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**The Effects of PAT on the Savannah River
Ecosystem — Particularly Fisheries**

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Ecosystem — Particularly Fisheries

INTRODUCTION

Description of the Watershed

The Savannah River is formed in the Blue Ridge mountains of North Carolina by the joining of the Tugaloo and Seneca streams and flows in a southeasterly direction, forming the boundary between Georgia and South Carolina, to the city of Savannah where it enters the Atlantic Ocean. The watershed is approximately 27,294 km² (1,192 square miles). The watershed lies in the Blue Ridge, Piedmont, and Coastal Plain provinces. In the Blue Ridge and Piedmont, the river bed is consolidated so the river tends to be broad and shallow with relatively shallow banks. Once it enters the coastal plain, rocks disappear and the river becomes deep and the banks steep.

In the coastal plain, the river is bordered on either side by swamplands. The size of the swampland is variable. This swampland is naturally flooded. It is a very valuable resource as a breeding and nursery ground for many species of organisms. Many endangered species live within these swamps. These swamps serve as a great buffer to flooding of the mainland. Typically these swamps are vegetated by Cypress (Taxodium distichum) and Blackgum (Nyssa aquatica) along with Swamp Maple (Acer rubrum var tridens (Wood)) and Hickory (Carya sp.) in the higher portions of the swamp and in

the one to five year floodplain. The Cypress has an interesting life cycle in that the seeds fall to the ground, but the seeds will not germinate and grow unless there is a dry period at the time when the seeds mature. Other species are also timed to the flooding of the swamp. Before the creation of the dams in the river, the one to five year floodplains were breeding grounds for many species of invertebrates and fish. Today the swamps continue to function, but the one to five year floodplains are sporadically flooded at times of releases from the dam. This depends on the amount of water released.

Tidal influence extends approximately 63 km upstream from the mouth of the estuary, and the salt water is present upstream for a distance of about 45 km. The upper estuary is divided into two main channels commonly known as the front and back channel.

Geology and Soils

The geology of the watershed, which affects the chemical composition of the water, varies in the three geological provinces: the Blue Ridge, the Piedmont, and the Lower Coastal Plain. In the Blue Ridge providence, the bedrock consists of gneisses, schists, quartzites, and granites. The Piedmont province has deeply weathered bedrock which consists of ancient sediments intruded by granites and other basic and ultrabasic rock. It is dominated with red soils of sandy clay and silty clay texture. The dense geological formations do not transmit water freely except along fissures such as fault zones where the rocks have been broken.

Bedrock on the Coastal Plain consists of stratified silts, sands, limestones, and clays which outcrop in wide bands parallel to the fall line.

Soils of the Savannah River watershed consist of several major subgroupings. In the Blue Ridge area, they are weathered granites, gneisses, and schists. The primary soil texture is sandy loams with stone outcroppings, while the subsoils are clay loams and clays. External drainage of these soils is moderate to rapid and internal drainage is moderate. The surface soils of the Piedmont area range from sandy loams to silt loams with subsoils ranging from sandy clay loam to silty clay. External or surface drainage is moderate to rapid and internal or subsurface drainage is moderate. The soils in the Upper Coastal Plain area consist of loamy sand, sandy loam with sandy clay loam to sandy clay subsoils. Soil texture and drainage along the stream varies. However most areas are somewhat poorly drained with grayish soils formed from thin beds of sandy clay loam and sandy loam. Surface runoff and internal drainage is slow in the broad, flat areas. The gradient in the Blue Ridge province of the Savannah River basin ranges from 1,000 feet at the headwaters of the Tallulah River to approximately 550 feet at the piedmont. The Piedmont province of the basin descends from 550 feet along the mountain foothills to approximately 200 feet near Augusta, Georgia. From Augusta, Georgia to the Atlantic coast the area is divided into the higher, undulating Upper Coastal Plain and the flat, low-lying, Lower Coastal Plain. The gradient, therefore, is from approximately 200 feet to 0 in the estuary.

Average daily temperature of the Savannah River basin in the central areas, varies from 47°F in December to 87°F in July. Those are average temperatures. Average yearly rainfall varies from more than 72 inches in the mountains to 44 inches in the central area, and 50 inches on the coast.

Land Use

Land use for agricultural purposes is greatest in the Piedmont and in Glascock, Burke, and Effingham counties. A major land user is the Fort Gordon Military Reservation. Public, institutional, social, physical and other land constraints have served as major limitations to land use within the Savannah River basin. In the northern portion of the basin, development has been limited due to the steep topography. Towns and industries are mainly located near the tributaries or main stem of the Savannah River. In the Coastal Plain portion of the basin, the soils are poorly drained and are subject to flooding. These soil conditions are limitations on land development within the basin. The swamps constrain land development along the Savannah River corridor and major tributaries of the Savannah River. These areas should remain open and be used for recreation, fish and wildlife, pasture, forest, or scenic areas.

Regulating for Controlling Water Quality

The use of the Savannah River and the maintenance of its quality are controlled by Georgia and South Carolina. These greatly

affect the suitability of the river for aquatic life. For establishing water quality standards in the river, nine water uses have been recognized by Georgia and South Carolina. They are recreation; fishing; propagation of fish, shellfish, game, and other aquatic life; wild river; scenic river; urban stream; agriculture; industrial; and navigation. For each of these classifications there are specific criteria which apply. In nearly every case the criteria relate to the parameters of dissolved oxygen, pH, fecal coliform, and temperature. Specific parameter limitations for each use classification have been identified (Appendices A and B). Also there are a number of general criteria which apply to all waters and are the same regardless of water-use classification.

In summary, the states prohibit materials which produce turbidity, odor, color, or other objectionable conditions; substances which can be harmful to aquatic life; radioactive substances in amounts which exceed federal or state regulations; and stream-bed alterations which may result in violation of stream quality standards. The standards also address the approach to be followed to maintain existing high-quality waters (Appendix A). In addition to the four specific parameters mentioned above, the state regulates all pollutants on a case-by-case basis that would have detrimental impact on the beneficial uses of water.

The state has found it better to control pollutants through the establishment of adequate effluent limitations on the source, rather than through the use of the in-stream water quality

standards. This is done using guidelines produced by U.S. Environmental Protective Agency and other sources. Certain of the streams in some of the counties have been designated as supporting a self-sustaining population of rainbow, brown, or brook trout. These streams are in Elbert County, Haversham County, Art County, Raven County, Stevens County and Towns County.

Classification of Savannah River

The main stem of the Savannah River has been classified as follows: the Georgia/South Carolina state line to Clark Hill Dam for recreation; from Clark Hill Dam mile 238 to Augusta 13th Street Bridge -- drinking water; from U.S. Highway 301, mile 129 to U.S. Highway 17 Bridge, mile 22 -- drinking water; U.S. Highway 17 bridge, mile 22 to Field Cut, mile 5 -- industrial navigation; Fort Pulaski, mile 0 to open sea and all legal waters of Tybee Island -- recreation. The headwaters are classified as follows: Chattooga River, a headwater stream, Georgia/North Carolina state line to Tugaloo Reservoir -- wild and scenic; West Fork of the Chattooga River, confluence of Overflow Creek and Clear Creek, to confluence of Chattooga River -- wild and scenic river; Tallulah River, headwaters of Lake Britton, to confluence with Chattooga River -- recreation; and Tugaloo River, confluence of Tallulah and Chattooga Rivers to Yonah Dam -- recreation.

Point source control is based upon Public Law 92500, the Federal Water Pollution Control Act Amendments of 1972. These amendments established the basic approach for point source

pollution control to be followed by all states. Water quality standards are the driving force behind point source control needs. Therefore, point sources listed for each basin must achieve the highest level of waste water treatment necessary to prevent violation of local water quality standards (Appendices A and B). This requirement creates two types of stream segments as defined by rules and regulations for water quality control, chapter 391-3-6 revised October 1980, Georgia Department of Natural Resources.

1. Water Quality Limited Segment

Any segment where it is known that the water quality does not meet applicable water quality standards and/or is not expected to meet applicable water quality standards even after the application of the effluent limited requirements by sections 301(b)(1)(B) and 301(b)(2)(A) of the federal act.

2. Effluent Limited Segment

Any segment where it is known that water quality is meeting and will continue to meet applicable water quality standards or where there is adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by sections 301(b)(1)(B) and 301(b)(2)(A) of the federal act.

Pollutant sources which are designated as minor sources are not listed in the basin plan. They are of two types: municipal and privately-owned facilities discharging less than 10,000 gallons per day and industrial facilities that meet any of the following requirements:

- a. No discharge
- b. Discharge consisting only of contaminated cooling water, groundwater, and/or rainwater runoff
- c. Discharges with 1) no significant organic content (less than 2.5 lbs of BOD5 per day); or 2) no chemical contaminants.

The fact that the minor sources are unlisted does not mean that they are unregulated. All discharging sources have been issued NPDES permits, all no discharge systems have been issued state permits, and all systems are inspected regularly by Division staff and required to meet conditions of their permits. Information on these sources is contained in the Division's files. By law, all point sources must provided for at least the minimum of secondary treatment. Any required level of treatment in excess of secondary imposes additional cost that must be properly justified. In order to insure that no discharge is penalized unfairly by requiring treatment levels in excess of those needed to protect water quality

standards, the Division uses the following approach on data needs. No waste discharge owner will be required to provide a level of waste water treatment above a secondary treatment for domestic or municipal waste without defensible proof of the need for a higher level of treatment. This proof may include, but is not limited to, one or more of the following:

1. A calibrated, mathematical water quality model
2. Data from intensive surveys or the state's trend monitoring network for water quality
3. A history of fish kills or other nuisance problems in the stream

Furthermore, no municipality will be required to go past step 1 in the construction process for advanced waste treatment unless the need for such treatment is substantiated with field data. Thus the technical methods and data needs for developing defensible waste load allocations can be divided into two categories: those for effluent limited segments and secondary treatment called "table top methods" and 2) those for water quality limited segments called "field calibrated" or "field data based". Waste load allocations (WLA's) reflect a specific design, stream flow, water temperature, and background water quality at which standards will be protected. This means that WLA's can be developed to represent a specific time

in each year, specific periods of time in each year, various levels of stream flow, and/or various levels of natural background water quality. Currently, the division develops three different types of waste load allocations: 1) Annual waste load allocations; 2) seasonal or monthly waste load allocations; 3) hydrographic control releases (HCR) of waste load allocations. HCR allocation permits waste discharges during wet periods, but requires that waste be stored on-site during dry periods. Because of the design and operational complications, the HCR waste load allocation is restricted to those situations where the annual, seasonal, or monthly WLA's do not apply.

Impacts on River Affecting Aquatic Life

The Savannah River has been impacted in many different ways. These impacts change the kind of species composing the fauna and flora of the river and, if too severe, can hinder its functioning in a natural, healthy manner. Typically a natural river has four stages of nutrient and energy transfer. At the base of the food web are those organisms that break up detritus, such as bacteria, fungi, protozoans, and some invertebrates; and those organisms that typically feed on algae. These are the producers of energy and nutrients for the food web. The detritivores and herbivores typically feed upon detritus or algae or both. The omnivores feed upon the detritivores, herbivores, algae and detritus, and the carnivores typically feed on other animals such as insects, protozoans, worms, young fish, and so forth. At each stage of

nutrient and energy transfer there are typically many species performing each of these functions belonging to many different major groups of organisms. Thus the diversity at each stage of nutrient, energy transfer is high in a natural, functioning stream.

These species change with various environmental conditions and with seasons of the year. One can determine by the kinds and numbers of species and their functional activities whether or not the river is functioning normally or is healthy or whether it has been perturbed. Typically the ecosystems in a natural river are very robust and can stand a certain amount of perturbation. This is the case of the Savannah River where there have been a very large number of perturbations, but the system is robust and therefore generally remains in what is termed a natural or healthy condition. This healthy condition will produce plenty of food for the fish and, hence, support diversified fisheries.

The impacts that have occurred in the Savannah River are typically chemical and physical, but also may be biological. The chemical impacts are mainly pollution from non-point and point sources. The State of Georgia and the State of South Carolina have permitted a variety of pollutants to be acceptable to the Savannah River. These include organic toxicants; heavy metals; oxygen-demanding substances; and substances high in nutrients, particularly nitrogen (Appendices A and B).

There have also been severe physical alterations of the river. The most severe of these is the damming of the river. In 1951, when the Academy of Natural Sciences started, Clark Hill Dam had not

been built. There was a small dam, for navigation purposes, at Augusta, but that was the only dam on the river. Since then, the Clark Hill Reservoir, the Richard B. Russell Lake, and the Hartwell Reservoir have been constructed. A dam and its reservoir are severe impacts on the natural flowing water. The pattern of flow as well as the amount of flow at various seasons of the year is severely altered. Flooding is controlled and releases are made when they are most favorable to industry. This may be very damaging to the swamp areas, as has occurred in the Savannah River. Dr. R.R. Sharitz and others believe that it is the program of water releases in the lower Savannah that has prevented the summer dry period which is so necessary for the germinating Cypress. This has hindered the regeneration of the Cypress in the swamps. These swamplands and floodplains are very valuable in maintaining the natural variety and succession of many rare and endangered species. The areas where these floodplains join the river are recruitment areas for some of the riverine species.

Dams usually prevent much of the flooding of the floodplain and, as a result, this recruitment source is damaged. Furthermore, flooding enables the regeneration of groundwater in the one and five year floodplains. When this flooding is limited or stopped this has a very definite effect upon the quantity of water in the groundwater aquifers. These shallow aquifers are becoming more and more important as water sources as our population increases.

The dams also change the temperature regime in the river. This was noted in our 1952-53 studies when Clark Hill Dam was built. The

lack of flooding also stabilizes the banks of the river in the coastal plain and thus prevents as much sloughing as occurred under natural conditions.

Controlled releases from the dam also influence the salinity of the water in the estuary. This sometimes can have very severe effects on the natural distribution of species particularly those that are breeding and the young that are feeding in the nursery ground. After a dam is built, the extent of these areas of varying salinity is changed over time.

Another physical alteration in the riverine system has been the dredging of the Savannah River to maintain a channel to Augusta. This has resulted in the cutting out of many of the sloughs and oxbows. These shallow water areas, where the water is relatively clear, are the most valuable areas for the growth of algae and hence the feeding and breeding of invertebrates and fish. When these are cut off the productivity of the system is impaired. This has been happening in the Savannah River.

Another type of deleterious change has been brought about by the introduction of the Japanese clam, Corbiculum. This clam can live in a great many habitats. It reproduces rather rapidly and can cause the elimination of populations of species that are native to the river. This has been very noticeable at Stations 1 (above the Plant Site) and Station 3 (below Upper Three Runs) where, when we originally studied these areas in 1952-53, there were six species of Pelecypoda at Station 1 and 12 at Station 3. Today or during our last survey there were 0 species at Station 1 and two species at

Station 3. Undoubtedly this, to a large part, has been caused by the invasion of the Corbicula which have taken over their habitat.

SCOPE OF PAPER

The main purpose of this study was to determine whether or not the pre-startup activities at K-Reactor, i.e., Power Ascension Testing (PAT), have caused damage because of temperature rises in the Savannah River. Therefore, the biological studies were mainly aimed at providing information as to changes that might cause the damage of the fish population, and to other important organisms in the ecosystem. To determine if deleterious effects had occurred, one had to review the past studies to determine the condition and diversity of aquatic life before these PAT studies started. Therefore old reports were reviewed and a current study made in 1992.

THE CONDITION OF THE SAVANNAH RIVER

Alteration of the Flooding Regime

Over the forty years of study there have been many changes in the Savannah River fauna and flora. This has undoubtedly been caused by many factors. Some of the most important have been mentioned as being caused by the increased pollution, the effects of dams, the straightening of the river and elimination of sloughs and bayous and oxbows. Another cause for the shift in species undoubtedly is the control of the flow of the river. No longer are

the floodplains flooded in the early spring. These areas used to be more effective breeding grounds for many species of fish and invertebrates. This was true in the Piedmont as well as in the Coastal Plain. Now, with spring flooding almost entirely eliminated and with controlled flooding downstream from the dams, which often takes place in dry rather than wet seasons, these nursery grounds have been pretty well eliminated and the water supply of the shallow water aquifers have been at times greatly reduced. This means that what used to be wetlands are now drylands in many cases. However, in the Coastal Plains extensive swamp forests continue to function as the breeding and nursery grounds for many species. As seen by the study of the pollution in the basin, many of the tributaries now receive pollutants of various types. Their natural productivity of fish and other organisms has been harmed.

Changes in the Biodiversity of the Ecosystem Over Time

When one studies the biodiversity of the system it is interesting to compare over time the fauna and flora in the fall surveys, when the ecological conditions were within a range that should sustain the same cadre of species. The fauna and flora consists of a mixture of those species that are typically found in natural waters. Some of these can tolerate a fair amount of organic pollution and other types of perturbation. One would expect such species to be present as there has been a decided increase in ammonia (1952 - 1992), nitrate, phosphate ranges, and other pollutants entering the river.

A very few species were always present at all stations in these fall surveys. Among the algae, they were Navicula minima (characteristic of natural and high nutrient water), Navicula rhynchocephala var. germainii (characteristically found in natural water), Ghomphonema parvulum (characteristically found in natural waters but also it can tolerate waters with a considerable amount of organic pollution), and Achnanthes minutissima, Synedra ulna, Nitzschia palea (characteristic of natural and organic polluted water) and Nitzschia filiformis (characteristic of natural water). Among the invertebrates that were always present at these stations was Physa sp. (usually found in large numbers in organically polluted water). An insect always occurring at each of these four stations was the mayfly, Baetis spp. The fish, Lepomis macrochirus (usually found in natural water) was always collected.

Besides those species which were collected at all stations during all fall surveys, some species were collected at one or more stations on all surveys. This means they were always in the species pool. At Station 1 were the diatoms Navicula minima, Navicula cryptosephala var germainii, Ghomphonema parvulum, Achnanthes minutissima, Synedra ulna, Nitzschia palea, Navicula cryptosephala, and Synedra rumpens. Most of these diatoms can tolerate a fairly high organic load. At Station 1 on all the surveys was Physa spp. and the mayfly, Baetis spp., and Lepomis macrochirus, the bluegill.

At Station 3 was Navicula minima; Ghomphonema parvulum; Achnanthes minutissima; Navicula cryptosephala; Physa sp.; and the mayfly, Baetis spp.; the fish, Lepomis macrochirus (the bluegill)

and Micropterus salmoides and Gambusia ephinis. All of the diatoms and the snail are known to tolerate somewhat polluted waters.

Always occurring at Station 5 during the 10 fall surveys, were Navicula minima; Ghomphonema parvulum; Synedra ulna; Nitzschia filiformis; Nitzschia palea; Physa sp.; the mayfly, Baetis sp.; and the fish, Lepomis macrochirus and Micropterus salmoides. All of the diatoms except N. filiformis and the snail are known to tolerate some pollution. The fish are characteristic of natural waters.

At Station 6, always occurring was Navicula minima, Ghomphonema parvulum, Achnanthes minutisima, Nitzschia filiformis, Nitzschia palea, Achnanthes lanceolata var. dubia, and Cymbella minuta. Of the invertebrates other than insects, Physa sp. was always present. Of the insects, two mayflies were always present at Station 6, Baetis spp. and Stenonema spp. Unfortunately, when determinations are only to genus one cannot make sure that the same species were there; one can only say that the same genera were there. Fish that were always present at Station 6 were the bluegill, Lepomis macrochirus, and Lepisosteus osseus. As at the previous stations, most of the diatoms and the snail can tolerate polluted water.

From this we see that there is a certain cadre of species that occurred at each of the stations during all of the surveys. Other species, which were apparently present in the species pool and available but not always present at all the stations, but were at one or more stations during all the surveys. They were Melosira distans var. alpigena, Synedra rumpens, Gyrosigma nodiferum,

Gyrosigma spencerii, Navicula confervicia, Ghomphonema gracile, Nitzschia amphibia, Nitzschia clausii, and Surirella angustata. All of these are characteristic of natural water. The invertebrates that were always available in the species pool were Dugesia tigrina (tolerant of pollution) and Pseudosuccinea columella (Lymnaea columella), Physa sp. (tolerant of pollution), and an unidentified sponge. The insects, Baetis spp. and Stenonema spp. were the only two groups of insects that were always present and they are both mayflies. The fish, besides those that occurred on all surveys at a single station, that should be added are Dorosoma cepedianum, Notropis hudsonius, Lepomis auritus, and Trinectes maculatus.

An analysis of the list of species shows that at all stages of the food web -- the detritivores, the primary producers, the herbivores, carnivores, and omnivores -- there are a great variety of species that are present as seen by the numbers of species found on each survey in each of the groups.

Effects of the Effluents from Pen-Steel on the Savannah River

The first question was, how important is the Savannah River as a recruitment station and habitat; in other words as a spawning and nursery ground and as a habitat, not only for anadromous fish but for those that live in the area. The second question was whether Pen and Steel swamps were important recruitment areas for the Savannah River.

It is well-known that many of the smaller fish prefer shallow water habitats and vegetation as spawning and nursery grounds. The

cutting out of the oxbows and the sloughs in the Savannah River has greatly limited the vegetation and shallow water areas which were available to these fish at spawning time. However, since spawning usually occurs at high water levels, many of the plants that are not available during low water flows, furnished habitats when spawning is present at higher flows of the river. Thus we find in the Savannah River that there were quite a few spawning and nursery grounds for the local panfish as well as the open waters being nursery and spawning grounds for the anadromous fish.

Dr. Paller et al. (Westinghouse Savannah River Technology Center) have studied, during the '80s and early '90s, the suitability of the Savannah River in the vicinity of the Plant Site as a spawning ground and a habitat for anadromous and local fish.

They found that there is a great diversity of species in the Savannah River in the vicinity of the Savannah River site, that the species composition of these ecosystems has changed over time, and this change seems to be in response to the varying amounts of pollution and other types of perturbation that enter the river and, at present, are influencing it. The chemical analyses indicate increases in nutrients over time and at times the presence of trace, toxic chemicals. The rich species diversity indicates that there is a great variety of habitats in the Savannah River to support the different organisms. For example there are shallow slow-flowing areas such as in oxbows and sloughs which are rich in rooted aquatics that support burrowing and other types of invertebrates that live in and on the sediments and various types of algae.

The edges of the Savannah River are often lined by trees that have trailing branches in the water. These form another type of habitat where the flow is rapid. Other species live in or on the point bars for a part of their life history.

Temperature of the river is quite variable. Even naturally, when the temperature of the water reaches 32° or 33°C, the water in depths of a few feet will be in the middle to low 20°C range.

Most of the flow of water of the Savannah River comes from the piedmont area, but also comes from the black waters of the coastal plain that contain fulvates and humates. The river is circumneutral and typically has fairly low conductivity. These conditions favor different kinds of algae and other plants than those found in the swamps. Typically these circumneutral waters are rich in insects, a variety of other invertebrates and fish. This rich fauna consists of species that spawn and raise their young in the open water and resident species which often prefer the vegetation and shallow waters as suitable habitats for laying their eggs and rearing their young. Others prefer the deeper water.

Swamp water, in contrast, is typically black water with low pH and very rich in humates and fulvates. Though these streams have rather large amounts of dissolved organic carbon in them, this carbon is not a suitable type of food for many species of organisms. As a result there is a specialized fauna and flora in these blackwater swamps. Pen Branch and Steel Creek differ from typically the river or typically the swamps because they receive, through the reactors, river water. Thus they provide a habitat

which is quite different from that of the typical black waters. It also is different from that of the open Savannah River. Because the flow is very slow in these swamps, typically anadromous fish that prefer to spawn in moderate to fast flowing water do not enter them to spawn or raise their young. Even when the water was flowing from the K-Reactor during start up, it lost its momentum in a short distance after entering the swamp.

The type of fish that one finds in the oxbows and sloughs in the Savannah River are also common in these swamp waters. Typically very few fish or invertebrates migrate from these swamps into the open water. Some do, but the relative proportion of populations of fish and invertebrates in the Savannah River contributed by the swamps is small.

A question which we wished to answer was whether the preoperational heating of the water in connection with the startup of K-Reactor affected the temperature of Pen Branch and Steel Creek and damaged the fisheries of the Savannah River. These studies were made during the pre-startup time. During these experiments the K-Reactor was only raised to approximately one-third power and the hottest water released during these experiments was about 37°C. The water entered Indian Grave Creek and flows through it to Pen Branch Creek.

Several areas were selected for study. They were: the boardwalk near where Indian Grave Creek enters Pen Branch; Stave Island; an area that appeared to be unaffected in Steel Creek swamp near where Pen Branch and Steel Creek join, the mouth of Steel-Pen

Branch; and a control area, Briar Creek. Studies were also made of the ichthyoplankton of the Savannah River in the vicinity of the mouth of Pen Branch and Steel Creeks. If there was an effect of the temperature on the fisheries in the Savannah River, the sensitive ichthyoplankton would be reduced.

One of the questions to be answered was whether or not the eggs and larvae of fish that spawned moved from the mouth of Pen and Steel Creek into the river and vice versa. We also had to determine whether the food for fish was harmed and therefore their reduction might harm the larvae and young fish that would migrate into the Savannah River.

The results of my study showed that the control area, Briar Creek, which is across the river from Pen and Steel Creek and is a black water stream, receives some organic and other wastes in its headwaters. It is very similar in structure to Pen Branch and Steel Creek in their natural conditions. Cypress and gum are the main types of tree vegetation. Floating mats of aquatic plants are common. These were composed of various species of Polygonum and mats of Egeria. In among these mats of higher plants were various algae particularly some of the green algae and diatoms.

Mosses were found on the bark of logs and on the buttresses of trees and on fallen leaves of the cypress. Algae was scraped from these areas. Sponge spicules were found in and among the mosses and in and among the algae indicating the presence of freshwater sponges. Also present were small gastrotrichs and small flagellated protozoa.

The diatom community of Briar Creek was modeled. The model which is a truncated normal curve, extended over ten intervals. The height of the mode was 28 species which is typical for natural, black water communities of diatoms. The total number of species identified was 164. The ratio of pollution-tolerant species to those characteristic of natural waters was 48 to 74 or 0.65 to 1. This is a little high and shows the presence of some organic pollution, but it is within a natural range.

Many invertebrates were present in Briar Creek. There were three species of worms, seven species of molluscs, one species of crustacea, and three species of crayfish. The insects were represented by six species of mayflies, five species of Anisoptera, and one species of dragonfly, one species of stonefly, two species of true bugs, two species of caddisflies, one species of beetles, and seven species of chironomids. Diverse fauna of chironomids and beetles are characteristic of many acid waters. Also characteristic is the presence of only a very few species of mayflies and stoneflies.

The area which is most seriously affected by K-Reactor effluents is the boardwalk. This is an area in Pen Branch which receives the water from Indian Grave Creek. This area has been badly affected by hot water in previous releases. No cypress trees and very few swamp gum trees were present. It is difficult to know why they died. One suspects hot water, but also it is true that the releases from Clark Hill Dam are at such times that would prevent the regeneration of small cypress trees (according to Dr. Sharitz).

In this area we found alligator weed (Alternanthera philoxeroides (Mart. Griseb)) and Ceratophyllum and Myriophyllum. The protozoans in and among these weeds included the colonial Vorticella and many flagellates and other types of ciliates. Nematodes were present.

In and among these various substrates were various algae. They included the blue-green algae belonging to the genus Oscillatoria; the yellow-green algae, Vaucheria; a few desmids in poor condition (Closterium sp.); and the green algae, Zygnemia. Filamentous desmids were also found, but they were not identified. Diatoms were collected from logs and aquatic plants as noted above, and from barrels that supported the boardwalk.

In July, the diatom community consisted of a great many species. The effects of pollution (temperature) were determined by the shape of the truncated normal curve. It covered ten intervals. The height of the mode was 20 which is less than the height of the mode at Steel Creek and much less than the height of the mode at Briar Creek. It was also less than at Stave Island. The highest ratio of pollution-tolerant species to those characteristic of natural waters was present in this area. This ratio was 52 pollution-tolerant species to 65 species occurring in natural waters or a ratio of 0.8 to 1. The number of species composing the truncated model was 131. Thus we see some effects of the present discharges from K-Reactor at the boardwalk. But these effects had dissipated by the time they reached Stave Island (ANSP, 1993).

In July, the invertebrates indicate as did the algae deleterious effects of the warm water. Flatworms, which are commonly found when there are other adverse effects (Dugesia tigrina), and five species of tolerant worms were identified and six species of molluscs from the area. Some of these are known to tolerate unnatural conditions. Several of them are also characteristic of a fairly high organic load. Four crustacea were present, one of which is characteristically found in the presence of an organic load or similar type of stress, and one grass shrimp. Only one species of mayflies were taken. Whereas usually in black water streams the mayflies are relatively few, there are usually more than one species. Two species of gomphids and two species of dragonflies were present. Of the true bugs, two species were present. The caddisflies were represented by two species and the Coleoptera or beetles were represented by five species. Diptera were represented by six species. This is the type of fauna one would expect to find under somewhat stress conditions in a black water stream. The temperature reached 30°+ in this area.

Stave Island is in the path of the effluent from the K-Reactor discharges, however the temperature rise is not as much in this area. This is evidenced by the fact that the cypress and swamp gum trees have not been killed. A dense shade was present and this resulted in cooler water, whereas at the boardwalk where there was no shade cover, the water was exposed not only to the thermal rises in temperature due to the tests, but also due to direct sunlight.

Algae was scraped from the buttresses of cypresses and from various large logs that were lying in the water. Mosses were common on the logs and on the cypress buttress and they were collected and squeezed. Spanish moss that had fallen to the water was also squeezed for algae. Here and there various plant roots were found in the water. These too were examined for attached algae. Among these collections were various protozoans such as flagellates and the thecated amoeba, Arcella. Gastrotrichs and rotifers were also present. Crawling in and over the substrates were found some flat worms.

The model of the diatom community indicated that this area was in not quite as good condition as was the condition in Briar Creek. The height of the mode was 22 species as compared with 28 at Briar Creek and 23 at Steel Creek Marsh. The intervals covered by the curve were 10 showing that no species was particularly dominant. The ratio of pollution-tolerant species to those characteristic of natural waters was 33 to 60 or 0.55 to 1. This would indicate that Stave Island diatom community was near that of a natural community such as Briar Creek.

The invertebrate fauna was represented by three species of worms and three species of mollusc, also three species of crustacea (two of which are known to tolerate perturbed conditions), three species of crayfish and one of grass shrimp. The insects were represented by a single species of mayflies. Four species of gomphids were present. The dragonflies were represented by a single species. True bugs were represented by one species. There were more

caddisflies here than at the boardwalk, three species being present, and the beetles were represented by five species. As previously, the Diptera were represented by the largest number of species, eight species of chironomids. Many of these species have been collected in perturbed conditions.

The Steel Creek area was near the point where Pen Branch joins Steel Creek. It had previously been effected by discharges of hot water and had been in a recovery period for a number of years. As a result the diatom flora was fairly natural.

Large beds of Polygonum and Egeria were common here. Mosses were also common on trunks of trees and logs. Green algae that were found in floating mats were Spirogyra and Zygnemia. They were at the edges of the floating mats of Polygonum and in and among them. Also in this habitat were various desmids belonging to the genus, Closterium.

The diatom community was intermediate between that found at Briar Creek and Stave Island. The height of the mode was 23 species and the ratio of species characteristic of natural waters to those tolerant of pollution were 46 to 73 or 0.63 to 1. This is a little higher ratio of pollution-tolerant species to those occurring in natural waters than was found at Stave Island but probably it is not significant.

This was the area in which we had the greatest diversity of insects: one species of mayfly, six species of gomphids, one species of dragonfly, one species of Megaloptera, five species of beetles, and eight species of chironomids. Three species of worms

were present, three species of mollusc, three species of crustacea that may tolerate perturbed conditions, three species of crayfish, and a species of grass shrimp. This is a well-diversified fauna typical of black waters that are somewhat enriched.

The most important question being asked was whether these pre-startup tests, in which the temperature of the water reached 34°C at discharge and a little over 30°C at the boardwalk, would affect the eggs and larvae or the fish in the Savannah River. For these reasons, most of the study was devoted to the fish in the river and in the mouths of various tributaries. It is well-known that these tributaries contribute to the fisheries of the open water.

One would not expect very severe effects because the temperature of this area only slightly exceeded 30°C and that was only for a short time. It is at this temperature that shifts in the algal population may occur, that is the diatom community decreases and green algae become more common. Temperature is probably the reason why the community was not as well developed as at Briar Creek and some of the other stations.

Relation of Fish in Pen and Steel Creek and

Other Tributaries to Those in the Savannah River

The populations of fish in the Savannah River consist of the anadromous species such as various species of shad, striped bass and sturgeon as well as many local species of fish such as mosquito fish, dollar and spotted sunfish, pirate perch, and redbreast sunfish. Also such fish as redbfin, pickerel, coastal shiners, and

many others as seen in the report of Horowitz et al., 1992. The Savannah River contains suitable spawning areas for fish that spawn in rapid open waters as well as fish that spawn in and among the vegetation and in the oxbows and sloughs.

The tributary fish are mainly fish that spawn in and among the vegetation and in the channels of the swamp. Many of these are the same as those that spawn in the river. Therefore it is very difficult to estimate the relationship of the fish communities in the tributaries to those of the river.

Data clearly show that the tributaries are important contributors to the fish fauna of the river. Furthermore data has shown that the mouth of Pen Branch and Steel Creek as it enters the Savannah River is an important spawning area for some anadromous species as the ichthyoplankton collected in this area is relatively high for a tributary, but similar to the amount of spawning that occurs in Briar or Ebenezer Creeks and much less than the total transport found in the Savannah River.

Studies by Paller and Saul, 1987; Paller et al., 1989 showed reduced fish communities during K-Reactor operations which they interpreted as being due to the high resulting temperatures. Samples were taken at three times during periods of outage caused by the shutdown of K-Reactor. Mosquito fish were common and a few dollars and sunfish were also collected in each sample. Pirate perch, and redbreast sunfish were collected in cooler waters. Mosquito fish were observed in the cooler portion of Pen Branch delta during periods of reactor operation. A minimal use by sunfish

may also have occurred during reactor operation. The ichthyoplankton studies indicate that at Pen Branch Delta, which is probably near Horowitz's station, PB1, very few ichthyoplankton were present. One minnow, one darter larvae, and an unidentified egg were collected when the reactor was down and the water temperature was 26°. These studies had found no ichthyoplankton in Pen Branch just above the delta.

During sampling by backpack electric shockers in '85 and '89 when partial recovery of the fish population following reactor shutdown in early 1982 had occurred, 13 species were collected over four sampling periods with 7 to 9 species in each collection. Lake chub sucker and spotted sunfish were common in all collections. Redfin pickerel, coastal shiner, mosquito fish, and dollar sunfish were common in some surveys as well.

In 1992 fish collections were made in the same locations as the ichthyoplankton collected in 1988-89 during March through July. A total of 20 species were collected by backpack electroshocking. Five to 13 species were collected in each sample, medium 10 species. Three species, redbreast sunfish, tessellated darter, and bowfin collected in 1988-89 were not collected in 1992. The first two species were primarily creek species which are probably more common in the upland part of the creek.

In 1988-89 collections, spotted sunfish, lake chub sucker, dollar sunfish, Eastern mosquito fish, and redfin pickerel were common. In 1992 the coastal shiner was uncommon while the dusky shiner and pirate perch were common. Many of the species which were

apparently more common in 1992 than in 1988-89 are species most typical of the marsh swamp and lentic habitats such as the eastern mud minnow, tadpole madtom, goldentop minnow, pirate perch, swamp fish, largemouth bass, flier, banded pygmy sunfish, and sawtooth darter.

Apparent changes between 1988-89 and 1992 may reflect different patterns of recolonization with earlier recolonization by some lotic species from upstream and slower recolonization of the lotic species from the Savannah River swamp. The slower recolonization could also be due to differences in rate and patterns of dispersal of these fish. Alternately, the difference could reflect response to changes in habitat structure with lentic, marsh, and swamp species recolonizing later in response to regrowth of macrophyte vegetation.

In 1992 collections the fish community at Pen Branch delta showed similar patterns with the dominant species in shallow vegetative marsh habitats in Steel Creek. It should be pointed that many of these species found in Pen Branch delta and Steel Creek marshes have also been found in the Savannah River proper. There is evidence that there are breeding grounds for these fish within the Savannah River as well as in these tributaries.

The question has arisen as to how important are the populations of fish in tributaries to the Savannah River fisheries. Certainly Pen-Steel delta is an important one, but not as important as Briar Creek.

In order to put into perspective any change in the fisheries of the Savannah River that could be caused by PAT of K-Reactor, one must consider what is the possible contribution of the fisheries of Pen Branch and Steel Creek to the Savannah River. Are there any effects of discharges into the river from these activities that could change the resiliency of species and hence the fish community that would be caused by temperature. To answer this question, one must understand the pollution entering the Savannah River ecosystem and how resilient the river is to change in order to evaluate the effects of temperature in these tests. My studies show that the Savannah River is very resilient. The fluctuations of the flora and fauna over time (Table 1) clearly show that perturbations over time have been variable and have effected various species more than others. However at all times the biodiversity and the transfer of nutrients and energy through the foodweb has appeared to be that of a natural stream. This is evidenced by sizes of populations of species in various stages of the foodweb.

Studies have shown that the mouth of Pen and Steel Creek, or the mouth of Steel Creek into which Pen Creek discharges, is a breeding and to some extent a nursery ground for shad, a commercially important species of fish, as well as for fish that are important in sports fisheries. The question that was to be answered was, "Is this resource significant, and would its elimination affect the fisheries in the river?"

It is well-known that naturally many thousand of eggs and larvae are produced by the fish but only a very few survive if the

TABLE 1
LIST OF TAXA IDENTIFIED

	1951-52	1955	1960	1965	1968	1973	1976	1980	1984	1989
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	Station 1									
Algae	34	102	76	110	92	113	50	70	61	94
Protozoa	22	43	54	56	47	57	57	50	70	72
Invertebrates	16	13	12	26	18	39	27	16	16	21
Insects	33	55	29	41	38	59	60	34	33	29
Fish	9	35	33	28	35	25	34	24	32	39
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	Station 3									
Algae	54	90	92	121	43	86	73	54	61	73
Protozoa	31	32	60	48	48	73	75	39	60	54
Invertebrates	21	13	13	25	23	30	18	9	18	16
Insects	39	46	34	45	53	52	35	31	53	29
Fish	12	25	32	25	28	34	30	20	28	37
<hr/>										
	Station 5									
Algae	53	104	105	125	61	74	61	68	43	80
Protozoa	33	47	63	35	56	80	66	39	61	65
Invertebrates	9	19	19	21	19	35	31	20	29	14
Insects	33	64	39	41	44	51	46	37	43	49
Fish	11	30	36	30	33	34	35	29	38	37
<hr/>										
	Station 6									
Algae	52	189	114	109	65	82	60	60	56	91
Protozoa	30	55	69	42	44	79	73	50	77	58
Invertebrates	12	30	29	35	12	47	21	24	27	17
Insects	53	71	27	53	46	49	43	59	46	47
Fish	10	33	33	32	35	30	31	30	37	34
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population is to remain constant or grow slightly. Is the food supply of the young larvae severely damaged by these tests? It is known that temperature of 30° to 34°C can cause the death of diatoms which are known to be very important food for fish larvae and for some adults.

How significant are the food losses by shifts in algal species to some invertebrates as well as to the fish larvae and the fish in various stages of development? Whereas locally within the swamp this effect may be severe, it probably is negligible outside of a particular section of a swamp. This conclusion is supported by the fact that there is a well-developed fish fauna in the swamp and its channels. This fauna differs in some respects from that of the river in that the species are only those that spawn in vegetation and channels of swamps and do not migrate long distances. Since the highest temperature at the boardwalk during these tests was between 30° and 31°C, the adverse effects were very local and did not seem to extend down to Stave Island.

To try to answer this complex question of the contribution of ichthyoplankton from the tributaries to the river, studies were done from 1984-1992 to determine the distribution of ichthyoplankton in the Savannah River and in the swamps and thermal streams on the Plant site. In the 1985 studies, the Savannah River was divided into a Lower Farfield from approximately river mile 90 to 130; Nearfield from river mile 130 to 160; and Upper Farfield from 160 to 190 river miles. In this study not only were river transects made, but also collections were made in intake canals and

oxbows and mouths of 17 tributaries between river mile 89.3 and river mile 187.1. In general, the dominant group were Clupeidae, including the blueback herring, American shad, threadfin shad, and gizzard shad. Other abundant taxa were sunfish and spotted suckers.

The total number of fish eggs collected in the study period between February and July, 1985 were 15,749 in the Savannah River, tributaries, oxbows, and intakes. Of these 108 were collected from the oxbows, 44 from intake canals, and 539 from tributary creeks. By far the largest percentage of eggs were American shad (73.0%); gizzard shad and/or threadfin shad was 2.2%, striped bass eggs 7.2%, and blueback herring eggs were 3.1%.

As for the ichthyoplankton of anadromous fish in the river, the greatest number per 1,000 m³ was found in May in the Upper Farfield, and also the greatest number in June and in July was in the Upper Farfield. In March, the greatest density was in the Lower Farfield (36.5%) and this was also true in April in the Lower Farfield, with a density of 193.6 m³. In the Nearfield in April, the density was 153.7 m³ and in the Upper Farfield it was 134.9 m³. Thus it was quite evident when one considers all the data that, for ichthyoplankton of anadromous fish, the Upper Farfield of the Savannah River was more productive for these species than the Nearfield or the Lower Farfield of the Savannah River. The Nearfield was more productive than the Lower Farfield.

For fish eggs it is often more difficult to determine numbers than for larvae, because of irregular concentration caused by spawning patterns of various species and irregular sinking patterns

of the eggs. Depending on the spawning preference of various fish, the suitability of oxbows, open river, and tributaries vary greatly (Paller et al., 1985). There are indications that spawning begins earlier in Steel Creek (February) than in other non-thermal Savannah tributaries. In April the density was highest in the creek. The most abundant ichthyoplankters (egg and larvae) were American shad, blueback herring, and darters. The high percentages of shad and herring indicate that the lower reaches of the creek are spawning areas for these anadromous fish. It is estimated that 5.2 million fish larvae and eggs were transported from Steel Creek to the Savannah River during 1985 and this was higher than for any other time that was studied.

The thermally effected creeks such as Four Mile and Beaver Dam Creek had very low densities of ichthyoplankton and eggs. Ichthyoplankton densities in the river were characterized by pronounced temporal changes. Densities ranged from a mean of 0.3 organisms per 1,000 m³ in February to 156.6 per 1,000 m³ in April. Most variability was associated with the date of sampling. That is seasonal changes. Dominant taxa included American shad, spotted sucker, and gizzard shad and/or threadfin.

A comparison of the ichthyoplankton in Ebenezer Creek, Briar Creek, and the mouth of Steel Creek shows that Briar Creek contributed the greatest number of ichthyoplankton followed by Ebenezer Creek. The mouth of Steel-Pen Creek was third in 1992. However, the amount of ichthyoplankton of American shad was similar for Briar Creek and Steel-Pen Creek mouth. Also for sunfish, the Steel-Pen Creek mouth made a higher contribution to the river than Briar Creek.

CONCLUSIONS

The results of the 1992 studies indicate there were no detrimental effects of PAT on the ichthyoplankton contribution of Pen-Steel Creek water to the Savannah River. Nor were there any indications that the organisms forming the food supply of these larvae or of more mature stages of the fish had been adversely affected by the temperature rises caused by PAT. This is probably because the characteristics of the environment, including temperature, were similar in these tributaries entering the river to those existing in the river.

It is true a dark plume is seen on the South Carolina side of the river entering from the mouth of Pen-Steel Creek. This type of plume is evident whenever dark swamp water enters a circumneutral river. However, the temperature in the plume was similar to that in the river.

Appendix A
State of Georgia
Water Quality Management Plan 1992

The Water Quality Objectives

All streams within the Savannah River basin are classified according to the listings given in Section 3 of this document. In order to determine if water quality objectives are being met, a combination of fixed water quality trend monitoring stations and intensive field surveys are employed. There are 13 trend monitoring stations that are currently being sampled in 1992. Any discharge less than 10,000 gallons a day are not required to be permitted. When the Richard B. Russell Lake is in place, practically all of the waters from the headwaters to below Clark Hill Dam will show the effect of these dams. Present trend monitoring stations are located at U.S. Highway 76, Georgia Highway 368, Augusta Canal Lock, New Savannah Bluff Lock and Dam, Old Georgia Route 56 Bridge on Butler Creek a $1\frac{1}{2}$ mile downstream of Phinizy Ditch, Butler Creek upstream of Levee, Savannah River $1\frac{1}{2}$ downstream of Spirit Creek, Savannah River Plant, Savannah River Site water intake, South Carolina Lock and Dam LSCLRRN North of Cleo, U.S. Highway 17, Savannah Machine and Foundry Company, and at Fort Jackson.

Natural Characteristics of the Savannah River Basin

The drainage area encompasses approximately 1,192 square miles in Georgia alone plus the area in South and North Carolina.

Headwaters of the Savannah River are formed by the joining of the Tallulah and Chattooga Rivers which form the Tugaloo River along the Georgia/South Carolina state line. Tugaloo River with the Seneca at Hartwell, Georgia form the Savannah River which travels approximately 300 miles along the Georgia/South Carolina state line into the Atlantic Ocean at Savannah, Georgia. The main tributaries of the Savannah River are the Beaver Dam Creek, Broad River, Fishing Creek, Little River, Kiokee Creek, Uchee Creek, Butler Creek, Spirit Creek, and Briar Creek.

Water Quality Management, the Savannah River Basin, was divided into 15 hydrological subdivisions. The watershed or basin of the Savannah River includes 28 Georgia counties either wholly or partially within the river basin. The two largest cities in the basin are Savannah with a population of 118,349 and Augusta with a population of 59,864.

Average daily temperature of the Savannah River basin in the central areas, varies from 47°F in December to 87°F in July. Those are average temperatures. Average yearly rainfall varies from more than 72 inches in the mountains to 44 inches in the central area, and 50 inches on the coast.

Savannah River drainage basin or watershed is located in three geological provinces: the Blue Ridge, the Piedmont, and the Lower Coastal Plain. In the Blue Ridge providence, the bedrock consists of gneisses, schists, quartzites, and granites. The Piedmont province has deeply weathered bedrock which consists of ancient sediments intruded by granites and other basic and ultrabasic rock.

The province is dominated with red soils of sandy clay and silty clay texture. The dense geological formations do not transmit water freely except along fissures such as fault zones where the rocks have been broken. Bedrock on the Coastal Plain consists of stratified silts, sands, limestones, and clays which outcrop in wide bands parallel to the fall line.

Soils of the Savannah River watershed consist of several major subgroupings. In the Blue Ridge area, they are weathered granites, gneisses, and schists. The primary soil texture is sandy loams with stone outcroppings, while the subsoils are clay loams and clays. External drainage of these soils is moderate to rapid and internal drainage is moderate. The surface soils of the Piedmont area range from sandy loams to silt loams with subsoils ranging from sandy clay loam to silty clay. External drainage is moderate to rapid and internal drainage is moderate. The soils in the Upper Coastal Plain area consist of loamy sand, sandy loam with sandy clay loam to sandy clay subsoils. Soil texture and drainage along the stream varies. However most areas are somewhat poorly drained with grayish soils formed from thin beds of sandy clay loam and sandy loam. Surface runoff and internal drainage is slow in the broad, flat areas. The gradient in the Blue Ridge province of the Savannah River basin ranges from 550 feet at the headwaters of the Tallulah River to approximately 1,000 feet. The Piedmont province of the basin descends from 1,000 feet along the mountain foothills to approximately 200 feet near Augusta, Georgia. From Augusta, Georgia to the Atlantic coast the area is divided into the higher,

undulating Upper Coastal Plain and the flat, low-lying, Lower Coastal Plain. The gradient, therefore, is from 200 feet to 0.

Population

The population of the Savannah River watershed is predominantly rural. In 1980, the population of the drainage basin was estimated to be 553,680 persons. Since then the population has increased. Augusta and Savannah metropolitan areas are the two major urban population centers in the watershed. Rapid growth in these two large urban areas has accounted for much of the watershed's growth. Major growth unto the year 2000 is expected be in the upper part of the watershed that is above Augusta in the Piedmont region and it is expected that the population will reach about 634,400 people.

Employment in the Savannah River watershed is predominantly water associated with trades and services. Manufacturing and agricultural employment centers also exist within the Savannah River basin, mostly concentrated in the rural areas of the basin. Agricultural production includes tobacco, peanuts, cotton, corn, and soy beans. Livestock and livestock products are also major items. Industrial employment opportunities are apparel, textile, lumber, and the food industries. The Augusta area provides a major employment center for basically all types of non-agricultural employment. Major counties that have been designated by the Economic Development Administration as redevelopment areas are: Glascock, Green, Lincoln, Madison, Taliaferro, Warren, and Wilkes

counties. Designated as redevelopment areas, these counties were entitled to priority with regards to federal projects. Whether or not a substantial growth occurs in these areas, will be contingent upon the creation of attractive living and working conditions and the establishment of proper community services, facilities, and utilities.

Land use for agricultural purposes is greatest in the Piedmont and in Glascock, Burke, and Effingham counties. A major land user is the Ward Gordon Military Reservation. Public, institutional, social, physical and other land constraints have served as major deterrents of land use within the Savannah River basin. In the northern portion of the basin, development has been limited due to the steep topography. In the Coastal Plain portion of the basin, the soils are poorly drained and are subject to flooding. These soil conditions are limitations on land development within the basin. Use constrains land development along the Savannah River corridor and major tributaries of the Savannah River. These areas should remain open and be used for recreation, fish and wildlife, pasture, forest, or scenic areas.

For establishing water quality standards, nine water uses have been recognized. They are recreation; fishing; propagation of fish, shellfish, game, and other aquatic life; wild river; scenic river; urban stream; agriculture; industrial; and navigation. For each of these classifications there are specific criteria which apply. In nearly every case the criteria relate to the parameters of dissolved oxygen, pH, fecal coliform, and temperature. Specific

parameter limitations for each use classification are identified in Table 3.1. Also a number of general criteria which apply to all waters are the same regardless of water-use classification.

In summary, the state prohibits materials which produce turbidity, odor, color, or other objectionable conditions; substances which can be harmful to aquatic life; radioactive substances in amounts which exceed federal or state regulations; and stream-bed alterations which may result in violation of stream quality standards. The standards also address the approach to be followed to maintain existing high-quality waters. In addition to the four specific parameters mentioned above, the state regulates all pollutants on a case-by-case basis that would have detrimental impact on the beneficial uses of water.

The state has found it better to control pollutants through the establishment of adequate effluence limitations on the source, rather than through the use of the in-stream water quality standards. This is done using guidelines produced by U.S. Environmental Protective Agency and other sources. Certain of the streams in some of the counties have been designated as supporting a self-sustaining population of rainbow, brown, or brook trout. These streams are in Elbert County, Haversham County, Art County, Raven County, Stevens County and Towns County.

The Savannah River has been classified as follows according to Ukes: the Georgia/South Carolina state line to Clark Hill Dam for recreation; from Clark Hill Dam mile 238 to Augusta 13th Street Bridge -- drinking water; from U.S. Highway 301, mile 129 to U.S.

Highway 17 Bridge, mile 22 -- drinking water; U.S. Highway 17 bridge, mile 22 to Field Cut, mile 5 -- industrial navigation; Fort Pulaski, mile 0 to open sea and all legal waters of Tybee Island -- recreation; Chattooga River, a headwater stream, Georgia/North Carolina state line to Tugaloo Reservoir -- wild and scenic; West Fork of the Chattooga River, confluence of Overflow Creek and Clear Creek, to confluence of Chattooga River -- wild and scenic river; Tallulah River, headwaters of Lake Britton, to confluence with Chattooga River -- recreation; and Tugaloo River, confluence of Tallulah and Chattooga Rivers to Yonah Dam -- recreation. Table 3.2 describes the classification of the trout-designated rivers.

The source control is based upon Public Law 92500, the Federal Water Pollution Control Act Amendments of 1972. These amendments established the basic approach for point source pollution control to be followed by all states. Water quality standards are the driving force behind point source control needs. Therefore, point sources listed for each basin must achieve the highest level of waste water treatment necessary to prevent violation of local water quality standards. This requirement creates two types of stream segments as defined by rules and regulations for water quality control, chapter 391-3-6 revised October 1980, Georgia Department of Natural Resources.

1. Water Quality Limited Segment

Any segment where it is known that the water quality does not meet applicable water quality standards and/or is not

expected to meet applicable water quality standards even after the application of the effluent limited requirements by sections 301(b)(1)(B) and 301(b)(2)(A) of the federal act.

2. Effluent Limited Segment

Any segment where it is known that water quality is meeting and will continue to meet applicable water quality standards or where there is adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by sections 301(b)(1)(B) and 301(b)(2)(A) of the federal act.

Pollutant sources are designated as minor sources. These are not listed in the basin plan. They are of two types: municipal and privately-owned facilities discharging less than 10,000 gallons per day and industrial facilities that meet any of the following requirements:

- a. No discharge
- b. Discharge consisting only of contaminated cooling water, groundwater, and/or rainwater runoff

- c. Discharges with no significant organic: less than 2.5 lbs of BOD5 per day or chemical contaminants

The fact that the minor sources are unlisted does not mean that they are unregulated. All discharging sources have been issued NPDES permits, all no discharge systems have been issued state permits, and all systems are inspected regularly by Division staff and required to meet conditions of their permits. Information on these sources is contained in the Division's files. By law, all point sources must provided for at least the minimum of secondary treatment. Any required level of treatment in excess of secondary imposes additional cost that must be properly justified. In order to insure that no discharge is penalized unfairly by requiring treatment levels in excess of those needed to protect water quality standards, the Division uses the following approach on data needs. No waste discharge owner will be required to provide a level of waste water treatment above a secondary treatment for domestic or municipal waste without defensible proof of the need for a higher level of treatment. This proof may include, but is not limited to, one or more of the following:

1. A calibrated, mathematical water quality model
2. Data from intensive surveys or the state's trend monitoring network for water quality

3. A history of fish kills or other nuisance problems in the stream

Furthermore, no municipality will be required to go past step 1 in the construction graph process for advanced waste treatment unless the need for such treatment is substantiated with field data. Thus the technical methods and data needs for developing defensible waste load allocations can be divided into two categories: those for effluent limited segments and secondary treatment called "table top methods" and 2) those for water quality limited segments called "field calibrated" or "field data based". Waste load allocations (WLA's) reflect a specific design, stream flow, water temperature, and background water quality at which standards will be protected. This means that WLA's can be developed to represent a specific time in each year, specific periods of time in each year, various levels of stream flow, and/or various levels of natural background water quality. Currently, the division develops three different types of waste load allocations: 1) Annual waste load allocations; 2) seasonal or monthly waste load allocations; 3) hydrographic control releases (HCR) of waste load allocations. HCR allocation permits waste discharges during wet periods, but requires that waste be stored on-site during dry periods. Because of the design and operational complications, the HCR waste load allocation is restricted to those situations where the annual, seasonal, or monthly WLA's do not apply.

Stream Flow

In Georgia, the designed stream flow is specified by law. The WLA shall apply to all stream flows equal to or exceeding the seven day, 10 year minimum flow.

Water Temperature

Each WLA requires a pre-specified designed temperature. However, unlike stream flow, designed temperatures are not specified by law. Instead the Division follows development procedures approved by U.S. EPA that produce consistent design temperatures.

Background Water Quality

Unlike stream flow, designed background conditions are not specified by state law. Like water temperature, background water quality for each WLA is developed from procedures approved by U.S. EPA to insure consistency of application and equal fairness to all dischargers.

Methods and Procedures for Waste Load Allocations

In one respect all waste load allocations are the same. Each represents the maximum discharge allowable to protect the water quality standard. However, the methods and procedures for developing waste load allocations vary tremendously, depending on the type of stream segment, the type of substance being considered,

the type of receiving water, the number of discharges involved among other factors. They all share the following common properties:

1. Each procedure can be applied consistently to ensure that from case-to-case, each discharger is treated with equal fairness.
2. Each procedure conforms to Division policies, especially those establishing minimum data needs for various types of allocations.
3. Each procedure conforms to U.S. EPA guidelines and regulations and adheres to the standards of general practice prevailing in the engineering community.
4. Each procedure ensures a level of technical defensibility consistent with the type of waste load allocation being developed.

Three types of stream segments are recognized. Effluent limited segments are those in which the water quality standards can be met with a minimum of secondary treatments. Since the minimum of secondary treatment is always required, the data needed for the defensible allocations is, likewise, minimum. This fact gives rise to the application of table-top procedures which do not require

site-specific field data, but rely instead on estimates contained in official and unofficial guidance documents. Water quality limited segments, on the other hand require more extensive technical analyses to pinpoint the precise level of treatment for the protection of standards. According to EPD procedures and general engineering practice, WLA's in these segments should be field data based and, where appropriate supported by field calibrated mathematical water quality models. As a general rule, the degree of technical defensibility increases as the amount of field data, technical rigor, and experienced judgement increases.

The type of substance influences the water quality standard involved. If the standard is DO, and the discharged substances are oxygen-demanding, carbonaceous, CBODs, and nitrogenous NH_3 waste, in this case waste load allocations should be based on mathematical models. On the other hand, if the discharged substance is a biological nutrient such as phosphate, the effect of which is to reduce water quality by triggering unwanted blooms of green algae, mathematical models may be too cumbersome and the allocation procedure thus relies on the examination of field data and the exercise of informed judgement.

In Georgia, the type of receding waters or recognized receding waters, include freshwater streams, swamps, marshes, tidal-effected estuaries, and lakes. Usually WLA's for freshwater streams can be developed using the computer program, Georgia DOSAG. Secondly, by modeling Procedures Manual EPD January 1981, and by state EPA Regional Floor Agreement on the Development of Waste Load

Allocations and Waste Water Permit Limitations SEA 1982. For swamps, marshes, and lakes, mathematical models usually prove to be too cumbersome to be used for waste load allocations. In these cases, the determination of effluent limits relies on a close examination of field data followed by exercise of experienced judgement. For effluent limited waters, table top methods, along with an analysis of existing field data are usually adequate. For segments that are water quality limited, field data base procedures would typically special intensive field studies before defensible waste load allocations could be developed. Models most frequently used are Georgia's DOSAG for freshwater streams and Georgia EST for non-complex tidal-effected estuaries. Either model can be applied in the table top mode for effluent limited segments or in the field calibrated mode for water quality limited segments. However, the Division uses extensively the open scientific literature and standards established by the engineering community.

Georgia DOSAG, developed by EPD in cooperation with the Georgia district of USDS is a computer program used for most of the WLA's of freshwater streams and rivers. The primary objective of Georgia DOSAG is to compute the dissolved oxygen sag curve, below waste discharge point. The model, which is applicable to unbranched river segments, takes into account carbonaceous and biochemical oxygen demand BOD contributions from the river upstream of the discharge point, multiple waste sources, tributary inflows, and incremental inflows. Given a steady-state DO profile, waste load allocations can be developed by varying carbonaceous and

nitrogenous waste loads until the predicted minimum in-stream dissolved oxygen conforms to the local water quality standard.

Georgia EST is particularly well-suited to develop steady-state waste load allocations in non-complex tidal estuaries. This model specifically gives the design for the Division's microprocessor. It is one dimensional, steady-state, tidally averaged mid-tide (currently non-branching, coupled, and feed-forward). Oxygen dynamics include the effects of surface reaeration, CBOD/NBOD/deficit loadings from point sources to non-point sources, sediment oxygen demand, and net photosynthesis/respiration. This means that Georgia EST is conceptually equivalent to the Georgia DOSAG, although more complex because of the greater complexity of the estuarine situation. A model building a tidally-affected river can be subdivided into a sequence of n fully-mixed segments or tanks often around one mile in length. The computer code then appropriates a solution to the advection/dispersion equation for each segment by: 1. Writing a mass balance for each segment i , and then 2. Solving the end simultaneous linear equations created using matrix inversion. The final solution comprises values for salinity, CBOD, NBOD, DO, and DO deficits for each segment expressed as a steady-state segment average representing tidally-averaged mid-tide conditions. With the ability to calculate DO profiles that result in different levels of waste treatment, waste load allocation can be developed from Georgia EST in the same fashion as those from DOSAG.

Georgia has divided into water quality management units (WQMU's) the tributary streams (into 15 water quality management units) and the Savannah River proper (into three water quality management units).

Water Quality Management Units

Water quality management units include the northern extremity of the Savannah River Basin and is within the Blue Ridge Physiographic Province. There is currently one water pollution control plant, large enough to be included in this document, which discharges to a stream within the WQM unit. There are two public water supply units in this area. One supplies Clayton, Mountain City, and Tiger from Black Creek and the other one is the Kingswood County water supply system. Into unit 0102, into Eastanollee Creek are, besides the ordinary organic BOD nitrogens and such, chromium, phenols, sulfides, zinc, and copper discharged by Coates and Clark Inc. and Toccoa Stephens. Into Big Tom's Creek Tributary, Milliken and Co. and Avalon Stephens discharge BOD and total suspended solids. Into Toccoa Creek, the city of Toccoa discharges and also Toccoa Stephens supplies the ordinary BOD's and suspended solids and ammonia. TRC's are monitored as well as zinc. Into Lake Hartwell, Georgia DOT, Safety Rest Area, and Hart County discharge ordinary organic material. Into Eastanolle Creek, the city of Toccoa discharges and Toccoa Stephens. Besides the usual organic materials, the following are monitored: TRC's, chromium, nickel, zinc, and copper. Into Ogg's Branch, Dogwood Lane MHP and Toccoa

Stephens discharge BOD and suspended solids load. Into Toccoa Falls Creek, Toccoa Falls College and Toccoa Falls/Stephens discharge ordinary organic material which is BOD's, suspended solids, fecal coliform, and such.

Water Quality Management Unit 0103 is the upper reaches of the Broad River and is located in the northern part of the Savannah River basin. It is bounded on the west and south by the Hudson River watershed and to the east by the upper reaches of the Savannah River's west watershed and the western watershed of the Tugaloo. The northern boundary of this WQMU is formed by the Chattahoochee River basin. The total management unit consists of approximately 289.7 square miles, which is 5.6% of the total Savannah River basin. The streams in the unit are Middle Fork, Broad River; North Fork, Broad River; Bear Creek; and Nancy Town Creek. Georgia DOT Safety Rest Area number 81 and Franklin Springs/Franklin discharge into a tributary to Indian Creek BOD, suspended solids, and fecal coliform in small amounts. Davidson Mineral Properties, Inc. and Toccoa/Stephens discharge into the North Fork of the Broad River total suspended solids. Into Bear Creek the city of Lavonia and Lavonia/Franklin discharge fecal coliform, suspended solids, BOD, and ammonia. The TRC's are monitored. Into Bear Creek, Lavonia WPCP and Lavonia/Franklin discharge suspended solids, fecal coliform, BOD, ammonia. Into Dix Creek, Milliken and Co., Humphrey Plant and Toccoa/Stephens discharge BOD and total suspended solids. Into Stephens Creek,

Carnesville WPCP and Carnesville/Franklin discharge BOD and suspended solids.

Water Quality Management 0104 is formed by the watershed which lies west of the Savannah River between Hartwell Dam and the upper arm of Clark Field Reservoir. It is bounded on the north by the west watershed of Tugaloo to the west by the upper reaches of the Broad River and the Hudson River watershed and to the south by the Broad River watershed. The eastern boundary is formed by the Georgia/South Carolina state line. The total management unit consists of approximately 286.3 square miles which is 5.5% of the total Savannah River basin. Franklin Mineral Products Co. and Hartwell/Hart discharge total suspended solids. Into Fortson Creek, Fortson, Elberton/Elbert discharge BOD, suspended solids, and ammonia, and TRC's and priority pollutants are monitored. Into Beaver Dam Creek tributary, CSX Transportation and Middleton/Elbert discharge Benzene, Ethylbenzene, Toluene, Nitrobenzene, Zylene (which is monitored) and Methoxy Butoxy Ethanol. The Zylene and the Methody Butoxy Ethanol are monitored. Into Cedar Creek, the city of Hartwell and Hartwell/Hart discharge BOD, suspended solids, ammonia, fecal coliform, COD, phosphorus, and TRC. Phosphorus and TRC are monitored. Cadmium, chromium, zinc, and copper and nickel are monitored. Into Forest Creek, Milliken and Company, Newton Plant and Hartwell/Hart discharge BOD, total suspended solids, and chlorine. All of these are monitored. Into Beaver Dam Creek, Elbert County, Beaver Dam Elementary School, and Elberton/Elbert discharge BOD, suspended solids, and fecal coliform. Into Cedar Creek, Mearl

Corporation and Hartwell/Hart discharge oil and grease and fluorides and some turbidity.

Water Quality Management Unit 0105. This water quality unit is bounded by the upper reaches of the Savannah River west watershed to the south by the Clark Hill Reservoir watershed and Little River watershed and to the west by the South Fork of the Broad River watershed and the Hudson River watershed. It is also bounded on the west by the Oconee River basin. The total management unit consists of 488 square miles which is 9.4% of the total Savannah River basin. There are no EPD water quality trend monitoring stations located in this unit. There is one U.S.G.S. stream-flow gaging station currently active in this unit. Into Falling Creek, the city of Elberton and Elberton/Elbert discharge ammonia, fecal coliform, and COD and TRC are monitored. Into Bertram Creek, Herdmont Health Care Center and Elberton/Elbert discharge BOD and suspended solids. Into Tanyard Branch Tributary, the town of Tignall and Tignall/Wilkes discharge BOD, suspended solids, ammonia, and priority pollutants are monitored.

Water Quality Management Unit 0106. Hudson River watershed lies in the upper third of the Savannah River basin. This is bounded on the north by the upper reaches of the Broad River, to the east by the west watershed of the Tugaloo and the Broad River watershed, and to the south by the South Fork of the Broad River watershed. The western boundary is formed by the Chattahoochee River basin and the Oconee River basin. The total management unit consists of approximately 466.2 square miles or 9% of the total

Savannah River basin. There are no EPD water quality trend monitoring stations or U.S.G.S. stream-flow gaging stations currently active in this area. Into Hayes' Creek, Franklin Springs WPCP and Franklin Springs/Franklin discharge BOD, suspended solids, and priority pollutants are monitored. Into Fork Creek, the city of Bowman and Bowman/Elbert discharge BOD and suspended solids. Into a tributary to the Hudson River, Georgia Stone Quarries, Inc. and Homer/Banks discharge total suspended solids. Into Grove Creek, the city of Commerce, Davis House WSP and Commerce/Jackson discharge BOD and suspended solids. Into Crooked Creek, the city of Commerce, Holiday Inn WSP, and Commerce/Jackson discharge BOD and suspended solids. Into Beaver Dam Creek, Commerce Northside WPCP, and Commerce/Jackson discharge suspended solids, fecal coliform, BOD, ammonia, and TRC is monitored. Into a tributary to Mountain Creek, Georgia Department of Correction, Georgia Industrial Institute, and Alto/Banks discharge BOD, suspended solids, and fecal coliform. Into Hanna Creek, Royston WPCP and Royston/Franklin discharge BOD, suspended solids, and ammonia.

Water Quality Management Unit 0107. The South Fork of the Broad River is located on the western boundary of the upper third of the Savannah River basin. It is bounded by the Hudson River watershed (0106) to the east and the Broad River watershed (0105) to the south. The western boundary is formed by the Oconee River basin. The South Fork, Broad River arises in Madison County and flows in a southeasterly direction to its confluence with the Broad River on the Madison/Oglethorpe county line. The total management

unit consists of approximately 241.4 square miles or 4.6% of the total Savannah River basin. There are no EDP water quality trend monitoring stations or U.S.G.S. stream-flow gaging stations currently active in this area. There are two water pollution control plants in this unit and there are no water surface intakes. Groundwater provides the main source of drinking water for the communities. The city of Crawford Eastside WPCP, Crawford/Oglethorpe discharge into Grove Creek BOD and suspended solids. The city of Danielsville, Danielsville/Madison discharge BOD and suspended solids into the South Fork, Broad River. The city of Comer serving Comer/Madison also discharges suspended solids and BOD into the South Fork, Broad River.

Water Quality Management Unit 0108 is bounded by the Broad River watershed (0105) to the north and west and Little River watershed (0109) to the south. The eastern boundary is formed by the Georgia/South Carolina state line. The total unit is approximately 303.7 square miles or 5.8% of the total river basin. There are no water quality trend monitoring stations or U.S.G.S. stream-flow gaging stations currently active in the area. The city of Lincolnton utilizes the Clark Hill Reservoir for water supply. The city of Lincolnvile discharges into Reedy Creek, BOD, suspended solids, and phosphorus and priority pollutants are monitored. Fecal coliform is also discharged. This often is from sewage treatment plants.

Water Quality Management Unit 0109 is bounded to the north by the Broad River watershed and the Clark Hill Reservoir watershed,

to the east by the city of Augusta watershed, and to the south by the upper reaches of Briar Creek. The western boundary is formed by the Oconee River and the Ogeechee River basins. The total management area is approximately 754.9 square miles and approximately 14.5% of the total Savannah River basin. There is no water quality trend monitoring station or U.S.G.S. stream-flow gaging station in this watershed unit. The cities of Washington and Union Point utilize streams as their raw water source. Martin Marietta Aggregates, Kemac Quarry discharge into Middle Creek total suspended solids. The city of Washington/Rocky Creek discharge into Rocky Creek, BOD, suspended solids, fecal coliform, ammonia. Color is monitored. Copper, cyanide, and zinc are also discharged as are TRC's. Lincolnton/Lincoln discharges into Lloyd's Creek total suspended solids.

Watershed unit 0110 is bounded on the north by Little River watershed, on the west by the upper reaches of Briar Creek, to the south by McBean Creek watershed. The eastern boundary is formed by the Georgia/South Carolina state line, the Savannah River. The total management unit consists of approximately 480.6 square miles or 9.3% of the total Savannah River basin. There are three EPD water quality monitoring stations located in this unit and there is one U.S.G.S. stream-flow gaging station that is currently active. The city of Augusta utilizes the Augusta Canal for raw water supply. The city of Augusta, Augusta/Richmond discharge into Phinizy Ditch Tributary, BOD, suspended solids, fecal coliform. Ammonia and TRC's were monitored. The Albion Kaolin Company and

Hephzibad/Richmond discharge into Grindstone Branch to Spirit Creek mainly suspended turbidity. Columbia County, Crawford Creek, and Martinez/Columbia discharge BOD, suspended solids, fecal coliform, ammonia, and TRC's into this creek. Olken Materials Company and Augusta Quarry discharge into Little Kiokee Creek, suspended solids. Reed Creek Water Pollution Control Unit and Martinez/Columbia discharge into Reed Creek, BOD, suspended solids, fecal coliform. Ammonia and TRC's are monitored. Lease-Purchase Corporation, Timbers Subdivision, and Augusta/Richmond discharge BOD, suspended solids, and fecal coliform into a tributary to Spirit Creek. Hephzibad, Dunbartons/DWPCP in Richmond County discharge into Little Spirit Creek, BOD, suspended solids, DO, and fecal coliform. The city of Harlem, Harlem/Columbia discharge into Uchee, BOD, suspended solids, fecal coliform, and priority pollutants are monitored. Monsanto Company, Augusta/Richmond discharge into Butler Creek, phosphorus and zinc which are monitored. The conductivity is also monitored. Fort Gordon WPCP, Fort Gordon/Richmond discharge into McCoy Creek, BOD, suspended solids, and fecal coliform. Castle Pines MHP, Augusta/Richmond discharge into Twig's Dead River, BOD and suspended solids, fecal coliform, and ammonia. Martin Marietta Aggregates, Augusta Quarry, and Richmond County discharge into Augusta Canal, total suspended solids. Flow is also monitored. MT Ceramics Inc., Augusta/Richmond discharge into Rocky Creek, BOD, suspended solids all in grease. Non-contact coolant water, coolant water, and process waste water are discharged. The flow is monitored. Spirit Creek WPCP, Augusta/

Richmond discharge into Spirit Creek, BOD, suspended solids, ammonia, fecal coliform, and TRC's are monitored. Georgia DHR, Gracewood State School and Hospital, Gracewood/Richmond discharge into Spirit Creek, BOD, suspended solids, fecal coliform, TRC's, and ammonia.

Watershed unit 0111 is bounded on the north by Little River watershed (0109) and east by the city of Augusta watershed (0110), the Bean Creek watershed (0112), and the Briar Creek watershed (0113). The southern and western boundaries are formed by the Ogeechee River basin. The total management unit is approximately 187.9 square miles or 3.6% of the total Savannah River basin. There are no water quality trend monitoring stations located in the unit. There are two U.S.G.S. stream-flow gaging stations that are currently active in this area and two currently active water pollution control plants. The city of Thompson utilizes Sweet Water Creek for raw water supply. The city of Wrens WPC, Wrens/Jefferson discharge into Brushy Creek, BOD, suspended solids, and fecal coliform and ammonia. Thiele Kaolin Company, Wrens/Jefferson discharge into Thompson's Ford Branch, turbidity. Excel International discharges into Jordon Creek, turbidity. The flow is monitored. The city of Thompson, Thompson/McDuffie discharge into White Creek, BOD, suspended solids, fecal coliform, and ammonia. Thiele Kaolin Company and Hobbs Mines/Warren discharge into Big Branch, turbidity, and the flow is monitored. Georgia Kaolin and Wrens/Jefferson discharge into Rayburn Creek, turbidity, and the

flow is monitored. Jay Huber Corporation, Wrens/Jefferson discharge turbidity into Reedy Creek/Briar Creek and the flow is monitored.

McBean Creek watershed is 0112. It is located in the lower half of the Savannah River basin. It is bounded to the north by the city of Augusta watershed, to the west by the upper reaches of Briar Creek, to the south by the Briar Creek watershed. The eastern boundary is the Savannah River. The total management unit is 294.1 square miles or 5.7% of the total Savannah River basin. There is no water quality trend monitoring station here or U.S.G.S. stream-flow gaging station. There are no allocated discharges in this area.

Water Quality Management Unit 0113 is bounded by the upper reaches of Briar Creek and McBean Creek on the north and Ebenezer Creek watershed (0114) to the south. The western boundary is formed by the Ogeechee River basin and the eastern boundary is formed by the Georgia/South Carolina state line or, in other words, the Savannah River. It consists of 408.1 square miles or 7.9% of the total Savannah River basin. There are no water quality trend monitoring stations in this unit. However, there are two U.S.G.S. stream-flow gaging stations that are currently active. Two water pollution control plants in this unit discharging into Briar Creek are Sardias WPCP, Burkes County -- BOD, suspended solids, and fecal coliform. Waynesborough WPCP, Waynesborough/Burke discharge into McIntosh Creek, fecal coliform and TRC's.

Water Quality Management Unit 0114 is bounded by two Savannah River basin Water quality monitoring units, the Briar Creek watershed monitoring unit to the north (0113) and Savannah Harbor

(0115) to the south. The western boundary is formed by the Ogeechee River basin and the eastern boundary is formed by the Savannah River. The total management unit is 363.4 square miles or 7% of the total river basin. There are no water quality trend monitoring stations or U.S.G.S. stream-flow gaging stations in this unit. The cities of Sylvania and Springfield have developed facility plants and there are currently two water pollution control plants. There are no surface water intakes as groundwater provides the main source of drinking water for the communities in this area. The city of Sylvania, Sylvania/Scraven discharge into Buck Creek, BOD, suspended solids, ammonia, fecal coliform. TRC's and COD's are monitored. They also discharge small amounts of zinc and cyanide. Georgia Department of Industry, Trade, and Tourism discharge into a tributary to Savannah River, BOD, suspended solids, fecal coliform, and ammonia. Springfield WPCP, Effingham County discharge into Ebenezer Creek, suspended solids, BOD, ammonia, fecal coliform, and TRC's are monitored. Effingham County Board of Education and South Effingham Elementary School, Springfield/Effingham discharge into a tributary to Black Creek, BOD and suspended solids.

Water Quality Management Unit 0115 extends from the mouth of Lochner Creek on the Savannah River to the Atlantic Ocean. It is bounded to the northwest by Ebenezer Creek watershed (0114), to the northeast by the Savannah River, to the southwest by the Ogeechee water basin, and to the southeast by the Atlantic Ocean. It consists of approximately 399 square miles of drainage which

includes approximately 88 square miles in Effingham County and 311 square miles in Chatham County. There are no water quality trend monitoring stations or U.S.G.S. stream-flow gaging stations in this area. The cities of Rincon and Savannah have developed facility plans. There are currently eight water pollution control plants. The city of Savannah utilizes Abercorn Creek for raw water supply. In this monitoring unit, Garden City WPCP, Chatham County discharge into Pipemaker's Canal, BOD, suspended solids, fecal coliform, and ammonia. Southern State Phosphate and Fertilizer Company discharges into the Keystone Canal, COD, which is monitored and the flow is monitored. Central Georgia Railroad Company Dilliard Yard Engine Terminal discharges into the Ogeechee Canal, suspended solids and oil and grease. The flow is monitored. Coastal Water and Sewage Company, Westwood Heights Subdivision discharge into Sweigoffer Creek, BOD and suspended solids. The city of Savannah on President's Street discharges into Keystone Canal, CBOD's, fecal coliform, ammonia, cyanide, copper, lead, silver, zinc, phenol, chromium, and nickel. Phenol and chromium are monitored. The city of Savannah, President Street WPCP discharges into Kayton Canal, CBOD, suspended solids, fecal coliform, ammonia, cyanide, copper, lead, silver, zinc, phenol, chromium, nickel. Phenol, chromium, and TRC's are monitored. Gulf Stream Aerospace discharges into Pipemaker's Canal, BOD, COD, nitrates, aluminum, TSS, total chromium, cadmium, copper, lead, nickel, silver, cyanide, oil, and grease. Pine Forest Utility Corporation discharges into Black Creek, BOD and suspended solids. Postal Equities Corporation

(Budget Inn) discharges into Springfield Canal Tributary, BOD, suspended solids, and fecal coliform. Georgia's Welcome Center Safety Rest Area, Fort Wentworth/Chatham discharge into Knoxville Creek, BOD, suspended solids, and fecal coliform. Hercules discharges into Dundee Canal, BOD, COD, total suspended solids, and oil and grease are monitored.

Watershed Management Unit 0190 is the drainage basin of the upper Savannah River. It is bounded on the west, by the Chattahoochee River basin, to the north by the Tennessee River basin in Georgia and North Carolina, to the east by the Talulah and Stephen's Creek basins in South Carolina, and to the south by the drainage area of the middle Savannah River. It comprises approximately 3,550 square miles in Georgia and 2,570 square miles or a total drainage area of 6,120 square miles. There are two water quality trend monitoring stations located here and one U.S.G.S. stream-flow gaging station. There are currently no water pollution control plants in this unit. The city of Hartwell withdraws its water from the Hartwell Reservoir. The Elijah-Clark State Park discharges into Clark Hill Reservoir, BOD and suspended solids and fecal coliform. Mistlatoe State Park discharges into the Clark Hill Reservoir, BOD, suspended solids, and fecal coliform.

Water Quality Management Unit 0191, the mainstem of the middle Savannah River, extends from Clark Hill Dam to U.S. Highway 301. The basin is bounded on the northwest by the Little River watershed, to the south and southwest by Briar Creek, to the southeast by the Salkehatchie River basin, and to the northeast by

the Edisto River basin. Two water quality monitoring units comprise the western drainage basin of the mainstem of the middle Savannah River (0110 and 0112). The basin east of the main channel lies entirely within South Carolina. There are four water quality trend monitoring stations located in this unit and there are two U.S.G.S. stream flow units. There are currently four water pollution control plants. Primary water uses consist of drinking water, fishing, and navigation. The Savannah River serves as supply source for the city of Augusta, Columbia County, and Continental Forest Industries. Discharging into this area are the Arcadia Inc. Augusta Plant and Columbia Nitrogen. They discharge into the Savannah River and many of the effluents are monitored such as flow, ammonia, organic nitrogen, nitrates. Total nitrogen is limited to 2,630 lbs a day. Also discharged are BOD and total suspended solids. Yolin Corporation discharges into the Savannah River, mercury and TRC's and TSS. Monitored are chlorides, lead, nickel, selenium, and zinc. Columbia County WPCP discharges into the Savannah River, BOD, suspended solids, ammonia, fecal coliform, and TRC's are monitored. Federal Paper Board Company, TSS, total suspended solids, and BOD, DSM Chemicals discharges into the Savannah River, BOD, total suspended solids, COD, total Kjeldahl nitrogen is monitored as well as ammonia, total nitrogen, benzene, toluene, phenols, and other organics. The Electric Generating Plant discharges into Savannah River and Beaver Dam Creek. Flow and hydrazene and residual chlorine are monitored. Other discharges are available chlorine, chromium, zinc, total suspended solids, oil, and grease.

Water Quality Management Unit 0192, the mainstem of the lower Savannah River, extends from U.S. Highway 301 to the mouth of the river at the Atlantic Ocean. The basin is bounded to the north by Little River watershed and the McBean Creek watershed, to the west by the Ogeechee River basin, to the southeast by the Great Swamp, to the east by the Coosawhatchie, and to the northeast by the McBean Creek watershed. Four water quality monitoring units comprise the drainage basin west of the mainstem of the lower Savannah River. These are 01110, 01113, 01114, and 01115. There is one continuous-flow recording station on the mainstem of the lower Savannah River. The flow has been estimated to be 6,700 cubic feet per second from a drainage area of 9,850 square miles. There are four water quality trend monitoring stations in this unit. There are currently five water pollution control plants large enough to be included. Discharging into this unit are Stone Container Corporation -- BOD, total suspended solids, and monitored are color, BOD, lead, and zinc. Intermarine U.S.A. discharges into the Savannah River and the flow is monitored. Discharged are BOD, total suspended solids, and oil and grease. Union Camp discharges into the Savannah River. The flow and color and BOD40 are monitored. BOD and total suspended solids are also discharged with limits. Kemira Inc. discharges into the Savannah River total suspended solids, chromium, nickel, and iron. Hunter Army Airfield discharges into the Savannah River, BOD, total suspended solids, fecal coliform, and TRC's are monitored. The city of Tybee discharges into the Savannah River, BOD, total suspended solids, fecal coliform,

ammonia, and the TRC's are monitored. UOP/Katalistics International discharges into the Savannah River; ammonia, total suspended solids, nickel, and chloroform are monitored. Beatrice Hunt, Wesson discharge into the Savannah River. COD and oil and grease are monitored as is the flow. Dontar Gypsum discharges into the Savannah River, BOD, total suspended solids, and fecal coliform. Marcona Ocean Industries discharges into the Savannah River total suspended solids. Amoco Oil Company discharges into the Savannah River, BOD, total suspended solids, COD, oil and grease, phenolic compounds, ammonia, sulfide, and chromium. The Newington Plant discharges into the Savannah River, BOD, TOC, TSS, ammonia, and monitored are the flow and COD. Savannah Foods Industry discharges into the Savannah River, BOD, and the flow is monitored. Liquid Air Corporation has monitored its flow and conductivity. Atlantic Wood Industries discharges TOC's, phenols, BOD, TSS, oil and grease, total KOO1, and the COD and flow are monitored. Columbia Nitrogen Corporation Savannah River Plant discharges into the Savannah River, ammonia, nitrates, and urea, and the flow is monitored. Savannah Electric Fort Wentworth Station discharges into the Front River, the Savannah River, total suspended solids, oil and grease, copper, iron, mercury, residual oxidants, and monitored are heavy metals and flow. Savannah Electric Plant, McIntosh discharges into the Savannah River, BOD, TSS, oil and grease, copper, iron, and monitored are the flow, chlorine, and fecal coliform. Savannah Electric Riverside Station discharges into the Front River of the Savannah River, total suspended solids, oil and grease, and

residual oxidants. Georgia Pacific Resins Incorporated discharges into the Savannah River total suspended solids, and monitored are the flow and COD. Fort Howard Corporation discharges into the Savannah River, BOD, total suspended solids, and monitored are the flow, the PCB-1242, color, BOD40, cyanide, zinc, nickel, lead, chromium, chloroform, toluene, mercury, chloroethene, and Hexachloroethene. The city of Savannah Travis Field WPCP discharges BOD, suspended solids, fecal coliform, ammonia, and TRC's and zinc are monitored. The city of Savannah, Wilshire/Windsor WPCP discharge BOD, suspended solids, fecal coliform, ammonia, and monitored are TRC's, phenol, and zinc.

Appendix B

South Carolina Permitted Pollutants

Many different types of pollutants are allowed to enter the Savannah River directly or indirectly through the tributaries from the South Carolina Watershed. Examples are listed below.

Easttator Creek receives a great many sources of pollution. BOD and total solids are allowed from a number of industries. Also entering from industry is a great deal of ammonia nitrogen. In the report BOD, pH, and toxic chemicals are given plus nitrogen, ammonia, and phosphorus. Chlorine and coliforms enter through many creeks.

Entering from Clearwater Creek to Shaw Creek and from Four Mile Creek to the Savannah River, is oil and grease. Entering from Lake Kedwee and Kedwee River are carbon, arsenic, cadmium, chromium, lead. A considerable amount of lead is allowed to enter from Horse Creek, Lemon Creek, Battery Creek and from Kedwee Lake. Also from Lake Kedwee and Kedwee River, silver, zinc, selenium. Lake Hartwell, Horse Creek, Lemon Creek, and Battery Creek have effluents of methyl tertiary butyl ether. From Kedwee Lake and Lake Hartwell are 1-2 dichloroethane and toluene. They enter through Horse Creek, Lebanon Creek, Jackson Creek, Kedwee Lake. From Lake Hartwell, Horse Creek, Lemon Creek, Jackson Branch, Kedwee Lake, and Battery Creek, benzene is permitted to be discharged. To Battery Creek, and Lake Hartwell acenaphthalene and acenaphthene

are allowed. Chlorobenzene enters through Jackson Branch. Ethylbenzene is allowable through Jackson Branch, Kedwee Lake, Battery Lake, and Murray Creek and Jackson Lake.

Fluorine is allowable into Lake Hartwell. Into Kedwee Lake and Horse Creek enter 1-1-2 chloroethane and 2-4 dimethylphenol. Also various compounds of phenol enter Ashepod River. Into Lake Hartwell and into Horse Creek, Lemon Creek, Jackson Branch, Kedwee Lake, and Battery Creek naphthalene enters. PCB's are allowed into Towne Creek into Twelve Mile Creek into Lake Hartwell. Total mercury is allowed into Lake Kedwee and Kedwee River. Fecal coliform enters from a number of places.

Xylene is allowed into Lake Hartwell, Horse Creek, Lemon Creek, Jackson Branch, Battery Creek, and Kedwee Lake. BOD is controlled in a number of places. Chlorine is allowable in the Salkehatchie. Phenol is also allowable in the Salkehatchie as are nitrogen, sulfides, and chromium. In a number of places, 48 hour toxicity tests are required on effluents. Ammonia nitrogen is allowed in the Little Salkehatchie. Also into Lemon Creek and into the Little Salkehatchie, are allowed ethylbenzene, 1-2 dichlorobenzene, naphthalene. Xylene in small amounts is also allowed into Lemon Creek and the Little Salkehatchie. Ammonia is allowed in the Buckhead Swamp as is oil and grease. Into Ireland Creek and into the Ashepod River, are allowed ammonia nitrogen, cadmium, copper, lead, zinc, phenol, and Bis(2 ethylhexyl)phthalate.

It should be stated that there are many sources that have

allowed amounts of BOD. Oil and grease that enter through Black Creek. Ammonia nitrogen also enters through Black Creek. Chlorine is allowed through Sander's Branch as are oil and grease and ammonia nitrogen, cadmium, copper, lead, zinc, and phenolics. Ammonia nitrogen is allowed through a ditch in the Black Swamp into the Savannah River. As stated above, allowed are certain amounts of materials that affect pH and BOD throughout the system.

Oil and grease, freon are allowed into the Beaufort river. Into Whale Branch and the Coosaw River the following chemicals are allowed - ammonia, cyanide, arsenic, cadmium, copper, lead, nickel, and, of course, total coliform. Also through Whale Branch the following chemicals may enter the Savannah River - 1-2 dichloroethene, carbon tetrachloride, toluene, benzene, acenaphthalene, and acrylanitrile, anthracene, benzo(K)fluoranthene, benzo(A)pyrene, chlorobenzene, chloroethane, chrysene, diethylphthlate, 1-2 diphenyl, ethylbenzene, fluoranthene, fluorene, hexachloroethane, methylchloride, methalenechloride, nitrobenzene, phenanthrene, pyrene, tetrachloroethylene, 1-1 dichloroethane, 1-1-1 dichloroethane, benzo(A)anthracene, 1-2 dichlorobenzene, 1-2 dichloropropane, 1-2 transdichloroethylene, 1-3 dichloropropane.

Chlorine is allowable in Hartwell Lake from a number of industries and localities. Into Twelve Mile Creek are allowed tetrachloroethylene, 1-1 dichloroethane, 1-1 dichloroethylene, and 1-1-1 trichloroethane, 1-1-2 trichloroethane, benzoanthracene, and 1-2 dichlorobenzene, 1-2 dichloropropane, 1-2 trans-dichloroethylene,

trichloroethylene, dichlorobenzene, chlorophenol, nitrophenol, dichlorophenols, dinitro-O-cresol, phenol. Into Lake Hartwell, BIS(2)ethylhexylphthalate, di-N-butyl, phthalate alatal, vinyl chloride, trichloroethylene, hexachlorobutadiene. Oil and grease enter into the Seneca River. Ammonia nitrogen enters into Twelve Mile Creek and Salem Creek and into Lake Hartwell to the Savannah River.

Entering into Steel Creek and Hartwell Lake is ammonia nitrogen. Entering from Little River into Hartwell Lake is phosphorus. Also entering into Twelve Mile Creek to Lake Hartwell, cyanide. Into Lake Hartwell to the Savannah River enter sulfides, cadmium, chromium, copper, lead, zinc. Into TWM Creek to Twelve Mile Creek to Hartwell Lake, zinc, aluminum enter. Ammonia nitrogen enters into Twelve Mile Creek and Lake Hartwell. Cadmium and copper feed into Twelve Mile Creek. Into Golden Creek, and hence to Lake Hartwell and into Twelve Mile Creek, are zinc, lead, and phenol. Into Coneross Creek are ammonia, phosphate, phosphorus, cadmium, lead, aluminum. Into Eighteen Mile Creek, and hence into Lake Hartwell, is chlorine. Into Three and Twenty Creek is allowed atxadecone, toluene, benzene, phenol, naphthalene, ethylbenzene, cyanide, sulfide, chromium, lead, and zinc.

Into Jerry Creek may be discharged ammonia, phosphorous, cadmium, copper, lead, and zinc. Toluene is permitted into Generostee Creek and Whitner Creek. Benzene is also permitted into Whitner Creek and into Five Mile Creek. Acenaphthalene is permitted into Generostee Creek. Also into Generostee Creek are permitted

acrolein, acrylonitrile, anthracene, chlorobenzene, benzopyrene, chloroethane, chrysene, dimethylphthalate, and ethylbenzene. Also into this creek is allowed methylene chloride, nitrobenzene, phenanthrene, pyrene, tetrachloroethylene, 1-2 dichloropropane, 1-2-4 trichlorobenzene, 1-3 dichloropropane, 4 nitrophenol, 4-6 dinitro-o-cresol, phenol, naphthalene, BIS(2)ethylhexylphthalate, BI-N-butyl, and phthaletal. It is very evident that Generostee Creek receives a great deal of pollution. It also receives vinyl chloride, trichloroethylene, and hexachlorobutadiene.

Oil and grease is received into Richland Creek as well as Generostee Creek. Ammonia nitrogen is received into both of these creeks. Cyanide, sulfides, arsenic, cadmium, and chromium are received into Generostee Creek as well as lead and nickel and zinc and aluminum. Ammonia nitrogen is permitted into Cherokee Creek, Rocky Creek, Cupboard Creek, Betsy Creek. Into Tim's Branch and Upper Three Runs are permitted phosphorus, carbon, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, zinc, and aluminum. Into Indian Grave Creek aluminum, uranium, and tetrachloroethylene are permitted. Into Tim's Branch tetrachloroethylene and 1-1-1 trichloroethane, nitrates, and fecal coliform are permitted.

Other pollutants allowed into the Savannah River are oil and grease and ammonia nitrogen, magnesium, sulfate, chromium, copper, iron, lead, manganese, nickel, zinc, aluminum, and uranium. Into Davis Branch and Lower Three Runs are permitted oil and grease, sulfides, chromium, phenolics, fecal coliform.

Into Armstrong Creek, Hard Labor Creek, Rocky Creek and Steven's Creek, ammonia nitrogen is permitted. Into Steven's Creek is also permitted cadmium, copper, lead. Chlorine is permitted into Hard Labor Creek, Cow Head Creek, Muskrat Pond Branch into Hard Labor Creek, Rocky Creek, Steven's Creek, Persimmon's Branch to Rocky Creek and into the Savannah River direct.

These are examples and not a complete list of permitted chemicals entering the tributaries and the Savannah River proper.

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