one-day count are presented in Table 5-6.

Bald eagle use of the SRS was studied between September 1984 and August 1985. Ground and/or aerial surveys were conducted on the Par Pond system at least twice per month during this period. Other eagle sightings (i.e., golden eagles) reported on the SRS during that period also were documented. The location, date, time of day, number of adult and immature birds, and behavior were recorded. Descriptions of any tags or bands present were also noted (Mayer et al., 1986).

A total of 36 bald eagles were seen in 31 instances during this 12-month period. The details of these sightings are listed in Table 5-7. The majority (91.7%) of the bald eagle sightings were on the Par Pond system. Within this system, the largest number of sightings (66.7%) were on the main portion of the Par Pond system (Figure 5-9). Fewer eagles were seen on Pond C (24.2%), Pond B (6.1%), and Pond 2 (3.0%). On Par Pond, the Big Lake section adjacent to the Cold Dam had the most use (22.7%), followed by Loyal's Lair (18.2%), and then the Hot Arm, North Arm, and Pump House Cove in the West Arm (13.6%). On Pond C, most of the sightings were between the main lake and Sanctuary Cove. In part, the thermal fish kills on Pond C (Gladden et al., 1985) attract bald eagles to that impoundment. A number of the sightings on Pond C have been of birds that were feeding on the dead fish present in the littoral zone (Mayer et al., 1986). Seventy-two percent of all of the bald eagles sighted were adults. Thirteen percent of the sightings were paired birds. Of these five pairs, two were both adults, two were both immatures, and one was an adult/immature pair. Several social groupings of three bald eagles have been observed previously on the SRS (Mayer et al., 1986). No social groupings larger than a pair, however, were noted during the 1984-1985

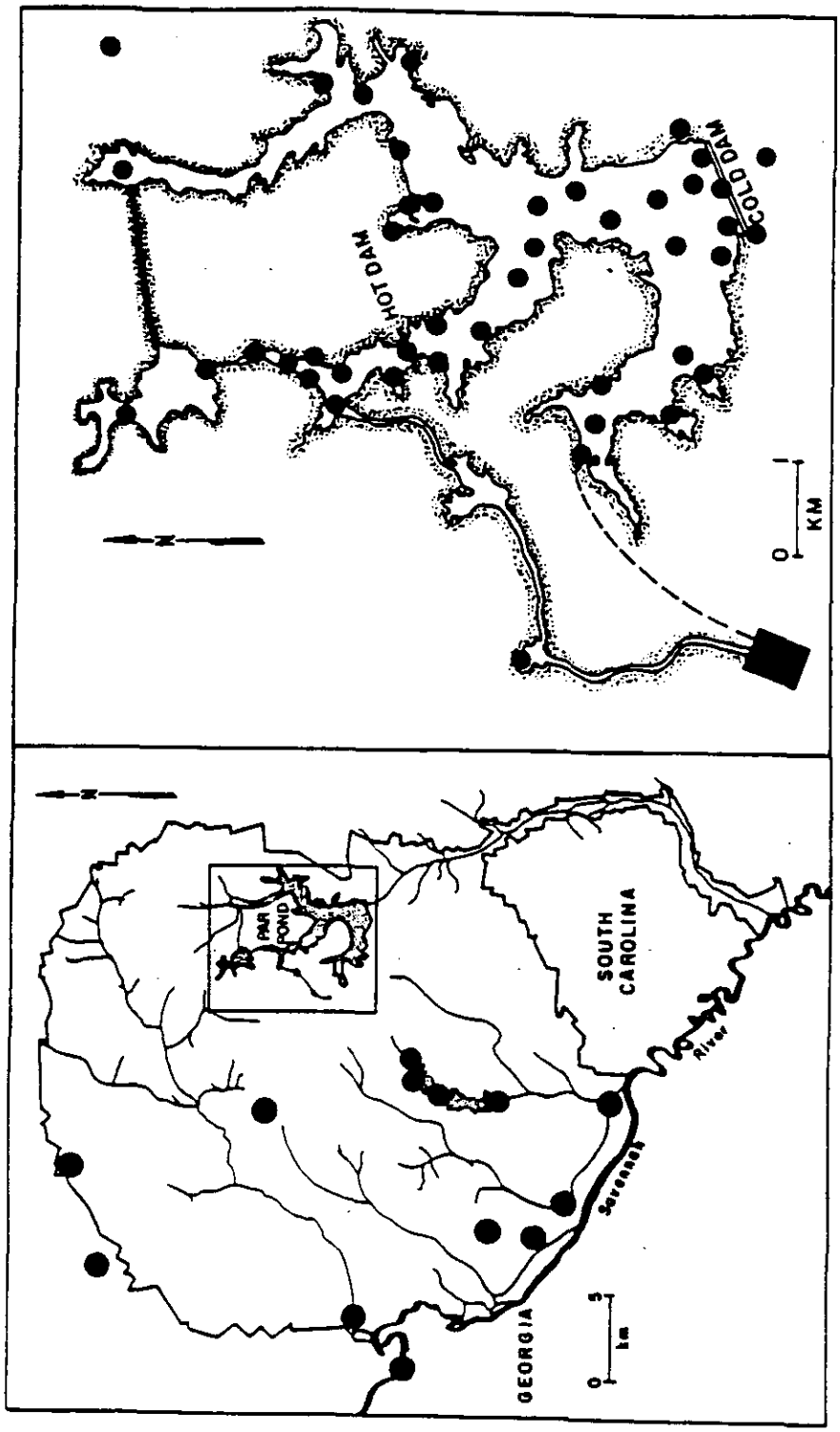

FIGURE 5-8. **Locations of Bald Eagle Sightings on the Savannah River Plant and Specifically on the Par Pond Reservoir System Between 1971 and 1986.** Each dot represents one or more sightings of this species at that location. Sightings are based on this study, the SRS Christmas Bird Count, the SRS waterfowl aerial surveys, and reports of reliable sightings prior to September 1984 (source: Mayer et al., 1986)

TABLE 5-6

Bald Eagle Sightings on the Savannah River Plant from the Annual Christmas Bird Count

Date	Number of Birds Seen		Location - Par Pond*
	Adults	Immatures	
12/23/78	1	-	Big Lake
12/23/78	-	1	Pumphouse Cove
12/15/79	1	-	North Shore of East Lake
12/18/82	1	-	Gentry's Gulch

* See Figure

Source: Mayer et al. (1986a)

TABLE 5-7

Bald Eagle Sightings on the Savannah RIver Plant from September 1984 to August 1985

Date	Time	Number of Eagles Seen: Adults	Number of Eagles Seen: Immatures	Location on the SRS
09/10/84	1030	-	1	Pond C, Sanctuary Cove
09/12/84	1415	1[a]	-	Pond C, Canal Cove
10/17/84	1500	1	-	Par Pond, Loyal's Lair
11/06/84	1130	1	-	Par Pond, Pump House Cove
11/15/84	1425	1	-	Pond B, Pond B Dam
12/03/84	1515	1	-	Par Pond, Cold Dam
12/15/84	0930	1	-	SRS Rd 2, on roadside near New Ellenton barricade
12/15/84[b]	1030	-	1	Par Pond, Cold Dam
12/19/84	1130	1	-	Pond C, near Boatdock Cove
01/07/85	1100	1	1	Par Pond, North Arm
01/17/85	1630	1[c]	-	Par Pond, Cold Dam
01/20/85	1030	-	1	Par Pond, Cold Dam
01/22/85	1400	1	-	Par Pond, Loyal's Lair
01/25/85	1300	-	1	Par Pond, Loyal's Lair
02/03/85	1120	1	-	Par Pond, Loyal's Lair
03/20/85	1400	-	2	Par Pond, Hot Arm; flew to Pond C
03/25/85	1440	-	2	Par Pond, Pump House Cove
03/30/85	1330	-	1	Par Pond, Cold Dam
04/04/85	1030	1	-	Par Pond, Hot Arm
04/04/85	1600	1	-	Par Pond, North Arm
04/14/85	1230	1	-	Par Pond, Big Lake Section; flew to Main Lake
04/19/85	1015	1	-	Upper Three Runs Creek, near mouth
05/02/85	1215	1	-	Savannah River, near Crackerneck GMA
05/13/85	1000	1	-	Pond B
05/25/85	1600	1	-	Pond C, near Sanctuary Cove
06/25/85	1000	1	-	Pond 2
07/03/85	1000	1	-	Pond C, near Sanctuary Cove
07/12/85	0930	2	-	Pond C, near Sanctuary Cove
07/18/85	1030	1	-	Par Pond, South Lake Section of West Arm
07/18/85	1400	2	-	Par Pond, West Lake; flew to Hot Arm
08/05/85	0930	1	-	Pond C, near Sanctuary Cove

[a] Bird had a red band on left wing.
[b] 1984 annual SRS Christmas Bird Count.
[c] Bird had a red streamer attached to back.

Source: Mayer et al. (1986)

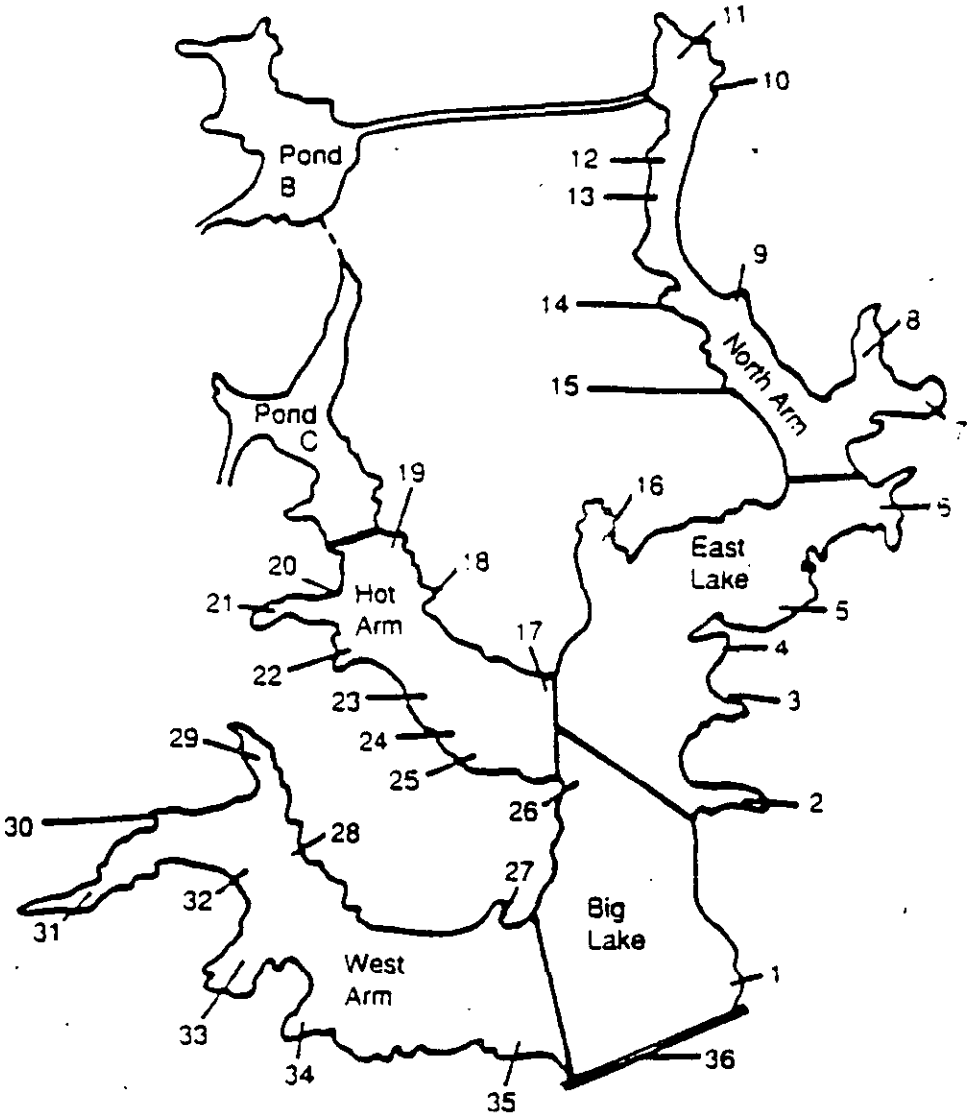

FIGURE 5-9. Location Map on the Par Pond System. The numbers are: 1 - Sarah's Beach; 2 - Susan's Swamp; 3 - Fairman's Landing; 4 - Fred's Bay; 5 - Nancy's Nook; 6 - Gus's Swamp; 7 - South Dave's Lake; 8 - North Dave's Lake; 9 - Callahan Slough; 10 - Kim's Cove; 11 - Little Lake; 12 - Nell's Nook; 13 - Erin's Elbow; 14 - Chris's Cove; 15 - Herde's Inlet; 16 - Loyal's Lair; 17 - Parrot Point; 18 - Jim's Joint; 19 - Coleman's Cove; 20 - Larry's Landing; 21 - Beyer's Bay; 22 - Carol's Bay; 23 - Patsy's Cove; 24 - Golley Bay; 25 - Rosemary's Bay; 26 - Peggy's Point; 27 - Ilehr's Inlet; 28 - Barbara's Landing; 29 - Mike's Marsh; 30 - Pumphouse Cove; 31 - Kenyon Bay; 32 - Dayton's Landing; 33 - Gentry's Gulf; 34 - Fran's Inlet; 35 - Jack's Bay; and 36 - Cold Dam (source: Mayer et al., 1986b)

study period. Bald eagles were seen during every month of the survey. Most of the birds (63.9%) were seen during the winter and spring months (November through May). This was also the period when the majority of the immature birds (90.0%) was observed. Only one immature bald eagle was seen in the fall, and none were seen during summer.

Mid-summer migration of bald eagles that have nested in the southeast to the northern states and into Canada has been demonstrated by banding studies (Sprunt & Chamberlain, 1970). These birds then return south in the fall and early winter to nest and rear their young and remain there until late spring (Sprunt & Chamberlain, 1970). The majority of birds are observed on the SRS during that period of time when this species is nesting and wintering in South Carolina. Those birds seen during the summer and early fall are most likely transients migrating either north or south. Two of the adult birds (7.7%) observed were marked. One of these had been tagged as a fledgling along the South Carolina coast north of Charleston. The second bird was of unknown origin because the tagging method and color were neither registered with nor known to either the U.S. Fish and Wildlife Service or the Raptor Information Center (Mayer et al., 1986).

Since the completion of this one-year study, 22 more bald eagles have been sighted on the SRS. The details of these sightings are listed in Table 5-8. Seven of the 22 sighting localities are new records. Bald eagle use of L Lake was reported within one month of its completion of the filling. An immature bird was seen feeding on dead fish in the outflow of L-Lake Dam and three adult bald eagles were observed soaring above the lake. Reports of bald eagle use of that new impoundment will likely increase with time (Mayer et al., 1986).

Bald eagle use of the SRS is more common than had been previously known. This apparent increase may be a result of either poor earlier documentation or recent increase in the use of the SRS by bald eagles, or both. Because of the presence of large impoundments on the SRS with high densities of fish, bald eagles will probably continue to be attracted to the SRS.

5.6.1.1 Bald Eagle Nesting on the SRS

The first documented bald eagle nesting site on the SRS was on May 21, 1986 (Figure 5-10). By June 6, 1986 the nest and presence of two juvenile eagles was confirmed. The adult female parent was a banded individual whose banding indicated fledging on the Cooper River or near Georgetown during the 1978-1981 nesting seasons. The eagle pair has returned to the nest every year since 1986. During 1987, two chicks were hatched and fledging was confirmed for one (Austin, 1989a). During 1988, three chicks were hatched and fledged. In 1989 two chicks were hatched, but were presumed lost along with the nest during extreme winds (87 mph) associated with a storm front passing through the SRS in April. The Savannah River Forest Service (SRFS) has undertaken action at the nest site to encourage the return of this nesting pair as part of their ongoing extensive management plan to encourage and protect bald eagle nesting at SRS (Irwin, 1989).

TABLE 5-8

Bald Eagle Sightings on the Savannah RIver Plant from September 1985 to August 1985 to January 1986

Date	Time	Number of Eagles Seen Adults	Immatures	Location on the SRS
09/03/85	1000	1	-	Pond C, near Sanctuary Cove
09/13/85	0945	1	-	Pond C, near Sanctuary Cove
09/14/85	0820	1	-	Par Pond, West Lake
09/14/85	0956	1	-	Par Pond, South Lake
10/05/85	1530	1	-	One mile east of the SRS Rd 8 causeway over the North Arm of Par Pond
10/22/85	1400	1	-	Par Pond, Hot Dam
10/27/85	1145	1	-	Par Pond, Cold Dam; flew down Lower Three Runs Creek
11/13/85	1100	1	-	Par Pond, Cold Dam
11/13/85	1520	1	-	Par Pond, Cold Dam
11/15/85	1020	1	-	H Area, field near junction of SRS Rd E and 4
11/19/85	1430	-	1	L Lake, L-Dam outflow
12/03/85	0915	1	-	Hunt Compartment 44, adjacent to Rd A-13 near 1985 Deer Hunt Stand and D-19
12/05/85	1030	1	-	Par Pond, West Arm
12/06/85	1500	1	-	L Lake, center of impoundment
12/11/85	1015	1	-	Par Pond, Cold Dam
12/13/85	1445	1	-	L Lake, near Rd B
12/13/85	1530	1	-	L Lake, near L-Reactor effluent canal
12/30/85	1620	1	-	Par Pond, Cold Dam
12/31/85	1045	1	-	Par Pond, West Arm
01/14/86	1045	1	1	Par Pond, Cold Dam
01/04/86	1410	1	-	Par Pond, West Arm, Fran's Inlet

Source: Mayer et al. (1986)

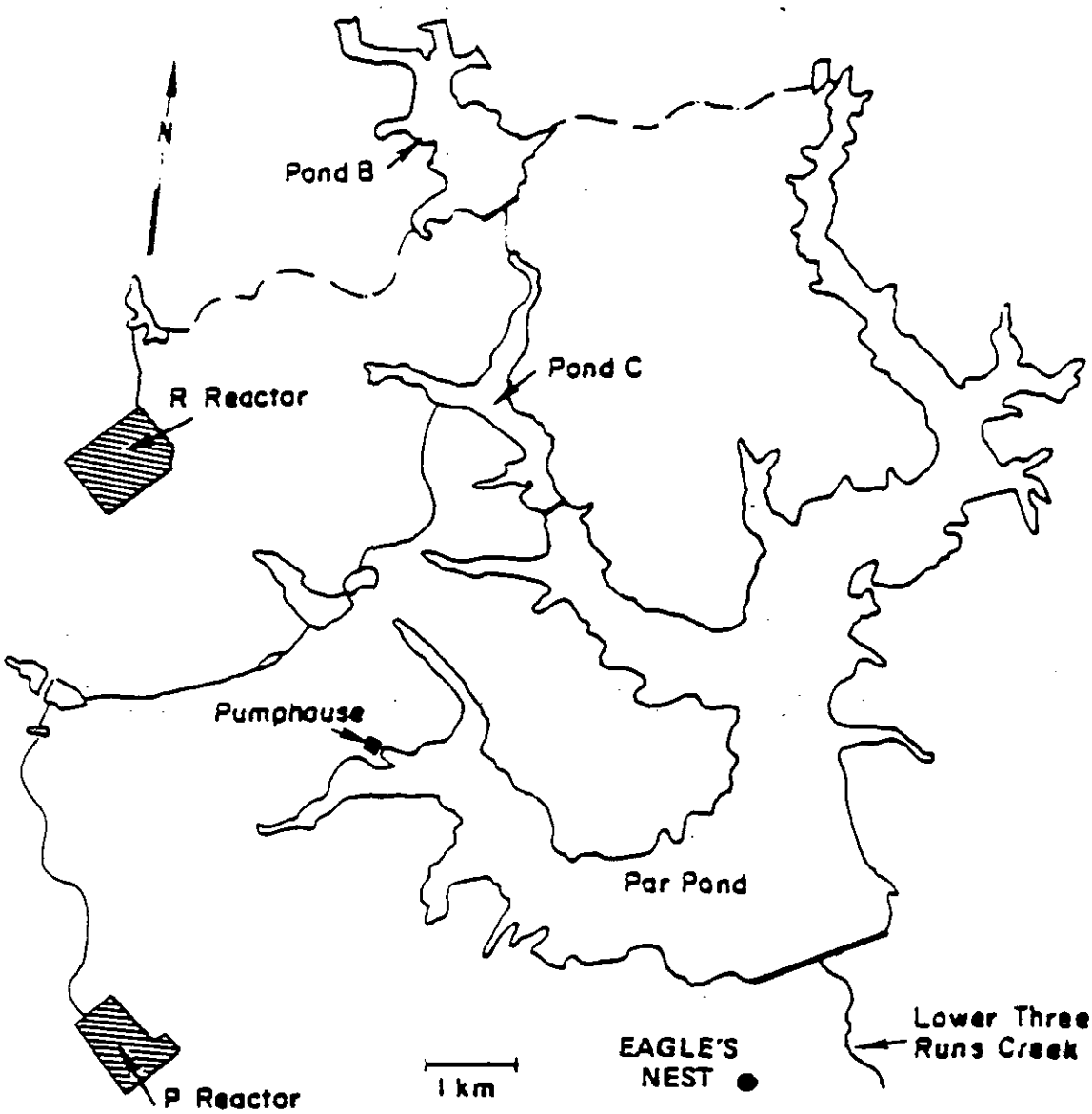

FIGURE 5-10. Location of Bald Eagle Nest on the Savannah River Site (source: Mackey, 1987)

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5.6.1.2 Bald Eagle Management on the SRS

The SRFS began an active management program to minimize disturbance of the eagle nest site as soon as it was sighted by filing an application and permit for site use (Austin and Smith, 1986). In addition, the SRFS developed the Eagle Bay Management Plan (Austin, 1989a) detailing management protocols and implementation procedures for protection of the existing eagle nest and providing nesting and perching areas around Par Pond (Figure 5-11). Due to the extensive management plan, and availability and distance from existing facilities of suitable habitat, it is expected that continued operation of the reactor facilities at the SRS will have no adverse effect on the bald eagle.

5.6.2 Red-Cockaded Woodpecker

The red-cockaded woodpecker (Picoides borealis) was included in the federal list of endangered species in 1970 due to the declines in local populations, its perceived rarity, and the apparent reduction in available nesting habitat (Lennartz and Henry, 1984).

Although the red-cockaded woodpecker was once common, its current status can be largely attributed to its unique life history requirements and how they are affected by the reduction of mature pine forests. The red-cockaded woodpecker is a native of the southern pine forests of the United States with the largest populations found in the Coastal Plain forests of the Carolinas, Florida, Alabama, Mississippi, Louisiana, and eastern Texas. Populations are also found in the Sandhills forests of the Carolinas.

An endangered species recovery plan (Lennartz and Henry, 1984) prepared for the U.S. Fish and Wildlife Service provides a description of the life history, ecology, and the historic and current status of the species. A short summary of information follows, but the reader is referred to the original document for greater detail.

The red-cockaded woodpecker is a cooperative breeder using auxiliary or helper birds to aid the mated pair with incubation, feeding, and brooding. Clans with helpers generally have higher reproductive success. These clans are nonmigratory and maintain year-round territories around their nesting and roost trees. Clans can range in size from only the mated pair up to nine birds including helpers and fledglings. The normal clan size is two to four birds prior to nesting and four to six birds after fledging. Nesting season is usually April and May, with clutch initiation in late April or early May. Clutch size is generally between two and five eggs. Incubation takes approximately 10 days and fledging occurs between 26 to 29 days after hatching. Juveniles remain in their natal territory through summer into fall. Juvenile females disperse during late fall, winter, and early spring, while some juvenile males may remain with their clan and become helpers.

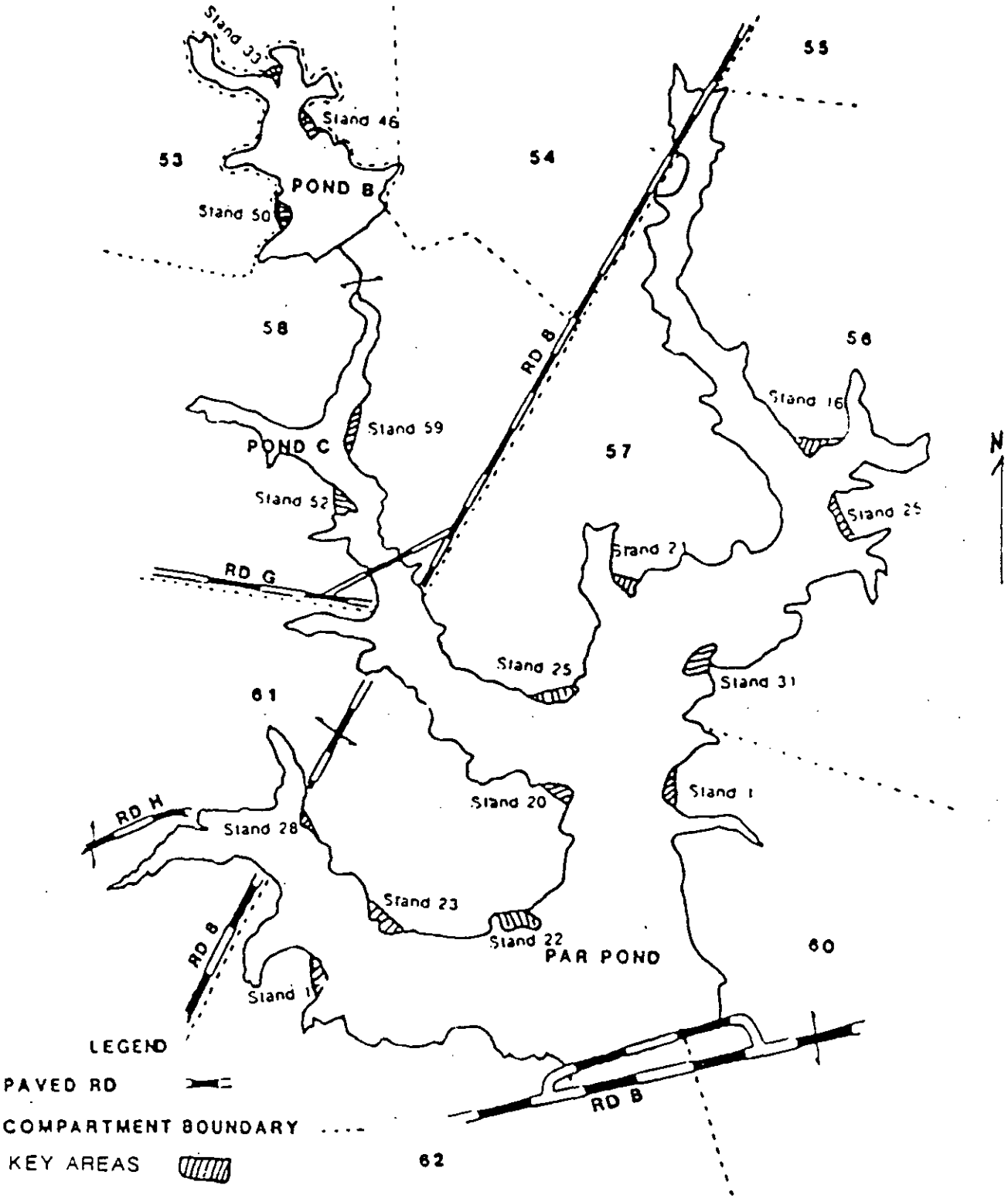

FIGURE 5-11. Key Eagle Management Areas, Par Pond Area
(source: Austin, 1989a)

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The red-cockaded woodpecker is the only species to use living pines exclusively for cavity excavation. The birds use many species of pines, preferring older trees, usually over 70 years, and may actively select for trees suffering from heart rot. The same cavity trees may be used for many years, possibly even decades, and the trees used by a clan tend to be clustered in what are referred to as colonies. Trees in most colonies are within a 1500-ft-diameter area in open stands of pine with sparse midstories. Sparse midstory is an important factor, as dense hardwood midstories may promote abandonment by the red-cockaded woodpeckers. This may be due to more intense interspecific competition from other woodpecker species inhabiting the wetter habitats that promote thicker midstory stocking.

Living pines are also the preferred foraging substrate for red-cockaded woodpeckers. Other species, such as cypress, are also used, but primarily when pine foraging areas are of low quality. The preferred habitat would have more than 50% basal area in pine, more than 24 pine stems per acre larger than 10 in. in diameter at breast height, and be at least 30 years old. Based on the relationship of home range, available foraging area, and reproductive success, a clan of red-cockaded woodpeckers requires 125 acres of well-stocked pine or pine-hardwood stands over 30 years old for survival and productivity.

There is evidence, primarily anecdotal, that the red-cockaded woodpecker was common during the last century. In the late 1930's population declines and loss of habitat contributed to the contraction of range and greater fragmentation of the total population.

Since its inclusion as an endangered species, the red-cockaded woodpecker has been the focus of extensive research and population censusing. The total number of active colonies on federal lands may exceed 3,000. There have been documented losses of active colonies in recent literature. Red-cockaded woodpecker population trends will most likely parallel the trends in availability of suitable habitat. Stands of old-growth pines are a scarce and declining resource throughout the south, with the total acreage of old growth pine having declined by 13% over the last 30 years. On federal lands there is a significant positive correlation between old-growth longleaf-slash pine and active red-cockaded colonies.

Since 1979, the SRFS wildlife management program has been actively working to improve red-cockaded woodpecker habitat. In 1980, a program was initiated to reduce encroaching hardwood understories in several colonies (Table 5-9). The planted pine forests on SRS are less than 40 years old and therefore do not provide optimum habitat for the woodpeckers (DOE, 1987).

SRFS monitors 35 colony sites of four different categories (Figure 5-12). There are four active colonies that contain productive clans, seven inactive sites that supported active colonies within the last ten years, abandoned sites that supported active colonies more than ten years ago, and recruitment sites containing appropriate habitat (Austin, 1989a).

TABLE 5-9

SRFS Wildlife Management Activities Showing Number of Acres of Red Cockaded Woodpecker (RCW) Habitat Improved

		Wildlife Activities				
Fiscal Year	RCW Habitat Improved[a]	(Acres) Burned[b]	Beaver & Hog Control No. Trapped		Stabilization Roads (mi)	(Acres) Borrow Pits
1980	15	-	-	-	9.7	62
1981	96	50	-	-	6.8	55
1982	100	38	-	-	10.0	45
1983	29	29	196	-	13.3	126
1984	0	0	44	-	14.8	84
1985	148	0	192	160	27.3	31
1986	622	0	148	238	20.7	18
1987	972	222	84	170	5.0	7

[a] Includes acres chemically treated and chain sawed.
[b] Acres burned surrounding RCW colonies.

Source: SRFS (1988)

In 1987, SRS had three active colonies of red-cockaded woodpeckers. In 1988 another colony (colony 2) was established and produced young in 1989. Single individual birds were moved to two unoccupied colony sites (3 and 28) in 1989. A summary of 1988 and 1989 clan members and breeding activities appears in Table 5-10. The concern of limited genetic diversity in a small breeding population is currently being addressed with a program of cross-fostering chicks from the Francis Marion National Forest.

Due to active management to enhance suitable habitat and the lack of negative effects from previous operation, it is expected that continued reactor operation at the SRS will have no adverse effect on the red-cockaded woodpecker populations.

5.6.3 Wood Stork

5.6.3.1 Introduction

During the last 50 years, the North American breeding population of the wood stork (Mycteria americana) has decreased from an estimated 20,000 breeding pairs in the early 1930s to 4800 pairs in 1980 and 3650 pairs in 1983 (Ogden and Nesbitt, 1979; Ogden and Patty, 1981; DOI, 1983). This population decline prompted the United States Fish and Wildlife Service of the Department of Interior to list the wood stork as an endangered species (DOI, 1984). Since 1980, the number of breeding pairs of wood storks has remained relatively stable at roughly 4500 pairs in 1981, 3700 in 1982, 4000 in 1983, 5100 in 1984, and 5100 in 1985 (Coulter, 1986c).

Twenty-three colonies of wood storks were identified in Florida and Georgia by the DOI in the proposed listing (DOI, 1983). The Birdsville Colony, the most northern and inland wood stork colony, is located at "Big Dukes Pond," a 567 ha cypress swamp, 12.6 km northwest of Millen, Jenkins County, Georgia (32°52'N, 82°03'W). This wood stork colony (Figure 5-13) was believed to be the source of storks observed at the Steel Creek Delta in the SRS Savannah River swamp during 1980-1982 (Smith et al., 1982a, 1982b). The SRS Savannah River swamp is 45 km from the Birdsville Colony, a distance within the 60 to 70 km radius that wood storks can travel during daily feeding flights.

In 1983, studies were initiated to provide an assessment of the potential effects of the operation of the SRS on the wood stork (Meyers, 1984). The objectives of the study included the following:

- To determine the foraging locations of storks from the Birdsville Colony,

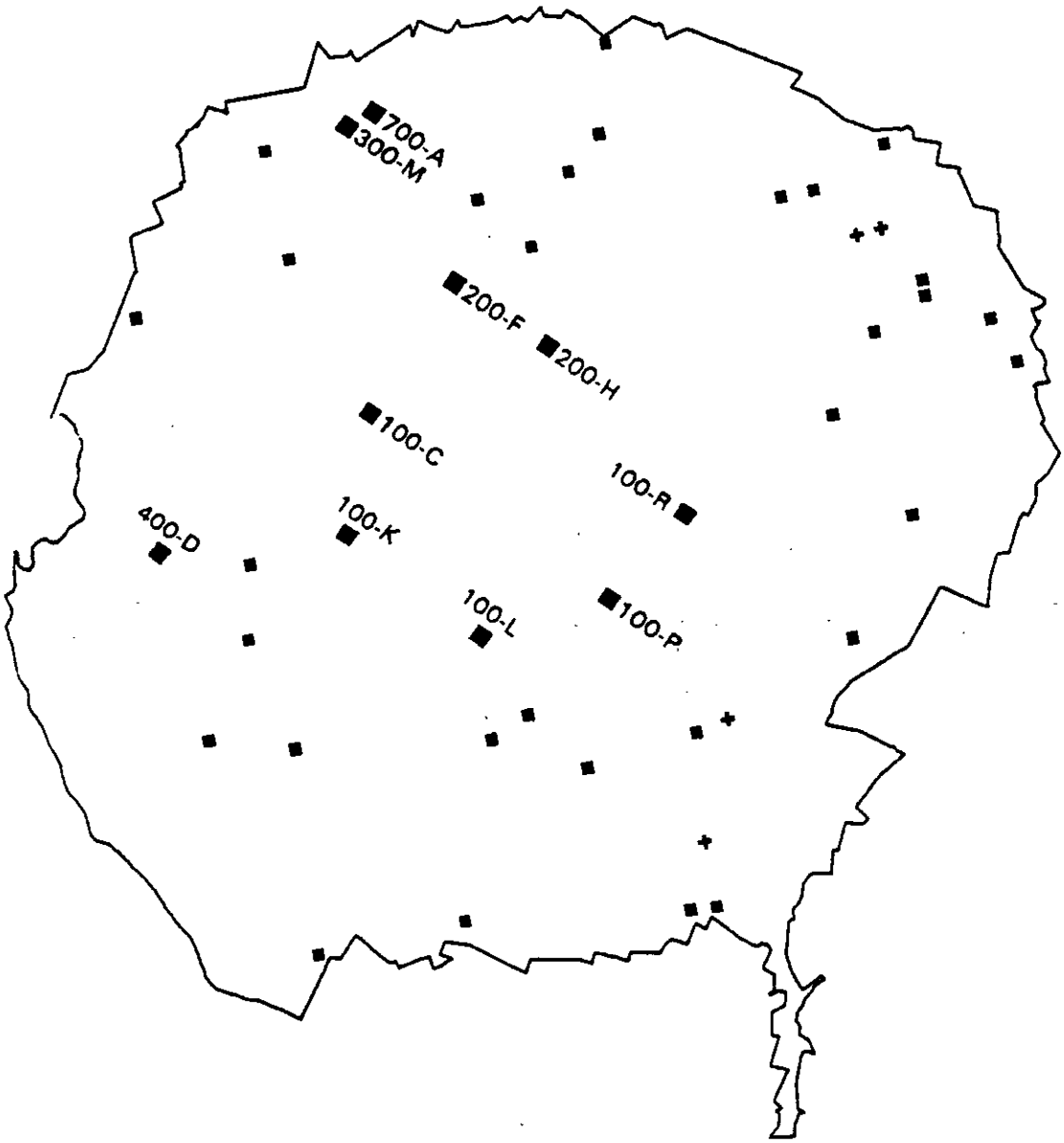

FIGURE 5-12. Monitored Red Cockaded Woodpecker Colony Sites. Active Colonies are Marked by +.

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TABLE 5-10

Red-Cockaded Woodpecker Colony Status, 1988-1989

	FWS Number	Sex	Status	Origin
Colony 2				
1988				
Pre-breeding		M	Yearling	Colony 19
Post-breeding	981-89264	M	Yearling	Colony 19
	961-25361	F	Yearling	Colony 16 (1/2 FMNF)
1989				
Pre-breeding	981-89264	M	Yearling	Colony 19
	961-25361	F	Yearling	Colony 16 (1/2 FMNF)
Post-breeding	981-89264	M	Breeder	Colony 19
	961-25361	F	Breeder	Colony 16 (1/2 FMNF)
	8011-85016	M	Chick	Fledged, 1989
Colony 3				
1989				
Post-breeding	8011-85017	M	Chick	Fledged Colony 2, 1989
Colony 5				
1988				
Pre-breeding	-	M	Breeder	Colony 5
	-	F	Yearling	Colony 16 (1/2 FMNF)
Post-breeding	891-08710	M	Breeder	Colony 5
	961-25675	F	Breeder	Colony 16 (1/2 FMNF)
	8001-24649	F	Fledgling	Colony 5
	8001-24648	F	Fledgling	Colony 5
1989				
Pre-breeding	891-08710	M	Breeder	Colony 5
	961-25675	F	Breeder	Colony 16 (1/2 FMNF)
	8001-24649	F	Yearling	Fledged, 1988, Colony 5
Post-breeding	891-08710	M	Breeder	Colony 5
	961-25675	F	Breeder	Colony 16 (1/2 FMNF)
	8001-24653	F	Chick	Fledged, 1989
	8001-24652	M	Chick	Fledged, 1989
	8001-24654	M	Chick	Fledged, 1989

Source: Austin (1989b)

TABLE 5-10, Contd

	FWS Number	Sex	Status	Origin
Colony 16				
1988				
Pre-breeding	-	F	Breeder	FMNF, 1986
	-	F	Yearling	Colony 16 (1/2 FMNF)
	-	M	Yearling	Colony 16 (1/2 FMNF)
Post-breeding	961-25362	M	Yearling	Colony 16 (1/2 FMNF)
1989				
Pre-breeding	961-25362	M	Breeder	Colony 16 (1/2 FMNF)
	8001-24648	F	Breeder	Colony 5, 1988
Post-breeding	961-25362	M	Breeder	Colony 16 (1/2 FMNF)
	8001-24648	F	Breeder	Colony 5, 1988
	8011-85019	M	Chick	Fledged, 1989
Colony 19				
1988				
Pre-breeding	-	M	Breeder	
	-	F	Breeder	
	-	M	Helper	
	-	M	Yearling	FMNF
Post-breeding	891-09184	M	Breeder	
	961-25688	F	Breeder	
	981-89229	M	Helper	Fledged, 1986
	981-89263	M	Helper	Fledged, 1987
	981-89266	F	Fledgling	Colony 19
	981-89267	F	Fledgling	Colony 19
1989				
Pre-breeding	891-09184	M	Breeder	Colony 19, 1981
	961-25688	F	Breeder	Colony 30, 1985
	981-89229	M	Helper	Fledged, 1986
	981-89263	M	Helper	Fledged, 1987
	981-89267	F	Yearling	Colony 19, 1988
Post-breeding	891-09184	M	Breeder	Colony 19, 1981
	961-25688	F	Breeder	Colony 30, 1985
	981-89229	M	Helper	Fledged, 1986
	8011-85014	F	Chick	Fledged, 1989
	8011-85015	F	Chick	Fledged, 1989
Colony 28				
1989				
Post-breeding	981-89263	M	-	Colony 19, 1987

FMNF = Francis Marion National Forest.

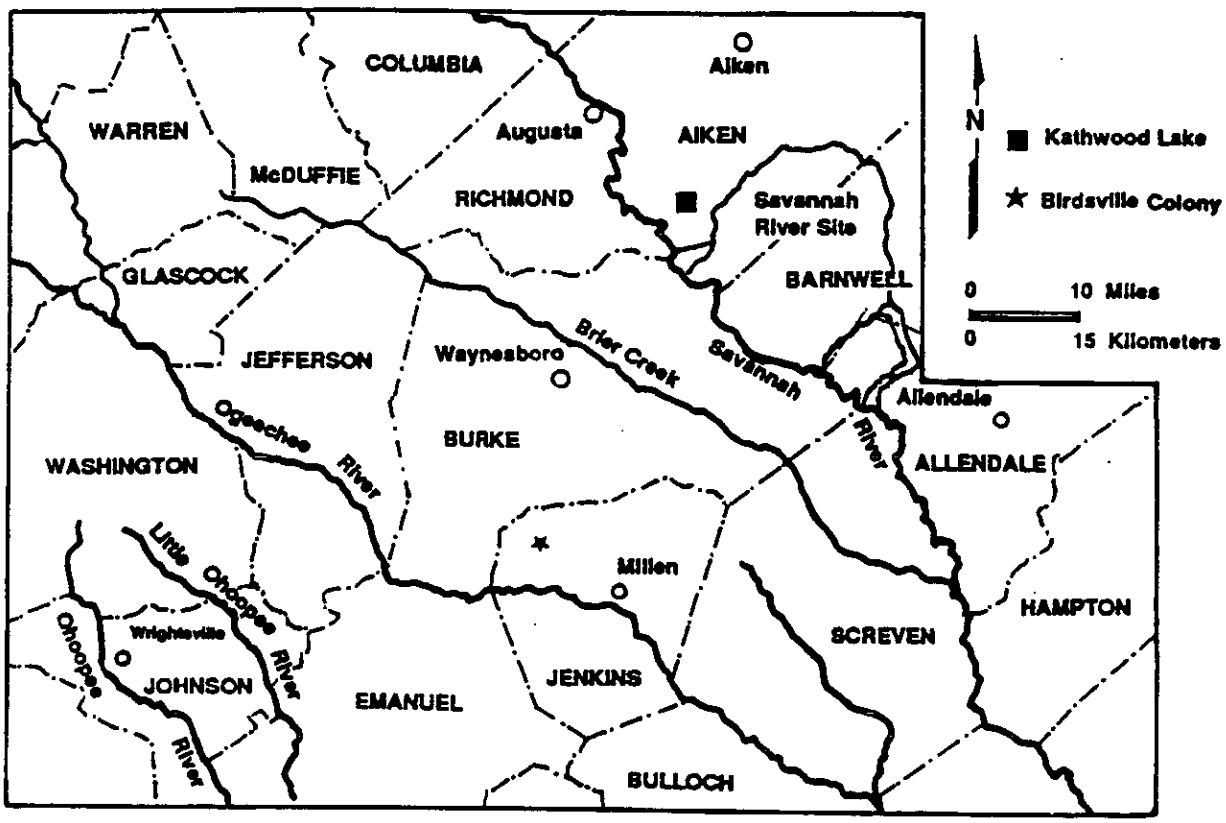

FIGURE 5-13. Location of the Birdsville Wood Stork Colony, the Savannah River Site (SRS), and Kathwood Lake

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- To characterize the habitat, water quality, and fish density and biomass at foraging sites,

- To determine food resources used by wood storks from the Birdsville Colony, and

- To assess the importance of the SRS Savannah River swamp to wood storks.

Much of the data and information presented here are summarized from the studies and reports by the Savannah River Ecology Laboratory (SREL) (Meyers, 1984; Coulter, 1986a, 1986b, 1986c, 1987, 1988, 1989).

The SRS Savannah River swamp comprises about 3800 ha bordering the Savannah River on the southwestern edge of the SRS (Jensen et al., 1984). The swamp area, including the deltas of Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek, contains nonpersistent and persistent emergent wetlands, deciduous forest wetlands including cypress/tupelo forest, and scrub-shrub wetlands. Particular emphasis was placed on wood stork use of the Steel Creek Delta in the earlier studies (Meyers, 1984; Coulter, 1986a, 1986b), because the forage potential of this area would be reduced due to increased water depths associated with L Reactor restart in October 1985. Although the cooling water used by L Reactor is cooled in L Lake, the waterflow below L Lake increases the depth in areas of the Steel Creek Delta where storks have been observed foraging. Because it was anticipated that the Steel Creek Delta could be lost as a foraging site for wood storks following L Reactor restart, alternate foraging ponds have been built at the site of Kathwood Lake on the National Audubon Society's Silver Bluff Plantation Sanctuary (Figure 5-13) (Mackey, 1985).

The wood stork studies by SREL have changed over the years to reflect an increased understanding of the storks and the habitats in east-central Georgia. In general, the same methods have been maintained throughout the studies so that data collected are comparable between years. However, some differences in the kinds of data collected have been inevitable due to the changing scope of the studies and to different environmental conditions among the years. For example, in 1985 the storks abandoned the colony in Big Dukes Pond and moved to Little Dukes Pond to the east of Big Dukes Pond. Because of this move, limited information on breeding biology in the early part of 1985 was collected (Coulter, 1986b). From 1985 to 1988, drought conditions generally occurred throughout the southeastern United States. Additional data were collected to document the impact of the drought on the storks (Coulter, 1986c, 1987, 1988, 1989).

5.6.3.2 Birdsville Colony Survey

The SREL wood stork surveys began in 1983 (Meyers, 1984). During the first year of the study, 1983, there were only a few observations made at the colony. From 1984 through 1988, the study of the breeding biology of the storks was expanded. Since 1980, the number of chicks in nests has been counted as a measure of breeding success (Table 5-11). In 1984 and

TABLE 5-11

Number of Active Nests in the Birdsville Colony

Year	Number of Active Nests
1980	About 100[a,b]
1981	Failed[b]
1982	About 60[a,b]
1983	113[b,c]
1984	About 100[d]
1985	About 108[e]
1986	160[f]
1987	193[g]
1988	101[h]

[a] Estimated from ground and aerial surveys
[b] Meyers (1984)
[c] Actual counts from 26 trees
[d] Coulter (1986a)
[e] Coulter (1986b)
[f] Coulter (1987); maximum number of nests counted on May 14
[g] Coulter (1988); maximum number of nests counted on May 26
[h] Maximum number of nests counted on May 31, Coulter (1989)

1985, with more complete data available, unsuccessful nests were also included in measuring breeding success (Coulter, 1986c). As shown in Figure 5-14, storks begin to arrive at the Birdsville Colony in early March. Breeding and chick rearing are variable from year to year and usually extend from March through May with fledging dispersal from the colony from late May through mid-summer. Reproductive success estimated as the number of chicks fledged per nest for 1983 through 1988 is given in Table 5-12. As can be seen from Table 5-12, reproductive success has varied from year to year at the Birdsville Colony.

5.6.3.3 Foraging Surveys, 1983-1988

Storks have been followed by using a fixed-wing airplane from the colony to foraging sites in all years. The majority of foraging sites (75%) were in Jenkins, Burke, and Emanuel counties, Georgia (Figure 5-13) (Hodgson et al., 1987, 1988). The number of storks and other wading birds was counted at each foraging site, and the water depth and the minimum distance to the shore were measured. In 1983, Meyers (1984) recorded five foraging habitat types, including a shrub swamp type that was incorporated into the different swamp types of later surveys. Drainage ditches, hardwood swamps, and natural ponds were added to the types of foraging sites in 1984 (Coulter, 1986a). In 1985, a category for Carolina Bays was also added (Coulter, 1986b). In 1984 and 1985, there were a few sites that did not fit into the general classification, including logging roads and powerline right-of-ways. These were listed as "other" in the survey reports (Coulter, 1986a, 1986b). The average straight-line distance for 1983 through 1988 between the colony and the foraging sites is presented in Table 5-13.

The foraging habitats are described below and include (in brackets) the comparable category of the U.S. Fish and Wildlife Service system for classifying wetland habitats (Cowardin et al., 1979). Blackgum (*Nyssa sylvatica*) and cypress (*Taxodium distichum*) swamps [palustrine forested] were the predominant species present in the swamp foraging sites. Hardwood swamps [palustrine forested] had a mixture of hardwood tree species including red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*). Shrub swamps [palustrine scrub-shrub] contained predominantly buttonbush (*Cephalanthus occidentalis*). Natural ponds [palustrine unconsolidated shore/lacustrine littoral unconsolidated shore] contained open water with little or no vegetation. Carolina Bays [forested wetland/palustrine scrub-shrub/persistent emergent] are common in east-central Georgia. Man-made ponds [palustrine unconsolidated shore/lacustrine littoral unconsolidated shore] included "agricultural" and "fish" ponds. Drainage and agricultural ditches are also common. Open marshes [palustrine emergent] were usually seasonally flooded pastures. Table 5-14 summarizes the types and frequency of foraging habitats commonly used by wood storks from the Birdsville Colony. Water quality parameters including temperature, pH, dissolved oxygen concentration, turbidity, and conductivity were measured at each foraging site (Coulter, 1986c).

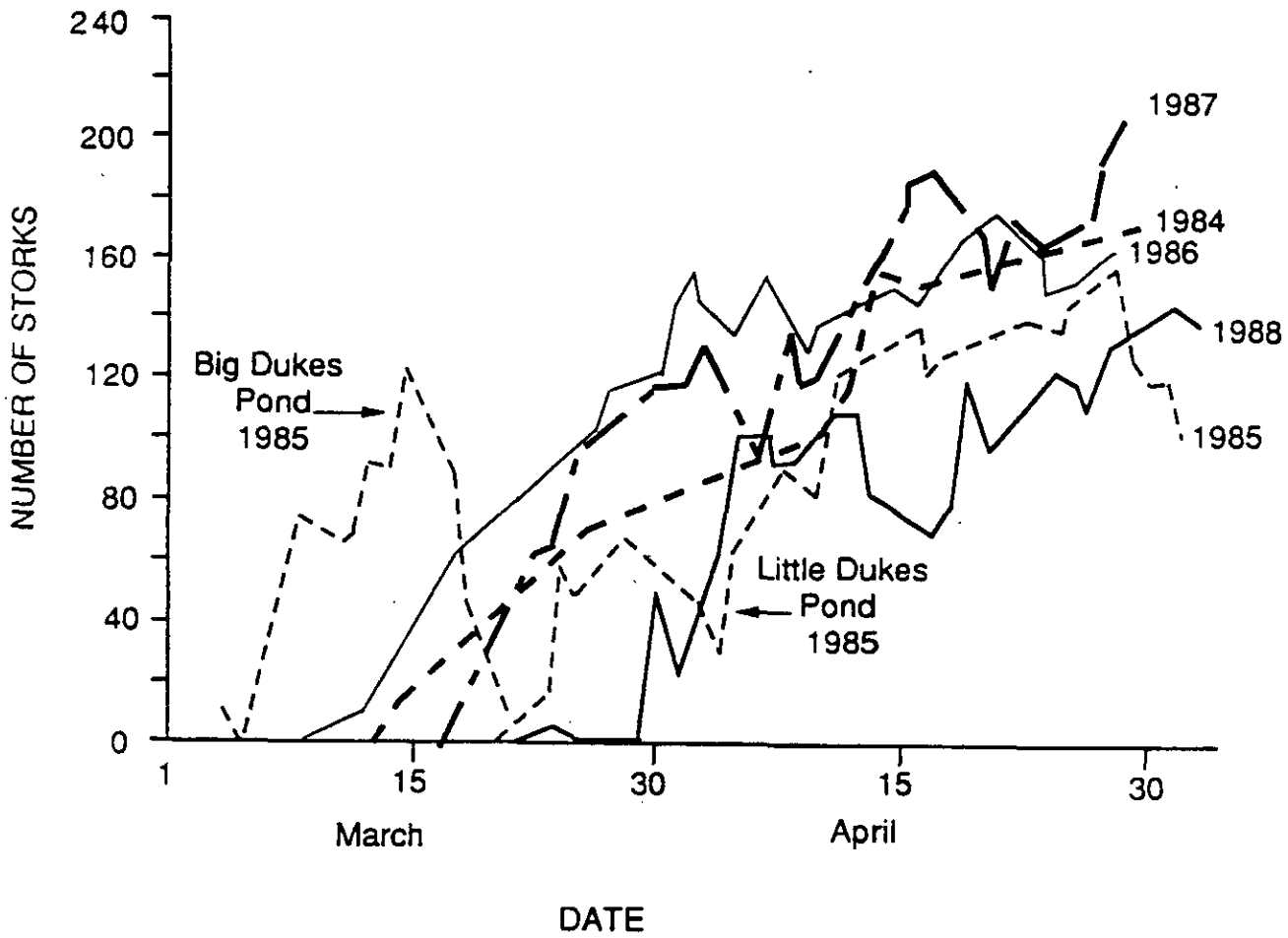

FIGURE 5-14. Wood Stork Numbers in the Birdsville Colony, 1984-1988
(source: Coulter, personal communication)

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TABLE 5-12

Reproductive Success of Wood Storks at the Birdsville Colony

Year	Mean Number of Young per Nest[a]
1980	About 2[b,c]
1981	0[c,d]
1982	No data[c]
1983	2.19[c]
1984	2.39[e,f], 2.04[f,g]
1985	2.50[e,h], 0.33[g,h]
1986	2.86[e,i], 2.68[g,i], 2.16[i,j]
1987	2.33[e,k], 2.09[g,k], 1.96[k,l]
1988	1.80[e,m], 0.35[g,m]

[a] Young at least five weeks old
[b] Estimated from ground or aerial surveys
[c] Meyers (1984)
[d] Colony failed in 1981
[e] Chicks at least 50 days old; this does not include whole nests that were lost
[f] Coulter (1986a)
[g] Chicks at least 50 days old; this includes whole nests that were lost
[h] Coulter (1986b)
[i] Coulter (1987)
[j] Includes the 25% decline in numbers of nests recorded during the ground censuses
[k] Coulter (1988)
[l] Includes the 20% decline in numbers of nests recorded during the ground censuses
[m] Coulter (1989)

TABLE 5-13

Mean Distances of Wood Stork Foraging Sites from the Birdsville Colony in 1983 Through 1988

Year	Number of Storks	Mean Distance (km)	Standard Deviation
1983[a]	30	17.39	15.60
1984[a]	55	13.75	13.16
1985[a]	39	11.94	7.87
1986[b]	36	11.85	8.33
1987[c]	44	13.2	12.97
1988[d]	40	9.1	7.35

[a] Coulter (1986c)
[b] Coulter (1987)
[c] Coulter (1988)
[d] Coulter (1989)

TABLE 5-14

Habitat Types of Wood Stork Foraging Sites in East-Central Georgia in 1983 Through 1988

Habitat Type	Year 1983 Number (%)	1984 Number (%)	1985 Number (%)	1986 Number (%)	1987 Number (%)	1988 Number (%)
Blackgum Swamp	14 (31)	10 (20)	6 (29)	7 (23)	4 (18)	-
Hardwood Swamp	-	4 (8)	-	2 (6)	2 (9)	11 (38)
Cypress Swamp	13 (28)	7 (14)	6 (29)	9 (29)	3 (14)	3 (10)
Shrub Swamp	8 (17)	-	-	-	-	-
Carolina Bay	-	-	3 (14)	-	-	-
Open Marsh	9 (20)	3 (6)	-	1 (3)	2 (9)	5 (17)
Natural Pond	-	2 (4)	-	-	1 (4.5)	-
Man-Made Pond	2 (4)	11 (22)	2 (9)	5 (16)	3 (13.5)	4 (14)
Drainage Ditch	-	4 (8)	-	-	-	-
Other	-	9 (18)	4 (19)	7 (23)	7 (32)	6 (21)
Total	46 (100)	50 (100)	21 (100)	31 (100)	22 (100)	29 (100)

Source: Coulter, 1986c, 1987, 1988, 1989

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The wood storks foraged in various wetland habitat types (Table 5-14). Storks were followed most frequently to swamps, of which blackgum swamps and cypress swamps were the most commonly used (Hodgson et al., 1988). The extent of the canopy cover ranged from completely open (marsh or pond) to completely covered (swamp). Most sites had little understory or woody vegetation. At all sites the water was either still or very slowly moving.

The vegetation structure of a wetland may contribute to its suitability as a foraging site for wood storks, or a dense canopy may obscure a site from a flying stork. The birds may not be able to land if the understory is very thick. Aquatic vegetation may make it difficult for the birds to wade through the water and grope with their bills. Most sites had little aquatic vegetation, although a few sites had dense submergent or emergent vegetation. Submergent vegetation included such species as Myriophyllum spp. and algae; emergents included Nuphar luteum, Nymphaea odorata, Utricularia inflata, and Ludwigia spp., as well as various species of duckweeds, sedges, and rushes.

The median water depth at the location where storks landed at the foraging sites was 18 to 23 cm during the six years of the survey (Table 5-15). The water depths ranged from 0 to 63 cm. Meyers (1984) suggested that the length of the legs of storks set an upper limit to water depth at about 50 cm. Kahl (1964) stated that wood storks fed in water between 15 and 50 cm deep.

The densities of potential prey species (fish, crustaceans, and amphibians) were determined at sites to which storks were followed. Meyers (1984) reported that storks did not eat fish smaller than 25 mm long. All the fish regurgitated by chicks during the colony surveys were over 25 mm long (Coulter, 1986c, 1987, 1988, 1989).

The regurgitation and stomach samples, as well as the recent literature, indicate that sunfish comprise the major component of the diet of wood storks. Mosquito fish (Gambusia) were common at many sites, but storks do not seem to prefer this species (Ogden et al., 1976).

5.6.3.4 SRS Savannah River Swamp Surveys

5.6.3.4.1 Introduction

Wood storks were reported in the vicinity of the SRS before the plant was established in 1952 and before the discovery of the Birdsville Colony (Murphy, 1937). Murphy, describing the status of storks in the area in the early 1900s, noted that the birds probably did not breed locally, but that flocks of more than 30 birds were seen regularly in August and September. In June 1956 and July 1957, storks were recorded on the SRS (Norris, 1963). In July of 1973 and 1974, flocks of 200 and over 400 storks, respectively, were observed in the Steel Creek Delta (Coulter, 1986c). Storks have been followed from the Birdsville Colony to the SRS

TABLE 5-15

Water Depth (cm) at Locations Where Wood Storks Landed at Foraging Sites, 1983 Through 1988

Year	Number	Median	50% Range[a]	70% Range[b]	90% Range[c]	Total Range
1983	29	18	13-24	10-31	10-37	0-46
1984	47	21	16-31	12-34	6-44	4-50
1985	20	22	14-25	11-32	11-32	10-39
1986	28	18	12-23.5	7.5-34	6.5-42	6-51
1987	21	22	14-29	12.5-44	11-54	8-63
1988	29	23	18.5-26.5	16.0-34	13.5-40	0-44

[a] Median ±25% of sites
[b] Median ±35% of sites
[c] Median ±45% of sites

Source: Coulter (1986c, 1987, 1988, 1989)

(Coulter, 1986c). Some of the birds observed foraging in the SRS Savannah River swamp may be storks from farther south, either nonbreeders or birds having already finished breeding for the year (Coulter, 1986c).

Wood storks foraging on the SRS Savannah River swamp were monitored from an airplane to determine the amount of stork use, the areas used most frequently, and seasonal patterns. Kathwood Lake was included in the SRS survey beginning July 3, 1984, when that area was considered as a possible site for stork foraging ponds. Table 5-16 summarizes the aerial survey periods of the SRS Savannah River swamp from 1983 through 1988. Six areas within the SRS Savannah River swamp were delineated: Beaver Dam Creek Delta, Four Mile Creek Delta, the swamp between Four Mile Creek and Pen Branch deltas, Pen Branch Delta, the swamp between Pen Branch and Steel Creek deltas, and the Steel Creek Delta (Figure 5-15).

5.6.3.4.2 Results of the SRS Aerial Surveys

Six hundred thirty-seven aerial surveys were conducted to census feeding or roosting storks in the SRS Savannah River swamp from mid-June 1983 through mid-November 1988 (Table 5-16). Wood storks are most commonly observed in the SRS Savannah River swamp during July and August (Table 5-17). In 1983, storks were observed most frequently in July when storks were present during approximately 55% of the surveys, with an average of 30 storks per survey. However, aerial surveys in 1983 did not begin until mid-June. The Steel Creek and Beaver Dam Creek delta areas had the greatest frequency (15%) of stork observations during the surveys and the greatest amount of wood stork use. The Pen Branch and the Four Mile Creek deltas had little stork use during the same period (Coulter, 1986c).

In 1984, the SRS surveys began in late May. Wood storks were observed most frequently in June and September. Stork use was greatest in June, with an average of 13 storks per survey. Storks were observed most often (23% of the surveys) in the Beaver Dam Creek Delta area, but storks were observed during over 10% of the surveys in the Steel Creek and Four Mile Creek deltas, and in the swamp between Pen Branch and the Four Mile Creek deltas. Stork use was greatest in the Beaver Dam Creek Delta area, followed by the Steel Creek Delta, the swamp between Pen Branch and the Four Mile Creek deltas, and the Four Mile Creek Delta (Coulter, 1986c).

In 1985, storks were observed on the swamp during approximately 95% of the July surveys. An average of 21 storks was recorded during the surveys in July, when there was the greatest stork use. Most storks were observed in the Four Mile Creek Delta and the swamp between Pen Branch and Four Mile Creek deltas. Storks were observed during 18.5% of the surveys during the entire season. These areas also had the greatest amount of stork use. Storks were observed on the Steel Creek Delta during only 3% of the surveys. No storks were observed in the Beaver Dam Creek Delta in 1985 (Coulter, 1986c).

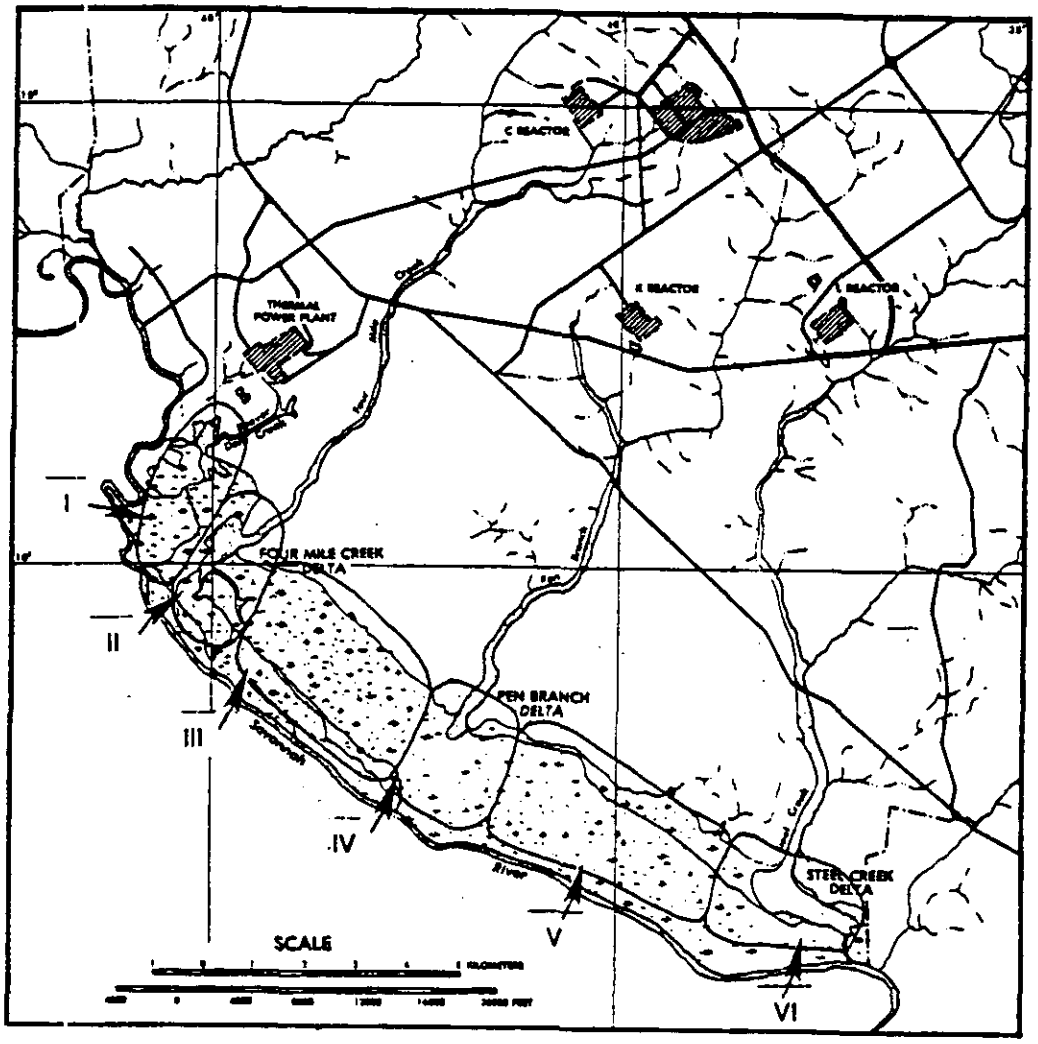

FIGURE 5-15. The Six Areas of the Savannah River Swamp Which Were Monitored for Foraging Wood Storks

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TABLE 5-16

Number of Aerial Surveys Used to Monitor the Number of Wood Storks on the SRS Savannah River Swamp, 1983 Through 1988

Year	Month Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1983	0	0	0	6	24	12	9	0	0	0	51
1984	0	0	1	7	15	19	19	20	8	0	89
1985	7	17	19	16	21	20	12	6	3	0	121
1986	10	20	12	11	19	16	11	8	6	1	114
1987	14	19	14	11	16	13	16	9	6	5	123
1988	18	19	21	20	20	16	15	7	3	0	139

Source: Meyers (1984); Coulter (1986c, 1987, 1988, 1989)

TABLE 5-17

Number of Wood Storks Observed in the SRS Savannah River Swamp During the Summer, 1983 Through 1988

Period	Number of Storks	Percentage
Before June	3	0.2
June 1-15	88	6.1
June 16-30	66	4.5
July 1-15	539	37.1
July 16-31	315	21.7
Aug 1-15	139	9.6
Aug 16-31	156	10.7
Sept 1-15	37	2.5
Sept 16-30	94	6.5
After Sept	15	1.0
Total	1452	99.9

One hundred fourteen aerial surveys over the SRS were flown in 1986, and the Kathwood ponds were observed from March 4 through December 3, 1986. Storks in the swamp were seen on July 24 in the Steel Creek Delta (25 birds) and in the Four Mile Creek Delta (4 birds). Storks were recorded through July and August and on one day in September. Storks were seen during 75% of the surveys in August. Stork use was also greatest in August, when an average of seven storks was recorded per survey. Although the numbers of storks were lower in 1986 than in previous years, June, July, and August have been the months when storks have foraged in the SRS swamp most in the past (Coulter, 1986c). The Steel Creek and Four Mile Creek deltas received the greatest amount of stork use, and had the greatest frequency of stork observations in 1986. No storks were in the area between the Four Mile Creek and Pen Branch deltas in 1986. In 1985, storks were observed in this area during more surveys than in other areas of the SRS swamp (Coulter, 1986b). Fifteen storks were seen in Beaver Dam Creek on July 29. Beaver Dam Creek has been heavily used in previous years (Coulter, 1987).

One hundred twenty-five aerial surveys were flown over the SRS swamp from March 3 through December 23, 1987. Storks were observed on July 14, when 15 birds were counted in the Steel Creek Delta. Birds were recorded for a total of five days in July and on August 21, compared with a total of 17 days in 1986. Storks were seen during 31% of the surveys in July. Stork use was also greatest in July, with an average of nine storks seen per survey. Although stork numbers were lower in 1987 than in previous years, June, July, and August have been the months when storks have foraged in the SRS swamp most in the past (Coulter, 1986c). Steel Creek and Four Mile Creek deltas were the only areas where recorded stork use was observed in the SRS in 1987. Steel Creek Delta had the greatest frequency of stork observations. No storks were observed in any of the other areas of the SRS swamp in 1987 (Coulter, 1988).

One hundred thirty-nine aerial surveys were flown over the SRS swamp in 1988 from March 2 through November 29. Storks were observed in the SRS swamp during only four surveys. A stork was seen on June 3 in the area between the Steel Creek and Pen Branch deltas. One, two, and three storks were observed in the Steel Creek Delta during three of five surveys between July 12 and 20. This level of stork observations was lower than in previous years (Coulter, 1989).

5.6.3.4.3 SRS Stream Flows and Numbers of Foraging Storks

The water depth in the SRS Savannah River swamp is dependent on the water flow from two sources. The SRS swamp receives overflow from the Savannah River during flooding. The river flow and the amount of water that reaches the swamp are influenced by the amount of water discharged from the Clarks Hill Dam, almost 160 km upstream. The water level in the swamp also depends on the water that flows into the swamp from Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek, and other smaller streams on the SRS. The waterflow in these streams depends on both rainfall and

the outflow of water used to cool the reactors and D-Area power plant on the SRS. Meyers (1984) suggested that water depth may affect the suitability of a wetland as a wood stork foraging site on the SRS.

Tables 5-18 and 5-19 indicate that both the number of observations of wood storks and the number of wood storks seen during aerial surveys of the SRS Savannah River swamp are greater in those areas of the swamp receiving lower flows, especially in the flow class of 51 to 100 cubic feet per second (cfs) (Figure 5-16). The one area which may be different is an area of former river channels or sloughs between the Four Mile Creek and the Pen Branch deltas (Figures 5-15 and 5-16; Tables 5-18 and 5-19).

Four Mile Creek Delta has experienced a wide variation in flows since the wood stork surveys of the SRS swamp began. Prior to C-Reactor shutdown in late June 1985, most of the flows to the Four Mile Creek Delta were in the 351 to 450 cfs range (Table 5-20). From late June 1985 through the summer of 1986, flows declined to less than 100 cfs (Table 5-20), and in the summers of 1987 and 1988, flows have been primarily below 50 cfs. Stork use prior to late June 1985 was low to moderate, was high to moderate after late June 1985 and in the summer of 1986, but very low in the summer of 1987 and 1988 (Figure 5-17).

Wood stork use of the Pen Branch Delta area has been the lowest of all the delta areas on the SRS (Table 5-19). This has probably been the result of high flow and thermal conditions (Jensen et al., 1988) in this delta with flows in excess of 100 cfs most of the time (>90% frequency) during the summer survey months from 1983 through 1987 (Table 5-21). No storks were observed during the summer months of 1988 under low flow conditions (Table 5-21). Low stork use was observed during the summer of 1988 for the entire SRS Savannah River swamp.

There has been a shift in the summer flows to Steel Creek following L-Reactor restart in the fall of 1985 (Table 5-22 and Figure 5-18). Flows in excess of 100 cfs were common from early June to mid-July in late September in 1986, 1987, and 1988. However, total numbers of storks observed in the three summers (1983, 1984, 1985) prior to L-Reactor restart and the three summers after restart (1986, 1987, and 1988) are similar in spite of this shift in flow patterns (Figure 5-18). Most of the flow ranges to Steel Creek in the summer months after restart are still in the 51 to 100 cfs flow class during 1986 to 1988 (Table 5-22).

Beaver Dam Creek (Table 5-23) has had low to moderate use over the period of the survey with lower use in the past three summers.

Data from the aerial wood stork surveys of the SRS Savannah River swamp and the studies at the Birdsville Colony suggest that the SRS Savannah River swamp is probably not used extensively during the breeding nor pre-fledging phase of the Birdsville Colony. Most of the observations of storks on the SRS occur during late fledging or the post-fledging period. High flows (>100 cfs) to the SRS Savannah River creeks probably limit the

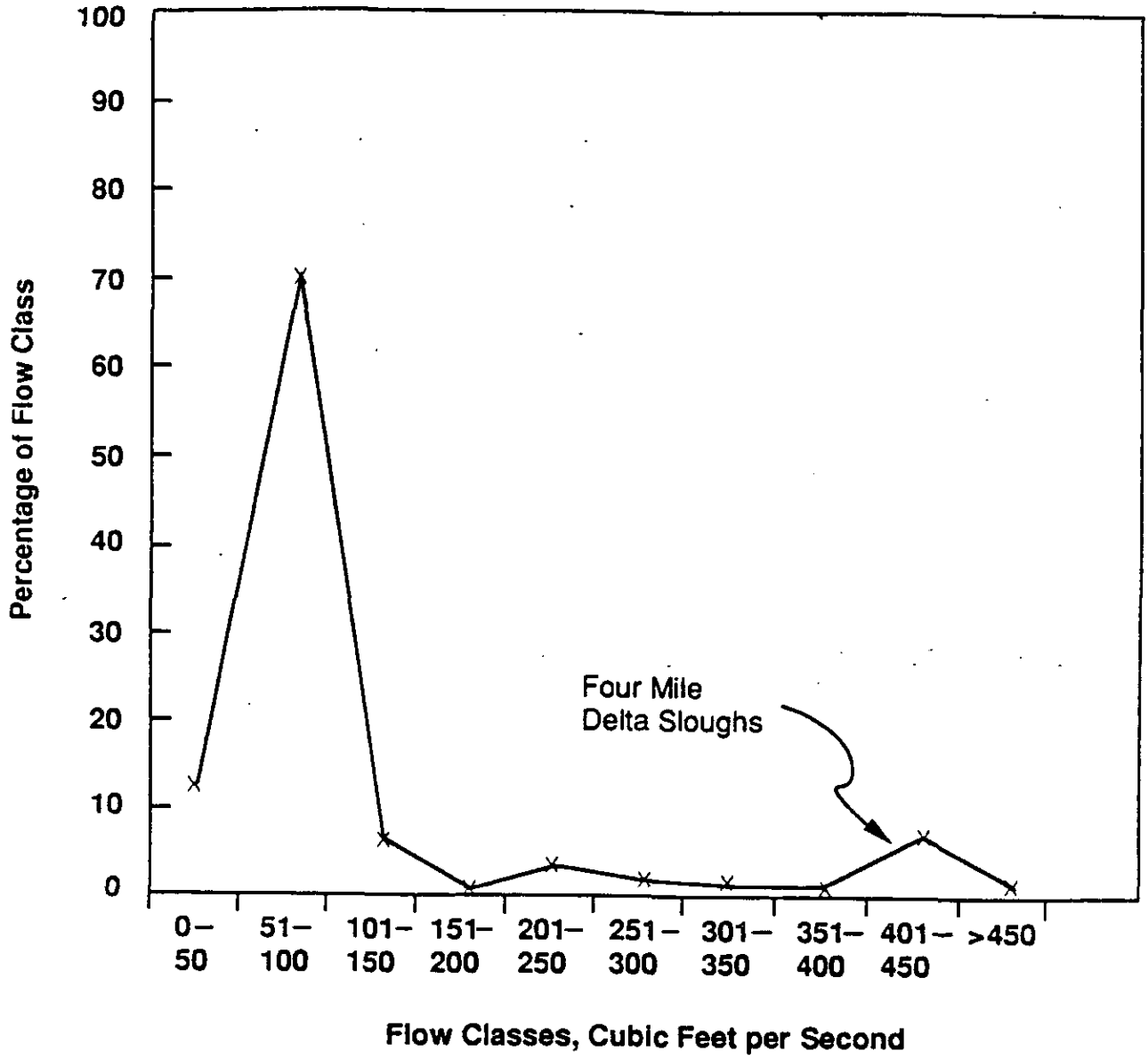

FIGURE 5-16. Percentage of Wood Storks Observed in the SRS Swamp from 1983 to 1988 Under Different Stream Flow Classes

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TABLE 5-18

Number of Observations of Wood Storks in the SRS Savannah River Swamp, June Through September, 1983-1988

Flow Classes in the Creeks (cfs)	Number of Wood Stork Observations						Percentage	Cumulative Percentage
	BDC	FM	FMS	PB	SC	Total		
0 - 50	-	10	2	-	15	27	19.42	19.42
51 - 100	24	19	20	2	18	83	59.71	79.13
101 - 150	1	0	0	0	5	6	4.32	83.45
151 - 200	-	0	1	0	0	1	0.72	84.17
201 - 250	-	0	1	1	0	2	1.44	85.61
251 - 300	-	-	0	1	0	1	0.72	86.33
301 - 350	-	0	0	0	0	0	0.00	86.33
351 - 400	-	0	0	0	-	0	0.00	86.33
401 - 450	-	7	11	0	-	18	12.95	99.28
>450	-	0	0	1	-	1	0.72	100.00
Total	25	36	35	5	38	139	100.00	-

cfs = cubic feet per second
BDC = Beaver Dam Creek Delta area
FM = Four Mile Creek Delta area
FMS = Four Mile Creek sloughs between Four Mile Creek and Pen Branch deltas
PB = Pen Branch Delta area
SC = Steel Creek Delta area

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TABLE 5-19

Total Numbers of Wood Storks Observed in the SRS Savannah River Swamp, June Through September, 1983-1988

Flow Classes in the Creeks (cfs)	Number of Wood Storks						Percentage	Cumulative Percentage
	BDC	FM	FMS	PB	SC	Total		
0 - 50	0	97	3	0	92	192	12.43	12.43
51 - 100	291	291	235	27	249	1093	70.74	83.17
101 - 150	1	0	0	0	67	68	4.40	87.57
151 - 200	-	0	8	0	0	8	0.52	88.09
201 - 250	-	0	16	1	0	17	1.10	89.19
251 - 300	-	0	0	10	0	10	0.65	89.84
301 - 350	-	0	0	0	0	0	0.00	89.84
351 - 400	-	0	0	6	0	6	0.39	90.23
401 - 450	-	36	101	4	0	141	9.13	99.36
>450	-	0	0	10	-	10	0.65	100.01
Total	292	424	363	58	408	1545	100.01	-

cfs = cubic feet per second
BDC = Beaver Dam Creek Delta area
FM = Four Mile Creek Delta area
FMS = Four Mile Creek sloughs between Four Mile Creek and Pen Branch deltas
PB = Pen Branch Delta area
SC = Steel Creek Delta area

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TABLE 5-20

Cumulative Percentage of Flow Classes in Four Mile Creek Delta Area for 1983 Through Late June 1985, Late June 1985 Through 1986, and 1987 Through 1988

Flow Class (cfs)	Pre-Shutdown (1983 through late June 1985)			Post-Shutdown (late June 1985 through 1986)			June 1987 Through September 1988		
	Number	Percentage	Cumulative Percentage	Number	Percentage	Cumulative Percentage	Number	Percentage	Cumulative Percentage
0 - 50	0	0.00	0	119	53.36	53.36	239	97.95	97.95
51 - 100	9	3.44	3.44	91	40.81	94.17	5	2.05	100.00
101 - 150	5	1.91	5.35	1	0.45	94.62	0	0.00	100.00
151 - 200	0	0.00	5.35	3	1.35	95.97	0	0.00	100.00
201 - 250	1	0.38	5.73	9	4.04	100.01	0	0.00	100.00
251 - 300	0	0.00	5.73	0	0.00	100.01	0	0.00	100.00
301 - 350	15	5.73	11.46	0	0.00	100.01	0	0.00	100.00
351 - 400	93	35.50	46.96	0	0.00	100.01	0	0.00	100.00
401 - 450	134	51.15	98.11	0	0.00	100.01	0	0.00	100.00
>450	5	1.91	100.02	0	0.00	100.01	0	0.00	100.00
Total	262	100.02	-	223	100.01	-	244	0.00	100.00

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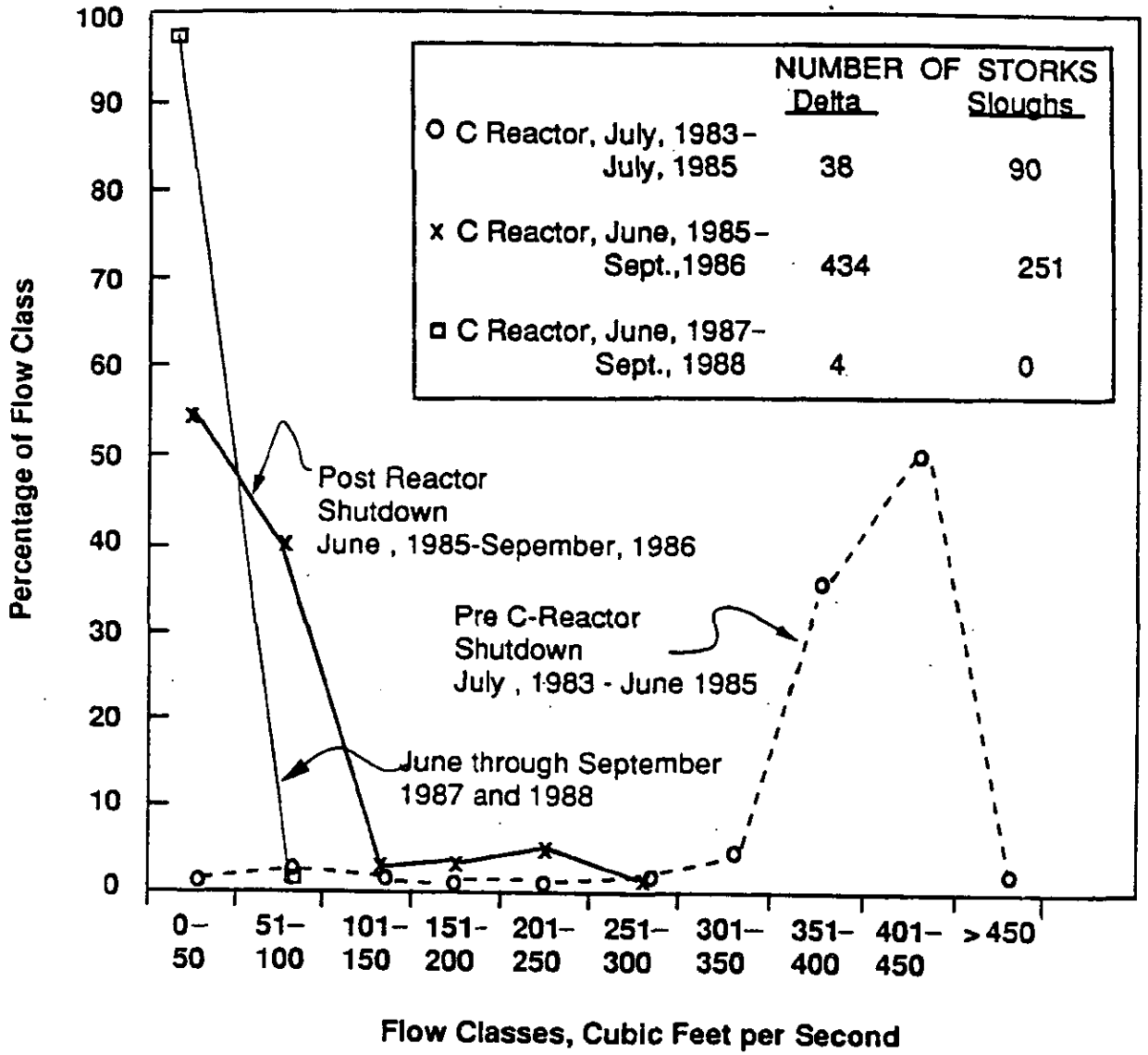

FIGURE 5-17. Number of Storks Observed in the Four Mile Creek Delta and Sloughs with C Reactor Operating (prior to June 28, 1985); and after C Reactor shutdown (after June 28, 1985 through summer 1986; and during summer 1987 and 1988).

TABLE 5-21

Cumulative Percentage of Flow Classes in Pen Branch Delta Area for 1983 Through 1987 and Following Shutdown in 1988

Flow Class (cfs)	Pre-Shutdown (1983 through 1987)			Post-Shutdown (June 1988 through September 1988)		
	Number	Percentage	Cumulative Percentage	Number	Percentage	Cumulative Percentage
0 - 50	0	0.00	0.00	80	65.58	65.58
51 - 100	35	5.72	5.72	42	34.43	100.01
101 - 150	23	3.76	9.48	0	0.00	100.01
151 - 200	65	10.62	20.10	0	0.00	100.01
201 - 250	20	3.27	23.37	0	0.00	100.01
251 - 300	14	2.29	25.66	0	0.00	100.01
301 - 350	29	4.74	30.40	0	0.00	100.01
351 - 400	214	34.97	65.37	0	0.00	100.01
401 - 450	201	32.84	98.21	0	0.00	100.01
>450	11	1.80	100.01	0	0.00	100.01
Total	612	100.01	0	122	100.01	-

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TABLE 5-22

Cumulative Percentage of Flow Classes in Steel Creek Delta Area Prior to L-Reactor Restart (1983 Through 1985) and After L-Reactor Restart (1986 through 1988)

Flow Class (cfs)	Pre-Reactor Restart (1983 through 1985)			Post-Reactor Restart (1986 through 1988)		
	Number	Percentage	Cumulative Percentage	Number	Percentage	Cumulative Percentage
0 - 50	188	55.46	55.46	1	0.28	0.28
51 - 100	106	31.27	86.73	184	51.40	51.68
101 - 150	33	9.73	96.46	32	8.94	60.62
151 - 200	6	1.77	98.23	42	11.73	72.35
201 - 250	6	1.77	100.00	10	2.79	75.14
251 - 300	0	0.00	100.00	29	8.10	83.24
301 - 350	0	0.00	100.00	5	1.40	84.64
351 - 400	0	0.00	100.00	29	8.10	92.74
401 - 450	0	0.00	100.00	26	7.26	100.00
>450	0	0.00	100.00	0	0.00	100.00
Total	339	100.00	-	358	100.00	-

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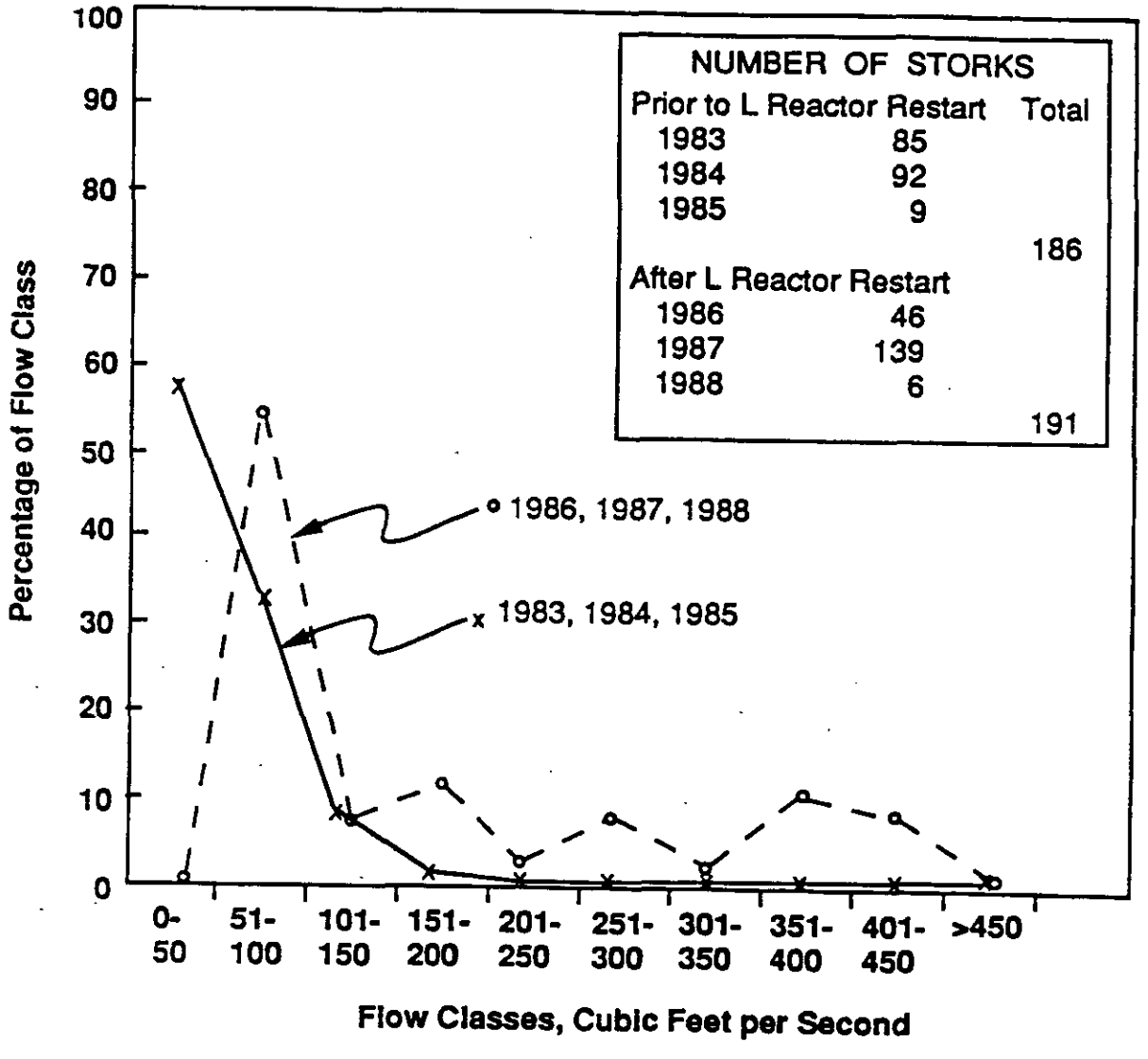

FIGURE 5-18. Number of Storks Observed in the Steel Creek Delta Prior to L-Reactor Restart (1983-1985) and After L-Reactor Restart (1986-1988) Versus Flow Classes

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TABLE 5-23

Cumulative Percentage of Flow Classes in Beaver Dam Creek Delta Area, June through September, 1983 Through 1988

Flow Classes (cfs)	Number	Percentage	Cumulative Percentage
0 - 50	34	4.76	4.76
51 - 100	603	84.34	89.10
101 - 150	78	10.91	100.01
Total	715	100.01	-

usefulness of the swamp as a foraging site. Low flows (<50 cfs) may likewise limit the usefulness of the SRS swamp for stork foraging. During periods of low flow (<50 cfs) the streams are more confined to their channels, and habitats are not suitable for stork foraging. During periods of high flow, water depths may be limiting. Flows and flooding patterns also can influence vegetation patterns, thus influencing available foraging sites. Typical wood stork foraging sites have reduced quantities of both submerged and emergent macrophytes (Coulter, 1986c). Moderate flows (>50 cfs, but less than 150 cfs) to the SRS deltas during the summer months would probably benefit and/or assist in maintaining wood stork foraging sites in the SRS Savannah River swamp. Also, larger numbers of wood storks have been observed foraging in the SRS Savannah River swamp during periods following successful breeding and fledging years at Birdsville (i.e., 1983, 1984, 1986, 1987) with lower numbers during less successful years (i.e., 1985 and 1988).

5.6.3.5 Wood Stork Use on Kathwood Lake

Because preliminary data from the wood stork surveys of the Steel Creek Delta indicated that the increased flow following the restart of L Reactor could result in loss of potential foraging areas, DOE, the U.S. Fish and Wildlife Service, and the National Audubon Society agreed to construct a series of foraging ponds on the Silver Bluff Plantation Sanctuary (Mackey, 1985; Figures 5-13 and 5-19). The site selected for the foraging ponds is referred to as "Kathwood Lake."

The Kathwood Lake site has an area of approximately 15 ha. It is located west of SRS and about 45 km north of the Birdsville Colony. The lake was originally formed for operation of a mill by diking a shallow depression and diverting water via a canal from Hollow Creek (Figure 5-19). Kathwood Lake drained in May 1977, when the wooden water control structure at the lower end of the lake failed. Wood storks (about 24) were observed foraging in pools of water left in the lake bed in September 1977. A few wood storks were observed during aerial surveys at Kathwood Lake in late July and early August 1984 (Mackey, 1985).

Water control structures were added to control flow and assist in fish rearing and to lower the water levels to make subdivisions of the lake available during the wood stork foraging season (Figure 5-20). Construction was completed in the early fall of 1985 and the ponds were stocked beginning in late November 1985.

Wood storks have used the foraging ponds at Kathwood Lake extensively during the summers of 1986, 1987, and 1988 (Figures 5-21 through 5-23). Most of these storks have been juveniles, and a few banded wood storks from the Birdsville Colony have been observed (Coulter, 1987, 1988, 1989). The observed level of use at Kathwood Lake more than compensates for any potential decline in available wood stork foraging sites on the Steel Creek Delta.

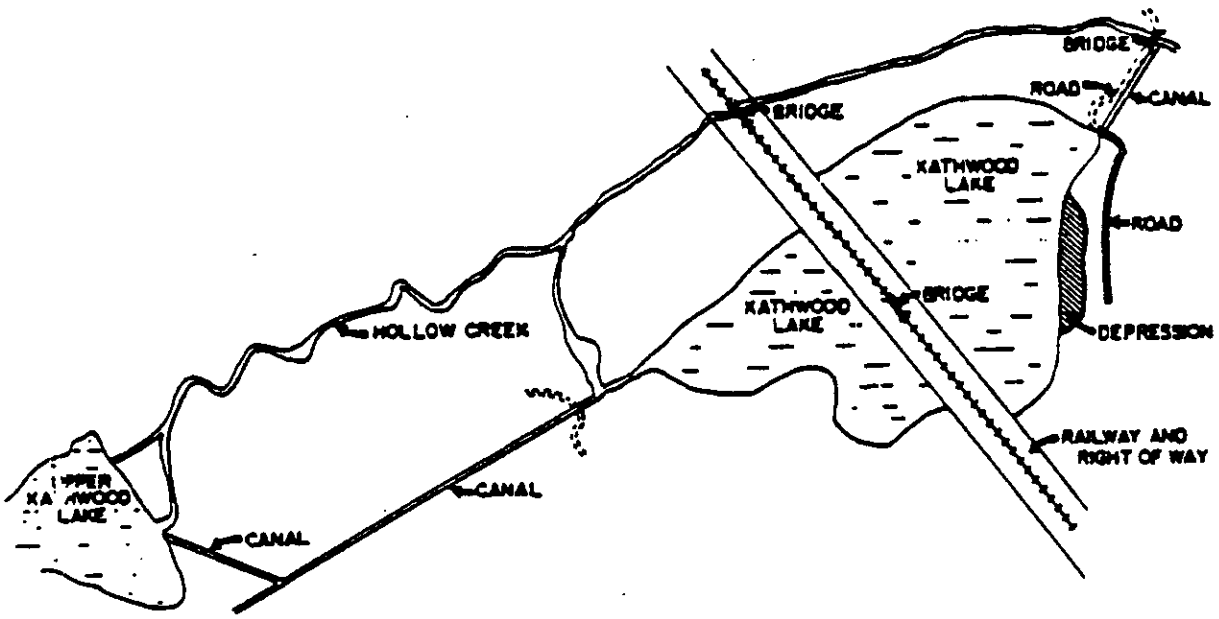

FIGURE 5-19. Location of Kathwood Lake and Hollow Creek (source: Mackey, 1985)

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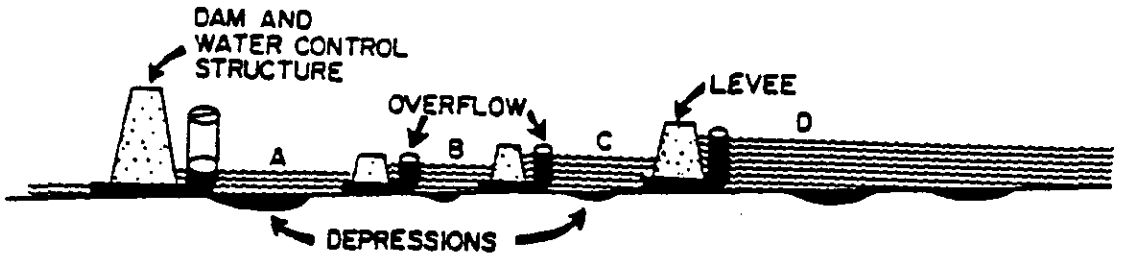

FIGURE 5-20. Logitudinal Section Through Kathwood Lake Showing General Features of the Subimpoundments and Water Levels (source: Mackey, 1985)

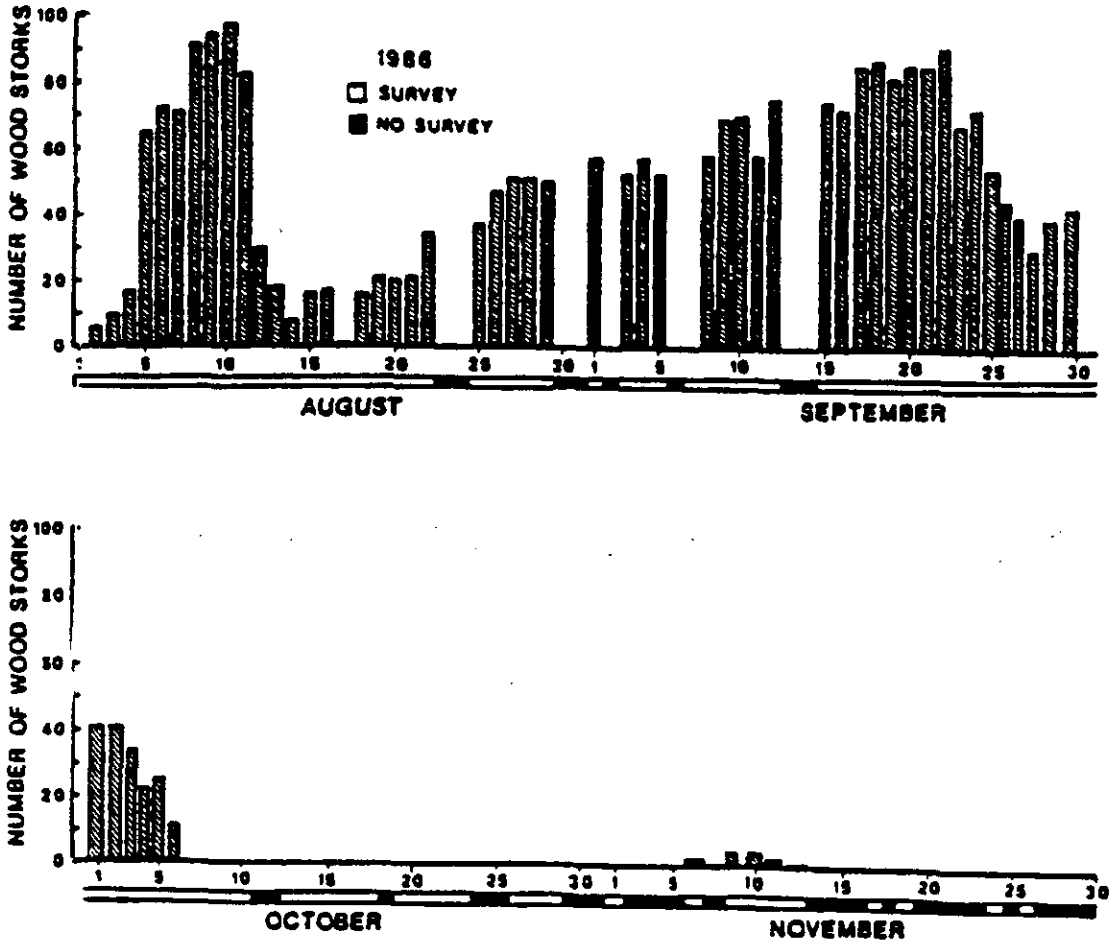

FIGURE 5-21. Maximum Numbers of Wood Storks Observed During Ground Surveys at Kathwood Lake During 1986 (source: Coulter, 1987)

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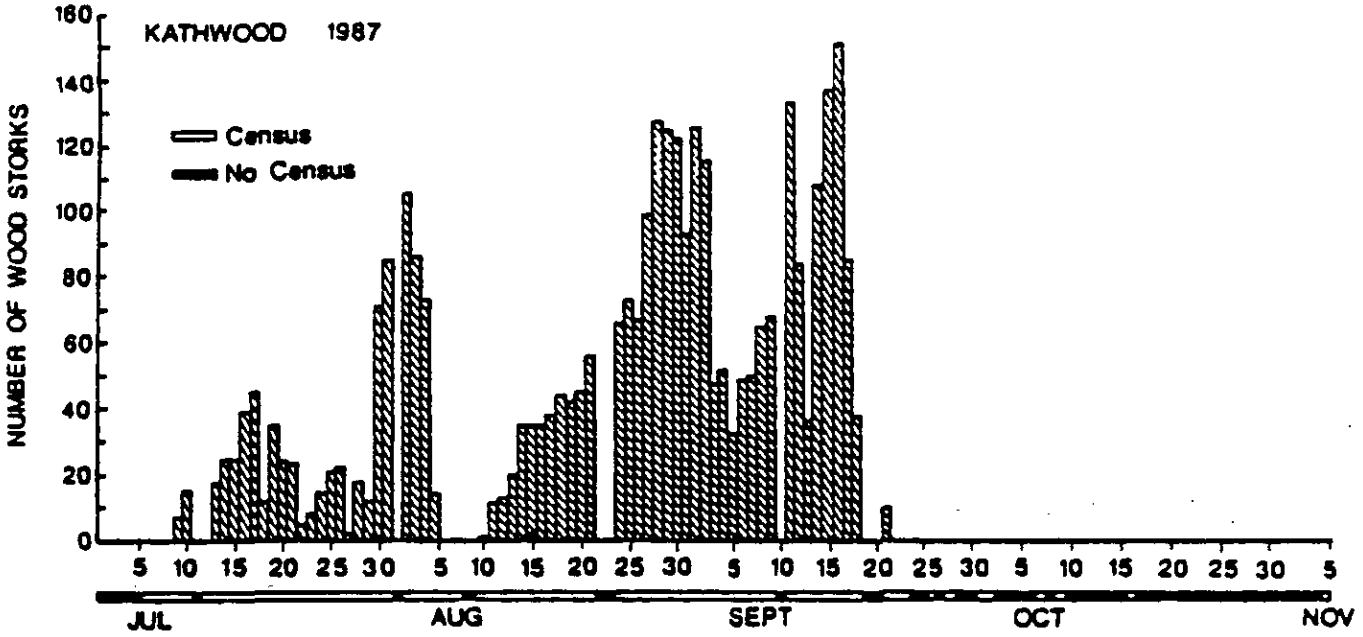

FIGURE 5-22. Maximum Numbers of Wood Storks Observed During Ground Surveys at Kathwood Lake During 1987 (source: Coulter, 1988)

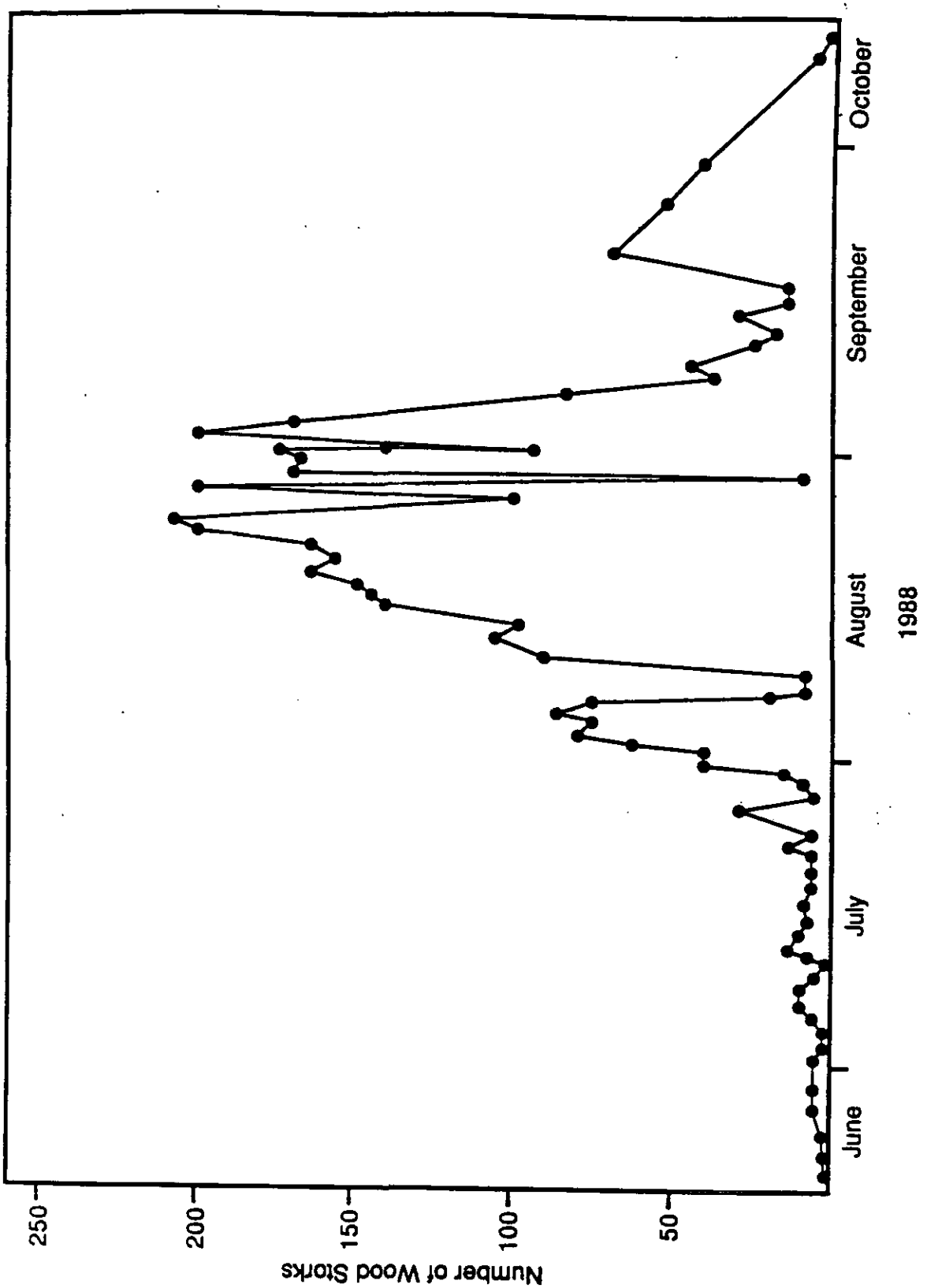

FIGURE 5-23. Maximum Number of Wood Storks Observed During Ground Surveys at Kathwood Lake in 1988 (source: Coulter, 1989)

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TABLE A-1

Radioactivity in Savannah River Water, 1987

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			Alpha, pCi/L				
Savannah River							
R-2 dissolved	52	0.63	±0.61	-0.16	±0.22	0.07	±0.30
R-2 suspended	52	0.34	±0.52	-0.16	±0.22	0.06	±0.20
R-3A above Vogtle	51	0.50	±0.55	-0.16	±0.22	0.06	±0.24
R-3B below Vogtle	52	0.25	±0.29	-0.16	±0.22	0.05	±0.16
R-8C below Little Hell	26	0.38	±0.34	-0.16	±0.22	0.05	±0.22
R-8 below Steel Creek	27	0.91	±0.68	-0.16	±0.22	0.06	±0.40
R-8B	27	0.25	±0.50	-0.09	±0.17	0.03	±0.16
R-10 dissolved	49	0.50	±0.58	-0.16	±0.22	0.02	±0.18
R-10B Highway 301	51	1.1	±0.49	-0.16	±0.22	0.05	±0.38
R-10 suspended	50	0.31	±0.34	-0.16	±0.22	0.05	±0.20
GDNR-River-2	13	0.58	±0.64	-0.08	±0.17	0.09	±0.34
GDNR-River-10A	13	0.66	±0.66	-0.08	±0.15	0.07	±0.38
Control							
Edisto River	50	1.5	±0.75	0.00	±0.23	0.51	±0.64
			Nonvolatile Beta, pCi/L				
Savannah River							
R-2 dissolved	52	3.8	±1.4	-0.05	±0.88	1.5	±1.4
R-2 suspended	52	0.88	±1.1	-0.74	±0.79	0.02	±0.58
R-3A above Vogtle	51	2.8	±1.3	-0.12	±1.1	1.5	±1.2
R-3B below Vogtle	52	3.3	±1.3	0.06	±1.1	1.5	±1.1
R-8C below Little Hell	26	2.7	±1.3	0.76	±0.93	1.6	±1.0
R-8 below Steel Creek	27	4.1	±1.4	-0.25	±1.0	1.5	±1.5
R-8B	27	2.8	±1.3	-0.49	±1.1	1.4	±1.1
R-10 dissolved	49	2.6	±1.1	-0.13	±1.0	1.5	±1.1
R-10B Highway 301	51	2.7	±1.5	-0.57	±1.2	1.6	±1.1
R-10 suspended	51	1.3	±1.2	-0.55	±1.0	0.12	±0.68
GDNR-River-2	13	4.0	±1.3	-0.92	±0.99	1.8	±1.6
GDNR-River-10A	13	2.2	±1.1	-0.81	±1.1	1.6	±0.76
Control							
Edisto River	49	2.9	±1.4	-0.06	±1.1	1.0	±1.3
			H-3, pCi/mL				
Savannah River							
R-2 above plant	52	0.83	±1.0	0.05	±0.21	0.37	±0.32
R-3A above Vogtle	52	4.4	±0.31	0.16	±0.21	0.81	±1.7
R-3B below Vogtle	52	2.4	±0.23	-0.26	±0.99	0.66	±0.86
R-8C below Little Hell	26	6.2	±0.27	1.8	±0.31	3.3	±1.7
R-8 below Steel Creek	26	5.2	±0.26	0.72	±0.30	2.6	±1.7
R-10 Highway 301	53	7.0	±0.31	1.5	±0.31	3.3	±2.0
R-10B Highway 301	55	8.5	±0.32	0.23	±1.1	3.2	±2.3
Control							
Edisto River	50	0.94	±0.21	-0.42	±0.34	0.41	±0.38

- Insufficient data.

Source: Mikol et al. (1988)

TABLE A-1

Radioactivity in Savannah River Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			Sr-89, 90, pCi/L				
Savannah River							
R-8C below Little Hell	12	1.3	±1.4	-0.55	±1.3	0.15	±0.96
R-8 below Steel Creek	11	1.2	±1.8	-1.3	±1.2	0.24	±1.1
R-8B	11	0.90	±1.8	-1.6	±1.2	0.01	±0.76
R-2 above Plant 1C	12	0.81	±0.32	-0.07	±0.37	0.20	±0.50
R-3A above Vogtle	12	0.37	±0.28	-0.09	±0.37	0.12	±0.26
R-3B below Vogtle	12	0.41	±0.32	-0.18	±0.25	0.17	±0.28
R-10 Highway 301 1C	12	0.37	±0.42	0.03	±0.25	0.19	±0.22
Average						0.17	±0.33
			Mn-54, pCi/L				
R-2 above Plant 1C	50	0.00	±0.21	0.00	±3.4	0.00	-
R-3A above Vogtle	51	0.00	±0.21	0.00	±3.0	0.00	-
R-3B below Vogtle	50	0.00	±0.21	0.00	±3.4	0.00	-
R-10 Highway 301 1C	51	0.00	±0.21	0.00	±1.8	0.00	-
Average						0.00	-
			Cr-51, pCi/L				
R-2 above Plant 1C	50	0.00	±0.21	0.00	±15	0.00	-
R-3A above Vogtle	51	0.00	±0.21	0.00	±15	0.00	-
R-3B below Vogtle	50	0.00	±0.21	0.00	±17	0.00	-
R-10 Highway 301 1C	51	0.00	±0.21	0.00	±8.5	0.00	-
Average						0.00	-
			Co-60, pCi/L				
R-2 above Plant 1C	50	22	±4.2	0.00	±1.5	0.45	±6.6
R-3A above Vogtle	51	6.5	±1.2	0.00	±1.1	0.13	±1.8
R-3B below Vogtle	50	0.00	±1.2	0.00	±1.2	0.00	-
R-10 Highway 301 1C	51	6.0	±1.0	0.00	±0.67	0.12	±1.7
Average						0.17	±3.4
			Zn-65, pCi/L				
R-2 above Plant 1C	50	0.00	±1.2	0.00	±2.7	0.00	-
R-3A above Vogtle	51	0.00	±1.2	0.00	±2.6	0.00	-
R-3B below Vogtle	50	0.00	±1.2	0.00	±2.7	0.00	-
R-10 Highway 301 1C	51	0.00	±1.2	0.00	±1.2	0.00	-
Average						0.00	-
			Zr-95, Nb-95, pCi/L				
R-2 above Plant 1C	50	0.00	±1.2	0.00	±2.1	0.00	-
R-3A above Vogtle	51	0.00	±1.2	0.00	±1.9	0.00	-
R-3B below Vogtle	50	0.00	±1.2	0.00	±2.4	0.00	-
R-10 Highway 301 1C	51	0.00	±1.2	0.00	±1.4	0.00	-
Average						0.00	-
			Ru-103, 105, pCi/L				
R-2 above Plant 1C	50	0.00	±1.2	0.00	±12	0.00	-
R-3A above Vogtle	51	0.00	±1.2	0.00	±11	0.00	-
R-3B below Vogtle	50	0.00	±1.2	0.00	±11	0.00	-
R-10 Highway 301 1C	51	0.00	±1.2	0.00	±5.9	0.00	-
Average						0.00	-

TABLE A-1

Radioactivity in Savannah River Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			I-131, pCi/L				
R-2 above Plant 1C	50	0.00	±1.2	0.00	±3.7	0.00	-
R-3A above Vogtle	51	0.00	±1.2	0.00	±3.4	0.00	-
R-3B below Vogtle	50	0.00	±1.2	0.00	±4.0	0.00	-
R-10 Highway 301 1C	51	0.00	±1.2	0.00	±2.2	0.00	-
Average						0.00	-
			Cs-134, pCi/L				
R-2 above Plant 1C	50	0.00	±1.2	0.00	±1.4	0.00	-
R-3A above Vogtle	51	0.00	±1.2	0.00	±1.1	0.00	-
R-3B below Vogtle	50	0.00	±1.2	0.00	±1.2	0.00	-
R-10 Highway 301 1C	51	0.00	±1.2	0.00	±0.64	0.00	-
Average						0.00	-
			Cs-137, pCi/L				
R-2 above Plant 1C	50	9.7	±2.2	0.00	±1.3	0.32	±3.0
R-3A above Vogtle	51	11	±2.9	0.00	±1.3	1.0	±5.7
R-3B below Vogtle	50	8.9	±1.9	0.00	±1.4	0.43	±3.5
R-10 Highway 301 1C	51	1.6	±25	0.00	±0.62	0.03	±0.44
Average						0.45	±3.7
			Ce-141, 144, pCi/L				
R-2 above Plant 1C	50	2.6	±20	0.00	±7.4	0.05	±0.72
R-3A above Vogtle	51	0.00	±20	0.00	±6.0	0.00	-
R-3B below Vogtle	50	0.00	±20	0.00	±7.5	0.00	-
R-10 Highway 301 1C	51	0.00	±20	0.00	±3.8	0.00	-
Average						0.01	±0.36
			Ba-140, La-140, pCi/L				
R-2 above Plant 1C	13	0.00	±1.9	0.00	±17	0.00	-
R-3A above Vogtle	13	0.00	±1.9	0.00	±17	0.00	-
R-3B below Vogtle	13	0.00	±1.9	0.00	±17	0.00	-
R-10 Highway 301 1C	13	0.00	±1.9	0.00	±17	0.00	-
Average						0.00	-
			SR-90, pCi/L				
R-2 above Plant 1C	11	1.30	±0.65	0.07	±0.30	0.46	±0.37
R-3A above Vogtle	11	0.55	±0.28	0.03	±0.16	0.27	±0.14
R-3B below Vogtle	11	1.40	±0.66	-0.02	±0.16	0.32	±0.39
R-10 Highway 301 1C	11	1.40	±0.36	0.29	±0.20	0.56	±0.31

TABLE A-2

Radioactivity in Savannah River Water, 1988

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Gross Alpha, pCi/L				
Savannah River							
R-2 dissolved	52	0.35	±0.35	-0.18	±0.25	0.03	±0.22
R-2 suspended	51	0.77	±0.57	-0.17	±0.23	0.08	±0.30
R-3A above Vogtle	52	0.50	±0.57	-0.26	±0.30	0.02	±0.26
R-3B below Vogtle	52	0.50	±0.41	-0.17	±0.23	0.04	±0.26
R-8C below Little Hell	26	0.34	±0.34	-0.17	±0.24	0.00	±0.16
R-8 below Steel Creek	26	0.18	±0.39	-0.17	±0.24	0.02	±0.14
R-8B	26	0.21	±0.39	-0.17	±0.24	0.02	±0.16
R-10 dissolved	52	0.49	±0.56	-0.26	±0.30	0.04	±0.26
R-10B Highway 301	52	0.24	±0.28	-0.26	±0.30	0.00	±0.14
R-10 suspended	52	0.45	±0.42	-0.26	±0.30	0.04	±0.24
GDNR-River-2	12	0.17	±0.24	-0.13	±0.05	0.01	±0.14
GDNR-River-10A	13	0.26	±0.38	-0.12	±0.05	0.06	±0.22
Control							
Edisto River	51	1.9	±0.93	-0.09	±0.17	0.64	±0.80
			Nonvolatile Beta, pCi/L				
Savannah River							
R-2 dissolved	52	3.3	±1.4	-0.19	±1.1	1.8	±1.3
R-2 suspended	51	3.0	±1.2	-1.3	±2.0	0.22	±1.2
R-3A above Vogtle	52	2.9	±1.3	-0.25	±1.0	1.6	±1.3
R-3B below Vogtle	52	2.9	±1.2	-0.44	±0.95	1.8	±1.1
R-8C below Little Hell	26	3.0	±1.2	-0.32	±1.1	1.6	±1.3
R-8 below Steel Creek	26	2.7	±1.2	-0.06	±1.0	1.6	±1.3
R-8B	26	3.2	±1.0	-0.26	±1.1	1.7	±1.3
R-10 dissolved	52	3.0	±1.3	-0.16	±0.91	1.5	±1.1
R-10B Highway 301	52	2.9	±1.4	-0.16	±0.91	1.8	±1.3
R-10 suspended	52	2.3	±1.2	-1.1	±0.93	0.43	±1.1
GDNR-River-2	12	2.9	±1.0	±1.2	±1.0	2.0	±1.1
GDNR-River-10A	13	2.0	±1.2	-1.1	±1.0	1.5	±0.54
Control							
Edisto River	51	3.4	±1.3	-0.26	±1.1	1.2	±1.2
			H-3, pCi/mL				
R-2 above plant	52	0.81	±0.21	-0.35	±0.18	0.27	±0.40
R-3A above Vogtle	52	11	±0.38	-0.11	-0.11	1.5	±3.6
R-3B below Vogtle	52	3.6	±0.24	0.16	±0.18	1	±1.7
R-8C below Little Hell	26	5.3	±0.25	2.1	±0.19	3.4	±1.9
R-8 below Steel Creek	26	5	±0.33	0.97	±0.16	2.5	±1.9
R-10 Highway 301	52	5.5	±0.25	1.8	±0.13	3.4	±2.2
R-10B Highway 301	52	5.7	±0.25	0.37	±0.20	3.3	±2.4
Control							
Edisto River	51	0.75	±0.28	-0.14	±0.18	0.33	±0.34

Source: Davis et al. (1989)

TABLE A-2

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Sr-89, 90, pCi/L				
Savannah River							
R-8C below Little Hell	12	0.87	±0.81	-0.41	±1.3	0.24	±0.74
R-8 below Steel Creek	12	1.2	±1.0	0.00	±0.78	0.44	±0.82
R-8B	12	1.4	±1.2	0.00	±0.80	0.33	±0.98
R-2 above plant 1C	12	1.7	±3.0	0.00	±0.09	0.32	±0.96
R-3A above Vogtle	12	0.33	±1.3	-0.05	±2.6	0.13	±0.24
R-3B below Vogtle	12	0.38	±0.32	-0.15	±2.7	0.08	±0.28
R-10 Highway 301	12	4.1	±1.0	-0.61	±2.7	0.72	±3.1
			Mn-54, pCi/L				
R-2 above Plant 1C	52	0.00	±37	0.00	±0.02	0.00	-
R-3A above Vogtle	52	0.00	±36	0.00	±0.02	0.00	-
R-3B below Vogtle	50	0.00	±99	0.00	±0.02	0.00	-
R-10 Highway 301 1C	52	0.00	±14	0.00	±0.02	0.00	-
			Cr-51, pCi/L				
R-2 above Plant 1C	52	0.00	±660	0.00	±0.30	0.00	-
R-3A above Vogtle	52	0.00	±600	0.00	±0.30	0.00	-
R-3B below Vogtle	50	0.00	±990	0.00	±0.30	0.00	-
R-10 Highway 301 1C	52	0.00	±700	0.00	±0.30	0.00	-
			Co-60, pCi/L				
R-2 above Plant 1C	52	23[a]	±2.1	0.00	±0.03	0.45	±6.3
R-3A above Vogtle	52	0.00	±35	0.00	±0.03	0.00	-
R-3B below Vogtle	50	0.00	±130	0.00	±0.03	0.00	-
R-10 Highway 301 1C	52	0.00	±19	0.00	±0.03	0.00	-
			Zn-65, pCi/L				
R-2 above Plant 1C	52	0.00	±70	0.00	±0.05	0.00	-
R-3A above Vogtle	52	0.00	±66	0.00	±0.05	0.00	-
R-3B below Vogtle	50	0.00	±250	0.00	±0.05	0.00	-
R-10 Highway 301 1C	52	0.00	±36	0.00	±0.05	0.00	-
			Zr-95, Nb-95, pCi/L				
R-2 above Plant 1C	52	0.00	±75	0.00	±0.06	0.00	-
R-3A above Vogtle	52	0.00	±83	0.00	±0.06	0.00	-
R-3B below Vogtle	50	0.00	±220	0.00	±0.06	0.00	-
R-10 Highway 301 1C	52	0.00	±36	0.00	±0.06	0.00	-
			Ru-103, 106, pCi/L				
R-2 above Plant 1C	52	0.00	±370	0.00	±0.23	0.00	-
R-3A above Vogtle	52	0.00	±300	0.00	±0.23	0.00	-
R-3B below Vogtle	50	0.00	±760	0.00	±0.23	0.00	-
R-10 Highway 301 1C	52	0.00	±170	0.00	±0.23	0.00	-

[a] Based on Savannah River Laboratory analyses of ^{60}Co concentration in the Savannah River, this data is considered anomalous.
- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-2

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			I-131, pCi/L				
R-2 above Plant 1C	52	0.00	±530	0.00	±0.10	0.00	-
R-3A above Vogtle	52	0.00	±530	0.00	±0.10	0.00	-
R-3B below Vogtle	50	0.00	±1000	0.00	±0.10	0.00	-
R-10 Highway 301 1C	52	0.00	±380	0.00	±0.10	0.00	-
			Cs-134, pCi/L				
R-2 above Plant 1C	51	0.00	±36	0.00	±0.02	0.00	-
R-3A above Vogtle	52	0.00	±32	0.00	±0.02	0.00	-
R-3B below Vogtle	50	0.00	±72	0.00	±0.02	0.00	-
R-10 Highway 301 1C	52	0.00	±19	0.00	±0.02	0.00	-
			Cs-137, pCi/L				
R-2 above Plant 1C	52	0.068	±0.0054	0.0015	±0.02	0.014	±0.032
R-3A above Vogtle	52	7.2[a]	±1.7	0.00	±0.02	0.14	±2.0
R-3B below Vogtle	50	0.00	±87	0.00	±0.02	0.00	-
R-10 Highway 301 1C	52	0.123	±0.014	0.035	±0.02	0.065	±0.051
			Ce-141, 144, pCi/L				
R-2 above Plant 1C	52	0.00	±330	0.00	±0.17	0.00	-
R-3A above Vogtle	51	0.00	±300	0.00	±0.17	0.00	-
R-3B below Vogtle	50	0.00	±190	0.00	±0.17	0.00	-
R-10 Highway 301 1C	52	0.00	±140	0.00	±0.17	0.00	-
			Pu-238, pCi/L				
R-2 above Plant 1C	4	0.89	±2.00	-0.04	±0.32	0.21	-
R-3A above Vogtle	4	0.38	±1.22	-0.31	±0.44	-0.01	-
R-3B above Vogtle	4	0.77	±3.48	-0.23	±0.59	0.10	-
R-10 Highway 301 1C	4	0.16	±0.32	-0.23	±2.00	0.01	-
			Pu-239, pCi/L				
R-2 above Plant 1C	4	13.10	±4.43	-0.12	±0.24	3.55	-
R-3A above Vogtle	4	10.87	±3.72	0.06	±0.37	2.91	-
R-3B below Vogtle	4	12.97	±7.19	0.36	±0.34	3.75	-
R-10 Highway 301 1C	4	15.88	±5.79	0.12	±0.29	4.15	-

[a] Based on downriver ^{137}Cs concentrations during this time, R-3A ^{137}Cs data evaluated as anomalous.

- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-3

Radioactivity in Plant Stream Water, 1987

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			Alpha, pCi/L				
Tims Branch							
TB-2 A effluent	52	3.7	±1.1	-0.08	±0.34	0.36	±1.1
TB-3 M effluent	50	12	±10	-0.78	±5.8	3.3	±5.4
TB-5 near Road C	26	1.7	±0.91	0.08	±0.15	0.41	±0.68
700-A1 outfall	26	1.0	±0.60	-0.08	±0.15	0.33	±0.56
Upper Three Runs Creek							
U3R-2 F storm sewer	52	230	±8.8	0.16	±0.31	6.8	±64
Crouch Branch	26	3.2	±1.1	0.00	±0.38	0.59	±1.4
McQueen Branch	11	1.0	±0.62	0.00	±0.17	0.26	±0.58
U3R-3 Road C	27	1.5	±0.70	0.15	±0.31	0.74	±0.80
U3R-4 Road A	26	1.3	±0.63	0.16	±0.38	0.73	±0.62
U3R F-3	51	1.7	±0.78	0.00	±0.22	0.41	±0.72
Beaver Dam Creek							
400-D effluent	55	0.54	±0.46	-0.23	±0.27	0.08	±0.30
Four Mile Creek							
Burial ground ditch	12	1.2	±0.66	0.15	±0.44	0.53	±0.54
FM-1B cool tower eff	54	7.2	±1.6	-0.08	±0.17	1.2	±2.8
HP 52 paddle wheel	26	2.7	±0.94	0.23	±0.34	1.5	±1.2
H H-3 fac outfall 50	26	7.3	±1.5	0.00	±0.31	1.7	±3.7
FM-1C H effluent	54	43	±3.4	0.00	±0.23	1.6	±12
FM-2 Road 4	26	2.5	±0.91	0.08	±0.35	0.72	±1.3
FM-2B above F eff	26	12	±2.0	0.00	±0.15	0.86	±4.5
FM-3 F effluent	53	6.0	±1.4	0.08	±0.29	1.1	±2.1
FM-3A below F eff	26	15	±2.3	0.00	±0.23	1.1	±5.6
FM-A7 Road A-7	26	4.5	±1.3	0.08	±0.27	0.73	±1.7
FM-6 Road A	26	0.54	±0.41	-0.16	±0.22	0.18	±0.38
Indian Grave Branch							
IGB-7	4	0.33	±0.33	0.08	±0.16	0.19	-
IGB-21 800' S of 6-1	4	0.41	±0.37	0.00	±0.00	0.17	-
Pen Branch							
PB-1 K sec effluent	51	0.77	±0.49	-0.16	±0.22	0.14	±0.40
PB-3 Road A	26	0.38	±0.34	-0.08	±0.27	0.07	±0.20
Steel Creek							
SC 2A	26	0.69	±0.46	0.00	±0.00	0.22	±0.34
SC-4 Road A	26	0.41	±0.44	-0.08	±0.15	0.10	±0.28
Par Pond							
R-Area effluent	52	0.77	±0.53	-0.08	±0.27	0.21	±0.42
PP-2 pumphouse	51	13	±2.0	-0.08	±0.29	0.32	±3.5
Lower Three Runs Creek							
SC-1 P sec effluent	52	0.77	±0.53	-0.08	±0.17	0.14	±0.32
L3R-1A Road B	25	0.83	±0.74	-0.16	±0.22	0.06	±0.36
L3R-2 Patterson Mill	26	0.91	±0.76	-0.08	±0.16	0.11	±0.38
L3R-3 Road A	12	0.23	±0.35	0.00	±0.22	0.12	±0.18
Savannah River Swamp							
TNX 1	26	1.2	±0.83	0.00	±0.24	0.41	±0.52

- Insufficient data.

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TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
		Nonvolatile Beta, pCi/L					
Tims Branch							
TB-2 A effluent	52	9.1	±1.8	-0.65	±0.85	1.1	±3.0
TB-3 M effluent	50	38	±25	-8.0	±17	7.2	±18
TB-5 near Road C	26	2.5	±1.1	0.85	±0.77	1.4	±1.4
700-A1 outfall	26	4.6	±1.5	-0.24	±1.1	1.7	±1.8
Upper Three Runs Creek							
U3R-2 F storm sewer	52	11000	±51	7.1	±1.5	240	±2900
Crouch Branch	26	1000	±16	2.6	±1.1	46	±410
McQueen Branch	11	3.5	±1.5	0.42	±0.96	2.1	±2.1
U3R-3 Road C	27	2.6	±1.1	-0.58	±0.84	1.1	±1.2
U3R-4 Road A	26	2.1	±1.1	0.00	±0.87	1.1	±1.1
U3R F-3	51	11	±1.9	1.6	±1.4	5.0	±3.9
Beaver Dam Creek							
400-0 effluent	55	3.4	±1.5	0.42	±0.90	1.9	±1.2
Four Mile Creek							
Burial ground ditch	12	39	±3.0	9.6	±1.8	20	±19
FM-1B cool tower eff	54	380	±9.8	5.3	±1.5	26	±100
HP 52 paddle wheel	26	25	±2.5	6.8	±1.5	11	±8.9
H H-3 fac outfall 50	26	16	±2.1	0.82	±1.2	5.7	±8.2
FM-1C H effluent	54	62	±3.8	0.83	±0.55	19	±24
FM-2 Road 4	26	96	±5.0	8.7	±1.6	29	±37
FM-2B above F eff	26	140	±5.8	20	±2.3	45	±47
FM-3 F effluent	53	340	±9.3	0.75	±0.52	45	±110
FM-3A below F eff	26	80	±4.6	11	±2.0	26	±37
FM-A7 Road A-7	26	64	±3.8	24	±2.7	49	±23
FM-6 Road A	26	35	±3.1	18	±2.2	25	±8.6
Indian Grave Branch							
IGB-7	4	1.8	±1.2	0.16	±0.92	1.0	-
IGB-21 800' S of 6-1	4	1.4	±1.3	-0.26	±0.87	0.63	-
Pen Branch							
PB-1 K sec effluent	51	4.0	±1.5	0.92	±1.0	2.1	±1.4
PB-3 Road A	26	2.8	±1.2	0.49	±0.92	1.6	±1.0
Steel Creek							
SC 2A	26	11	±2.0	3.8	±1.3	8.1	3.8
SC-4 Road A	26	3.5	±1.4	0.95	±0.98	2.0	±1.2
Par Pond							
R-Area effluent	52	210	±6.8	5.0	±1.3	20	±57
PP-2 pumphouse	51	13	±2.0	3.3	±1.2	5.9	±3.4
Lower Three Runs Creek							
SC-1 P sec effluent	52	9.7	±1.8	3.2	±1.4	5.3	±2.2
L3R-1A Road B	25	7.1	±1.6	2.2	±1.1	5.1	±2.4
L3R-2 Patterson Mill	26	6.0	±1.5	0.58	±0.94	3.5	±2.5
L3R-3 Road A	12	5.7	±1.6	0.90	±1.0	3.4	±2.4
Savannah River Swamp							
TNX 1	26	9.1	±1.7	0.35	±0.97	4.3	±3.5

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TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
		H-3, pCi/mL					
Tims Branch							
TB-2 A effluent	51	2.3	±1.1	-0.86	±0.73	0.31	±1.1
TB-5 near Road C	26	2.8	±0.91	0.69	±0.88	1.6	±1.0
700-A1 outfall	26	1.6	±0.85	-0.38	±0.88	0.59	±1.0
Upper Three Runs Creek							
U3R-4 Road A	26	3.3	±1.1	1.6	±0.80	2.4	±1.0
Beaver Dam Creek							
400-D effluent	54	360	±5.0	-0.01	±0.81	19	±110
Four Mile Creek							
Burial ground ditch	12	22000	±450	79	±2.4	3600	±14000
FM-1B cool tower eff	52	10	±1.2	0.62	±0.99	4.3	±4.4
HP 52 paddle wheel	24	5.5	±1.1	0.50	±0.85	2.1	±2.8
H H-3 fac outfall 50	27	910	±7.9	14	±1.4	220	±450
FM-1C H effluent	51	5200	±100	4.9	±1.0	240	±1600
FM-2 Road 4	27	200	±4.1	34	±1.7	120	±94
FM-2B above F eff	26	1500	±33	460	±5.4	920	±510
FM-3 F effluent	51	52	±2.0	0.86	±0.77	6.3	±14
FM-3A below F eff	26	3300	±67	300	±9.0	2400	±940
FM-A7 Road A-7	27	1700	±35	430	±5.3	1100	±620
FM-6 Road A	26	780	±16	280	±4.5	590	±310
Indian Grave Branch							
IGB-7	4	230	±4.1	62	±10	110	-
IGB-21 800' S of 6-1	49	9600	±190	2000	±37	5800	±4300
Pen Branch							
PB-1 K sec effluent	51	76	±2.4	-0.42	±0.81	6.8	±28
PO-19	52	48	±1.9	7.9	±1.1	11	±11
PB-3 Road A	27	66	±2.5	8.1	±1.1	18	±25
Steel Creek							
SC 2A	26	70	±2.5	12	±1.1	49	27
SC-4 Road A	26	4.5	±1.0	1.6	±0.86	2.8	±1.8
Par Pond							
R-Area effluent	52	37	±1.8	4.3	±1.1	10	±11
PP-2 pumphouse	52	12	±1.4	6.9	±1.1	9.3	±2.2
Lower Three Runs Creek							
SC-1 P sec effluent	52	89	±2.4	7.0	±1.1	15	±26
L3R-1A Road B	26	12	±1.1	8.0	±1.1	9.8	±2.1
L3R-2 Patterson Mill	26	7.6	±1.4	0.77	±0.82	5.2	±3.8
L3R-3 Road A	11	4.1	±0.99	0.80	±0.76	2.6	±2.0
Savannah River Swamp							
TNX 1	26	1.7	±0.92	-0.58	±0.76	0.34	±1.0

TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			SR-89, 90, pCi/L				
Four Mile Creek							
FM-1B cool tower eff	12	0.99	±1.0	-0.74	±1.3	0.22	±1.1
HP 52 paddle wheel	12	2.3	±1.5	-0.59	±1.3	0.59	±1.5
FM-1C H effluent	12	7.9	±1.7	0.17	±1.5	2.3	±5.0
FM-2 Road 4	12	7.6	±1.7	0.00	±1.2	2.7	±4.1
FM-2B above F eff	12	19	±2.4	5.6	±1.7	12	±7.3
FM-3 F effluent	12	8.9	±2.2	1.8	±1.4	4.0	±3.8
FM-3A below F eff	12	4.5	±1.7	0.46	±1.6	2.4	±2.8
FM-A7 Road A-7	12	23	±2.9	15	±2.3	19	±4.5
FM-6 Road A	12	16	±2.5	6.7	±1.8	9.4	±4.7
Indian Grave Branch							
IGB-7	4	1.0	±1.5	-0.29	±1.2	0.31	-
IGB-21 800' S of 6-1	4	0.41	±1.4	-1.8	±1.2	0.46	-
Pen Branch							
PB-3 Road A	12	0.62	±1.4	-0.58	±1.5	0.09	±0.44
Steel Creek							
SC 2A	12	2.0	±1.5	-0.35	±1.5	0.38	±1.2
SC-4 Road A	12	0.51	±1.3	-1.2	±1.1	0.11	±0.42
Par Pond							
PP-2 pumphouse	12	0.98	±1.4	-0.88	±1.4	0.08	±0.92
Lower Three Runs Creek							
L3R-1A Road B	12	0.92	±1.3	-0.76	±1.4	0.15	±0.84
L3R-2 Patterson Mill	12	0.79	±1.3	-0.88	±1.4	0.03	±0.72
L3R-3 Road A	12	1.8	±1.6	-0.86	±1.3	0.22	±1.3
			Chem. Cs, pCi/L				
Upper Three Runs Creek							
U3R-4 Road A	12	1.3	±1.4	-1.5	±1.1	0.13	±0.84
Four Mile Creek							
FM-1C H effluent	12	18	±2.8	4.7	±1.4	8.9	±7.6
FM-2 Road 4	12	23	±3.0	4.5	±1.6	14	±13
FM-3 effluent	12	91	±5.3	4.5	±1.7	25	±48
FM-3A below F eff	12	42	±3.7	5.9	±1.8	17	±24
FM-A7 Road A-7	12	16	±2.6	4.0	±1.4	9.1	±8.0
FM-6 Road A	12	5.7	±2.0	1.4	±1.4	3.7	±2.6
Pen Branch							
PB-3 Road A	12	1.4	±1.2	-0.80	±1.5	0.14	±0.96
Steel Creek							
SC 2A	27	11	±2.3	1.4	±1.3	5.3	±4.9
SC-4 Road A	27	3.2	±1.6	-1.1	±1.4	0.32	±1.7
Par Pond							
PP-2 pumphouse	11	6.3	±1.8	1.6	±1.2	4.5	±2.8
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	8.1	±1.9	0.89	±1.7	3.1	±4.4
L3R-3 Road A	12	2.6	±1.5	0.11	±1.3	1.3	±1.4

TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			U/Pu, pCi/L				
Tims Branch							
TB-2 A effluent	51	13	±2.3	-0.17	±0.58	0.93	±3.8
TB-3 M effluent	52	34	±20	-7.8	±16	5.9	±16
Upper Three Runs Creek							
U3R-4 Road A	26	0.55	±0.64	-0.33	±0.47	0.11	±0.36
U3R F-3	50	4.5	±1.5	-0.13	±0.45	0.91	±2.3
Four Mile Creek							
FM-6 Road A	25	0.55	±0.63	-0.34	±0.48	0.11	±0.34
Pen Branch							
PB-3 Road A	26	0.38	±0.53	-0.33	±0.47	0.10	±0.36
Lower Three Runs Creek							
L3R-2 Patterson Mill	26	0.56	±0.65	-0.34	±0.48	0.04	±0.34
L3R-2 dip	50	1.6	±1.1	-0.34	±0.48	0.11	±0.64
Savannah River Swamp							
TNX 1	26	0.50	±0.58	-0.18	±0.35	0.13	±0.38
			Mn-54, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±7.3	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±7.3	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±7.3	0.00	-
			Cr-51, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±240	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±240	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±240	0.00	-

TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			Co-60, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±9.9	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±9.9	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±14	0.00	-
			Zn-65, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±28	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±20	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±25	0.00	-
			Zr-95, Nb-95, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±55	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±56	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±53	0.00	-
			Ru-103, 106, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±110	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±99	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±120	0.00	-

TABLE A-3

Radioactivity in Plant Stream Water, 1987, Contd

Location	No. of Samples	Maximum	CTERR 95% CI	Minimum	CTERR 95% CI	Arithmetic Mean	Arithmetic 2 Std Dev
			I-131, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±890	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±840	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±980	0.00	-
			Cs-134, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.00	±35	0.00	±6.9	0.00	-
Pen Branch							
PB-3 Road A	11	0.00	±35	0.00	±8.5	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±35	0.00	±7.5	0.00	-
			Cs-137, pCi/L				
Four Mile Creek							
FM-6 Road A	11	25	±4.5	0.00	±9.1	3.0	±15
Pen Branch							
PB-3 Road A	11	0.00	±4.5	0.00	±8.6	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	3.4	±2.4	0.00	±9.3	0.36	±2.0
			Ce-141, 144, pCi/L				
Four Mile Creek							
FM-6 Road A	11	0.48	±0.83	0.00	±88	0.04	±0.28
Pen Branch							
PB-3 Road A	11	0.00	±0.83	0.00	±88	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	0.00	±0.83	0.00	±89	0.00	-

Source: Mikol et al. (1988)

TABLE A-4

Radioactivity in Savannah River Water, 1988

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Alpha, pCi/L				
Tims Branch							
TB-2 A effluent	52	4.2	±1.2	-0.08	±0.29	0.50	±1.3
TB-3 M effluent	52	9.6	±3.3	-1.7	±3.4	4.1	±5.4
TB-5 near Road C	26	3.3	±0.78	0.16	±0.33	0.68	±1.2
700-A1 outfall	25	3.5	±0.60	0.08	±0.17	0.68	±1.3
Upper Three Runs Creek							
U3R-2F storm sewer	52	23	±2.8	0.35	±0.43	3.0	±7.0
Crouch Branch	26	1.7	±0.63	-0.09	±0.13	0.46	±0.98
McQueen Branch	20	5.7	±1.0	-0.06	±0.23	1.0	±2.9
U3R-3 Road C	26	2.8	±0.59	0.5	±0.52	1.2	±0.98
U3R-4 Road A	26	3.6	±0.68	0.25	±0.44	1.2	±1.4
U3R F-3	52	5.8	±2.5	-0.12	±0.67	0.68	±2.1
Beaver Dam Creek							
400-0 effluent	52	0.6	±0.46	-0.33	±0.05	0.13	±0.32
Four Mile Creek							
Burial ground ditch	11	12	±2.1	0.43	±0.46	2.1	±6.8
FM-1B cool tower eff	51	4.3	±0.97	0.25	±0.28	1.2	±1.8
HP 52 paddle wheel	27	6.5	±1.9	-0.28	±0.09	1.9	±3.2
H H-3 fac. outfall 50	24	3.8	±1.1	0.32	±0.40	1.2	±1.4
FM-1C H effluent	52	2.2	±1.1	0.05	±0.56	0.88	±1.1
FM-2 Road 4	26	1.9	±0.79	-0.09	±0.18	0.54	±0.94
FM-2B above F eff	26	2.4	±0.69	0.00	±0.18	0.43	±1.0
FM-3 F effluent	52	6.5	±1.4	0.43	±0.38	1.7	±2.5
FM-3A below F eff	26	4.5	±0.85	0.08	±0.06	0.95	±1.8
FM-A7 Road A-7	26	2.2	±0.85	0.00	±0.23	0.53	±1.1
FM-6 Road A	26	1.3	±0.36	-0.08	±0.16	0.27	±0.70
Indian Grave Branch							
1GB-7	4	0.69	±0.49	0.00	±0.23	0.28	-
1GB-21 800' S of 6-1	4	0.86	±0.54	0.16	±0.32	0.37	-
Pen Branch							
PB-1 K sec effluent	52	0.56	±0.55	-0.09	±0.17	0.15	±0.34
PB-3 Road A	26	0.77	±0.52	-0.20	±0.04	0.13	±0.44
Steel Creek							
SC 2A	26	1.0	±0.60	-0.05	±0.19	0.34	±0.60
SC-4 Road A	25	0.43	±0.38	-0.17	±0.23	0.07	±0.32
Par Pond							
R-Area effluent	53	1.8	±0.59	-0.09	±0.17	0.20	±0.62
PP-2 pumphouse	53	0.46	±0.32	-0.22	±0.04	0.06	±0.24

- Insufficient data; standard deviation not calculated for <5 samples.

Source: Davis et al. (1989)

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Alpha, pCi/L				
Lower Three Runs Creek							
SC-1 sec effluent	53	0.72	±0.58	-0.32	±0.03	0.08	±0.36
L3R-1A Road B	26	0.51	±0.35	-0.18	±0.04	0.05	±0.30
L3R-2 Patterson Mill	25	1.1	±0.34	0.00	±0.00	0.19	±0.52
L3R-3 Road A	12	0.42	±0.38	-0.09	±0.17	0.13	±0.28
Savannah River Swamp							
TNX 1	26	3.0	±0.70	0.17	±0.24	0.98	±1.4
			Nonvolatile Beta, pCi/L				
Tims Branch							
TB-2 A effluent	52	7.6	±1.7	-0.19	1.1	1.7	±3.1
TB-3 M effluent	52	38	±21	8.8	±21	8.7	±16
TB-5 near Road C	26	6.9	±0.96	1.0	±0.74	2.8	±2.5
700-A1 outfall	25	14	±1.4	3.0	±1.4	7.5	±6.5
Upper Three Runs Creek							
U3R-2 F storm sewer	52	62	±3.8	2.4	±5.2	11	±18
Crouch Branch	25	6.7	±0.96	2.5	±1.3	3.9	±2.3
McQueen Branch	20	11	±2.1	0.99	±0.71	5.1	±6.7
U3R-3 Road C	26	2.9	±1.1	0.25	±1.1	1.8	±1.3
U3R-4 Road A	26	4.9	±0.79	0.31	±1.1	1.6	±1.9
U3R F-3	52	20	±2.5	-1.2	±0.88	8.3	±9.2
Beaver Dam Creek							
400-0 effluent	52	5.2	±0.86	1.1	±1.2	2.2	±1.7
Four Mile Creek							
Burial ground ditch	11	74	±4.5	13	±2.1	32	±35
FM-1B cool tower eff	51	35	±3.1	6.8	±1.5	16	±12
HP 52 paddle wheel	27	36	±3.2	-0.21	±0.60	16	±18
H H-3 fac outfall 50	24	9.2	±1.9	2.2	±1.1	4.7	±3.0
FM-1C H effluent	52	150[a]	±5.9	6.3	±1.7	30	±62
FM-2 Road 4	26	170[a]	±6.6	12	±2.1	35	±65
FM-2B above F eff	26	150[a]	±6.2	26	±2.9	68	±61
FM-3 F effluent	52	160[a]	±6.0	6.4	±1.5	42	±68
FM-3A below F eff	26	84	±4.4	5.7	±1.2	26	±38
FM-A7 Road A-7	26	92	±5.8	34	±3.3	53	±22
FM-6 Road A	26	59	±3.9	26	±2.5	34	±14
Indian Grave Branch							
IGB-7	4	1.6	±0.69	0.44	±1.1	0.85	-
IGB-21 800' S of 6-1	4	1.6	±1.2	1.0	±1.2	1.3	-

[a] Due to H-Area retention basin release on July 8, 1988.
- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Nonvolatile Beta, pCi/L, Contd				
Pen Branch							
PB-1 K sec effluent	52	4.8	±1.1	1.2	±1.2	2.2	±1.4
PB-3 Road A	26	3.8	±1.3	0.62	±0.93	1.9	±1.5
Steel Creek							
SC 2A	26	12	±1.2	5.6	±1.7	7.9	±3.0
SC-4 Road A	25	4.3	±1.3	1.1	±1.1	2.2	±1.4
Par Pond							
R-Area effluent	53	41	±2.9	10	±1.8	20	±14
PP-2 pumphouse	53	12	±1.2	2.6	±1.3	6.3	±3.4
Lower Three Runs Creek							
SC-1 P sec effluent	53	32	±7.8	0.6	±0.67	4.9	±8.2
L3R-1A Road B	26	12	±1.3	2.1	±1.4	5.4	±3.6
L3R-2 Patterson Mill	25	5.3	±1.6	2.4	±1.1	3.9	±1.4
L3R-3 Road A	12	6.1	±1.4	2.1	±1.3	3.9	±2.0
Savannah River Swamp							
TNX 1	26	27	±2.7	3.1	±1.4	5.9	±9.3
			H-3 pCi/mL				
Tims Branch							
TB-2 A effluent	52	2.3	±0.46	-0.98	±0.51	0.51	±1.3
TB-5 near Road C	26	2.6	±0.47	0.5	±0.77	1.5	±1.3
700-A1 outfall	26	1.9	±0.50	-0.58	±0.92	0.63	±1.4
Upper Three Runs Creek							
U3R-4 Road A	26	14	±0.61	1.2	±0.43	3.4	±5.5
Beaver Dam Creek							
400-D effluent	52	160	±1.9	0.82	±0.44	41	±95
Four Mile Creek							
Burial ground ditch	11	48000	±31	26	±0.84	5200	±29000
FM-1B cool tower eff	52	16	±0.70	0.43	±0.78	4.1	±6.0
HP 52 paddle wheel	26	16	±0.70	0.6	±0.98	3.7	±7.6
H H-3 fac outfall 50	26	85	±1.4	5.6	±1.2	32	±39
FM-1C H effluent	52	73	±2.3	3.8	±1.2	19	±32
FM-2 Road 4	26	200	±2.0	92	±2.0	140	±66
FM-2B above F eff	26	1000	±30	590	±20	800	±250
FM-3 F effluent	52	25	±0.80	1.1	±0.55	4.7	±8.4
FM-3A below F eff	26	2900	±52	1200	±15	2000	±920
FM-A7 Road A-7	26	1300	±35	900	±14	1100	±220
FM-6 Road A	26	740	±7.8	520	±3.2	630	±150

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			H-3 pCi/L, Contd				
Indian Grave Branch							
IGB-7	4	130	±14	56	±7.1	96	-
IGB-21 800' S of 6-1	52	12000	±240	1500	±39	6500	±4000
Pen Branch							
PB-1 K sec effluent	52	15	±1.2	0.26	±0.43	2.3	±4.6
PB-19	53	23	±0.79	1.7	±0.43	7.7	±7.6
PB-3 Road A	26	96	±1.5	13	±1.4	48	±48
Steel Creek							
SC-2A	27	130	±2.8	9.1	±0.62	91	±57
SC-4 Road A	26	4.5	±0.51	1.2	±0.79	2.7	±1.7
Par Pond							
R-Area effluent	52	43	±2.1	3.1	±0.46	17	±19
PP-2 pumphouse	52	14	±1.4	5.2	±0.47	8.5	±4.4
Lower Three Runs Creek							
SC-1 P sec effluent	52	43	±1.0	1.4	±0.44	10	±15
L3R-1A Road B	26	13	±1.5	5.7	±0.53	8.9	±4.1
L3R-2 Patterson Mill	26	8.7	±1.4	0.91	±0.48	5	±4.0
L3R-3 Road A	12	4.5	±1.2	0.97	±0.48	2.7	±2.0
Savannah River Swamp							
TNX 1	26	6.7	±1.2	-0.68	±0.40	0.4	±2.8
			SR-89, 90, pCi/L				
Four Mile Creek							
FM-1B cool tower eff	12	3.0	±3.4	-0.17	±1.3	1.1	±1.5
HP 52 paddle wheel	12	3.6	±1.4	0.00	±1.2	0.82	±2.1
FM-1C H effluent	12	4.3	±1.5	0.31	±1.3	1.7	±2.6
FM-2 Road 4	12	15	±3.2	2.7	±1.4	5.9	±7.1
FM-2B above F eff	12	28	±4.1	8.8	±2.2	18	±13
FM-3 F effluent	12	9.1	±2.5	0.0	±3.3	4.6	±6.4
FM-3A below F eff	12	9.9	±2.4	0.37	±1.1	4.2	±5.9
FM-A7 Road A-7	12	29	±3.9	12	±2.1	21	±9.7
FM-6 Road A	12	15	±3.5	2.9	±2.1	10	±6.8
Indian Grave Branch							
IGB-7	4	1.4	±2.9	-1.5	±1.7	0.03	-
IGB-21 800' S of 6-1	4	0.65	±2.0	0.00	±1.0	0.42	-
Pen Branch							
PB-3 Road A	12	1.7	±2.1	-0.09	±1.4	0.39	±0.96

[a] Due to H-Area retention basin release on July 8, 1988.
- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Sr-89, 90, pCi/L, Contd				
Steel Creek							
SC-2A	12	0.87	±1.9	-0.25	±1.3	0.30	±0.70
SC-4 Road A	12	2.4	±1.6	-0.44	±1.7	0.57	±1.5
Par Pond							
PP-2 pumphouse	12	2.2	±2.1	-1.1	±1.2	0.43	±1.4
Lower Three Runs Creek							
L3R-1A Road B	12	1.2	±1.9	-0.46	±1.5	0.34	±0.98
L3R-2 Patterson Mill	11	0.98	±1.6	-0.74	±1.3	0.11	±0.68
L3R-3 Road A	12	1.5	±1.6	-0.49	±1.7	0.59	±1.0
			Chemical Cs, pCi/L				
Upper Three Runs Creek							
U3R-4 Road A	12	3.7	±0.34	-1.6	±1.1	0.17	±2.3
Four Mile Creek							
FM-1C H effluent	12	71[a]	±4.8	2.1	±1.3	22	±44
RM-2 Road 4	12	120[a]	±6.8	5.0	±1.9	23	±66
FM-3 F effluent	12	67[a]	±5.1	1.1	±0.72	26	±41
FM-3A below F eff	12	48[a]	±4.4	1.2	±0.74	17	±29
FM-A7 Road A-7	12	27[a]	±3.5	7	±1.4	13	±12
FM-6 Road A	12	8.9	±1.9	1.8	±1.4	4.7	±4.3
Pen Branch							
PB-3 Road A	12	1.2	±0.72	-1.0	±1.7	0.16	±0.92
Steel Creek							
SC-2A	12	11	±2.1	0.21	±1.2	5.9	±6.6
SC-4 Road A	12	3.9	±2.2	-0.28	±1.1	0.91	±2.5
Par Pond							
PP-2 pumphouse	11	5.8	±5.6	1.5	±1.3	4.2	±2.6
Lower Three Runs Creek							
L3R-2 Patterson Mill	12	4.7	±1.8	0.44	±1.7	2.5	±2.9
L3R-3 Road A	12	2.5	±1.4	-0.1	±1.3	1.3	±1.8

[a] Due to H-Area retention basin release on July 8, 1988.
- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			U/Pu, pCi/L				
Tims Branch							
TB-2 A effluent	50	0.97	±0.61	-0.34	±0.48	0.32	±0.64
TB-3 M effluent	52	18	±16	-6.3	±12	5.8	±12
Upper Three Runs Creek							
U3R-4 Road A	24	0.64	±0.64	-0.33	±0.66	0.11	±0.48
U3R F-3	51	19	±11	-0.36	±2.2	2.6	±6.5
Four Mile Creek							
FM-6 Road A	26	0.66	±0.66	-0.49	±0.57	0.09	±0.44
Pen Branch							
PB-3 Road A	25	0.36	±0.51	-0.33	±0.66	0.03	±0.28
Lower Three Runs Creek							
L3R-2 Patterson Mill	27	0.68	±0.83	-0.18	±0.37	0.1	±0.44
L3R-2 dip	50	0.72	±0.89	-0.32	±0.45	0.1	±0.42
Savannah River Swamp							
TNX 1	25	0.36	±0.51	-0.18	±0.35	0.09	±0.26
			Mn-54, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±17	0.00	±1.5	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±44	0.00	±1.7	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±32	0.00	±1.3	0.00	-
			Cr-51, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±320	0.00	±58	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±1300	0.00	±42	0.00	-

- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			Co-60, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±18	0.00	±1.0	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±45	0.00	±2.2	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±26	0.00	±1.2	0.00	-
			Zn-65, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±49	0.00	±3.1	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±88	0.00	±5.4	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±120	0.00	±3.6	0.00	-
			Zr-95, Nb-95, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±30	0.00	±4.5	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±110	0.00	±4.8	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±66	0.00	±2.5	0.00	-
			Ru-103, 106, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±150	0.00	±13	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±110	0.00	±18	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±380	0.00	±14	0.00	-

- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-4

Radioactivity in Savannah River Water, 1988, Contd

Location	No. of Samples	Maximum	CT ERR 2σ or LLD	Minimum	CT ERR 2σ or LLD	Arithmetic Mean	Arithmetic 2 Std Dev
			I-131, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±4400	0.00	±33	0.00	-
Pen Branch							
PB-3 Road A	12	0	±5000	0.00	±65	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±4400	0.00	±37	0.00	-
			Cs-134, pCi/L				
Four Mile Creek							
FM-6 Road A	12	0.00	±17	0.00	±1.2	0.00	-
Pen Branch							
PB-3 Road A	12	0.00	±48	0.00	±1.8	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±39	0.00	±0.21	0.00	-
			Cs-137, pCi/L				
Four Mile Creek							
FM-6 Road A	12	3.7	±2.2	0.00	±2.5	0.31	±2.1
Pen Branch							
PB-3 Road A	12	0.00	±53	0.00	±1.9	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±38	0.00	±1.8	0.00	-
			Ce-141, 144, pCi/L				
Four Mile Creek							
FM-6 Road A	12	31	±16	0.00	±5.6	2.6	±18
Pen Branch							
PB-3 Road A	12	0.00	±410	0.00	±8.1	0.00	-
Lower Three Runs Creek							
L3R-2 Patterson Mill	11	0.00	±340	0.00	±7.8	0.00	-

- Insufficient data; standard deviation not calculated for <5 samples.

TABLE A-5

NPDES Outfall Locations

Outfall Identification	No. of Outfalls Permitted	Location
A	6	700-A Administration Area
C	4	100-C Reactor Area
D	7	400-D
DW	3	200-S Defense Waste Processing Facility
F	8	200-F Separations Area
FS	2	Flowing Streams Laboratory (SREL Laboratory on Upper Three Runs Creek)
H	8	200-H Separations Area
K	6	100-K Reactor Area
L	4	100-L Reactor Area
M	2	300-M Fuel Fabrication Facility
P	5	100-P Reactor Area
PP	1	Par Pond (SRL Environmental Laboratory)
S	4	Central Shops (Construction Shops)
T	3	TC-Area (Wackenhut Services, Inc. Headquarters)
X	5	TNX - Semiworks Experimental Facility
Y	1	Classification Yard (Railroad Repair Shop)
SC-4	1	L-Lake Overflow to Steel Creek

Source: Mikol et al. (1988)

TABLE A-6

NPDES Monitoring Data, 1987

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall A-1			
Flow	MGD	16	0.997	0.251	0.51
pH	pH	17	10	3.6	-
Temperature	°F	17	89	70	77
Total nonfilterable residue	mg/L	16	1.0	<1	1.0
Oil and grease	mg/L	16	1.4	<1	1.0
Biochemical oxygen demand	mg/L	16	2.4	<1	1.5
Tetrachloroethylene	µg/L	6	<1	<1	<1
Trichloroethylene	µg/L	6	5.0	<1	30
1,1,1-trichloroethane	µg/L	6	<1	<1	<1
		Outfall A-3			
pH	pH	18	9.8	6.9	-
Temperature	°F	19	80	57	69
Total nonfilterable residue	mg/L	17	8.0	<1	1.7
Oil and grease	mg/L	17	2.7	<1	1.2
Tetrachloroethylene	µg/L	6	<1	<1	<1
Trichloroethylene	µg/L	6	3.0	<1	1.0
1,1,1-trichloroethane	µg/L	6	<1	<1	<1
Chromium	µg/L	24	60	<50	50
		Outfall A-5			
Flow	MGD	17	0.22	0.04	0.12
pH	pH	17	8.8	6.7	-
Temperature	°F	17	83	62	69
Fecal coliform	#/100	17	31,201	<2	7
Total nonfilterable residue	mg/L	17	10	<1	1.9
Oil and grease	mg/L	18	2.7	<1	1.2
Biochemical oxygen demand	mg/L	17	13	1.0	3.7
Tetrachloroethylene	µg/L	17	3.0	<1	1.0
Trichloroethylene	µg/L	17	8.0	<1	3.0
1,1,1-trichloroethane	µg/L	17	<1	<1	<1
		Outfall A-11			
pH	pH	18	9.0	5.9	-
Temperature	°F	18	86	57	72
Total nonfilterable residue	mg/L	17	15	<1	4.0
Biochemical oxygen demand	mg/L	17	5.7	<1	1.9
Oil and grease	mg/L	18	3.6	<1	1.3
Tetrachloroethylene	µg/L	6	<1	<1	<1
Trichloroethylene	µg/L	6	<1	<1	<1
1,1,1-trichloroethane	µg/L	6	<1	<1	<1

Source: Mikol et al. (1988)

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall A-14			
Flow	MGD	14	4.8	1.1	2.3
pH	pH	24	8.5	6.0	-
Temperature	°F	16	72	65	69
Total nonfilterable residue	mg/L	13	2.0	<1	1.0
Oil and grease	mg/L	13	2.4	<1	1.2
Biochemical oxygen demand	mg/L	13	2.6	<1	1.2
Tetrachloroethylene	µg/L	14	3.0	<1	1.0
Trichloroethylene	µg/L	14	6.0	<1	4.0
1,1,1-trichloroethane	µg/L	14	2.0	<1	1.0
		Outfall A-15			
Flow	MGD	12	0.131	0.052	0.066
pH	pH	13	7.3	6.7	-
Fecal coliform	#/100	13	28	<2	8.0
Total nonfilterable residue	mg/L	13	18	2.0	8.3
Biochemical oxygen demand	mg/L	13	12	<1	5.3
		Outfall C-1			
pH	pH	15	7.4	6.6	-
Temperature	°F	15	81	57	70
Total nonfilterable residue	mg/L	14	2.0	<1	1.2
Oil and grease	mg/L	14	1.4	<1	1.1
		Outfall C-3			
pH	pH	15	8.1	6.4	-
Temperature	°F	15	77	68	72
Total nonfilterable residue	mg/L	14	4.0	<1	1.4
Oil and grease	mg/L	14	2.9	<1	1.2
		Outfall C-4			
pH	pH	15	7.8	6.4	-
Temperature	°F	10	112	44	73
Total nonfilterable residue	mg/L	14	2.0	<1	1.1
Oil and grease	mg/L	14	2.0	<1	1.1
		Outfall C-4A			
Flow	MGD	10	0.026	0.006	0.011
pH	pH	15	8.6	6.4	-
Fecal coliform	#/100	17	100	<2	3.0
Total nonfilterable residue	mg/L	15	44	1.0	7.4
Biochemical oxygen demand	mg/L	15	7.1	1.3	2.9

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall D-1			
pH	pH	17	7.6	6.2	-
Temperature	°F	17	90	55	73
Total nonfilterable residue	mg/L	16	19	1.0	7.2
Oil and grease	mg/L	19	1.4	<1	0.75
		Outfall D-1A			
Flow	MGD	12	0.024	0.006	0.01
pH	pH	15	7.4	6.6	-
Fecal coliform	#/100	17	20	<2	2.9
Total nonfilterable residue	mg/L	15	10	1.0	5.3
Biochemical oxygen demand	mg/L	15	8.9	<1	3.8
		Outfall D-1B			
Flow	MGD	52	no flow		
		Outfall D-1C			
Flow	MGD	16	6.4	2.8	4.1
pH	pH	17	8.8	4.8	-
Total nonfilterable residue	mg/L	16	6.0	<1	2.4
Oil and grease	mg/L	16	1.2	<1	1.0
		Outfall D-3			
pH	pH	17	7.7	6.3	-
Total nonfilterable residue	mg/L	16	6.2	<1	2.4
Oil and grease	mg/L	19	1.7	<1	1.0
		Outfall D-5			
Flow	MGD	3	1.5	0.072	0.64
pH	pH	3	7.5	6.4	-
Total nonfilterable residue	mg/L	3	59	3.0	25
		Outfall D-6			
pH	pH	17	7.7	6.3	-
Temperature	°F	16	84	50	66
Fecal coliform	#/100	16	5700	24	526
Total nonfilterable residue	mg/L	17	5.0	<1	2.6
Oil and grease	mg/L	17	3.3	<1	2.3
		Outfall DW-1			
Flow	MGD	11	0.61	0.26	0.52
pH	pH	12	8.5	6.8	-
Total nonfilterable residue	mg/L	11	66	2	13

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TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall OW-2			
Flow	MGD	24	0.094	0.001	0.028
pH	pH	16	7.7	6.2	-
Oil and grease	mg/L	24	16	<1	3.5
		Outfall OW-3			
Flow	MGD	13	0.036	0.006	0.011
pH	pH	12	8.1	6.7	-
Fecal coliform	#/100	13	68	<2	3.0
Total nonfilterable residue	mg/L	13	15	3.0	7.2
Biochemical oxygen demand	mg/L	13	12	0.5	6.9
		Outfall F-1			
Flow	MGD	15	0.18	0.021	0.11
pH	pH	15	8.9	7.1	-
Temperature	°F	17	86	69	79
Total nonfilterable residue	mg/L	15	4.0	<1	2.3
Oil and grease	mg/L	16	1.7	<1	1.1
		Outfall F-2			
Flow	MGD	16	0.216	0.014	0.060
pH	pH	16	8.7	7.4	-
Fecal coliform	#/100	15	81	51	69
Total nonfilterable residue	mg/L	15	5.0	<1	1.6
Biochemical oxygen demand	mg/L	17	2.2	<1	1.1
		Outfall F-3			
Flow	MGD	16	0.086	0.007	0.026
pH	pH	15	8.4	7.5	-
Temperature	°F	15	95	58	76
Total nonfilterable residue	mg/L	15	32	<0.5	5.3
Oil and grease	mg/L	17	2.7	<1	1.1
Biochemical oxygen demand	mg/L	15	2.5	<1	1.6
		Outfall F-3A			
Flow	MGD	11	0.019	0.003	0.006
pH	pH	15	8.2	6.9	-
Fecal coliform	#/100	17	4.0	<2	2.0
Total nonfilterable residue	mg/L	17	4.0	<1	1.8
Biochemical oxygen demand	mg/L	17	4.7	<1	2.6

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall F-5			
Flow	MGD	15	0.11	0.007	0.054
pH	pH	15	8.7	6.8	-
Temperature	°F	15	84	69	77
Total nonfilterable residue	mg/L	16	6.0	<1	1.9
Oil and grease	mg/L	16	2.5	<1	1.2
		Outfall F-7			
Flow	MGD	2	0.058	0.005	0.032
pH	pH	2	6.8	6.5	-
Total nonfilterable residue	mg/L	2	2.0	<1	1.5
Oil and grease	mg/L	2	<1	<1	<1
		Outfall F-8			
pH	pH	15	8.4	6.9	-
Temperature	°F	15	96	68	84
Total nonfilterable residue	mg/L	14	3.0	<1	1.8
Oil and grease	mg/L	16	3.0	<1	1.1
		Outfall F-8A			
Flow	MGD	12	0.071	0.034	0.049
pH	pH	13	7.7	6.4	-
Fecal coliform	#/100	14	130	<2	3.0
Total nonfilterable residue	mg/L	15	84	1.0	16
Biochemical oxygen demand	mg/L	15	9.5	1.9	4.6
		Outfall FS-1			
Flow	MGD	13		no flow	
		Outfall FS-2			
Flow	MGD	6	0.05	0.001	0.036
Fecal coliform	#/100	6	700	84	218
		Outfall H-2			
Flow	MGD	15	0.13	0.029	0.066
pH	pH	15	8.7	5.7	-
Temperature	°F	15	84	55	67
Total nonfilterable residue	mg/L	15	271	0.60	27
Oil and grease	mg/L	17	2.2	<1	1.1
		Outfall H-3			
Flow	MGD	1		no flow	

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall H-4			
Flow	MGD	15	0.35	0.058	0.16
pH	pH	15	8.5	5.6	-
Temperature	°F	15	82	65	72
Total nonfilterable residue	mg/L	14	56	1	7.0
Oil and grease	mg/L	16	2.1	<1	1.1
		Outfall H-6			
Flow	MGD	4	no flow		
		Outfall H-7			
Flow	MGD	12	0.072	0.004	0.032
pH	pH	12	7.6	6.4	-
Temperature	°F	12	81	41	61
Total nonfilterable residue	mg/L	12	21	0.80	6.7
Oil and grease	mg/L	13	1.5	<1	1.1
Residual chlorine	mg/L	12	<0.2	<0.1	<0.19
		Outfall H-8			
pH	pH	15	7.8	5.0	-
Temperature	°F	15	84	68	76
Total nonfilterable residue	mg/L	15	15	<1	4.4
Oil and grease	mg/L	17	1.3	<0.5	1.0
		Outfall H-8A			
Flow	MGD	9	0.13	<0.001	0.019
pH	pH	9	7.2	6.7	-
Total nonfilterable residue	mg/L	9	4.0	<1	1.9
Oil and grease	mg/L	11	1.3	<1	1.1
		Outfall H-12			
Flow	MGD	10	12	0.039	0.55
pH	pH	15	7.8	6.5	-
Temperature	°F	15	84	63	75
Total nonfilterable residue	mg/L	15	5.0	<1	1.4
Oil and grease	mg/L	17	1.3	<1	1.0
Sulfate	mg/L	9	16	11	12
		Outfall H-13			
Flow	MGD	12	0.10	0.014	0.027
pH	pH	15	7.2	6.5	-
Fecal coliform	#/100	17	4500	<2	8.0
Total nonfilterable residue	mg/L	15	20	4.0	11
Biochemical oxygen demand	mg/L	15	14	2.9	5.2

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall K-1			
Flow	MGD	14	0.072	0.009	0.035
pH	pH	14	8.2	6.1	-
Temperature	°F	14	82	65	72
Total nonfilterable residue	mg/L	13	32	1.0	11
Oil and grease	mg/L	14	4.7	<1	2.1
Sulfate	mg/L	7	10	4.2	7.8
		Outfall K-6			
Flow	MGD	13	0.98	0.12	0.51
pH	pH	14	8.2	7.1	-
Temperature	°F	14	87	68	76
Total nonfilterable residue	mg/L	13	86	<1	12
Oil and grease	mg/L	14	2.9	<1	1.2
		Outfall K-8			
Flow	MGD	14	1.8	0.052	0.62
pH	pH	14	8.1	6.8	-
Temperature	°F	14	81	56	67
Total nonfilterable residue	mg/L	13	11	1.0	5.8
Oil and grease	mg/L	13	<1	<1	<1
		Outfall K-10			
Flow	MGD	14	0.95	0.50	0.73
pH	pH	14	7.9	6.7	-
Temperature	°F	14	84	59	70
Total nonfilterable residue	mg/L	13	10	3.0	5.1
Oil and grease	mg/L	14	22	<1	2.5
		Outfall K-11			
pH	pH	10	7.9	7.3	-
Temperature	°F	10	139	55	102
Total nonfilterable residue	mg/L	13	14	2.0	6.9
Oil and grease	mg/L	15	<1	<1	<1
Biochemical oxygen demand	mg/L	13	2.6	<1	1.4
		Outfall K-17			
pH	pH	15	8.9	7.0	-
Fecal coliform	#/100	17	20	<2	3.0
Total nonfilterable residue	mg/L	15	56	1.0	6.2
Biochemical oxygen demand	mg/L	15	5.1	<1	2.4

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall L-7			
pH	pH	15	8.2	7.0	-
Temperature	°F	10	87	50	69
Total nonfilterable residue	mg/L	15	16	<1	7.7
Oil and grease	mg/L	16	1.4	<1	1.0
		Outfall L-7A			
Flow	MGD	12	0.017	0.004	0.006
pH	pH	13	8.3	7.0	-
Fecal coliform	°F	14	4.0	<2	2.0
Total nonfilterable residue	mg/L	13	4.0	<1	1.4
Biochemical oxygen demand	mg/L	13	3.0	<1	1.6
		Outfall L-8			
Flow	MGD	15	2.2	0.32	1.1
pH	pH	15	8.1	7.2	-
Temperature	°F	15	82	53	69
Total nonfilterable residue	mg/L	15	27	1.0	7.0
Oil and grease	mg/L	16	2.2	<1	1.2
		Outfall L-10			
Flow	MGD	2	no flow		
		Outfall M-4			
Flow	MGD	52	0.15	0.049	0.093
pH	pH	27	10	6.6	-
Nitrate	mg/L	14	309	39	175
Phosphate	mg/L	15	2.8	0.026	0.40
Total nonfilterable residue	mg/L	51	13	<1	4.6
Oil and grease	mg/L	51	2.3	<1	1.0
Uranium	mg/L	51	1.2	<0.02	0.12
Lead	µg/L	51	32	<0.003	4.8
Nickel	µg/L	51	313	44	85
Silver	µg/L	1	<0.50	<0.50	<0.50
Chromium	µg/L	2	<50	<50	<50
Aluminum	µg/L	51	1959	78	781
Copper	µg/L	51	<50	<10	<20
Cyanide	µg/L	1	<5.0	<5.0	<5.0
Cadmium	µg/L	2	<10	<6.0	<8.0
Zinc	µg/L	2	216	<39	127
		Outfall M-5			
Flow	MGD	47	0.58	0.49	0.55
pH	pH	24	6.8	4.7	-
Tetrachloroethylene	µg/L	50	3.0	<1	1.0
Trichloroethylene	µg/L	50	<1	<1	<1
1,1,1-trichloroethane	µg/L	50	14	<1	1.0

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TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall P-5			
Flow	MGD	14	1.2	0.001	0.25
pH	pH	14	9.3	6.9	-
Total nonfilterable residue	mg/L	14	25	1.0	6.2
Oil and grease	mg/L	15	1.5	<1	1.1
		Outfall P-7			
pH	pH	14	8.1	7.0	-
Temperature	°F	14	92	58	74
Total nonfilterable residue	mg/L	14	3.0	1.0	1.8
Oil and grease	mg/L	15	2.0	<1	<1
Aluminum	µg/L	14	237	68	120
Iron	µg/L	14	335	100	187
		Outfall P-13			
pH	pH	14	7.9	6.8	-
Temperature	°F	10	117	55	74
Total nonfilterable residue	mg/L	14	9.0	<1	2.0
Oil and grease	mg/L	15	<1	<1	<1
		Outfall P-19			
pH	pH	14	7.7	7.0	-
Temperature	°F	10	140	47	102
Total nonfilterable residue	mg/L	14	3.0	0.90	1.6
Oil and grease	mg/L	15	1.4	0.50	0.99
		Outfall P-20			
pH	pH	15	8.9	6.4	-
Fecal coliform	#/100	17	6.0	<2	2.0
Total nonfilterable residue	mg/L	15	20	2.0	7.8
Biochemical oxygen demand	mg/L	15	6.6	<1	3.5
		Outfall PP-1			
Flow	MGD	6	0.58	0.014	0.26
pH	pH	6	7.4	5.4	-
Oil and grease	mg/L	6	<1	<1	<1

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall S-2			
Flow	MGD	18	0.22	0.004	0.039
pH	pH	5	7.1	6.1	-
Temperature	°F	5	70	42	53
Total nonfilterable residue	mg/L	5	12	1.5	7.4
Oil and grease	mg/L	17	5.7	<1	1.6
Biochemical oxygen demand	mg/L	5	9.8	1.5	4.4
Aluminum	µg/L	5	2112	341	1080
Iron	µg/L	5	2210	1050	1561
		Outfall S-8			
Flow	MGD	3	0.086	0.003	0.044
pH	pH	3	7.1	6.6	-
Temperature	°F	3	65	49	60
Total nonfilterable residue	mg/L	3	<1	<1	<1
Oil and grease	mg/L	3	4.3	<1	1.9
Biochemical oxygen demand	mg/L	3	2.7	<1	1.1
		Outfall S-11			
Flow	MGD	12	0.055	0.009	0.013
pH	pH	15	7.3	6.2	-
Fecal coliform	#/100	17	16	<2	3.0
Total nonfilterable residue	mg/L	15	19	3.7	9.0
Biochemical oxygen demand	mg/L	15	9	<1	1.9
		Outfall S-14			
Flow	MGD	2	no flow		
		Outfall SC-4			
pH	pH	12	8.0	6.8	-
Arsenic	µg/L	12	<3	<3	<3
Chromium	µg/L	13	<50	<50	<50
Lead	µg/L	12	11	<3	4.0
Mercury	µg/L	12	0.30	<0.1	0.10
Selenium	µg/L	12	<6	<5	<6
Cadmium	µg/L	12	<10	<6	<8
Silver	µg/L	12	<0.5	<0.5	<0.5
Barium	µg/L	12	128	<50	91
Nitrate	µg/L	12	0.28	<0.1	0.14
Phosphate	µg/L	13	0.22	0.046	0.092
		Outfall T-1			
Flow	MGD	3	0.029	0.001	0.011

TABLE A-6

NPDES Monitoring Data, 1987, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall T-5			
Flow	MGD	9	0.14	0.021	0.049
pH	pH	9	8.1	6.7	-
Temperature	°F	9	79	53	68
Total nonfilterable residue	mg/L	9	13	<1	3.0
Oil and grease	mg/L	9	1.3	<1	0.96
Biochemical oxygen demand	mg/L	9	1.9	<1	1.1
		Outfall T-7			
pH	pH	26	8.1	6.4	-
Fecal coliform	#/100	27	12	1.0	2.1
Total nonfilterable residue	mg/L	26	10	<1	4.6
Biochemical oxygen demand	mg/L	26	11	<1	3.5
		Outfall X-4			
pH	pH	13	7.6	6.3	-
Temperature	°F	12	86	69	76
Total nonfilterable residue	mg/L	13	4.0	<1	1.4
Oil and grease	mg/L	13	11	<1	2.2
		Outfall X-8			
Flow	MGD	13	0.22	0.007	0.030
pH	pH	13	7.5	6.2	-
Temperature	°F	13	104	78	89
Total nonfilterable residue	mg/L	13	5.0	<1	2.6
Oil and grease	mg/L	14	2.6	<1	1.3
Aluminum	µg/L	13	480	<50	162
Iron	µg/L	13	2510	1014	1570
		Outfall X-11			
Flow	MGD	9	0.007	<0.001	0.002
		Outfall X-13			
pH	pH	16	7.8	6.9	-
Fecal coliform	°F	15	30	<2	5.0
Total nonfilterable residue	mg/L	15	42	6.0	17
Biochemical oxygen demand	mg/L	16	20	<1	5.9
		Outfall Y-1			
Flow	MGD	4	0.022	0.007	0.016
pH	pH	4	7.2	6.1	-
Temperature	°F	4	57	52	55
Total nonfilterable residue	mg/L	4	15	<0.5	4.4
Oil and grease	mg/L	4	4.2	<1	1.8
Biochemical oxygen demand	mg/L	4	5.8	1.0	3.4

TABLE A-7

NPDES Monitoring Data, 1988

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall A-1			
Flow	MGD	15	0.432	0.360	0.410
pH	pH	15	8.4	6.4	-
Temperature	°F	15	97	71	78
Total nonfilterable residue	mg/L	15	4.0	<1	1.2
Oil and grease	mg/L	15	1.3	<1	<1
Biochemical oxygen demand	mg/L	15	6.3	<1	2.4
Tetrachloroethylene	µg/L	4	<2	<1	<2
Trichloroethylene	µg/L	4	6.0	<2	3.0
1,1,1-trichloroethane	µg/L	4	<2	<1	<2
		Outfall A-3			
pH	pH	15	8.1	7.2	-
Temperature	°F	15	80	62	73
Total nonfilterable residue	mg/L	15	1.0	<1	<1
Oil and grease	mg/L	15	1.9	<1	<1
Tetrachloroethylene	µg/L	5	<2	<1	<2
Trichloroethylene	µg/L	5	1.7	<1	<2
1,1,1-trichloroethane	µg/L	4	<2	<1	<2
Chromium	mg/L	24	<0.05	<0.02	<0.02
		Outfall A-5			
Flow	MGD	16	0.122	0.108	0.113
pH	pH	15	8.0	7.4	-
Temperature	°F	15	78	63	71
Fecal coliform	#/100	16	34	<2	4.5
Total nonfilterable residue	mg/L	15	2.0	<1	1.1
Oil and grease	mg/L	17	2.1	<1	1.0
Biochemical oxygen demand	mg/L	16	68	<1	8.5
Tetrachloroethylene	µg/L	16	2.2	<1	1.0
Trichloroethylene	µg/L	16	12	<1	4.9
1,1,1-trichloroethane	µg/L	16	<5	<1	<2
		Outfall A-11			
pH	pH	13	9.0	7.4	-
Temperature	°F	12	87	59	74
Total nonfilterable residue	mg/L	13	12	<1	2.7
Oil and grease	mg/L	14	3.6	<1	1.3
Biochemical oxygen demand	mg/L	13	4.0	<1	1.6
Tetrachloroethylene	µg/L	4	<2	<1	<2
Trichloroethylene	µg/L	4	<2	<1	<2
1,1,1-trichloroethane	µg/L	4	<2	<1	<2

Source: Davis et al. (1989)

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall A-14			
Flow	MGD	16	3.6	1.16	2.26
pH	pH	24	8.2	6.8	-
Temperature	°F	14	76	62	70
Total nonfilterable residue	mg/L	13	4.0	<1	1.4
Oil and grease	mg/L	13	1.8	<1	<1
Biochemical oxygen demand	mg/L	13	15	<1	2.0
Tetrachloroethylene	µg/L	14	23	<1	3.2
Trichloroethylene	µg/L	14	12	<2	6.1
1,1,1-trichloroethane	µg/L	14	2.9	<1	1.8
		Outfall A-15			
Flow	MGD	12	0.153	0.07	0.115
pH	pH	13	7.5	6.6	-
Fecal coliform	#/100	13	20	<2	3.2
Total nonfilterable residue	mg/L	13	31	3.0	9.7
Biochemical oxygen demand	mg/L	13	9.7	1.3	4.1
		Outfall C-1			
pH	pH	13	8.0	6.7	-
Temperature	°F	13	79	56	65
Total nonfilterable residue	mg/L	13	1.0	<1	<1
Oil and grease	mg/L	13	<1	<1	<1
		Outfall C-3			
pH	pH	12	8.0	7.2	-
Temperature	°F	12	86	69	73
Total nonfilterable residue	mg/L	13	17	<1	2.5
Oil and grease	mg/L	14	<1	<1	<1
		Outfall C-4			
pH	pH	13	8.6	7.2	-
Temperature	°F	12	87	40	66
Total nonfilterable residue	mg/L	13	5.0	<1	2.1
Oil and grease	mg/L	13	1.0	<1	<1
		Outfall C-4A			
Flow	MGD	12	0.033	0.012	0.020
pH	pH	13	7.7	6.5	-
Fecal coliform	#/100	14	590	<2	50
Total nonfilterable residue	mg/L	13	17	1.0	4.4
Biochemical oxygen demand	mg/L	13	6.0	<1	2.8

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NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall D-1			
pH	pH	14	8.7	7.2	-
Temperature	°F	14	89	59	76
Total nonfilterable residue	mg/L	14	10	1.0	6.4
Oil and grease	mg/L	14	<1	<1	<1
		Outfall D-1A			
Flow	MGD	12	0.019	0.009	0.013
pH	pH	14	8.6	6.8	-
Fecal coliform	#/100	14	6.0	<2	2.5
Total nonfilterable residue	mg/L	12	44	1.0	12
Biochemical oxygen demand	mg/L	13	35	<1	5.4
		Outfall D-1B			
Flow	MGD	52	no flow		
		Outfall D-1C			
Flow	MGD	14	4.8	0.065	3.5
pH	pH	14	8.3	7.0	-
Total nonfilterable residue	mg/L	14	5.0	<1	2.2
Oil and grease	mg/L	14	<1	<1	<1
		Outfall D-3			
pH	pH	14	8.6	7.1	-
Total nonfilterable residue	mg/L	14	2.0	<1	1.1
Oil and grease	mg/L	15	3.0	<1	1.1
		Outfall D-5			
Flow	MGD	12	no flow		
		Outfall D-6			
pH	pH	13	8.4	6.7	-
Temperature	°F	13	90	56	70
Fecal coliform	#/100	13	560	42	192
Total nonfilterable residue	mg/L	13	14	<1	4.2
Oil and grease	mg/L	13	<1	<1	<1

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NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall DW-1			
Flow	MGD	11	0.40	0.033	0.29
pH	pH	11	8.5	6.5	-
Total nonfilterable residue	mg/L	11	16	3.0	7.9
		Outfall DW-2			
Flow	MGD	20	0.029	0.007	0.26
pH	pH	13	7.9	6.3	-
Oil and grease	mg/L	24	19	<1	6.7
		Outfall DW-3			
Flow	MGD	12	0.026	0.009	0.019
pH	pH	13	7.7	6.8	-
Fecal coliform	#/100	13	<2	<2	<2
Total nonfilterable residue	mg/L	13	12	<1	4.4
Biochemical oxygen demand	mg/L	13	14	<1	4.8
		Outfall F-1			
Flow	MGD	17	0.173	0.043	0.108
pH	pH	17	8.4	7.8	-
Temperature	°F	17	86	67	70
Total nonfilterable residue	mg/L	18	40	<1	3.6
Oil and grease	mg/L	18	<1	<1	<1
		Outfall F-2			
Flow	MGD	18	0.115	0.012	0.077
pH	pH	18	8.2	7.6	-
Temperature	°F	18	79	51	68
Total nonfilterable residue	mg/L	18	5.0	<1	1.8
Oil and grease	mg/L	19	2.6	<1	<1
		Outfall F-3			
Flow	MGD	17	0.058	0.007	0.026
pH	pH	17	8.2	7.1	-
Temperature	°F	17	83	55	72
Total nonfilterable residue	mg/L	17	110	<1	14
Oil and grease	mg/L	18	<1	<1	<1
Biochemical oxygen demand	mg/L	16	15	<1	2.9

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NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall F-3A			
Flow	MGD	12	0.016	0.006	0.010
pH	pH	13	8.1	7.0	-
Fecal coliform	#/100	15	<2	<2	<2
Total nonfilterable residue	mg/L	14	4.0	<1	1.3
Biochemical oxygen demand	mg/L	14	4.7	<1	2.1
		Outfall F-5			
Flow	MGD	15	0.115	0.026	0.074
pH	pH	15	8.3	7.6	-
Temperature	°F	15	78	66	74
Total nonfilterable residue	mg/L	15	7.0	<1	2.2
Oil and grease	mg/L	15	<1	<1	<1
		Outfall F-7			
Flow	MGD	12	no flow		
		Outfall F-8			
pH	pH	15	8.1	7.5	-
Temperature	°F	15	91	63	80
Total nonfilterable residue	mg/L	15	5.0	<1	2.4
Oil and grease	mg/L	15	1.6	<1	<1
		Outfall F-8A			
Flow	MGD	12	0.072	0.060	0.064
pH	pH	13	7.6	6.6	-
Fecal coliform	#/100	15	20	<2	3.0
Total nonfilterable residue	mg/L	14	8.0	<1	4.9
Biochemical oxygen demand	mg/L	14	5.4	1.3	2.9
		Outfall FS-1			
Flow	MGD	13	no flow		
		Outfall FS-2			
FLow	MGD	7	0.086	0.007	0.056
Fecal coliform	#/100	7	700	142	325

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall H-2			
Flow	MGD	16	0.17	0.036	0.101
pH	pH	17	8.3	6.1	-
Temperature	°F	15	84	66	75
Total nonfilterable residue	mg/L	17	375	<1	27
Oil and grease	mg/L	16	1.8	<1	<1
		Outfall H-4			
Flow	MGD	15	0.40	0.029	0.184
pH	pH	16	8.2	7.1	-
Temperature	°F	15	84	68	70
Total nonfilterable residue	mg/L	16	21	1.0	4.1
Oil and grease	mg/L	16	1.8	<1	<1
		Outfall H-6			
Flow	MGD	2	0.029	0.015	0.022
pH	pH	2	8.1	7.6	-
Temperature	°F	2	65	54	60
Oil and grease	mg/L	2	<1	<1	<1
		Outfall H-7			
Flow	MGD	8	0.05	0.001	0.014
pH	pH	8	7.3	6.8	-
Temperature	°F	8	80	43	66
Total nonfilterable residue	mg/L	8	12	2.0	4.7
Oil and grease	mg/L	8	1.9	<1	1.0
Residual chlorine	mg/L	8	0.27	<0.1	<0.19
		Outfall H-8			
pH	pH	16	7.6	6.4	-
Temperature	°F	14	84	57	73
Total nonfilterable residue	mg/L	16	408	1.0	29
Oil and grease	mg/L	15	1.7	<1	<1
		Outfall H-8A			
Flow	MGD	9	0.45	0.07	0.20
pH	pH	10	7.9	6.4	-
Total nonfilterable residue	mg/L	9	8.0	<1	3.9
Oil and grease	mg/L	10	2.7	<1	1.1

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall H-12			
Flow	MGD	12	9.7	0.51	3.3
pH	pH	17	9.3	6.2	-
Temperature	°F	14	87	68	72
Total nonfilterable residue	mg/L	16	35	<1	4.7
Oil and grease	mg/L	16	1.9	<1	1.0
Sulfate	mg/L	9	16	11	13
		Outfall H-13			
Flow	MGD	12	0.080	0.039	0.054
pH	pH	14	7.2	6.9	-
Fecal coliform	#/100	14	22	<2	5.4
Total nonfilterable residue	mg/L	14	13	2.0	6.6
Biochemical oxygen demand	mg/L	14	5.4	<1	3.0
		Outfall K-1			
Flow	MGD	12	0.050	0.001	0.024
pH	pH	12	8.8	7.0	-
Temperature	°F	12	82	49	73
Total nonfilterable residue	mg/L	12	5.0	<1	2.2
Oil and grease	mg/L	12	1.3	<1	<1
Sulfate	mg/L	4	10	3.1	7.8
		Outfall K-6			
Flow	MGD	13	0.58	0.086	0.22
pH	pH	14	8.2	7.4	-
Temperature	°F	14	90	60	77
Total nonfilterable residue	mg/L	14	8.0	2.0	4.7
Oil and grease	mg/L	15	5.2	<1	2.0
		Outfall K-8			
Flow	MGD	13	0.65	0.043	0.28
pH	pH	14	8.9	7.2	-
Temperature	°F	14	88	58	70
Total nonfilterable residue	mg/L	14	31	1.0	5.1
Oil and grease	mg/L	14	2.1	<1	<1
		Outfall K-10			
Flow	MGD	13	0.65	0.072	0.262
pH	pH	14	8.2	7.1	-
Temperature	°F	14	84	60	72
Total nonfilterable residue	mg/L	14	4.0	<1	2.5
Oil and grease	mg/L	14	1.6	<1	<1

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall K-11			
pH	pH	14	8.2	7.0	-
Temperature	°F	12	115	55	76
Total nonfilterable residue	mg/L	14	24	2.0	5.5
Oil and grease	mg/L	15	2.5	<1	<1
Biochemical oxygen demand	mg/L	14	16	<1	2.4
		Outfall K-12			
pH	pH	14	8.6	6.9	1.9
Fecal coliform	#/100	14	4.0	<2	-
Total nonfilterable residue	mg/L	14	17	<1	3.9
Biochemical oxygen demand	mg/L	14	3.5	<1	2.2
		Outfall L-7			
pH	pH	15	8.1	7.4	-
Temperature	°F	12	111	59	79
Total nonfilterable residue	mg/L	15	7.0	2.0	4.7
Oil and grease	mg/L	16	1.4	<1	<1
		Outfall L-7A			
Flow	MGD	12	0.030	0.007	0.029
pH	pH	14	8.2	6.6	-
Fecal coliform	#/100	14	6.0	<2	2.3
Total nonfilterable residue	mg/L	14	4.0	<1	1.8
Biochemical oxygen demand	mg/L	14	20	<1	4.6
		Outfall L-8			
Flow	MGD	14	1.44	0.18	0.90
pH	pH	15	8.2	7.1	-
Temperature	°F	15	84	50	70
Total nonfilterable residue	mg/L	15	6.0	2.0	3.4
Oil and grease	mg/L	16	1.5	<1	1.1
		Outfall L-10			
Flow	MGD	12	no flow		

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall M-4			
Flow	MGD	36	0.19	0.010	0.096
pH	pH	24	8.9	7.1	-
Nitrate	mg/L	15	268	47	90
Phosphate	mg/L	15	24	0.02	2.2
Total nonfilterable residue	mg/L	36	19	<1	2.7
Oil and grease	mg/L	36	1.9	<1	0.86
Uranium	mg/L	36	0.38	<0.02	0.06
Lead	mg/L	36	0.04	<0.003	0.007
Nickel	mg/L	36	0.46	<0.05	0.07
Silver	mg/L	3	<0.0005	<0.0005	<0.0005
Chromium	mg/L	4	<0.05	<0.02	<0.02
Aluminum	mg/L	36	2.1	0.05	0.73
Copper	mg/L	36	0.012	<0.01	<0.01
Cyanide	mg/L	3	0.12	<0.005	0.04
Cadmium	mg/L	3	<0.01	<0.01	<0.01
Zinc	mg/L	4	0.12	0.05	0.09
		Outfall M-5			
Flow	MGD	52	0.58	0.40	0.55
pH	pH	28	6.8	5.0	-
Tetrachloroethylene	µg/L	52	<5	<1	<2
Trichloroethylene	µg/L	52	<5	<1	<2
1,1,1-trichloroethane	µg/L	52	<5	<1	<2
		Outfall P-5			
Flow	MGD	11	0.49	0.007	0.187
pH	pH	12	10	7.0	-
Total nonfilterable residue	mg/L	12	10	1.0	4.2
Oil and grease	mg/L	13	1.1	<1	<1
		Outfall P-7			
pH	pH	13	8.9	7.4	-
Temperature	°F	13	84	53	72
Total nonfilterable residue	mg/L	13	2.0	<1	<1
Oil and grease	mg/L	14	1.6	<1	<1
Aluminum	mg/L	12	<1	<1	<1
Iron	mg/L	12	0.36	0.11	0.25
		Outfall P-13			
pH	pH	14	9.6	7.2	-
Temperature	°F	11	87	56	72
Total nonfilterable residue	mg/L	14	52	<1	7.8
Oil and grease	mg/L	15	1.5	<1	0.75

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall P-19			
pH	pH	12	8.1	7.2	-
Temperature	°F	10	122	32	76
Total nonfilterable residue	mg/L	12	4.0	<1	1.6
Oil and grease	mg/L	13	2.1	<1	<1
		Outfall P-20			
pH	pH	14	7.8	6.8	-
Fecal coliform	#/100	14	24	<2	3.1
Total nonfilterable residue	mg/L	14	6.0	<1	3.2
Biochemical oxygen demand	mg/L	14	12	<1	3.4
		Outfall PP-1[a]			
Flow	MGD	1	0.014	-	-
pH	pH	1	7.2	-	-
Oil and grease	mg/L	1	1.2	-	-
		Outfall S-2			
Flow	MGD	3	0.014	0.001	0.007
pH	pH	3	7.2	7.1	-
Temperature	°F	3	80	50	68
Total nonfilterable residue	mg/L	3	28	[illegible]	12
Oil and grease	mg/L	3	7.4	<1	3.6
Biochemical oxygen demand	mg/L	3	27	<1	9.7
Aluminum	mg/L	3	9.1	0.15	3.3
Iron	mg/L	3	4.9	0.45	2.0
		Outfall S-8			
Flow	MGD	12		no flow	
		Outfall S-11			
Flow	MGD	12	0.33	0.017	0.060
pH	pH	14	7.6	6.8	-
Fecal coliform	#/100	14	10	<2	2.6
Total nonfilterable residue	mg/L	14	11	1.0	4.6
Biochemical oxygen demand	mg/L	14	3.3	<1	1.3

[a] Sampling frequency changed to yearly during 1987.

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall S-14			
Flow	MGD	12	no flow		
		Outfall SC-4			
pH	pH	12	7.8	6.4	-
Arsenic	mg/L	12	<0.003	<0.003	<0.003
Chromium	mg/L	12	<0.05	<0.02	0.03
Lead	mg/L	12	0.01	<0.003	0.0002
Mercury	mg/L	12	<0.005	<0.0001	<0.0001
Selenium	mg/L	12	<0.006	<0.006	<0.006
Cadmium	mg/L	12	<0.02	<0.01	<0.01
Silver	mg/L	12	<0.0005	<0.0005	<0.0005
Barium	mg/L	12	0.014	<0.1	<0.1
Nitrate	mg/L	12	0.25	0.06	0.13
Phosphate	mg/L	12	0.08	0.03	0.06
		Outfall T-1			
Flow	MGD	4	0.007	0.004	0.006
		Outfall T-5			
Flow	MGD	12	no flow		
		Outfall T-7			
pH	pH	24	7.8	6.4	-
Fecal coliform	#/100	24	2.0	<2	<2
Total nonfilterable residue	mg/L	24	15	<1	3.8
Biochemical oxygen demand	mg/L	24	15	<1	4.0
		Outfall X-4			
pH	pH	14	7.9	7.1	-
Temperature	°F	14	83	67	74
Total nonfilterable residue	mg/L	14	17	<1	2.4
Oil and grease	mg/L	14	1.5	<1	<1
		Outfall X-8			
Flow	MGD	13	0.072	0.014	0.037
pH	pH	14	8.2	6.8	-
Temperature	°F	14	117	75	79
Total nonfilterable residue	mg/L	14	5.0	<1	1.7
Oil and grease	mg/L	15	1.8	<1	<1
Aluminum	mg/L	14	1.6	<0.05	0.18
Iron	mg/L	14	1.4	0.09	1.1

TABLE A-7

NPDES Monitoring Data, 1988, Contd

Measurement	Units	Freq/yr	Maximum	Minimum	Average
		Outfall X-11			
Flow	MGD	4	0.007	0.001	0.003
		Outfall X-13			
pH	pH	14	8.0	6.6	-
Fecal coliform	#/100	15	12	<2	2.7
Total nonfilterable residue	mg/L	14	32	2.0	8.9
Biochemical oxygen demand	mg/L	14	15	<1	3.2
		Outfall X-14			
Biochemical oxygen demand	mg/L	20	33	<1	8.5
Total suspended solids	mg/L	20	60	1.0	11
Oil and grease	mg/L	20	<1	<1	<1
Total organic carbon	mg/L	20	52	<1	6.0
Benzene	µg/L	20	<5	<1	<2
Phenol	mg/L	20	0.01	<0.002	<0.01
Mercury	µg/L	20	<1	<0.001	<0.1
		Outfall Y-1			
Flow	MGD	12		no flow	

TABLE A-8

Savannah River Water Quality, 1987

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
River 3B below Plant Vogtle[a]						
Water volume	L		7.143E+12 (total)			
Temperature[b]	°C	12	26	8.5	14	±16
pH[b]	pH	12	7.6	5.5	-	-
Dissolved oxygen[b]	mg/L	12	12	5.6	8.5	±4.5
Alkalinity	mg/L	12	24	11	17	±9.5
Hardness	mg/L	4	17	10	-	-
Conductivity[b]	µmho/cm	12	100	0.12	35	±63
Turbidity[b]	NTU	12	110	3.0	23	±65
Suspended solids	mg/L	12	40	4.0	13	±19
Volatile solids	mg/L	12	7.0	1.0	2.8	±3.3
Total dissolved solids	mg/L	12	86	33	62	±28
Total solids	mg/L	12	100	42	75	±34
Fixed residue	mg/L	12	33	3.0	10	±17
COD	mg/L	12	26	5.0	16	±12
Chloride	mg/L	12	9.8	3.9	6.8	±4.0
Nitrogen (as NO_2/NO_3)	mg/L	12	0.64	0.12	0.28	±0.27
Sulfate	mg/L	12	8.0	5.0	6.0	2.1
Phosphorus (as PO_4)	mg/L	12	0.19	0.03	0.10	±0.094
Aluminum	mg/L	4	0.19	0.13	-	-
Nitrogen (as NH_3)	mg/L	12	0.24	<0.01	0.12	±0.14
Calcium	mg/L	4	4.2	2	-	-
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	0.01	<0.01	-	-
Magnesium	mg/L	4	1.5	1.2	-	-
Manganese	mg/L	4	0.16	0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	12	5.2	-	-
Iron	mg/L	4	0.47	0.10	-	-
Lead	mg/L	4	<0.05	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-
River 2 above Plant[a]						
Water volume	L		5.697E+12 (total)			
Temperature[b]	°C	12	26	9.0	18	±13
pH[b]	pH	12	8.0	5.9	-	-
Dissolved oxygen[b]	mg/L	12	12	6.0	8.8	±4.1
Alkalinity	mg/L	12	25	10	18	±10
Hardness	mg/L	4	17	12	-	-
Conductivity[b]	µmho/cm	12	100	0.11	36	±61
Turbidity[b]	NTU	12	110	2.0	23	±65
Suspended solids	mg/L	12	50	3.0	14	±25
Volatile solids	mg/L	12	7.0	<1	2.5	±3.8
Total dissolved solids	mg/L	12	84	49	66	±23
Total solids	mg/L	12	106	63	80	±14
Fixed residue	mg/L	12	44	2	12	±23
COD	mg/L	12	22	10	15	±7.1
Chloride	mg/L	12	9.3	3.2	6.6	±4.4
Nitrogen (as NO_2/NO_3)	mg/L	12	0.43	0.13	0.25	±0.17

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

Source: Mikol et al. (1988)

TABLE A-8

Savannah River Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
River 2 above Plant, Contd						
Sulfate	mg/L	12	9.0	4.0	5.7	±2.9
Phosphorus (as PO_4)	mg/L	12	0.19	0.02	0.091	±0.091
Aluminum	mg/L	4	0.21	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.27	<0.01	0.11	±0.17
Calcium	mg/L	4	4.1	2.6	-	-
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.6	1.2	-	-
Manganese	mg/L	4	0.16	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	12	8.1	-	-
Iron	mg/L	4	1.5	0.17	-	-
Lead	mg/L	4	0.09	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-
River 10 below Plant[a]						
Water volume	L		7.219E+12 (total)			
Temperature[b]	°C	12	26	8.0	18	±12
pH[b]	pH	12	7.8	4.8	-	-
Dissolved oxygen[b]	mg/L	12	12	5.2	8.4	±4.8
Alkalinity	mg/L	12	24	10	17	±10
Hardness	mg/L	4	18	12	-	-
Conductivity[b]	µmho/cm	12	110	0.12	35	±63
Turbidity[b]	NTU	12	110	2.0	24	±65
Suspended solids	mg/L	12	36	5.0	12	±17
Volatile solids	mg/L	12	5.0	<1.0	2.5	±3.4
Total dissolved solids	mg/L	12	79	30	62	±24
Total solids	mg/L	12	92	39	74	±28
Fixed residue	mg/L	12	30	4.0	9.8	±14
COD	mg/L	12	20	6.0	13	±9.7
Chloride	mg/L	12	8.9	2.8	6.8	±3.3
Nitrogen (as NO_2/NO_3)	mg/L	12	0.58	0.18	0.31	±0.20
Sulfate	mg/L	12	9.0	4.0	5.8	±2.7
Phosphorus (as PO_4)	mg/L	12	0.15	0.03	0.08	±0.064
Aluminum	mg/L	4	0.15	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.16	<0.01	0.083	±0.11
Calcium	mg/L	4	0.46	0.26	-	-
Copper	mg/L	4	0.04	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.5	1.2	-	-
Manganese	mg/L	4	0.080	0.010	-	-
Mercury	µg/L	4	<0.2	<0.2	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	12	7.7	-	-
Iron	mg/L	4	1.3	0.07	-	-
Lead	mg/L	4	<0.05	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-9

Savannah River Water Quality, 1988

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
River 3B below Plant Vogtle[a]						
Water volume	L		5.151E+12 (total)			
Temperature[b]	°C	12	28	9.0	18	±12
pH[b]	pH	12	7.3	6.2	-	-
Dissolved oxygen[b]	mg/L	12	11	5.3	7.8	±3.4
Alkalinity	mg/L	12	29	20	25	±5.3
Hardness	mg/L	4	20	15	-	-
Conductivity[b]	µmho/cm	12	138	1.0	63	±108
Turbidity[b]	NTU	12	11	1.0	3.1	±5.5
Suspended solids	mg/L	12	20	3.0	9.2	±9.3
Volatile solids	mg/L	12	10	2.0	3.8	±4.6
Total dissolved solids	mg/L	12	85	44	70	±22
Total solids	mg/L	12	96	55	79	±25
Fixed residue	mg/L	12	14	<1	5.8	±7.4
COD	mg/L	12	20	4.0	11	±8.5
Chloride	mg/L	12	11	6.4	8.8	±3.3
Nitrogen (as NO_2/NO_3)	mg/L	12	0.65	0.20	0.34	±0.25
Sulfate	mg/L	12	10	6.0	7.8	2.4
Phosphorus (as PO_4)	mg/L	12	0.18	0.07	0.11	±0.06
Aluminum	mg/L	4	0.21	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.17	0.08	0.12	±0.07
Calcium	mg/L	4	5.5	4.0	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.7	1.3	-	-
Manganese	mg/L	4	0.09	<0.01	-	-
Mercury	µg/L	4	0.39	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	17	11	-	-
Iron	mg/L	4	0.42	0.03	-	-
Lead	mg/L	4	0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
River 2 above Plant[a]						
Water volume	L		4.678E+12 (total)			
Temperature[b]	°C	12	28	9.0	18	±12
pH[b]	pH	12	7.6	6.1	-	-
Dissolved oxygen[b]	mg/L	12	11	5.4	8.5	±4.0
Alkalinity	mg/L	12	27	21	24	±4.3
Hardness	mg/L	4	20	15	-	-
Conductivity[b]	µmho/cm	12	125	7.0	68	±99
Turbidity[b]	NTU	12	9.0	1.0	3.0	±4.6
Suspended solids	mg/L	12	16	3.0	7.8	±7.8
Volatile solids	mg/L	12	6.0	1.0	2.9	±2.6
Total dissolved solids	mg/L	12	94	23	73	±35
Total solids	mg/L	12	94	33	80	±35
Fixed residue	mg/L	12	10	2.0	5.2	±5.4
COD	mg/L	12	20	4.0	12	±8.9
Chloride	mg/L	12	11	6.5	9.1	±2.8
Nitrogen (as NO_2/NO_3)	mg/L	12	0.82	0.21	0.31	±0.33

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

Source: Mikol et al. (1988)

TABLE A-9

Savannah River Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
River 2 above Plant, Contd						
Sulfate	mg/L	12	10	6.0	7.4	±2.2
Phosphorus (as PO_4)	mg/L	12	0.17	0.07	0.11	±0.07
Aluminum	mg/L	4	0.17	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.21	0.05	0.14	±0.09
Calcium	mg/L	4	5.2	3.8	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.7	1.3	-	-
Manganese	mg/L	4	0.07	<0.01	-	-
Mercury	µg/L	4	0.70	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	17	11	-	-
Iron	mg/L	4	0.32	0.03	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
River 10 below Plant[a]						
Water volume	L		4.672E+12 (total)			
Temperature[b]	°C	12	26	9.0	18	±12
pH[b]	pH	12	7.4	5.1	-	-
Dissolved oxygen[b]	mg/L	12	11	5.0	7.8	±3.6
Alkalinity	mg/L	12	29	21	24	±4.9
Hardness	mg/L	4	21	16	-	-
Conductivity[b]	µmho/cm	12	122	2.0	62	±103
Turbidity[b]	NTU	12	6.0	1.0	2.5	±2.9
Suspended solids	mg/L	12	11	1.0	7.5	±7.1
Volatile solids	mg/L	12	3.0	1.0	2.2	±1.9
Total dissolved solids	mg/L	12	77	51	67	±14
Total solids	mg/L	12	88	62	74	±17
Fixed residue	mg/L	12	9.0	<1.0	5.7	±5.6
COD	mg/L	12	18	3.0	8.6	±8.9
Chloride	mg/L	12	11	6.0	8.8	±2.9
Nitrogen (as NO_2/NO_3)	mg/L	12	0.69	0.16	0.37	±0.33
Sulfate	mg/L	12	11	6.0	8.1	±3.2
Phosphorus (as PO_4)	mg/L	12	0.13	0.05	0.09	±0.05
Aluminum	mg/L	4	0.20	0.07	-	-
Nitrogen (as NH_3)	mg/L	12	0.13	0.02	0.07	±0.06
Calcium	mg/L	4	5.8	4.4	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.6	1.3	-	-
Manganese	mg/L	4	0.07	<0.01	-	-
Mercury	µg/L	4	0.26	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	17	11	-	-
Iron	mg/L	4	0.46	0.18	-	-
Lead	mg/L	4	0.06	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-10

Fecal Coliform Bacteria in SRS Streams and the Savannah River, 1987

Location	No. of Samples	Colonies/100 mL Weekly Values Maximum	Weekly Values Minimum	Monthly Geometric Mean[a] Maximum	Monthly Geometric Mean[a] Minimum	Monthly Geometric Mean[a] Average
River 2, above SRS	52	7,400	36	1,717	98	600
River 3 B, Vogtle discharge	52	4,300	30	861	54	315
River 10, below SRS	52	1,500	18	655	50	195
Upper Three Runs Creek at Road F	51	630	38	366	129	229
Upper Three Runs Creek at Road A	52	2,400	32	453	104	203
Beaver Dam Creek near swamp	52	900	8	584	20	199
Four Mile Creek at Road A	52	440	26	135	46	79
Pen Branch at Road A	52	14,000[b]	16	1,200	236	684
Steel Creek at Road A	12	130	10	130	10	48
Lower Three Runs Creek at Road A	52	3,700	<2	306	60	138
Lower Three Runs Creek at Tabernacle Church Road	52	2,200	52	434	93	213

[a] Maximum, minimum, and average of monthly geometric mean of weekly values. The standard for South Carolina states that the fecal coliform count should: not exceed a geometric mean of 1000 colonies/100 mL based on five consecutive samples during any 30-day period; nor exceed 2000 colonies/100 mL in more than 20% of the samples examined during such period (not applicable during or following periods of rainfall).

[b] Exceeded standard.

Source: Mikol et al. (1988)

TABLE A-11

Fecal Coliform Bacteria in SRS Streams and the Savannah River, 1988

Location	No. of Samples	Colonies/100 mL Weekly Values Maximum	Weekly Values Minimum	Monthly Geometric Mean[a] Maximum	Monthly Geometric Mean[a] Minimum	Monthly Geometric Mean[a] Average
River 2, above SRS	51	4,700	20	1,413	32	393
River 3B, Vogtle discharge	51	2,500	20	815	32	278
River 10, below SRS	51	1,110	8	494	22	141
Upper Three Runs Creek at Road F	51	2,100	62	355	122	228
Upper Three Runs Creek at Road A	51	2,400	64	350	91	193
Beaver Dam Creek near swamp	51	870	6	369	16	118
Four Mile Creek at Road A	51	2,000	2	220	14	78
Pen Branch at Road A	51	1,600	<2	1,600	32	457
Steel Creek at Road A	12	72	<2	40	4	25
Lower Three Runs Creek at Road A	51	1,300	<2	317	59	164
Lower Three Runs Creek at Tabernacle Church Road	51	3,400	48	579	42	191

[a] Maximum, minimum, and average of monthly geometric mean or weekly values. The standard for South Carolina states that the fecal coliform count should not exceed a geometric mean of 1000 colonies/100 mL based on five consecutive samples during any 30-day period; nor exceed 2000 colonies/100 mL in more than 20% of the samples examined during such period (not applicable during or following periods of rainfall).

Source: Davis et al. (1989)

TABLE A-12

SRS Stream Water Quality, 1987

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Tims Branch 5 DHEC[a]						
Water volume	L		1.424E+10 (total)			
Temperature[b]	°C	12	23	8.0	16	±12
pH[b]	pH	12	6.9	5.1	-	-
Dissolved oxygen[b]	mg/L	12	12	7.1	8.8	±2.9
Alkalinity	mg/L	12	20	9.0	14	±6.9
Hardness	mg/L	4	5.5	3.6	-	-
Conductivity[b]	µmho/cm	12	47	15	30	±25
Total organic carbon	mg/L	12	6.1	1.7	3.6	±2.7
Turbidity[b]	NTU	12	25	3.0	11	±14
Suspended solids	mg/L	12	30	2.0	7.1	±16
Volatile solids	mg/L	12	9.0	0.0	2.3	±4.8
Total dissolved solids	mg/L	12	64	26	39	±22
Total solids	mg/L	12	72	32	45	±26
Fixed residue	mg/L	12	21	1.0	5.0	±11
COD	mg/L	12	21	2.0	8.7	±12
Organic nitrogen	mg/L	12	0.36	<0.1	0.15	±0.22
Chloride	mg/L	12	2.9	0.54	2.0	±1.3
Nitrogen (as NO_2/NO_3)	mg/L	12	2.7	0.05	0.57	±1.4
Sulfate	mg/L	12	3.0	<2.0	1.8	1.8
Phosphorus (as PO_4)	mg/L	12	0.07	<0.02	0.029	±0.036
Aluminum	mg/L	4	0.44	<0.1	-	-
Nitrogen (as NH_3)	mg/L	12	0.03	<0.01	0.01	±0.02
Calcium	mg/L	4	1.3	0.67	-	-
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.52	0.44	-	-
Manganese	mg/L	4	0.09	<0.02	-	-
Mercury	µg/L	4	0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	9.4	6.0	-	-
Iron	mg/L	4	0.88	0.24	-	-
Lead	mg/L	4	0.19	<0.01	-	-
Chromium	mg/L	4	0.03	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-
Steel Creek at Road A DHEC[a]						
Water volume	L		2.006E+11 (total)			
Temperature[b]	°C	12	30	12	21	±13
pH[b]	pH	12	7.1	5.9	-	-
Dissolved oxygen[b]	mg/L	12	12	5.6	8.5	±3.8
Alkalinity	mg/L	12	20	12	16	±7.0
Hardness	mg/L	4	15	11	-	-
Conductivity[b]	µmho/cm	12	91	13	56	±56
Total organic carbon	mg/L	12	6.0	0.46	4.4	±3.2
Turbidity[b]	NTU	11	22	2.0	12	±12
Suspended solids	mg/L	12	11	3.0	5.9	±4.8
Volatile solids	mg/L	12	6.0	1.0	3.1	±2.9

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

Source: Mikol et al. (1988)

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Steel Creek at Road A DHEC, Contd						
Total dissolved solids	mg/L	12	59	40	50	±13
Total solids	mg/L	12	65	48	56	±13
Fixed residue	mg/L	12	6.0	<1.0	3.2	±3.5
COD	mg/L	12	20	5.0	14	±10
Organic nitrogen	mg/L	12	0.58	0.13	0.38	±0.24
Chloride	mg/L	12	7.4	4.9	6.3	±1.5
Nitrogen (NO_2/NO_3)	mg/L	12	0.33	0.02	0.14	±0.20
Sulfate	mg/L	12	6.0	2.0	4.2	±2.6
Phosphorus (as PO_4)	mg/L	12	0.06	<0.02	0.032	±0.035
Aluminum	mg/L	4	0.11	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.16	<0.01	0.028	<0.093
Calcium	mg/L	4	3.8	2.9	-	-
Copper	mg/L	4	<,0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.4	0.89	-	-
Manganese	mg/L	4	0.05	<0.02	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	9.3	5.5	-	-
Iron	mg/L	4	0.26	<0.02	-	-
Lead	mg/L	4	<0.05	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	0.010	<0.01	-	-
Upper Three Runs at Road A DHEC[a]						
Water volume	L		1.421E+11 (total)			
Temperature[b]	°C	12	24	8.4	17	±12
pH	pH	12	6.7	5.5	-	-
Dissolved oxygen	mg/L	12	10	7.1	8.3	±2.1
Alkalinity	mg/L	12	7.0	2.0	4.4	±3.7
Hardness	mg/L	4	6.1	4.2	-	-
Conductivity	µmho/cm	12	25	3.0	16	±13
Total organic carbon	mg/L	12	8.6	1.8	4.7	±4.4
Turbidity	NTU	11	22	2.0	13	±11
Suspended solids	mg/L	12	11	3.0	5.9	±5.7
Volatile solids	mg/L	12	5.0	<0.1	2.3	±2.7
Total dissolved solids	mg/L	12	33	13	22	±17
Total solids	mg/L	12	37	20	30	±10
Fixed residue	mg/L	12	8.0	0.0	3.5	±4.6
COD	mg/L	12	22	1.0	13	±19
Organic nitrogen	mg/L	12	0.70	<0.10	0.24	±0.51
Chloride	mg/L	12	2.6	0.73	1.7	±1.1
Nitrogen (NO_2/NO_3)	mg/L	12	0.19	0.05	0.11	±0.076
Sulfate	mg/L	12	7.0	0.50	2.4	±3.5
Phosphorus (as PO_4)	mg/L	12	0.07	<0.02	0.021	±0.038
Aluminum	mg/L	4	0.20	<0.10	-	-
Nitrogen (as NH_3)	mg/L	12	0.02	<0.01	0.005	±0.013
Calcium	mg/L	4	1.8	1.1	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Upper Three Runs at Road A DHEC, Contd[a]						
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.40	0.34	-	-
Manganese	mg/L	4	0.03	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	1.8	0.69	-	-
Iron	mg/L	4	0.30	0.17	-	-
Lead	mg/L	4	0.10	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-
Four Mile Creek at Road A-7 DHEC[a]						
Water volume	L		1.192E+11 (total)			
Temperature[b]	°C	12	26	7.8	18	±15
pH[b]	pH	12	6.7	5.7	-	-
Dissolved oxygen[b]	mg/L	12	11	6.5	8.2	±3.0
Alkalinity	mg/L	12	20	5.0	11	±11
Hardness	mg/L	4	11	7.8	-	-
Conductivity[b]	µmho/cm	12	78	0.15	48	±53
Total organic carbon	mg/L	12	5.8	1.4	2.9	±2.5
Turbidity[b]	NTU	11	22	4.0	12	±9.5
Suspended solids	mg/L	12	6.0	0.0	3.2	±3.7
Volatile solids	mg/L	12	4.0	0.0	1.9	±2.6
Total dissolved solids	mg/L	12	90	40	66	±35
Total solids	mg/L	12	93	46	69	±34
Fixed residue	mg/L	12	3.0	0.0	1.4	±2.5
COD	mg/L	12	16	3.0	9.0	±9.5
Organic nitrogen	mg/L	12	0.53	<0.01	0.21	±0.33
Chloride	mg/L	12	4.1	1.7	3.1	±1.5
Nitrogen (as NO_2/NO_3)	mg/L	12	3.5	1.3	2.4	±1.5
Sulfate	mg/L	12	13	4.0	7.8	4.8
Phosphorus (as PO_4)	mg/L	12	0.02	<0.02	0.13	±0.020
Aluminum	mg/L	4	0.36	<0.10	-	-
Nitrogen (as NH_3)	mg/L	12	0.06	<0.01	0.014	±0.036
Calcium	mg/L	4	3.4	2.1	-	-
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.74	0.62	-	-
Manganese	mg/L	4	0.04	<0.02	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	10	8.0	-	-
Iron	mg/L	4	0.36	0.09	-	-
Lead	mg/L	4	0.11	<0.01	-	-
Chromium	mg/L	4	0.01	<0.01	-	-
Zinc	mg/L	4	0.01	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Crouch Branch						
Water volume	L		1.620E+8 (total)			
Temperature[a]	°C	12	29	6.1	19	±16
pH[a]	pH	12	6.7	5.3	-	-
Dissolved oxygen[a]	mg/L	12	12	4.8	7.4	±4.3
Turbidity[a]	NTU	12	230	2.0	76	±145
Suspended solids	mg/L	12	210	8.0	57	±130
Lower Three Runs at Patterson Mill[b]						
Water volume	L		7.613E+10 (total)			
Temperature[b]	°C	12	28	9.4	19	±13
pH[b]	pH	12	7.4	5.9	-	-
Dissolved oxygen[b]	mg/L	12	9.5	6.2	7.7	±2.4
Alkalinity	mg/L	12	38	19	27	±12
Hardness	mg/L	4	43	20	-	-
Conductivity[b]	µmho/cm	12	120	11	48	±82
Turbidity[b]	NTU	12	38	1.0	7.4	±21
Suspended solids	mg/L	12	12	<1.0	3.5	±6.8
Volatile solids	mg/L	12	4.0	<1.0	2.0	±3.0
Total dissolved solids	mg/L	12	73	20	55	±26
Total solids	mg/L	12	85	22	58	±30
Fixed residue	mg/L	12	8.0	<1.0	1.8	±4.7
COD	mg/L	12	21	3.0	15	±11
Chloride	mg/L	12	5.8	2.0	4.1	±2.1
Nitrogen (as NO_2/NO_3)	mg/L	12	0.71	<0.02	0.13	±0.39
Sulfate	mg/L	12	6.0	0.05	3.1	±2.9
Phosphorus (as PO_4)	mg/L	12	0.04	<0.02	0.017	±0.03
Aluminum	mg/L	4	0.07	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.04	<0.01	0.018	±0.027
Calcium	mg/L	4	16	6.6	-	-
Copper	mg/L	4	0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.95	0.77	-	-
Manganese	mg/L	4	0.04	<0.02	-	-
Mercury	mg/L	4	<0.20	<0.20	-	-
Nickel	µg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	6.4	3.2	-	-
Iron	mg/L	4	0.21	<0.01	-	-
Lead	mg/L	4	<0.10	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	<0.02	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
McQueen Branch						
Water volume	L		6.575E+10 (total)			
Temperature[a]	°C	12	28	7.0	18	±14
pH[a]	pH	12	7.0	5.3	-	-
Dissolved oxygen[a]	mg/L	12	12	5.9	8.0	±3.3
Turbidity[a]	NTU	12	150	3.0	26	±81
Suspended solids	mg/L	12	72	2.0	12	±39
Pen Branch at Road A-17[b]						
Water volume	L		1.593E+11 (total)			
Temperature[b]	°C	12	44	7.2	28	±26
pH[b]	pH	12	7.3	5.1	-	-
Dissolved oxygen[b]	mg/L	12	11	4.2	7.6	±4.2
Alkalinity	mg/L	12	24	10	16	±8.2
Hardness	mg/L	4	16	9.8	-	-
Conductivity[b]	µmho/cm	12	97	10	40	±83
Turbidity[b]	NTU	12	23	2.0	9.5	±14
Suspended solids	mg/L	12	29	2.0	8.7	±15
Volatile solids	mg/L	12	10	0.0	2.7	±5.7
Total dissolved solids	mg/L	12	71	38	52	±21
Total solids	mg/L	12	79	44	61	±25
Fixed residue	mg/L	12	24	2.0	6.3	±13
COD	mg/L	12	21	9.0	14	±7.9
Chloride	mg/L	12	9.6	3.2	5.7	±4.1
Nitrogen (as NO_2/NO_3)	mg/L	12	0.42	0.13	0.26	±0.19
Sulfate	mg/L	12	8.0	3.0	4.8	±3.6
Phosphorus (as PO_4)	mg/L	12	0.11	0.02	0.059	±0.060
Aluminum	mg/L	4	1.8	<0.10	-	-
Nitrogen (as NH_3)	mg/L	12	0.10	0.0	0.037	±0.066
Calcium	mg/L	4	4.2	2.1	-	-
Copper	mg/L	4	0.02	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.4	0.95	-	-
Manganese	mg/L	4	0.18	<0.02	-	-
Mercury	mg/L	4	<0.20	<0.20	-	-
Nickel	µg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	12	7.0	-	-
Iron	mg/L	4	1.3	<0.01	-	-
Lead	mg/L	4	<0.05	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	0.02	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Four Mile Creek at Road A[a]						
Water volume	L		2.010E+10 (total)			
Temperature[b]	°C	12	27	6.3	19	±14
pH[b]	pH	12	7.5	4.5	-	-
Dissolved oxygen[b]	mg/L	12	11	6.9	8.5	±2.7
Alkalinity	mg/L	12	16	6.0	10	±7.3
Hardness	mg/L	4	11	6.8	-	-
Conductivity[b]	µmho/cm	12	73	11	34	±51
Turbidity[b]	NTU	12	23	1.0	7.3	±15
Suspended solids	mg/L	12	10	1.0	3.0	±5.6
Volatile solids	mg/L	12	3.0	<1.0	1.0	±2.1
Total dissolved solids	mg/L	12	71	41	52	±19
Total solids	mg/L	12	73	44	55	±18
Fixed residue	mg/L	12	7.0	<1.0	1.9	±4.3
COD	mg/L	12	16	5.0	10	±7.1
Chloride	mg/L	12	5.2	1.2	2.9	±2.2
Nitrogen (as NO_2/NO_3)	mg/L	12	1.8	0.62	1.1	±0.72
Sulfate	mg/L	12	18	3.0	6.3	±7.9
Phosphorus (as PO_4)	mg/L	12	0.04	<0.02	0.015	±0.030
Aluminum	mg/L	4	0.20	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.04	0.0	0.017	±0.025
Calcium	mg/L	4	3.1	1.8	-	-
Copper	mg/L	4	0.11	<0.05	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.73	0.57	-	-
Manganese	mg/L	4	0.04	<0.01	-	-
Mercury	mg/L	4	<0.20	<0.20	-	-
Nickel	µg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	7.1	6.2	-	-
Iron	mg/L	4	0.66	<0.01	-	-
Lead	mg/L	4	0.06	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	0.02	<0.01	-	-
Upper Three Runs at Highway 278[a]						
Water volume	L		1.584+11 (total)			
Temperature[b]	°C	12	26	9.5	18	±9.9
pH[b]	pH	12	6.9	4.8	-	-
Dissolved oxygen[b]	mg/L	12	10	6.2	7.9	±2.1
Alkalinity	mg/L	12	37	1.0	5.3	±20
Hardness	mg/L	4	2.7	1.7	-	-
Conductivity[b]	µmho/cm	12	76	7.0	26	±38
Turbidity[b]	NTU	12	120	2.0	19	±71
Suspended solids	mg/L	12	13	2.0	5.5	±7.8
Volatile solids	mg/L	12	6.0	1.0	2.7	±3.9
Total dissolved solids	mg/L	12	80	10	24	±39
Total solids	mg/L	12	83	13	30	±38
Fixed residue	mg/L	12	7.0	<1.0	2.9	±4.8
COD	mg/L	12	20	6.0	12	±8.7

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Upper Three Runs at Highway 278, Contd[a]						
Chloride	mg/L	12	4.5	0.50	2.2	±2.4
Nitrogen (as NO_2/NO_3)	mg/L	12	0.81	0.05	0.22	±0.39
Sulfate	mg/L	12	4.0	0.05	1.9	±2.1
Phosphorus (as PO_4)	mg/L	12	0.03	<0.02	0.012	±0.012
Aluminum	mg/L	4	0.10	<0.01	-	-
Nitrogen (as NH_3)	mg/L	12	0.02	<0.01	0.010	±0.067
Calcium	mg/L	4	0.49	0.22	-	-
Copper	mg/L	4	<0.05	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.36	0.26	-	-
Manganese	mg/L	4	0.02	0.01	-	-
Mercury	mg/L	4	<0.20	<0.20	-	-
Nickel	µg/L	4	<0.05	<0.01	-	-
Sodium	mg/L	4	1.4	0.29	-	-
Iron	mg/L	4	0.19	<0.01	-	-
Lead	mg/L	4	0.06	<0.01	-	-
Chromium	mg/L	4	<0.05	<0.01	-	-
Zinc	mg/L	4	0.02	<0.01	-	-

[a] Metals are analyzed quarterly from a continuous flow composite.
- Insufficient data.

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Beaver Dam Creek Water Quality Data Summary

Quarter 1, January 1 - March 31, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	83	54	67
pH	pH	6.9	5.8	-
Dissolved oxygen	mg/L	10.6	6.4	8.1
Conductivity	µmhos/cm	146	59	96
Oxidation/reduction potential	mV	322	288	304

Quarter 2, April 1 - June 30, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	89	67	80
pH	pH	8.8	5.7	-
Dissolved oxygen	mg/L	8.8	4.5	6.8
Conductivity	µmhos/cm	164	76	112
Oxidation/reduction potential	mV	336	173	300

Quarter 3, July 1 - September 30, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	89	72	81
pH	pH	8.0	5.9	-
Dissolved oxygen	mg/L	8.4	5.7	7.0
Conductivity	µmhos/cm	173	56	89
Oxidation/reduction potential	mV	381	286	300

Quarter 4, October 1 - December 31, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	79	63	71
pH	pH	7.5	6.2	-
Dissolved oxygen	mg/L	9.6	3.9	7.9
Conductivity	µmhos/cm	127	69	100
Oxidation/reduction potential	mV	313	260	296

TABLE A-12

SRS Stream Water Quality, 1987, Contd

Steel Creek Water Quality Data Summary

Quarter 1, January 1 - March 31, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	75	62	67
Dissolved oxygen	mg/L	9.7	7.5	8.4

Quarter 2, April 1 - June 30, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	82	64	75
Dissolved oxygen	mg/L	8.9	5.2	7.1

Quarter 3, July 1 - September 30, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	84	77	80
Dissolved oxygen	mg/L	6.6	3.5	5.2

Quarter 4, October 1- December 31, 1987

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	78	59	64
Dissolved oxygen	mg/L	9.1	5.5	7.9

TABLE A-13

SRS Stream Water Quality, 1988

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Tims Branch 5 DHEC[a]						
Water volume	L		5.610E+9 (total)			
Temperature[b]	°C	12	23	6.2	16	±10
pH[b]	pH	12	7.2	4.9	-	-
Dissolved oxygen[b]	mg/L	12	13	6.0	8.2	±4.6
Alkalinity	mg/L	12	29	14	19	±4.9
Hardness	mg/L	4	9.4	4.9	-	-
Conductivity[b]	µmho/cm	12	105	12	45	±62
Total organic carbon	mg/L	12	9.0	1.5	4.8	±5.4
Turbidity[b]	NTU	12	19	1.0	4.6	±9.8
Suspended solids	mg/L	12	32	4.0	13	±20
Volatile solids	mg/L	12	12	2.0	4.5	±5.9
Total dissolved solids	mg/L	12	79	28	49	±43
Total solids	mg/L	12	111	34	62	±50
Fixed residue	mg/L	12	25	<1	8.4	±15
COD	mg/L	12	21	1.0	8.2	±13
Organic nitrogen	mg/L	12	0.45	<0.01	0.25	±0.25
Chloride	mg/L	12	7.3	1.3	3.0	±3.0
Nitrogen (as NO_2/NO_3)	mg/L	12	1.5	0.02	0.57	±0.94
Sulfate	mg/L	12	31	2.0	7.1	±19
Phosphorus (as PO_4)	mg/L	12	0.16	0.01	0.04	±0.08
Aluminum	mg/L	4	1.9	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.23	<0.01	0.04	±0.14
Calcium	mg/L	4	2.6	1.1	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.70	0.49	-	-
Manganese	mg/L	4	0.40	<0.01	-	-
Mercury	mg/L	4	0.83	<0.20	-	-
Nickel	µg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	18	8.0	-	-
Iron	mg/L	4	1.5	0.24	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
Steel Creek at Road A DHEC[a]						
Water volume	L		2.177+11 (total)			
Temperature[b]	°C	12	28	11	20	±12
pH[b]	pH	12	7.6	5.6	-	-
Dissolved oxygen[b]	mg/L	12	10	5.0	7.2	±3.3
Alkalinity	mg/L	12	21	6.0	17	±7.8
Hardness	mg/L	4	12	11	-	-
Conductivity[b]	µmho/cm	12	92	10	53	±76
Total organic carbon	mg/L	12	13	2.1	5.0	±5.4
Turbidity[b]	NTU	12	4.1	<1	1.8	±2.2
Suspended solids	mg/L	12	14	3.0	6.8	±5.9
Volatile solids	mg/L	12	5.0	<1	2.8	±2.7

[a] Metals are analyzed quarterly from a continuous flow composite.
[b] Field measurement.
- Insufficient data.

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Steel Creek at Road A DHEC, Contd[a]						
Total dissolved solids	mg/L	12	152	14	55	±66
Total solids	mg/L	12	166	25	62	±77
Fixed residue	mg/L	12	9.0	2.0	4.4	±3.9
COD	mg/L	12	13	5.0	8.6	±4.9
Organic nitrogen	mg/L	12	0.44	<0.1	0.34	±0.38
Chloride	mg/L	12	7.9	1.9	6.7	±3.4
Nitrogen (NO_2/NO_3)	mg/L	12	0.26	0.04	0.11	±0.15
Sulfate	mg/L	12	7.0	2.0	4.9	±3.9
Phosphorus (as PO_4)	mg/L	12	0.10	0.02	0.04	±0.04
Aluminum	mg/L	4	<0.05	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.30	0.0	0.08	±0.17
Calcium	mg/L	4	3.0	2.3	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.3	1.1	-	-
Manganese	mg/L	4	0.17	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	1.3	9.1	-	-
Iron	mg/L	4	0.19	0.03	-	-
Lead	mg/L	4	0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
Upper Three Runs Creek at Road A DHEC[a]						
Water Volume	L		1.535E+11 (total)			
Temperature[b]	°C	12	23	7.3	17	±9.3
pH[b]	pH	12	7.3	4.7	-	-
Dissolved oxygen[b]	mg/L	12	12	4.9	7.7	±4.1
Alkalinity	mg/L	12	19	4.0	7.3	±9.0
Hardness	mg/L	4	6.4	5.8	-	-
Conductivity[b]	µmho/cm	12	31	11	23	±12
Total organic carbon	mg/L	12	7.2	1.3	3.8	±4.1
Turbidity	NTU	12	20	1.0	4.7	±12
Suspended solids	mg/L	12	97	5.0	22	±51
Volatile solids	mg/L	12	33	3.0	8.4	±17
Total dissolved solids	mg/L	12	42	15	27	±14
Total solids	mg/L	12	123	21	38	±45
Fixed residue	mg/L	12	64	3.0	14	±34
COD	mg/L	12	23	1.0	9.1	±15
Organic nitrogen	mg/L	12	0.52	<0.10	0.22	±0.26
Chloride	mg/L	12	8.8	0.77	2.3	±4.1
Nitrogen (NO_2/NO_3)	mg/L	12	0.71	0.08	0.19	±0.34
Sulfate	mg/L	12	5.0	2.0	2.9	±2.2
Phosphorus (as PO_4)	mg/L	12	0.04	<0.02	0.03	<0.02
Aluminum	mg/L	4	0.11	<0.05	-	-
Nitrogen	mg/L	12	0.09	<0.01	0.02	±0.05
Calcium	mg/L	4	2.1	1.8	-	-

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	2 Std Dev
Upper Three Runs at Road A DHEC, Contd[a]						
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.40	0.36	-	-
Manganese	mg/L	4	<0.01	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	2.2	1.6	-	-
Iron	mg/L	4	0.23	0.09	-	-
Lead	mg/L	4	0.02	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
Four Mile Creek at Road A-7 DHEC[a]						
Water volume	L		9.95E+09 (total)			
Temperature[b]	°C	12	26	7.0	18	±11
pH[b]	pH	12	7.3	5.4	-	-
Dissolved oxygen[b]	mg/L	12	11	5.5	7.4	±3.9
Alkalinity	mg/L	12	21	6.0	14	±9.2
Hardness	mg/L	4	12	2.0	-	-
Conductivity[b]	µmho/cm	12	107	12	53	±79
Total organic carbon	mg/L	12	7.1	0.60	3.0	±3.6
Turbidity	NTU	12	42	1.0	7.7	±23
Suspended solids	mg/L	12	27	1.0	8.1	±18
Volatile solids	mg/L	12	9.0	<1	3.2	±5.0
Total dissolved solids	mg/L	12	78	48	59	±18
Total solids	mg/L	12	105	49	67	±33
Fixed residue	mg/L	12	18	<1.0	5.4	±14
COD	mg/L	12	10	1.0	5.6	±6.3
Organic nitrogen	mg/L	12	0.60	<0.10	0.24	±0.39
Chloride	mg/L	12	8.7	1.6	5.2	±13
Nitrogen (NO_2/NO_3)	mg/L	12	4.5	0.47	2.6	±1.9
Sulfate	mg/L	12	10	4.0	6.8	±3.7
Phosphorus (as PO_4)	mg/L	12	0.03	<0.02	0.02	±0.01
Aluminum	mg/L	4	0.17	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.05	<0.01	0.02	0.03
Calcium	mg/L	4	3.6	3.3	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.78	0.65	-	-
Manganese	mg/L	4	0.03	<0.01	-	-
Mercury	µg/L	4	0.22	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	15	8.9	-	-
Iron	mg/L	4	0.45	0.16	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
Crouch Branch						
Water column	L		9.71E+10 (total)			
Temperature[a]	°C	12	25	9.0	18	±10
pH[a]	pH	12	7.7	4.5	-	-
Dissolved oxygen[a]	mg/L	12	10	3.6	7.4	±3.3
Turbidity	NTU	12	200	7.0	62	±119
Suspended solids	mg/L	12	611	3.0	103	±339

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	2 Std Dev
Lower Three Runs at Patterson Mill[b]						
Water volume	L		5.730E+10 (total)			
Temperature[b]	°C	12	29	10	19	±11
pH[b]	pH	12	7.5	6.3	-	-
Dissolved oxygen[b]	mg/L	12	9.8	5.8	7.8	±2.4
Alkalinity	mg/L	12	60	26	36	±23
Hardness	mg/L	4	47	27	-	-
Conductivity[b]	µmho/cm	12	140	13	59	±101
Turbidity	NTU	12	4.8	<1	1.4	±2.2
Suspended solids	mg/L	12	34	2.0	7.4	±17
Volatile solids	mg/L	12	14	0.0	3.8	±7.0
Total dissolved solids	mg/L	12	83	45	63	±28
Total solids	mg/L	12	112	48	71	±39
Fixed residue	mg/L	12	20	<1	3.7	±11
COD	mg/L	12	25	3.0	12	±14
Chloride	mg/L	12	6.2	1.5	4.2	±2.7
Nitrogen (NO_2/NO_3)	mg/L	12	1.1	0.04	0.15	±0.60
Sulfate	mg/L	12	5.0	2.0	3.3	±2.0
Phosphorus (as PO_4)	mg/L	12	0.03	0.0	0.02	±0.02
Aluminum	mg/L	4	0.16	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.05	<0.01	0.02	0.03
Calcium	mg/L	4	17	9.6	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.0	0.85	-	-
Manganese	mg/L	4	0.07	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	7.1	4.9	-	-
Iron	mg/L	4	0.52	<0.02	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-
McQueen Branch						
Water volume	L		2.410E+11 (total)			
Temperature[a]	°C	12	26	9.0	17	±10
pH[a]	pH	12	7.2	5.6	-	-
Dissolved oxygen[a]	mg/L	12	10	5.2	8.2	±2.7
Turbidity	NTU	12	200	2.2	36	±115
Suspended solids	mg/L	12	1555	2.0	175	±905
Pen Branch at Road A-17[b]						
Water volume	L		1.480E+11 (total)			
Temperature[b]	°C	12	56	9.0	26	±24
pH[b]	pH	12	7.9	5.7	-	-
Dissolved oxygen[b]	mg/L	12	10	5.5	7.9	±2.9
Alkalinity	mg/L	12	24	18	20	±3.9
Hardness	mg/L	4	18	14	-	-
Conductivity[b]	µmho/cm	12	115	13	57	±89
Turbidity	NTU	12	7.1	1.1	3.3	±3.7
Suspended solids	mg/L	12	13	3.0	6.7	±5.7
Volatile solids	mg/L	12	5.0	0.0	2.2	±2.6
Total dissolved solids	mg/L	12	72	32	59	±21
Total solids	mg/L	12	78	41	66	±20
Fixed residue	mg/L	12	10	2.0	4.6	±4.8

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Pen Branch at Road A-17[b], Contd						
COD	mg/L	12	20	4.0	9.4	±7.9
Chloride	mg/L	12	11	4.3	7.8	±3.9
Nitrogen (NO_2/NO_3)	mg/L	12	0.85	0.18	0.32	±0.35
Sulfate	mg/L	12	11	3.0	6.6	±4.2
Phosphorus (as PO_4)	mg/L	12	0.24	0.0	0.08	±0.12
Aluminum	mg/L	4	0.20	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.11	<0.01	0.04	0.07
Calcium	mg/L	4	5.1	3.8	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	1.2	1.2	-	-
Manganese	mg/L	4	0.05	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	14	10	-	-
Iron	mg/L	4	0.53	0.03	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	0.03	<0.01	-	-
Four Mile Creek at Road A[a]						
Water volume	L		1.796E+10 (total)			
Temperature[b]	°C	12	31	9.0	20	±13
pH[b]	pH	12	7.7	3.1	-	-
Dissolved oxygen[b]	mg/L	12	10	6.5	8.6	±2.0
Alkalinity	mg/L	12	17	2.0	12	±8.1
Hardness	mg/L	4	12	10	-	-
Conductivity[b]	µmho/cm	12	84	15	42	±53
Turbidity	NTU	12	18	<1	2.8	±9.7
Suspended solids	mg/L	12	7.0	0.0	2.6	±4.5
Volatile solids	mg/L	12	5.0	0.0	1.5	±3.0
Total dissolved solids	mg/L	12	55	34	45	±15
Total solids	mg/L	12	62	34	47	±17
Fixed residue	mg/L	12	6.0	0.0	1.5	±3.3
COD	mg/L	12	16	1.0	6.6	±8.6
Chloride	mg/L	12	3.7	2.1	3.0	±1.0
Nitrogen (NO_2/NO_3)	mg/L	12	2.7	0.18	1.3	±0.72
Sulfate	mg/L	12	8.0	4.0	6.3	±7.9
Phosphorus (as PO_4)	mg/L	12	0.03	<0.02	0.02	±0.01
Aluminum	mg/L	4	<0.05	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.06	0.0	0.02	0.04
Calcium	mg/L	4	3.6	3.1	-	-
Copper	mg/L	4	0.02	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.66	0.58	-	-
Manganese	mg/L	4	0.01	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.05	<0.05	-	-
Sodium	mg/L	4	10	7.5	-	-
Iron	mg/L	4	0.11	0.05	-	-
Lead	mg/L	4	<0.01	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	0.02	<0.01	-	-

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Parameter	Units	No. of Analyses	Maximum	Minimum	Arithmetic Mean	Arithmetic 2 Std Dev
Upper Three Runs at Highway 278[a]						
Water volume	L		7.941E+10 (total)			
Temperature[b]	°C	12	24	12	18	±8.0
pH[b]	pH	12	7.2	3.1	-	-
Dissolved oxygen[b]	mg/L	12	9.4	6.6	8.1	±1.7
Alkalinity	mg/L	12	4.0	2.0	2.6	±1.6
Hardness	mg/L	4	2.7	2.2	-	-
Conductivity[b]	µmho/cm	12	42	16	21	±14
Turbidity	NTU	12	6.1	<1	1.6	±3.2
Suspended solids	mg/L	12	19	2.0	6.2	±10
Volatile solids	mg/L	12	9.0	2.0	3.9	±4.4
Total dissolved solids	mg/L	12	114	6.0	26	±57
Total solids	mg/L	12	119	10	33	±59
Fixed residue	mg/L	12	10	0.0	3.0	±6.1
COD	mg/L	12	19	1.0	6.2	±12
Chloride	mg/L	12	2.7	0.05	1.5	±1.4
Nitrogen (NO_2/NO_3)	mg/L	12	1.1	0.15	0.28	±0.52
Sulfate	mg/L	12	3.0	<1.0	1.9	±1.1
Phosphorus (as PO_4)	mg/L	12	0.03	<0.01	0.01	±0.01
Aluminum	mg/L	4	0.07	<0.05	-	-
Nitrogen (as NH_3)	mg/L	12	0.03	0.0	0.01	0.02
Calcium	mg/L	4	0.48	0.37	-	-
Copper	mg/L	4	<0.01	<0.01	-	-
Cadmium	mg/L	4	<0.01	<0.01	-	-
Magnesium	mg/L	4	0.37	0.29	-	-
Manganese	mg/L	4	<0.01	<0.01	-	-
Mercury	µg/L	4	<0.20	<0.20	-	-
Nickel	mg/L	4	<0.20	<0.05	-	-
Sodium	mg/L	4	1.5	1.0	-	-
Iron	mg/L	4	0.37	0.05	-	-
Lead	mg/L	4	0.02	<0.01	-	-
Chromium	mg/L	4	<0.02	<0.02	-	-
Zinc	mg/L	4	<0.01	<0.01	-	-

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Beaver Dam Creek Water Quality Data Summary

Quarter 1, January 1 - March 31, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	82	56	88
pH	pH	6.9	6.1	-
Dissolved oxygen	mg/L	11	5.0	8.4
Conductivity	µmhos/cm	141	75	106
Oxidation/reduction potential	mV	317	272	304

Quarter 2, April 1 - June 30, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	90	58	79
pH	pH	8.0	5.8	-
Dissolved oxygen	mg/L	9.3	5.4	7.2
Conductivity	µmhos/cm	176	88	120
Oxidation/reduction potential	mV	322	252	309

Quarter 3, July 1 - September 30, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	89	71	81
pH	pH	8.4	5.4	-
Dissolved oxygen	mg/L	9.3	5.1	6.5
Conductivity	µmhos/cm	153	79	119
Oxidation/reduction potential	mV	330	260	303

Quarter 4, October 1 - December 31, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	85	51	64
pH	pH	8.1	5.7	-
Dissolved oxygen	mg/L	13	2.6	9.3
Conductivity	µmhos/cm	239	76	136
Oxidation/reduction potential	mV	305	262	281

TABLE A-13

SRS Stream Water Quality, 1988, Contd

Steel Creek Water Quality Data Summary

Quarter 1, January 1 - March 31, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	70	53	59
Dissolved oxygen	mg/L	10.5	7.5	8.9

Quarter 2, April 1 - June 30, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	82	64	73
Dissolved oxygen	mg/L	8.6	5.0	6.5

Quarter 3, July 1 - September 30, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	81	75	78
Dissolved oxygen	mg/L	7.2	5.0	5.8

Quarter 4, October 1 - December 31, 1988

Parameter	Units	Hourly Maximum	Hourly Minimum	Hourly Average
Temperature	°F	76	54	62
Dissolved oxygen	mg/L	10	6.3	8.4

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TABLE A-14

Radioactivity in Onsite Stream Waters, 1978-1984[a]

Parameter	Upper Three Runs Creek at SRS Road A[b]	Beaver Dam Creek at 400-D Area Effluent[c]	Four Mile Creek at SRS Road A-7[d]	Four Mile Creek at SRS Road A[e]	Pen Branch at SRS Road A[f]	Steel Creek at Hattiesville Bridge[g]	Lower Three Runs Runs Creek at Pattersons Mill[h]
Gross alpha	0.760 (361) -0.11 - 4.50	0.410 (365) -0.13 - 1.80	0.940 (359) -0.07 - 6.10	0.220 (361) -0.26 - 3.90	0.120 (361) -0.33 - 1.46	0.120 (360) -0.27 - 0.86	0.170 (346) -0.26 - 1.2
Nonvolatile beta	1.90 (362) -6.90 - 14.0	2.74 (363) -5.50 - 27.0	69.4 (361) 9.90 - 190	5.50 (359) -7.30 - 35.0	1.62 (359) -5.0 - 17.0	5.11 (358) -2.2 - 18.0	3.24 (351) -5.3 - 15.0
Tritium	2.89 (361) -0.7 - 11.0	48.3 (358) -0.08 - 1300	746 (355) 200 - 1700	88.4 (361) 19 - 2100	34.7 (361) 8.5 - 260	28.8 (361) 2.6 - 670	9.06 (347) -0.73 - 25.0
$^{89,90}Sr$	NA	NA	29.2 (244) 3.4 - 48.0	1.99 (247) -9.5 - 21.0	5.59 (249) -14.0 - 23.0	0.70 (251) -13.0 - 11.0	1.95 (243) -16.0 - 17.0
^{90}Sr	NA	NA	NA	2.56 (75) -2.9 - 8.5	0.53 (74) -2.7 - 6.8	0.68 (75) -1.4 - 2.7	0.92 (75) -1.4 - 9.4
Chemical cesium	1.06 (241) -8.30 - 16.0	NA	12.8 (243) -0.96 - 60	1.65 (245) -8.9 - 16.0	0.92 (249) -6.5 - 8.0	5.57 (270) -6.1 - 26.0	3.54 (243) -6.4 - 40.0
U/Pu	0.180 (353) -0.51 - 2.70	NA	NA	0.13 (350) -0.38 - 1.6	0.17 (345) -0.44 - 2.7	0.11 (353) -0.51 - 2.6	0.12 (319) -0.44 - 3.0

a All values represent mean pCi/L concentrations (except tritium pCi/mL), with the number of analyses conducted during 1978-1984 in parentheses. Range of minimum and maximum values during 1978-1984 indicated below the mean value.
b Health Protection Department Station U3R-4
c Health Protection Department Station 400-D effluent
d Health Protection Department Station FM-A7
e Health Protection Department Station FM-6
f Health Protection Department Station PB-3
g Health Protection Department Station SC-5
h Health Protection Department Station L3R-2

NA = no analysis conducted

Source: Lower (1987)

TABLE A-14

Radioactivity in Onsite Stream Waters, 1978-1984, Contd

Parameter	Upper Three Runs Creek at SRS Road A[b]	Beaver Dam Creek at 400-D Area Effluent[c]	Four Mile Creek at SRS Road A-7[d]	Four Mile Creek at SRS Road A[e]	Pen Branch at SRS Road A[f]	Steel Creek at Hattiesville Bridge[g]	Lower Three Runs Runs Creek at Pattersons Mill[h]
^{35}S	NA	NA	NA	0.95 (78) -33 - 7.2	0.99 (79) -8.5 - 5.1	1.1 (79) -18.0 - 5.6	0.76 (78) -4.8 - 8.1
^{51}Cr	NA	NA	NA	5.01 (84) 0.0 - 75.0	5.10 (84) 0.0 - 65.0	3.85 (84) 0.0 - 39.0	6.98 (33) 0.0 - 59.0
^{56}Mn	NA	NA	NA	0.29 (84) 0.0 - 6.0	0.28 (84) 0.0 - 4.2	0.20 (84) 0.0 - 2.4	0.20 (83) 0.0 - 6.2
^{60}Co	NA	NA	NA	2.94 (84) 0.0 - 66.0	2.29 (84) 0.0 - 18.0	1.10 (84) 0.0 - 15.0	1.48 (83) 0.0 - 35.0
^{65}Zn	NA	NA	NA	0.97 (84) 0.0 - 6.5	1.40 (84) 0.0 - 18.0	1.55 (84) 0.0 - 18.0	0.90 (83) 0.0 - 6.6
$^{95}Zr-^{95}Nb$	NA	NA	NA	0.59 (84) 0.0 - 10.0	0.34 (84) 0.0 - 5.6	0.24 (84) 0.0 - 2.5	0.40 (83) 0.0 - 3.7
$^{103,106}Ru$	NA	NA	NA	9.39 (84) 0.0 - 210	7.06 (84) 0.0 - 150	4.50 (84) 0.0 - 150	7.47 (83) 0.0 - 200
^{131}I	NA	NA	NA	6.73 (72) 0.0 - 230	8.21 (72) 0.0 - 120	8.23 (72) 0.0 - 170	8.85 (72) 0.0 - 280
^{134}Cs	NA	NA	NA	0.94 (60) 0.0 - 6.1	1.40 (60) 0.0 - 7.6	1.29 (60) 0.0 - 8.9	1.41 (59) 0.0 - 24.0
^{137}Cs	NA	NA	NA	0.72 (60) 0.0 - 3.9	0.58 (60) 0.0 - 4.3	2.90 (60) 0.02 - 12.0	1.54 (59) 0.0 - 9.6
$^{141,144}Cs$	NA	NA	NA	1.52 (84) 0.0 - 15.0	2.16 (83) 0.0 - 24.0	1.42 (84) 0.0 - 12.0	1.37 (83) 0.0 - 18.0

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TABLE A-15

Summary of Detection Limits for Pesticides, Herbicides, and PCBs, 1982-1985, µg/L

Material	1982-1984	1985
Aldrin	0.005	0.009
α - BHC	0.005	0.009
β - BHC	0.005	0.014
γ - BHC (lindane)	0.005	0.009
δ - BHC	0.005	0.01
Chlordane	0.08	0.11
4,4' - DDT	0.05	0.03
4,4' - DDE	0.05	0.01
4,4' - DDD	0.05	0.01
Dieldrin	0.005	0.009
α - endosulfan	0.05	0.007
β - endosulfan	0.05	0.008
Endosulfan sulfate	0.2	0.01
Endrin	0.01	0.01
Endrin aldehyde	0.05	0.02
Heptachlor	0.005	0.008
Heptachlor epoxide	0.005	0.008
PCB	5.0	0.17 to 0.34
PCN	0.5	0.13
Toxaphene	1.0	1.6
Methoxychlor	0.1	0.03
Mirex	0.05	0.05
Diazinon	0.1	0.05
M. parathion	0.05	0.01
Parathion	0.05	0.02
Perthane	1.0	0.36
Ethian	0.05	0.02
Trithian	0.05	0.009
Malathion	0.5	0.04
2,4-D	0.05	0.027
Silvex	0.05	0.007
2,4,5-T	0.1	0.007
2,4-DB	1.0	0.046

Source: Lower (1987)

TABLE A-16

Results of Pesticide and Herbicide Analyses of Onsite Stream and Savannah River Water Samples, 1982-1985 (mg/L). Parameters from Table A-15 not listed here were not detected.

	1982	1983	1984	1985
Savannah River upriver of SRS near Jackson, SC (nonthermal)				
γ - BHC	0.020	<0.005	<0.005	ND
α - BHC	0.014	<0.005	<0.005	ND
β - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.005	<0.005	<0.005	ND
2,4-D	<0.05	0.138	<0.05	ND
M. parathion	<0.05	0.100	<0.05	ND
Heptachlor epoxide	<0.005	<0.005	<0.005	ND
Savannah River downriver of SRS at US Highway 301 (nonthermal)				
γ - BHC	<0.005	0.008	<0.005	ND
α - BHC	0.022	<0.005	<0.005	ND
β - BHC	0.059	<0.005	<0.005	ND
Aldrin	0.018	0.005	<0.005	ND
2,4-D	<0.05	<0.05	<0.05	ND
M. parathion	<0.05	0.12	<0.05	ND
Heptachlor epoxide	<0.005	0.006	<0.005	ND
Upper Three Runs Creek at SRS Road F (nonthermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.005	<0.005	<0.005	ND
M. parathion	<0.05	0.180	<0.05	ND
Upper Three Runs Creek at SRS Road A (nonthermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.005	<0.005	<0.005	ND
M. parathion	<0.05	0.07	<0.05	ND
Four Mile Creek at SRS Road A (thermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	0.005	<0.005	<0.005	ND
M. parathion	<0.05	0.09	<0.05	ND
Silvex	<0.05	<0.05	<0.05	ND
Parathion	<0.05	<0.05	<0.05	ND

TABLE A-16, Contd

	1982	1983	1984	1985
Pen Branch at SRS Road A (thermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.005	<0.005	<0.005	ND
M. parathion	<0.05	0.09	<0.05	ND
Silvex	<0.05	0.09	<0.05	ND
Parathion	<0.05	0.09	<0.05	ND
Steel Creek at SRS Road A (post-thermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.003	ND	ND	ND
Heptachlor	<0.005	<0.005	<0.005	ND
M. parathion	<0.05	<0.09	<0.05	ND
Par Pond at Pumphouse (nonthermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.003	ND	ND	ND
Heptachlor	<0.005	<0.005	<0.005	ND
M. parathion	<0.05	0.11	<0.05	ND
Lower Three Runs Creek at SRS Road A (post-thermal)				
γ - BHC	<0.005	<0.005	<0.005	ND
Aldrin	<0.005	<0.005	<0.005	ND
M. parathion	<0.10	3.0	<0.10	ND

ND = not detected

Source: Lower (1987)

TABLE A-17

Pesticides, Herbicides, and PCB's in Stream and River Water, 1987 (μg/L)[a,b]

	River 2 Above Plant			River 10 Below Plant			Upper Three Runs at Road F		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
Aldrin	<0.009	<0.006	<0.02	<0.009	<0.006	<0.02	<0.009	<0.006	<0.02
αBHC	<0.009	<0.004	<0.01	<0.009	<0.004	<0.01		0.004	<0.01
βBHC	<0.014	<0.007	<0.01	<0.014	<0.007	<0.01			<0.01
γBHC	<0.009	<0.003	<0.01	<0.009	<0.003	<0.01	<0.009	<0.004	<0.01
σBHC			<0.02			<0.02			<0.02
Chlordane			<2.60			<2.60			<2.60
4,4-DDT			<0.12			<0.12			<0.12
4,4-DDE			<0.04			<0.04			<0.04
4,4-DDD			<0.08			<0.08			<0.08
Dieldrin			<0.04			<0.04			<0.04
α-Endosulfan			<0.04			0.21			<0.04
β-Endosulfan			<0.06			<0.06			<0.06
Endosulfan sulfate			<0.11			<0.11			<0.11
Endrin			<0.07			<0.07			<0.07
Endrin aldehyde			<0.13			<0.13			<0.13
Heptachlor			<0.02			<0.02			<0.02
Heptachlor epoxide	<0.008	<0.007	<0.03	<0.008	<0.007	<0.03			<0.03
PCB 1242			<0.92			<0.92			<0.92
PCB 1254			<0.68			<0.68			<0.68
PCB 1221			<0.61			<0.61			<0.61
PCB 1232			<0.81			<0.81			<0.81
PCB 1248			<0.45			<0.45			<0.45
PCB 1260			<1.04			<1.04			<1.04
PCB 1016			<0.98			<0.98			<0.98
Toxaphene			<1.76			<1.76			<1.76
2,4-D	<0.027	<0.26	<0.12	<0.027	<0.26	<0.12			<0.12
Silvex			<0.03			<0.03			<0.03
2,4,5-T			<0.04			<0.04			<0.04
2,4-DB			<0.78			<0.78			<0.78
2,4-DP			<0.58			<0.58			<0.58
Dicamba			0.87			0.56			<0.87
MCPP			<0.18			<0.18			<0.18

[a] Less than values represent the detection limit of the analysis.

[b] For 1981-1984 data, refer to SRS Environmental Report for 1986, Volume II (DPSPU-87-30-1), Table 4-2.

Blank space indicates either no analysis or not detected.

Source: Mikol et al. (1988)

TABLE A-17

Pesticides, Herbicides, and PCB's in Stream and River Water, 1987 (μg/L)[a,b], Contd

	Upper Three Runs Creek at Road A			Four Mile Creek at Road A			Pen Branch at Road A		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
Aldrin	<0.009	<0.006	<0.02	<0.009	<0.006	<0.02	<0.009	<0.006	<0.02
αBHC			<0.01			<0.01			<0.01
βBHC			<0.01			<0.01			<0.01
γBHC	<0.009	<0.003	<0.01	<0.009	<0.003	<0.01	<0.009	<0.004	<0.01
σBHC			<0.02			<0.02			<0.02
Chlordane			<2.60			<2.60			<2.60
4,4-DDT			<0.12			<0.12			<0.12
4,4-DDE			<0.04			<0.04			<0.04
4,4-DDD			<0.08			<0.08			<0.08
Dieldrin			<0.04			<0.04			<0.04
α-Endosulfan			<0.04			<0.04			<0.04
β-Endosulfan			<0.06			<0.06			<0.06
Endosulfan sulfate			<0.11			<0.11			<0.11
Endrin			<0.07			<0.07			<0.07
Endrin aldehyde			<0.13			<0.13			<0.13
Heptachlor			<0.02			<0.03			<0.02
Heptachlor epoxide			<0.03			<0.03			<0.03
PCB 1242			<0.92			<0.92			<0.92
PCB 1254			<0.68			<0.68			<0.68
PCB 1221			<0.61			<0.61			<0.61
PCB 1232			<0.81			<0.81			<0.81
PCB 1248			<0.45			<0.45			<0.45
PCB 1260			<1.04			<1.04			<1.04
PCB 1016			<0.98			<0.98			<0.98
Toxaphene			<1.76			<1.76			<1.76
2,4-D			<0.12			<0.12			<0.12
Silvex			<0.03	<0.007	<0.07	<0.03	<0.007	<0.07	<0.03
2,4,5-T			<0.04			<0.04			<0.04
2,4-DB			<0.78			<0.78			<0.78
2,4-DP			<0.58			<0.58			<0.58
Dicamba			0.38			2.02			0.56
MCPP			<0.18			<0.18			<0.18

[a] Less than values represent the detection limit of the analysis.

[b] For 1981-1984 data, refer to SRP Environmental Report for 1986, Volume II (DPSPU-87-30-1), Table 4-2.

Blank space indicates no analysis or not detected.

TABLE A-17

Pesticides, Herbicides, and PCB's in Stream and River Water, 1987 (μg/L)[a,b], Contd

	Steel Creek at Road A			Par Pond Pumphouse			Lower Three Runs at Road A		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
Aldrin			<0.02			<0.02			<0.02
αBHC			<0.01			<0.01			<0.01
βBHC			<0.01			<0.01			<0.01
γBHC	<0.009	<0.003	<0.01	<0.009	<0.003	<0.01	<0.009	<0.004	<0.01
σBHC			<0.02			<0.02			<0.02
Chlordane			<2.60			<2.60			<2.60
4,4-DDT			<0.12			<0.12			<0.12
4,4-DDE			<0.04			<0.04			<0.04
4,4-DDD			<0.08			<0.08			<0.08
Dieldrin			<0.04			<0.04			<0.04
α-Endosulfan			<0.04			<0.04			<0.04
β-Endosulfan			<0.06			<0.06			<0.06
Endosulfan sulfate			<0.11			<0.11			<0.11
Endrin			<0.07			<0.07			<0.07
Endrin aldehyde			<0.13			<0.13			<0.13
Heptachlor	<0.008	<0.005	<0.02	<0.008	<0.005	<0.02	<0.008	<0.005	<0.02
Heptachlor epoxide			<0.03			<0.03			<0.03
PCB 1242			<0.92			<0.92			<0.92
PCB 1254			<0.68			<0.68			<0.68
PCB 1221			<0.61			<0.61			<0.61
PCB 1232			<0.81			<0.81			<0.81
PCB 1248			<0.45			<0.45			<0.45
PCB 1260			<1.04			<1.04			<1.04
PCB 1016			<0.98			<0.98			<0.98
Toxaphene			<1.76			<1.76			<1.76
2,4-D			<0.12			<0.12			<0.12
Silvex			<0.03			<0.03			<0.03
2,4,5-T			<0.04			<0.04	<0.007	<0.12	<0.04
2,4-DB			<0.78			<0.78			<0.78
2,4-DP			<0.58			<0.58			<0.58
Dicamba			<0.02			<0.87			0.56
MCPP			<0.18			<0.18			<0.18

[a] Less than values represent the detection limit of the analysis.

[b] For 1981-1984 data, refer to SRP Environmental Report for 1986, Volume II (DPSPU-87-30-1), Table 4-2.

Blank space indicates no analysis or not detected.

TABLE A-18

Pesticides, Herbicides, and PCB's in Stream and River Water, 1988

Constituents (μg/L)[a]	River 2 Above SRS[b]	River 10 Below SRS[b]	Upper Three Runs at Road F[b]
Aldrin	<0.05	<0.05	<0.05
αBHC	<0.05	<0.05	<0.05
βBHC	<0.05	<0.05	<0.05
ΔBHC	<0.05	<0.05	<0.05
γBHC	<0.05	<0.05	<0.05
α-Chlordane	<0.05	<0.05	<0.05
γ-Chlordane	<0.05	<0.05	<0.05
Tech. chlordane	<0.25	<0.25	<0.25
4,4-DDD	<0.05	<0.05	<0.05
4,4-DDE	<0.05	<0.05	<0.05
4,4-DDT	<0.05	<0.05	<0.05
Dieldrin	<0.05	<0.05	<0.05
Endosulfan I	<0.05	<0.05	<0.05
Endosulfan II	<0.05	<0.05	<0.05
Endosulfan sulfate	<0.05	<0.05	<0.05
Endrin	<0.05	<0.05	<0.05
Endrin aldehyde	<0.05	<0.05	<0.05
Hepatachlor	<0.05	<0.05	<0.05
Hepatachlor epoxide	<0.05	<0.05	<0.05
Methoxychlor	<0.20	<0.20	<0.20
Toxaphene	<2.50	<2.50	<2.50
PCB 1016	<0.50	<0.50	<0.50
PCB 1221	<0.50	<0.50	<0.50
PCB 1232	<0.50	<0.50	<0.50
PCB 1242	<0.50	<0.50	<0.50
PCB 1248	<0.50	<0.50	<0.50
PCB 1254	<0.50	<0.50	<0.50
PCB 1260	<0.50	<0.50	<0.50
2,4-D	<0.20	<0.20	<0.20
2,4,5-TP (silvex)	<0.05	<0.05	<0.05

[a] Results reported by subcontracted offsite laboratory ECS/Normandeau Assoc.

[b] Samples collected July 22, 1988.

Source: Davis et al. (1989)

TABLE A-18

Pesticides, Herbicides, and PCB's in Stream and River Water, 1988, Contd

Constituents (µg/L)[a]	Steel Creek at Road A[b]	Par Pond Pumphouse[b]	Lower Three Runs at Road F[b]
Aldrin	<0.05	<0.05	<0.05
αBHC	<0.05	<0.05	<0.05
βBHC	<0.05	<0.05	<0.05
ΔBHC	<0.05	<0.05	<0.05
γBHC	<0.05	<0.05	<0.05
α-Chlordane	<0.05	<0.05	<0.05
γ-Chlordane	<0.05	<0.05	<0.05
Tech. chlordane	<0.25	<0.02	<0.05
4,4-DDD	<0.05	<0.05	<0.05
4,4-DDE	<0.05	<0.05	<0.05
4,4-DDT	<0.05	<0.05	<0.05
Dieldrin	<0.05	<0.05	<0.05
Endosulfan I	<0.05	<0.05	<0.05
Endosulfan II	<0.05	<0.05	<0.05
Endosulfan sulfate	<0.05	<0.05	<0.05
Endrin	<0.05	<0.05	<0.05
Endrin aldehyde	<0.05	<0.05	<0.05
Hepatachlor	<0.05	<0.05	<0.05
Hepatachlor epoxide	<0.05	<0.05	<0.05
Methoxychlor	<0.20	<0.20	<0.20
Toxaphene	<2.50	<2.50	<2.50
PCB 1016	<0.50	<0.50	<0.50
PCB 1221	<0.50	<0.50	<0.50
PCB 1232	<0.50	<0.50	<0.50
PCB 1242	<0.50	<0.50	<0.50
PCB 1248	<0.50	<0.50	<0.50
PCB 1254	<0.50	<0.50	<0.50
PCB 1260	<0.50	<0.50	<0.50
2,4-D	<0.20	<0.20	<0.20
2,4,5-TP (silvex)	<0.05	<0.05	<0.05

TABLE A-18

Pesticides, Herbicides, and PCB's in Stream and River Water, 1988, Contd

Constituents (µg/L)[a]	Upper Three Runs at Road A[b]	Four Mile Creek at Road A[b]	Pen Branch at Road F[b]
Aldrin	<0.05	<0.05	<0.05
αBHC	<0.05	<0.05	<0.05
βBHC	<0.05	<0.05	<0.05
ΔBHC	<0.05	<0.05	<0.05
γBHC	<0.05	<0.05	<0.05
α-Chlordane	<0.05	<0.05	<0.05
γ-Chlordane	<0.05	<0.05	<0.05
Tech. chlordane	<0.25	<0.02	<0.05
4,4-DDD	<0.05	<0.05	<0.05
4,4-DDE	<0.05	<0.05	<0.05
4,4-DDT	<0.05	<0.05	<0.05
Dieldrin	<0.05	<0.05	<0.05
Endosulfan I	<0.05	<0.05	<0.05
Endosulfan II	<0.05	<0.05	<0.05
Endosulfan sulfate	<0.05	<0.05	<0.05
Endrin	<0.05	<0.05	<0.05
Endrin aldehyde	<0.05	<0.05	<0.05
Hepatachlor	<0.05	<0.05	<0.05
Hepatachlor epoxide	<0.05	<0.05	<0.05
Methoxychlor	<0.20	<0.20	<0.20
Toxaphene	<2.50	<2.50	<2.50
PCB 1016	<0.50	<0.50	<0.50
PCB 1221	<0.50	<0.50	<0.50
PCB 1232	<0.50	<0.50	<0.50
PCB 1242	<0.50	<0.50	<0.50
PCB 1248	<0.50	<0.50	<0.50
PCB 1254	<0.50	<0.50	<0.50
PCB 1260	<0.50	<0.50	<0.50
2,4-D	<0.20	<0.20	<0.20
2,4,5-TP (silvex)	<0.05	<0.05	<0.05

TABLE A-19

Pen Branch Creek - Field Data

Site[a]	Air Temp. (°C)	Water Temp. (°C)	Stream Maximum Depth (cm)	Stream Velocity (cm/sec)	pH
19					
$\bar{x}$	17.5	15.2	75	48	6.93
SD	7.9	6.2	46	35	0.73
Med	19.0	15.5	49	35	6.93
Range	-3.0 - 30.0	1.5 - 24.0	40 - 164	9 - 140	5.10 - 9.00
N	42	46	28	40	46
Skewness	-0.62	-0.36	1.12	1.21	0.26
18					
$\bar{x}$	23.7	42.6	119	124	7.42
SD	8.5	16.5	11	38	0.55
Med	25.3	50.9	124	140	7.55
Range	4.8 - 37.0	7.1 - 60.0	91 - 127	7 - 180	5.60 - 8.59
N	40	45	28	39	44
Skewness	-0.36	-1.01	-1.12	-1.30	-1.19
20					
$\bar{x}$	19.4	48.1	100	183	7.42
SD	8.2	21.4	25	52	0.46
Med	19.5	58.5	111	198	7.44
Range	2.0 - 30.1	7.6 - 68.0	31 - 143	45 - 260	5.90 - 8.70
N	42	46	34	40	46
Skewness	-0.57	-0.89	-1.39	-0.97	-0.16

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-20

Pen Branch Creek - Physical Characteristics and General Chemistry

Site[a]	Dissolved Oxygen (mg/L)	% Saturated Dissolved Oxygen	Specific Conductance (μmho/cm)	Turbidity (NTU)	Total Suspended Solids (mg/L)
19					
$\bar{x}$	8.12	79.2	45.6	10.6	9.63
SD	1.55	6.3	12.1	9.2	12.40
Med	7.85	79.7	46.4	7.2	6.00
Range	5.80 - 12.30	63.1 - 97.3	28.2 - 75.0	3.1 - 52.2	0.25 - 72.40
N	46	46	38	43	45
Skewness	0.67	-0.09	0.38	2.83	3.49
18					
$\bar{x}$	5.63	83.9	73.4	21.3	13.91
SD	2.25	9.4	13.2	12.1	21.47
Med	4.70	86.8	76.2	18.0	9.86
Range	3.30 - 11.10	64.9 - 108.9	48.9 - 91.4	3.0 - 55.0	1.60 - 145.50
N	45	45	37	42	43
Skewness	1.11	-0.14	0.50	1.02	5.74
20					
$\bar{x}$	5.32	88.1	74.6	21.4	10.00
SD	2.58	8.7	11.6	13.4	8.12
Med	4.00	89.7	76.0	16.0	7.60
Range	2.70 - 11.50	64.3 - 108.7	50.7 - 90.1	7.3 - 61.5	0.25 - 43.20
N	45	45	36	43	45
Skewness	1.14	-0.75	-0.53	1.28	2.35

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-21

Pen Branch Creek - Major Anions

Site[a]	Total Alkalinity (mg/L as $CaCO_3$)	Chloride (mg/L)	Sulfate (mg SO_4/L)
19			
$\bar{X}$	13.84	2.48	2.53
SD	6.25	0.32	2.21
Med	13.80	2.60	1.68
Range	2.85 - 30.64	1.90 - 3.20	0.25 - 7.67
N	45	45	28
Skewness	0.48	0.02	0.70
18			
$\bar{X}$	16.84	5.64	5.03
SD	3.67	1.44	2.14
Med	17.63	5.40	5.23
Range	7.40 - 22.01	2.90 - 8.10	0.25 - 9.94
N	44	45	26
Skewness	-0.65	-0.16	-0.11
20			
$\bar{X}$	17.81	5.86	5.21
SD	3.20	1.45	1.96
Med	18.91	5.75	5.19
Range	11.71 - 22.31	2.70 - 8.40	0.75 - 10.34
N	44	46	28
Skewness	-0.48	-0.28	0.37

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

W890070

TABLE A-22

Pen Branch Creek - Major Cations (Dissolved)

Site[a]	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Aluminum (mg/L)	Iron (mg/L)	Manganese (mg/L)
19							
$\bar{x}$	5.692	0.512	1.879	0.432	0.064	0.225	0.059
SD	1.971	0.053	0.282	0.303	0.103	0.149	0.024
Med	5.655	0.505	1.866	0.390	<0.038	0.211	0.062
Range	2.549 - 10.610	0.430 - 0.733	1.144 - 2.819	<0.368 - 1.330	<0.038 - 0.596	0.015 - 0.709	<0.0004 - 0.100
N	39	39	39	39	39	39	17
Skewness	0.43	1.97	0.73	1.30	4.03	1.14	-0.35
18							
$\bar{x}$	3.677	1.234	7.649	1.347	0.078	0.147	0.062
SD	1.638	0.140	2.170	0.525	0.093	0.102	0.041
Med	3.425	1.243	7.959	1.321	0.064	0.138	0.053
Range	2.928 - 13.400	0.764 - 1.538	2.370 - 11.390	0.444 - 3.792	<0.038 - 0.565	<0.003 - 0.500	<0.0004 - 0.181
N	38	38	38	38	38	38	16
Skewness	5.95	-1.03	-0.39	2.67	4.18	1.45	1.62
20							
$\bar{x}$	3.276	1.290	8.270	1.412	0.061	0.135	0.052
SD	0.259	0.088	1.766	0.396	0.035	0.072	0.027
Med	3.284	1.288	8.519	1.394	0.056	0.125	0.043
Range	2.655 - 3.879	1.152 - 1.571	4.992 - 11.800	0.629 - 2.758	<0.038 - 0.155	0.017 - 0.346	<0.0004 - 0.115
N	38	38	38	38	38	38	17
Skewness	-0.29	0.90	-0.10	0.81	0.76	0.67	0.85

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

TABLE A-23

Pen Branch - Major Cations (Total)

Site[a]	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Aluminum (mg/L)	Iron (mg/L)	Manganese (mg/L)
19							
$\bar{x}$	5.274	0.524	1.853	<0.368	0.709	1.226	0.097
SD	2.105	0.158	0.730	0.279	0.718	0.531	0.065
Med	5.318	0.515	1.688	<0.368	0.456	1.245	0.081
Range	0.011 - 10.100	0.001 - 1.290	1.014 - 5.797	<0.368 - 1.222	<0.038 - 3.676	<0.003 - 2.359	<0.0004 - 0.231
N	39	39	39	39	39	39	15
Skewness	0.16	2.16	4.38	1.70	2.79	-0.09	1.09
18							
$\bar{x}$	3.891	1.203	6.461	1.013	1.020	0.999	0.104
SD	1.905	0.194	2.187	0.563	0.724	0.457	0.087
Med	3.518	1.246	7.091	1.031	0.817	0.894	0.066
Range	2.802 - 13.080	0.485 - 1.449	1.473 - 10.450	<0.368 - 2.081	0.049 - 3.025	0.006 - 2.323	<0.0004 - 0.322
N	38	38	38	38	38	38	15
Skewness	4.07	-1.83	-0.57	-0.01	1.13	0.81	1.21
20							
$\bar{x}$	3.299	1.321	7.304	1.124	1.092	1.114	0.100
SD	0.356	0.073	1.662	0.461	0.745	0.670	0.083
Med	3.312	1.323	7.486	1.228	0.792	0.872	0.060
Range	2.671 - 4.373	1.160 - 1.452	3.993 - 10.540	<0.368 - 2.024	0.105 - 2.871	0.035 - 3.219	<0.0004 - 0.291
N	39	39	39	39	39	39	16
Skewness	0.62	-0.003	-0.17	-0.37	1.14	1.37	1.38

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-24

Pen Branch Creek - Nutrients

Site[a]	Total Phosphorus (mg P/L)	Total Orthophosphate (mg PO_4 - P/L)	Dissolved Orthophosphate (mg N/L)	Organic Nitrogen (mg N/L)	Total Kjeldahl Nitrogen (mg N/L)	Ammonia (mg NH_3 - N/L)	Nitrite (mg NO_2 - N/L)	Nitrate (mg NO_3 - N/L)
19								
$\bar{x}$	0.042	0.017	0.007	0.216	0.236	0.039	0.002	0.050
SD	0.031	0.012	0.004	0.195	0.197	0.100	0.002	0.032
Med	0.033	0.015	0.005	0.143	0.160	0.024	0.022	0.044
Range	<0.010 - 0.147	0.003 - 0.059	0.002 - 0.022	0.012 - 0.860	0.045 - 0.900	0.005 - 0.700	<0.001 - 0.005	0.011 - 0.184
N	46	41	41	45	46	46	44	43
Skewness	1.30	1.41	1.65	1.63	1.63	6.62	0.49	2.35
18								
$\bar{x}$	0.093	0.071	0.059	0.171	0.239	0.075	0.021	0.310
SD	0.053	0.034	0.033	0.192	0.183	0.047	0.011	0.100
Med	0.091	0.064	0.055	0.099	0.180	0.070	0.021	0.329
Range	<0.010 - 0.286	0.013 - 0.133	0.005 - 0.124	0.010 - 0.829	0.080 - 0.855	0.016 - 0.230	<0.001 - 0.048	0.094 - 0.510
N	45	39	40	44	45	45	42	42
Skewness	1.06	0.29	0.22	2.08	2.23	1.21	0.70	-0.47
20								
$\bar{x}$	0.114	0.080	0.066	0.225	0.298	0.109	0.019	0.288
SD	0.049	0.030	0.028	0.180	0.178	0.050	0.008	0.119
Med	0.110	0.072	0.061	0.181	0.255	0.106	0.018	0.282
Range	0.028 - 0.275	0.037 - 0.146	0.015 - 0.128	0.015 - 0.680	0.075 - 0.770	0.013 - 0.210	0.005 - 0.041	0.038 - 0.685
N	45	41	41	39	46	46	43	43
Skewness	0.67	0.49	0.28	1.15	1.14	0.19	0.58	0.67

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-25

Pen Branch Creek - Trace Elements (Total)

Site[a]	Arsenic (μg/L)	Cadmium (μg/L)	Chromium (μg/L)	Copper (μg/L)	Lead (μg/L)	Nickel (μg/L)	Zinc (μg/L)
19							
$\bar{x}$	1.6	0.36	6.6	3.0	1.8	2.8	6.1
SD	1.8	0.51	12.9	3.4	1.6	2.6	6.5
Med	0.6	0.21	1.5	1.9	1.1	2.1	3.1
Range	<0.4 - 6.2	<0.04 - 2.00	<0.4 - 49.0	<0.4 - 14.1	<0.4 - 6.0	<0.4 - 8.7	<0.4 - 23.1
N	15	15	15	15	15	15	15
Skewness	1.36	2.80	2.96	2.68	1.94	1.57	1.73
18							
$\bar{x}$	2.8	0.99	10.1	3.0	1.3	4.3	5.7
SD	3.3	2.86	23.6	1.8	1.4	5.6	7.1
Med	1.7	0.20	1.8	2.4	1.0	1.9	3.3
Range	<0.4 - 10.7	<0.04 - 11.30	<0.4 - 90.0	<0.4 - 6.5	<0.4 - 5.0	<0.4 - 18.0	<0.4 - 27.7
N	15	15	15	15	15	15	15
Skewness	1.26	3.84	3.25	0.42	1.58	1.84	2.43
20							
$\bar{x}$	2.6	0.56	10.4	3.0	2.3	3.8	5.8
SD	3.2	0.56	18.8	2.4	2.7	3.1	6.5
Med	1.1	0.31	3.9	2.6	1.3	3.9	3.3
Range	<0.4 - 10.8	<0.04 - 1.80	<0.4 - 71.0	<0.4 - 9.1	<0.4 - 9.3	<0.4 - 11.0	<0.4 - 25.9
N	16	16	16	16	16	16	16
Skewness	1.42	1.15	2.79	1.15	1.82	0.86	2.21

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-26

Pen Branch Creek - Trace Elements (Dissolved)

Site[a]	Arsenic (μg/L)	Cadmium (μg/L	Chromium (μg/L	Copper (μg/L)	Lead (μg/L	Nickel (μg/L)	Zinc (μg/L)
19							
$\bar{x}$	0.9	0.29	0.7	1.4	0.6	1.5	2.7
SD	1.3	0.44	1.2	1.1	0.5	1.9	2.5
Med	<0.4	0.15	<0.4	1.4	<0.4	0.7	2.2
Range	<0.4 - 5.6	<0.04 - 1.80	<0.4 - 5.5	<0.4 - 4.6	<0.4 - 2.0	<0.4 - 7.0	<0.4 - 10.7
N	18	18	18	18	18	18	18
Skewness	2.89	2.63	3.75	1.43	1.48	1.89	2.17
18							
$\bar{x}$	1.2	0.15	0.9	2.1	0.5	2.5	2.5
SD	1.7	0.16	1.5	1.9	0.4	2.8	3.2
Med	<0.4	0.10	<0.4	1.6	<0.4	1.3	1.4
Range	<0.4 - 6.2	<0.04 - 0.60	<0.4 - 6.6	<0.4 - 7.1	<0.4 - 1.3	<0.4 - 7.8	<0.4 - 13.4
N	17	17	17	17	17	17	17
Skewness	2.15	1.49	3.72	1.48	1.28	1.13	2.85
20							
$\bar{x}$	1.3	0.26	0.9	1.2	0.6	1.7	2.5
SD	2.0	0.21	1.5	1.2	0.7	2.3	2.9
Med	0.5	0.27	<0.4	0.9	<0.4	0.8	1.5
Range	<0.4 - 6.9	<0.04 - 0.70	<0.4 - 6.5	<0.4 - 4.7	<0.4 - 2.5	<0.4 - 9.1	<0.4 - 12.9
N	18	18	18	18	18	18	18
Skewness	2.20	0.44	3.51	1.79	1.85	2.31	2.90

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

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TABLE A-27

Pen Branch Creek - Organic Carbon

Site[a]	Total Organic Carbon (mg C/L)	Dissolved Organic Carbon (mg C/L)	Particulate Organic Carbon (mg C/L)
19			
$\bar{x}$	5.99	5.12	3.40
SD	3.29	2.00	3.86
Med	5.80	4.90	1.47
Range	0.36 - 11.84	2.61 - 9.30	0.24 - 10.70
N	25	9	10
Skewness	0.21	0.98	1.20
18			
$\bar{x}$	6.82	5.73	3.44
SD	1.83	1.27	3.56
Med	6.74	5.59	2.50
Range	4.40 - 13.20	3.59 - 7.90	0.56 - 11.70
N	23	10	9
Skewness	1.78	0.18	1.78
20			
$\bar{x}$	6.49	5.04	2.66
SD	2.13	1.16	2.03
Med	6.60	5.00	2.40
Range	2.85 - 12.91	3.61 - 7.25	0.58 - 6.10
N	25	9	10
Skewness	0.86	0.64	0.50

[a] See Figure A-1

$\bar{x}$ = mean
SD = standard deviation
Med = median
N = number of samples

Source: Newman et al. (1986)

TABLE A-28

Pen Branch Creek - Biochemical Oxygen Demand (mg O_2/L)

Site[a]	Date	BOD_5	BOD_{20}	BOD_{20} Inhibited	$BOD_{Nitrogenous}$
19					
	061984	<1.00	1.83	0.50	1.33
	100984	<1.00	1.34	1.06	0.28
	012285	<1.00	<1.00	1.05	<0.10
18					
	070384	<1.00	1.74	2.06	<0.10
	082185	<1.00	2.18	2.02	0.16
20					
	121383	<1.00	2.37	2.23	0.14
	052284	1.44	2.47	1.65	0.82
	060584	1.03	2.69	1.85	0.84
	092584	1.22	1.67	1.25	0.42
	010984	1.42	3.51	1.25	0.42
	041785	1.13	3.33	2.57	0.76

[a] See Figure A-1

Source: Newman et al. (1986)

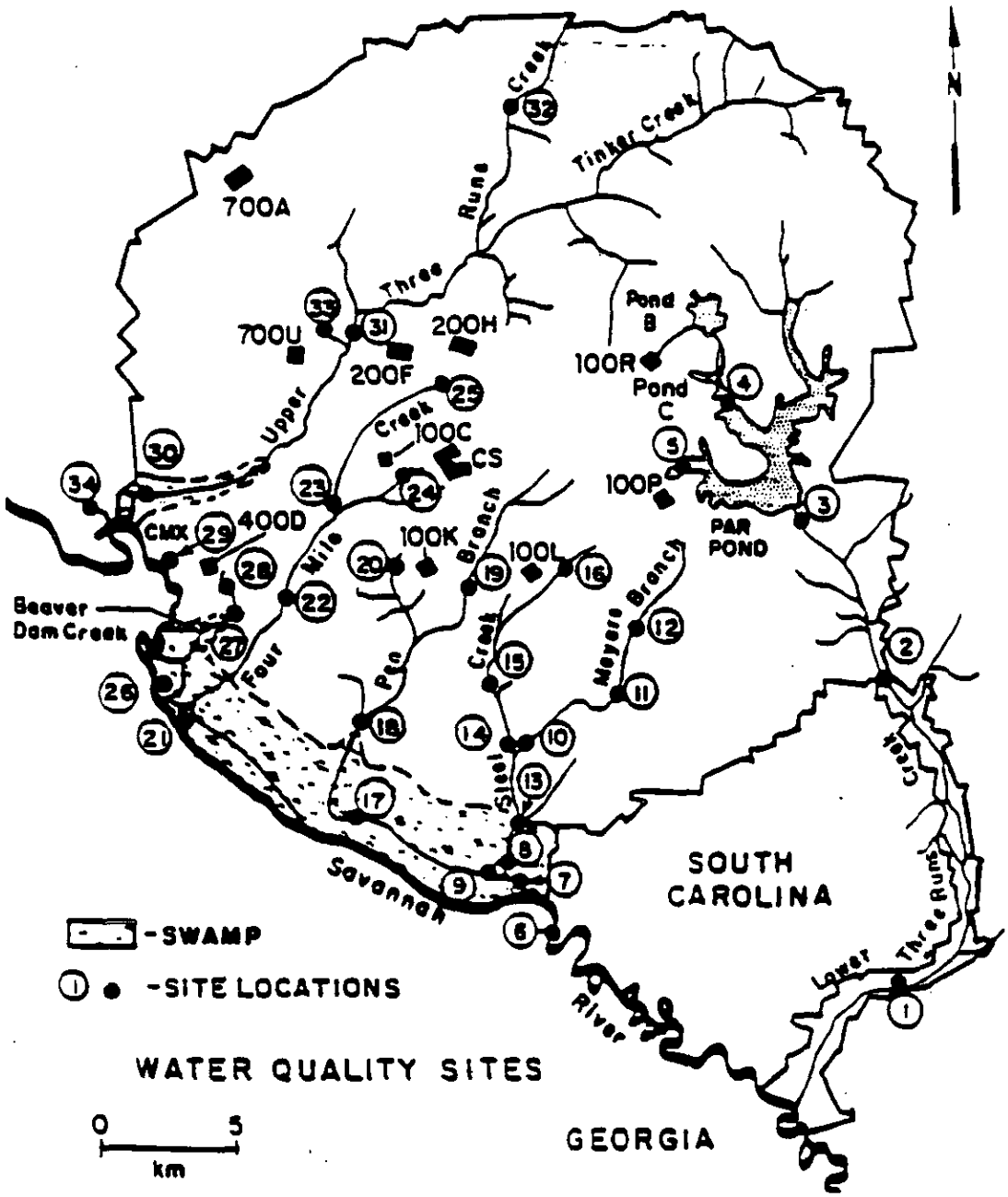

FIGURE A-1. Locations of the CCWS Water Quality Monitoring Sites (source: Lower, 1987)

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APPENDIX B

APPENDIX B

B.1 ENVIRONMENTAL CONSEQUENCES OF REACTOR OPERATION AT LESS THAN FULL POWER

The following information addresses possible changes in ecological environmental impacts associated with operating SRS production reactors at less than full power. Reactor operations at less than full power results in changes in reactor effluent temperatures, while the volume of water discharged does not change.

B.1.1 Terrestrial Ecology

No change is anticipated in consequences of reduced power operations.

B.1.2 Wildlife

Generally, no changes are expected in impacts on wildlife. However, waterfowl use of the Savannah River swamp may increase with lower water temperatures.

B.1.3 Endangered Species

The environmental consequences of reduced power operation would be little different than the consequences of full power operation for wood storks. Wood stork foraging on SRS in the swamp is primarily determined by water levels and cooling water flows will not change with changes in reactor power level.

Environmental consequences for other endangered species will not differ between full and reduced power reactor operation.

B.1.4 Wetlands

The environmental consequences of reduced power reactor operation are expected to be little different from the consequences of full power operation for the Par Pond macrophyte community.

The environmental consequences of reduced power reactor operation are expected to be little different from the consequences of full power operation for the L-Lake macrophyte community.

Little if any difference in wetland impacts in the Steel Creek corridor and delta would be expected between full power and reduced power operations of L Reactor.

Flow and temperature would be expected to be the major factors controlling macrophyte distribution in the upper (Indian Grave Branch) and mid-Pen Branch corridor. Reduced power operation could lead to enhanced growth (earlier emergence and possibly size) of these wetland communities. Delta growth rates (loss of cypress/swamp forest) would be expected to be less with reduced power operation.

B.1.5 Aquatic Ecology

B.1.5.1 Par Pond

There is no significant adverse impact on the phytoplankton, periphyton, or zooplankton communities of Par Pond as a result of P-Reactor operation. Primary and secondary productivity would decline slightly as power levels are decreased.

Operation of P Reactor at less than full power may reduce secondary production of macroinvertebrates in the Hot Arm of Par Pond because annual primary production in the Hot Arm would be expected to decline at ambient temperatures.

Operation of P Reactor at less than full power is not expected to alter the environmental consequences for fishery resources in Par Pond. Reduction of water temperatures below approximately 35°C would result in substantial reduction or elimination of fish kills in Pond C, a precooler pond for Par Pond.

B.1.5.2 Pen Branch/Indian Grave Branch

Reductions in power levels would provide improved opportunities for development of more diverse zooplankton and algal populations in the stream and delta as temperatures are reduced below upper thermal tolerances for most zooplankton and non-blue-green algal species (35 to 40°C). Reduced primary productivity might be expected in the stream and delta area as temperatures decline below the 40 to 50°C range, and highly productive blue-green algae are replaced by a more diverse algal community. No significant thermal impacts on algae and zooplankton would be expected much beyond the delta region with any power level.

Reductions in K-Reactor power levels will result in progressively greater improvement in the diversity of stream macroinvertebrate communities as effluent temperatures decrease from approximately 40 to 32°C. More comprehensive reductions in macroinvertebrate community quality would occur at temperatures above 38 to 40°C.

Environmental consequences for fishery resources will be altered if water temperatures are reduced to or below 30 to 35°C in Pen Branch or Indian Grave Branch. Those areas having water temperatures at or below this range will experience substantial increases in the abundance and diversity of fish.

B.1.5.3 L Lake/Steel Creek

Mid-lake thermal compliance criteria in L Lake necessitate that five-day average water temperatures be maintained at or below 32.2°C. L-Reactor power levels are altered to remain within these limits, while cooling water discharge volume remains constant regardless of reactor power level. Consequently, water temperatures in the lower half of L Lake change little with changes in reactor power level.

Reduced power operation of L Reactor may alter algal and zooplankton communities in the lower lake by improving conditions for most phytoplankton and zooplankton in the upper lake, which serves as a source area for down-lake communities. Reduced power operation might increase the dominance of the nuisance phytoplankton species, Microcystis aeruginosa. However, during reduced power operation in 1988, M. aeruginosa occurred in substantially lower densities than during previous years. Annual mean primary (algal) and secondary (zooplankton) production in the lower half of L Lake might decline as reactor power level is reduced.

Macroinvertebrate communities in the lower half of L Lake will not be affected by reductions in L-Reactor power levels because water temperatures at mid-lake are controlled to remain within tolerance limits of macroinvertebrate communities.

Operation of L Reactor at reduced power levels would be expected to reduce the magnitude of fish kills in the upper reaches of L Lake. Reduced power operation would not be expected to affect fish resources in the lower half of L Lake.

Steel Creek

Operation of L Reactor at reduced power is not expected to alter the environmental consequences of reactor operation for algal and zooplankton communities in Steel Creek.

Operation of L Reactor at reduced power levels may reduce the abundance of filter-feeding macroinvertebrate communities in the upper reaches of Steel Creek if plankton productivity in L Lake is reduced.

Operation of L Reactor at reduced power is not expected to affect fishery resources in Steel Creek.

B.2 FLOW AND WATER LEVEL REQUIREMENTS FOR THE AFFECTED RESERVOIRS AND STREAMS DURING COLD SHUTDOWN OF REACTORS

During cold shutdown of SRS reactors, all thermal discharges would cease. It is assumed that a cold shutdown will be essentially like the condition of L Reactor during the 1970's with no discharge from the reactor areas into the receiving water bodies unless such discharge is required by regulatory commitments. Ecological systems previously affected or limited by some aspect of reactor discharge will be released from such limitations, and ecological succession in stream and wetland areas is expected to proceed much as it did in Steel Creek following cessation of L-Reactor thermal discharges in 1968. Procedural factors controlling reservoir water levels and stream discharges may influence the nature and rate of ecological succession. Procedural requirements associated with each affected water body are identified below.

B.2.1 P Reactor

There is no regulatory requirement for the maintenance of water levels in Par Pond, nor are there any discharge requirements for Lower Three Runs Creek. WSRC procedures specify that the Par Pond water levels should normally fluctuate no more than one foot. Estimated annual average combined dam overflow and seepage from Par Pond are estimated to be approximately 14,000 gpm (Wilde, 1985). Discounting dam overflow, approximately 75 gpm is expected to be required to maintain water levels in Par Pond within acceptable limits.

B.2.2 K Reactor

There are no known minimum flow requirements for Indian Grave Branch or Pen Branch.

B.2.3 L Reactor

There is no regulatory requirement for the maintenance of water levels in L Lake. WSRC L-Lake operation procedures specify that the lake level be maintained between 189.5 and 190.0 ft above mean sea level (MSL), but temporary larger excursions of water levels are allowed. This procedure is highly protective of the shore zone biotic communities in L Lake, and continued observation of similar limitations during a cold shutdown are desirable.

The L-Lake operating procedure incorporates the requirement of the L-EIS (DOE, 1984) that minimum flow standards be adopted for Steel Creek below L-Lake dam. These requirements are 50,000 gpm discharge in Steel Creek during the fish spawning season and 25,000 gpm discharge at other times. Approximately 31 gpm have been estimated to seep through the L-Lake dam to Steel Creek. Maintenance of flow from the Savannah River to L Lake will be required if these discharges in Steel Creek are to be maintained.

However, during an extended cold shutdown, it may be possible to eliminate these minimum flow requirements and allow Steel Creek to revert to base flow conditions. Some water releases will likely be required through the L-Lake dam because of water input to the lake from the natural watershed. This flow will likely exceed the rate of seepage through the dam.

REFERENCES FOR APPENDIX B

DOE (U.S. Department of Energy). Final Environmental Impact Statement, L-Reactor Operation, Savannah River Plant, Aiken, South Carolina. DOE/EIS-0108, Savannah River Operations Office, Aiken, SC (1984).

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