- *Boreholes:* Eleven wells were installed in 1963 with 1-1/4-in. diameter steel pipes. On the average, these wells penetrate to a depth of 50 ft and were drilled through actual waste emplacements. They are dry wells not open to soil water. Once a year, these holes are monitored with a Geiger tube at 6-in. intervals from top to bottom. Comparison of readings year-by-year gives an indication of radioactivity movement.

- Trench Wells: Twenty-four wells were installed in 1969 with 1-1/2-in. diameter steel pipes screened at the level of burial trench bottoms. Their purpose is to sample any perched water that might collect by rain percolation through the soil-waste backfill in the burial trenches. The wells are sampled every two weeks.

- Grid Wells: Sixty-six wells were installed in 1973-1974 with 4-in.-diameter steel pipes penetrating the mean water table 10 ft. The bottom 20 ft are screened. The wells are sampled quarterly.

IDLE PRODUCTION FACILITIES

Reactor Areas

Two production reactors (R and L) and the Heavy Water Components Test Reactor (HWCTR) in U Area are no longer in service because of program considerations. When each reactor was shut down, measures were taken to remove all fissionable material and all radioactivity from the building as far as possible while allowing for possible reactivation of the reactors. Where radioactive materials were not removed, measures were taken to prevent spreading of the materials or access to them, as described below.

Status After Shutdown

Tables II-17 and II-18 summarize the status of each reactor and its auxiliary equipment. All known dischargeable reactor components have been removed from the reactor and fuel storage areas and shipped elsewhere for storage or processing, with the exceptions noted below:

1. The entire complement of irradiated control rods, safety rods, and miscellaneous non-fuel rods remain in HWCTR.

2. Some small irradiated components may have been dropped in the R- and L-Area disassembly basins and remain hidden under sludge on the basin floor.

All D_2O was removed from the reactor systems and recovered for other plant uses or for sale, except for minute amounts where recovery was not economical. The drained systems were flushed with H_2O and then air-dried or vacuum-dried to remove moisture. Expendable purification equipment, including deionizers, filters, and evaporators, was sent to the burial ground after recovery of D_2O.

The HWCTR spent fuel basin is empty and covered with a tarpaulin and wooden cover. The R and L basins are kept filled with water to provide shielding from residual radioactivity; overflow weirs are plugged to prevent release of waterborne radioactivity.

A small section of the R Area fuel and target storage basin known as the R emergency basin is filled with clay and capped with concrete because of its contamination level. This emergency basin had been used for tests on irradiated fuel. One fuel assembly ruptured during heating experiments several years before the shutdown. Most of the uranium from the assembly was caught in a sand-filled container. However, an estimated 15,000 to 20,000 Ci of fission product radioactivity escaped into the basin water. About 2700 Ci were sent to seepage basins (Appendix A). Most of the remainder settled to the basin floor.

At the shutdown, most of the radioactivity in the basin water was removed by passing the water through deionizers and filters. The failed fuel assembly and the contents of the container were removed from the basin and sent to the separations areas for disposal. At this point, more than 200 Ci of radioactivity remained distributed in sludge on the basin floor. Preliminary efforts to remove the sludge showed that this would not be practical. A detailed radiation survey was made to locate all intact fuel material stored in the basin; all of this material was then removed. The water was removed from the basin, resulting in radiation rates as high as 5 R/hr in some locations. The radiation rate in the general area rose to between 200 and 500 mR/hr. The basin was filled with clay to an average depth of 30 ft and capped with a layer of concrete. The area is identified with appropriate personnel warning signs attached to barricades installed around the basin.

Present Status

Table II-19 summarizes the present status of the idle reactors with regard to levels of radioactivity as compared to values at the time of shutdown. The radioactivity in R and L areas is almost entirely due to ^{60}Co induced in the stainless steel of the reactor vessel, and thus is an integral part of the vessel.

Area fences and reactor building doors in all three areas are kept locked; the keys are controlled to prevent access by any but specifically authorized personnel. The areas are inspected daily.

A monthly survey is made of each facility to confirm the status of radioactivity in the reactor building and equipment. Radioactivity is well-contained within the reactor buildings. In L Area, several ventilation fans are kept operating, and the stack exhaust is sampled continuously to determine that no activity is released via the stack. In R Area, all mechanical building ventilation has been shut off, so that no radioactivity is exhausted by this means to the atmosphere. One exhaust fan is running at all times in HWCTR. There is no routine monitoring of this exhaust because the HWCTR reactor vessel is tightly closed.

Other Processing Areas

The only non-reactor process building that has been taken out of service is Building 232-F. This building housed a tritium processing facility until October 6, 1958, when all process operations were shut down. Following the process shutdown, process vessels and piping were flushed with argon to remove all but trace amounts of tritium. The vessels and piping were then filled with argon. The process water lines were drained, and the air supply to various instruments was turned off. Early in 1963, the building ventilation was turned off. Subsequently many process valves and instruments have been salvaged for use in other buildings. At such times, no attempts were made to seal up the process lines.

An examination of the tritium content of the air in Building 232-F was made in 1963 during a seven-week period when no ventilation was supplied to the building. No increase in tritium content of the air was observed. Since 1963, tritium content of the air in the process rooms and other areas of the building have remained below the detection limit for the current Kanne chamber instrument used routinely in tritium measurements (1×10^{-5} µCi HTO/cc of air). Transferable contamination in process areas averaged less than 250 c/min per 100 cm^2 (clean zone guide is 50 c/min per 100 cm^2) during the period December 14, 1962 to January 18, 1963. Elsewhere in the facility, transferable contamination was insignificant, averaging less than the clean zone guide. In preparation for converting part of Building 232-F into office space, measurements were made on November 16, 1973, of transferable contamination in parts of the process and non-process areas. Transferable contamination was found to be less than the clean zone guide.

B. ANTICIPATED BENEFITS

Continued waste management operations in accordance with ERDA policies and standards provide protection of the population and the environment from adverse effects of radioactive and non-radioactive byproducts. This is accomplished by storing onsite as much of the waste as is technically and economically practical and reducing unavoidable releases to values that are well below applicable guidelines. ERDA policies and plant guidelines require regular assessment of waste management practices and continued improvement of waste reduction and storage techniques.

The Savannah River Plant was constructed during the 1950s to produce the basic materials used in the fabrication of nuclear weapons. These materials are primarily ^{239}Pu, which undergoes nuclear fission to provide the energy release of an atomic bomb, and ^{3}H (or tritium) which undergoes nuclear fusion in a hydrogen bomb. The primary purpose of the plant today remains the same, that is, to produce the nuclear materials required to maintain and improve the U. S. stockpile of nuclear weapons. A fraction of plant capacity has been used to produce other useful nuclear materials as required. These include:

- ^{238}Pu, a self-contained energy source that provides power for instruments used in space exploration and for heart pacemakers.
- ^{252}Cf, a material that spontaneously emits large quantities of neutrons that are effective in radiography, activation analysis, and possibly cancer therapy.
- ^{60}Co, a material that emits gamma rays that are effective in cancer therapy, irradiation preservation of food, and heat generation for self-contained power supplies.
- ^{244}Cm, another potential power source. Its principle advantages are its relatively long half-life of about 18 years and its high rate of heat generation.
- ^{233}U, a material used in many research programs, including programs to develop reactor technology based on the existing thorium reserves.

The waste management policies, plans, and operations described in this statement are designed to ensure continued protection of the population and the environment from wastes that have been stored onsite since operations began and wastes that will be generated in the future.

C. CHARACTERIZATION OF THE EXISTING ENVIRONMENT

1. PLANT HISTORY

The Atomic Energy Commission (now ERDA) selected the location of the Savannah River Plant in November 1950 after study of over 100 potential sites. Factors in the selection of the site included the low population density, accessibility of a large cooling water supply, and freedom from floods and major storms. The Savannah River Plant was the largest construction job undertaken by the Atomic Energy Commission. Construction began in February 1951, and it eventually involved over $1 billion in expenditures and a peak construction force of 39,000 workers. The operating force includes about 5000 workers.

Uranium fuel fabrication began in M Area and extraction of heavy water (D_2O) began in D Area in 1952.

The first production reactor (R) was started up in December 1953. Other production reactors began operation in February 1954 (P), July 1954 (L), November 1954 (K), and March 1955 (C). The Heavy Water Components Test Reactor (HWCTR) began operation in U Area in March 1962. Recirculation of cooling water for R and P reactors through Par Pond began in 1958. Reactors were shut down in June 1964 (R), December 1964 (HWCTR), and February 1968 (L).

The separations areas began processing radioactive fuel assemblies from the reactor areas in November 1954 (F) and July 1955 (H). Solid radioactive waste was first sent to the burial ground in the first half of 1953 when waste uranium from fuel fabrication in M Area was disposed of in this facility. The first waste tank was completed in March 1954. Waste discharges to the seepage basins and waste tanks began shortly after startup of the separations areas.

Baseline measurements of Savannah River conditions were made in 1951, before plant startup, by the Academy of Natural Sciences of Philadelphia. Since the baseline study, the Academy has maintained a continuous program of surveillance of river conditions.

During the period from 1951-1960, biologists from the University of South Carolina and the University of Georgia conducted surveys of biota and ecosystems on the SRP site for the AEC. The University of South Carolina described the major plant communities and collected data on comparison sites from nearby areas of South Carolina. Studies were made of plant succession in the abandoned fields. In addition, information was published on the effects of flooding of the vegetation along Steel Creek and on the environment in Steeds Pond which received effluent from the fuel fabrication facility.

The University of Georgia gathered information on the animal communities of the plantsite and produced studies of quantitative relationships within the old field ecosystems. In 1961, the Savannah River Ecology Laboratory was established to promote continuing ecological studies. It has been operated by the University of Georgia since its inception.

In 1972, SRP was declared the nation's first National Environmental Research Park.

2. SITE CHARACTERISTICS

INTRODUCTION

Characteristics of the SRP site that are pertinent to the operations of a waste management program include the geology, hydrology, meteorology, seismicity, biota, and background radiation. These characteristics are reviewed below. A more-detailed discussion may be found in DP-1323.[16]

GEOLOGY

SRP occupies an approximately circular site in South Carolina of about 300 square miles, bounded on the southwest by the Savannah River and centered approximately 25 miles southeast of Augusta, Ga. The plant is located in the Coastal Plain geologic province as can be seen on Figure II-38. This province is characterized by flat, mostly unconsolidated sediment of Cretaceous age or younger. About 20 miles northwest of the plantsite is the lower edge of the Piedmont Plateau (the other main geologic province in S. C.). The Piedmont Plateau is underlain by igneous and metamorphic rocks. The boundary between the two provinces is called the Fall Line. The Fall Line is not a sharp line of contact but a zone of transition from the typical land forms of one province to those of the other. It is often difficult to determine from the ground surface where the Piedmont Plateau ends and the Coastal Plain begins. Because the sediments of the Coastal Plain are more easily eroded than the hard crystalline rock of the Piedmont Plateau, the distinction is noticeable in river beds as the change in rock formation causes waterfalls or rapids. Figure II-38 also shows several other geologic provinces in the Appalachian Mountains.

The soil layers of the plantsite affect the migration rates and directions of ground water and of any radioisotopes present in the soils and ground water of the site. Geologic formations beneath the Savannah River Plant site are shown in Figure II-39, a cross section that originates at the Fall Line 20 miles to the northwest and bisects the plantsite. The formations are the

Hawthorn, Barnwell, McBean, Congaree, Ellenton, Tuscaloosa, and bedrock (crystalline metamorphic rock and the Dunbarton Triassic Basin).[17] The sediments that constitute the formations above bedrock are either unconsolidated or semiconsolidated. The crystalline metamorphic rocks outcrop at the Fall Line and dip approximately 36 ft/mi to the southeast underneath the Coastal Plain sediments.

A large Triassic deposit in a basin of the crystalline rock underlies one-third of the plant area and is located in the southeastern section of the site. This deposit consists of sedimentary material formed into sandstones, siltstones, and mudstones.

The geologic formation that immediately overlies the basement rock is called the Tuscaloosa Formation and is 500 to 600 ft thick below the plant. This formation consists of sand and clay and contains several prolific water-bearing beds, which supply over 1000 gal/min of water from each of several individual wells.

Overlying the Tuscaloosa Formation are several formations of the Tertiary Period that range in age from about 10 million to about 50 million years. These formations have a combined thickness of about 350 ft in the central part of the plant. They consist predominantly of compact clayey sand and sandy clay with a few beds of sand and a few beds of hard clay. At depths ranging from about 100 to 180 ft, there is a zone in which the sandy deposits include calcareous cement, small lenses of limestone, and some shells. At scattered discontinuous localities, slowly moving ground water has dissolved this calcareous material and left these lenses less consolidated than the sediments surrounding them. Some of these areas were filled with a concrete grout before major facilities were constructed. At some places on the Savannah River Plant, the rocks of the Tertiary Period are overlain by more recent terrace deposits of alluvium. These deposits are usually thin in the upland areas, but are of significant thickness in the valleys of the Savannah River and some of its larger tributaries.

The sediments form a wedge ranging in thickness from a few feet at the Fall Line to more than 1200 ft on the southeastern or downdip side of the plantside. They strike in an average direction of N6C°E and dip from 6 to 36 ft/mi to the southeast. The sediments are unbroken by large displacement faults or severe unconformities.

HYDROLOGY

Surface Water

Surface waters provide a mechanism for transporting unavoidable releases of radioactive elements, stable elements, and heat offsite. These materials, if discharged by operating facilities to a plant stream, will move toward the Savannah River because almost all of the plantsite is drained by tributaries of the river (Figure II-2). Only one small stream (not shown on Figure II-2) in the northeastern sector of the site drains to the Salkehatchie River to the east, and this small stream has no operating facilities on it. Each of the tributaries is fed by smaller streams; therefore, no location on the site is very far from a continuously flowing stream. Knowledge of the flow in the streams is used to predict the offsite consequences of various routine and accidental releases.

In addition to the flowing streams, surface water is held in over 50 artificial impoundments covering a total of over 3000 acres. The largest of these, Par Pond, has an area of approximately 2700 acres. Water is held intermittently in marshes and over 200 natural basins, called Carolina Bays. A large swamp bordering the Savannah River receives the flow from several of the plant streams.

The source of most of the surface water on the plantsite is either natural rainfall or water pumped from the Savannah River to cool the nuclear reactors. The cooling water is discharged to the streams to flow back to the river or to Par Pond. Additional small amounts are discharged from other plant processes to the streams.

Savannah River

The Savannah River Plant adjoins the Savannah River for 17 miles. The headwaters of the river are in the Blue Ridge Mountains of North Carolina, South Carolina, and Georgia. Formed at the junction of the Tugaloo and Seneca rivers near Hartwell, Georgia (100 miles northwest of SRP), the river empties into the Atlantic Ocean near Savannah, Georgia. The Savannah River basin is one of the major river basins in the southeastern United States. It has a surface area of 10,580 square miles, of which 8100 are above the Savannah River Plant.

Two large reservoirs upstream of the Savannah River Plant provide power, flood control, and recreational areas. Clark Hill Reservoir, completed in 1952, is 35 miles (70 river miles) upstream. Hartwell Reservoir, completed in 1961, is 90 miles (150 river miles) upstream. Operation of these reservoirs stabilized the river flow in the vicinity of the plant to a yearly average flow of 10,400 ±2900 cfs during 1961 to 1970. The minimum daily flow during this period was 6000 cfs. Figure II-40 shows monthly average flows for 1960 to 1970 for three locations on the river: at U. S. Highway 301 crossing (about 23 miles below SRP), at the SRP boat dock, and at Augusta. As the river flows by the Savannah River Plant, its nominal level drops 84 to 80 ft above mean sea level. River water requires a minimum of 3 days to reach the coast from SRP, and the average flow times of 5 to 6 days probably better represents the travel time.

The monthly average temperature of the river water measured at the SRP boat dock since July 1955 ranged from 6.8 to 26.8°C (Table II-20). The daily river temperature has reached 25.5°C or higher only during the months of June through September.

The Savannah River is used for fishing, both commercial and sport, and pleasure boating downstream of the plant, and also as a drinking water supply at Port Wentworth, Ga., for an effective consumer population of about 20,000, and at Hardeeville, S. C. (Beaufort - Jasper Water Treatment Plant), for a consumer population of approximately 50,000. Barge traffic is maintained on the 90-ft-wide and 9-ft-deep channel between Augusta and Savannah, Ga.

Onsite River Tributaries

The five main streams on the plantsite are Savannah River tributaries. These are Upper Three Runs, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs (Figure II-2). They arise on the Aiken Plateau and descend 100 to 200 ft before discharging to the river. On the plateau, the streams are clear except during periods of high water. Rainfall soaks into the ground, and seepage from the sandy soil furnishes the streams with a rather constant supply of water throughout the year. In addition, four of the streams have received reactor cooling water discharges. These discharges, many times the natural stream flows, cause the streams to overflow their original banks along much of their length.

Upper Three Runs

Upper Three Runs, the longest of the plant streams, differs from the other four streams in two respects: it is the only one with headwaters arising outside the plantsite, and it is the only one that has never received heated discharges of cooling water from the production reactors.

Upper Three Runs drains an area of about 190 square miles. Its significant tributaries are Tinker Creek, a rather lengthy headwaters branch, and Tims Branch, which receives industrial wastes from the fuel fabrication facilities (M Area) and the Savannah River Laboratory and flows through an impoundment, Steeds Pond. The M Area effluent flow averages about 1 cfs. Tims Branch flows at between 1-1/2 and 2 cfs below Steeds Pond and about 4 cfs just before discharge into Upper Three Runs.

The flow and temperature of Upper Three Runs have been monitored at the Highway 125 crossing (Figure II-2). Flow ranges between 190 to 520 cfs and averages 265 cfs. The average temperature for 1959 to 1966 was 16.9°C, with a maximum monthly average of 23.0°C in July.

Upper Three Runs was designated as a National Hydrologic Bench-Mark Stream by the United States Geological Survey in 1966. In Bench-Mark Streams the water quality, temperature, and flow are measured monthly to provide hydrologic data for a river basin in which the hydrologic regimen will likely be governed solely by natural conditions.

Four Mile Creek

Four Mile Creek follows a generally southwesterly path to the Savannah River for a distance of about 15 miles. In the swamp along the river, part of the creek flow empties into Beaver Dam Creek, a shorter stream that also discharges into the river. The remainder of the Four Mile Creek flow discharges through an opening in the levee into the river, or flows down the swamp and mixes with Steel Creek and Pen Branch.

Four Mile Creek and Beaver Dam Creek together drain about 35 square miles and receive discharges from four plant areas. Four Mile Creek receives effluents from F and H separations areas and the reactor cooling water discharge from C Reactor. The average flow upstream of any plant discharge is less than 0.5 cfs and is increased by drainage and F and H effluents to about 20 cfs just above the confluence with the C Reactor discharge. After the junction with the C Reactor cooling water, the creek flows about 7 miles before entering the river swamp. Beaver Dam Creek receives 65 to 130 cfs of effluent from the heavy water production process and the associated power generating plant in D Area.

Pen Branch

Pen Branch follows a path roughly parallel to Four Mile Creek until it enters the river swamp. The only significant tributary is Indian Grave Branch, which flows into Pen Branch about 5 miles above the swamp. Pen Branch enters the swamp about 3 miles from the river, flows directly toward the river for about 1.5 miles, and then turns and runs parallel to the river for about 5 miles before discharging into Steel Creek about 0.5 mile from its mouth.

Pen Branch with Indian Grave Branch drains about 35 square miles above the swamp. Indian Grave Branch receives the effluent cooling water from K Reactor. Above the K-Area discharge, Indian Grave Branch flow averages only about 1 cfs; above Indian Grave Branch, Pen Branch is also a small stream averaging 5 to 10 cfs.

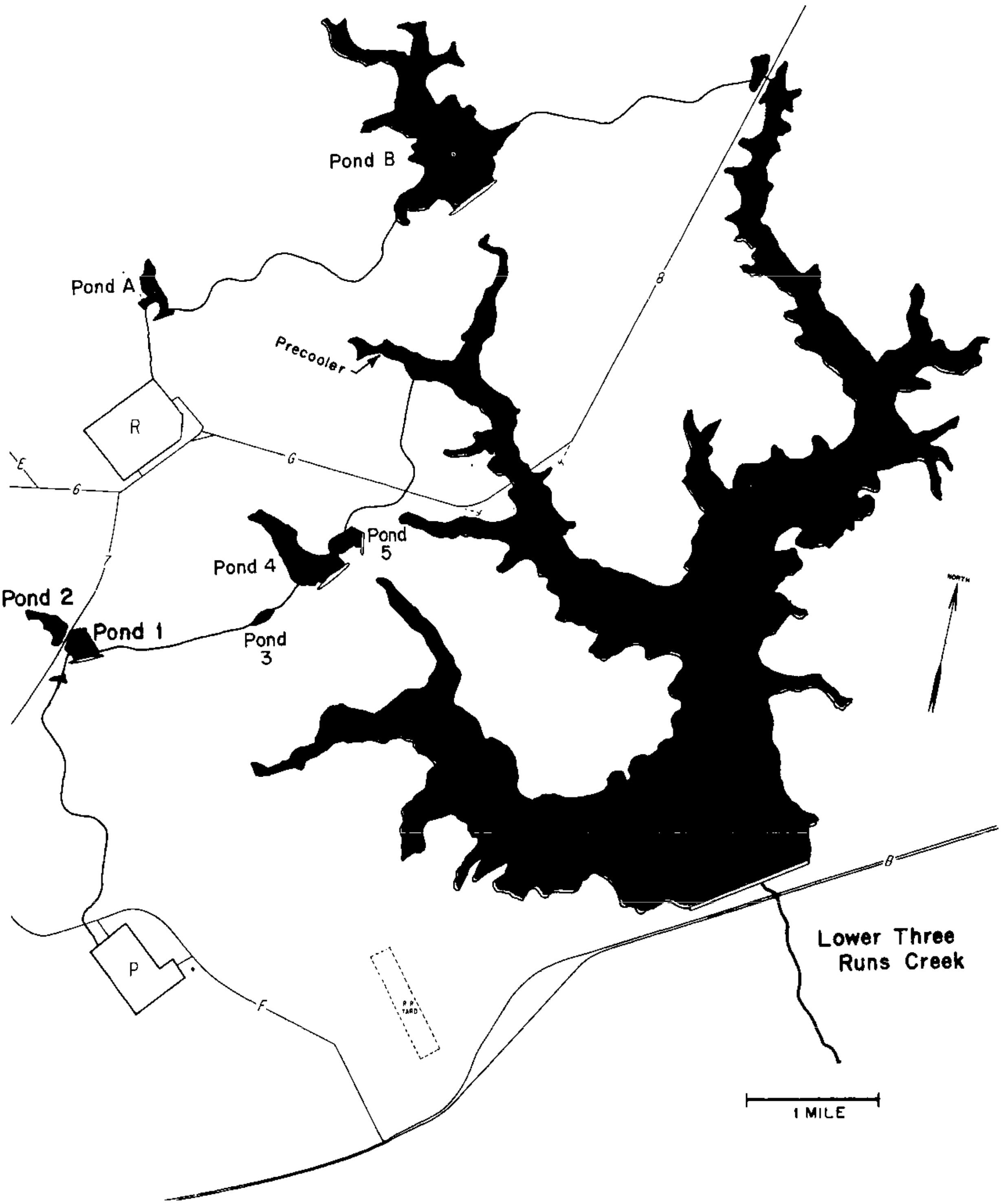
Steel Creek

Steel Creek flows southwesterly for about 4.5 miles, then turns to flow almost due south for about 5.5 miles, and enters the river swamp 2 to 3 miles from the river. In the swamp, it is joined by Pen Branch.

The drainage area of Steel Creek and its main tributary, Meyers Branch, is about 35 square miles. Steel Creek has received the cooling water discharges from two reactors, but it currently receives only about 15 cfs of water at about natural temperatures from P Area. The discharge of cooling water effluent from P Reactor to Steel Creek was discontinued in 1963 when this reactor was switched to cooling with recirculated water from Par Pond; L Reactor discharge ceased in 1968 when the reactor was shut down and placed in standby condition. Flow rates measured in Steel Creek at the Highway 125 crossing are about 30 cfs.

Lower Three Runs

Lower Three Runs has the second largest drainage area (about 180 square miles) of the plant streams (Figure II-2). Near its headwater a large impoundment, Par Pond (Figure II-41), has been formed by an earthen dam. The three main arms of the pond follow the streambed and drainage areas of the upper reaches of Lower Three Runs and its tributaries, Poplar Branch and Joyce Branch. From the dam, Lower Three Runs flows in a southerly, then southwesterly course for about 20 miles to the Savannah River. An arm of the plant follows the stream to the river. Several small tributaries arising off the plantsite flow into the creek in its lower reaches.



Par Pond and Effluent Canals

Before construction of Par Pond, effluent cooling water from R Reactor was discharged via Joyce Branch to Lower Three Runs. Since the pond filled in 1958, the overflow to Lower Three Runs has varied, depending on the utilization of the pond cooling water system by R and P reactors. In 1964, R Reactor was shut down and placed in standby condition. Even when both R and P reactors were utilizing the pond, the temperature of the pond overflow water was about natural. During periods of no dam overflow, about 5 cfs seeps through and under the dam to enter Lower Three Runs. When the pond is thermally stratified (primarily during the warmer months), this seepage is usually several degrees cooler than the surface water in the pond.

Par Pond

The Par Pond cooling water impoundment was formed in 1957-1958 by damming Lower Three Runs. The impoundment covers approximately 2700 acres to an average depth of about 20 ft. The maximum depth near the dam is about 60 ft. A 140-acre portion is separated from the main body by a dam to form the precooler, which is now considered part of the P-Reactor effluent canal system. There are three major arms in Par Pond (Figure II-41): the north or upper arm, the middle or warm arm, and the south or lower arm.

The canal systems for conducting the effluent cooling water from P to R reactors to Par Pond are also shown in Figure II-41. The P canal system is currently in use, but the R system has not received thermal discharges since 1964. From P Reactor, there are 4-1/4 miles of canals and 5 small impoundments. The largest impoundment besides the 140-acre precooler covers 36 acres; the total surface area of the small impoundments and canals is 227 acres. The now-unused R canal system consists of about 3.5 miles of canals and two impoundments, 7.4 and 260 acres in size, respectively. The total surface area of the system is 285 acres.

River Swamp

On the plantsite, a swamp lies in the floodplain along the Savannah River for a distance of about 10 miles and averages about 1.5 miles wide. A small embankment or natural levee has built up along the river from sediments deposited during periods of flooding. Next to the levee, the ground slopes downward, is marshy, and contains stands of large cypress trees and hardwoods. During periods of high river level, river water overflows the levee and stream mouths and floods the entire swamp area, leaving only isolated islands. When flow subsides, stagnant pools of water remain, but even with the pools and meandering channels, some of the land in the swamp is nearly dry.

Three breaches in the natural levee allow discharge of creek water to the river near the mouths of Beaver Dam Creek, Four Mile Creek, and Steel Creek. The Beaver Dam Creek discharge contains the effluent from the D-Area heavy water plant plus part of the Four Mile Creek flow. During swamp flooding, the water from these streams flows through the swamp parallel to the river and combines with the Pen Branch flow. Pen Branch does not discharge directly to the river, but flows through the swamp and joins Steel Creek about 0.5 mile above its mouth.

Figure II-42 shows the deltas of Four Mile Creek and Pen Branch where these streams flow into the swamp. Figure II-43 shows the deltas of Pen Branch and Steel Creek.

Chemical Composition of Surface Water

Knowledge of the chemical quality of surface waters is important for two reasons: it permits an estimate of alterations that have occurred as a consequence of plant operations and permits evaluation of the potential effects of releases into the aqueous environment.

Surface water on the plant and surrounding areas (Figure II-44) is very low in dissolved solids and iron and is very soft (Table II-21).[17] All surface water, except that from the Salkehatchie River near Barnwell, has pH values between 5 and 7; the pH of water from the Salkehatchie River is 7.3. Water from this river is also the hardest. The area around Barnwell is underlain by calcareous deposits; therefore seepage to the surface stream is characterized by the analogous chemical composition of water in the aquifer. Similarly, the composition of water from Holley Creek is characterized by the chemical composition of the water in the Tuscaloosa aquifer underlying this area.

Ground Water

Liquid materials discharged on the ground surface migrate slowly down to the ground water and then travel either with or slower than the ground water until emerging at a surface stream. The types of geological strata affect both the flow path and the velocity of the materials. The number, size, and shape of the openings in porous sediments and the degree of their interconnection determine the amount of water than can be stored in the openings and the effectiveness of any saturated geologic formation to transport water. A water-bearing bed or stratum of permeable rock, sand, or gravel capable of yielding considerable quantities

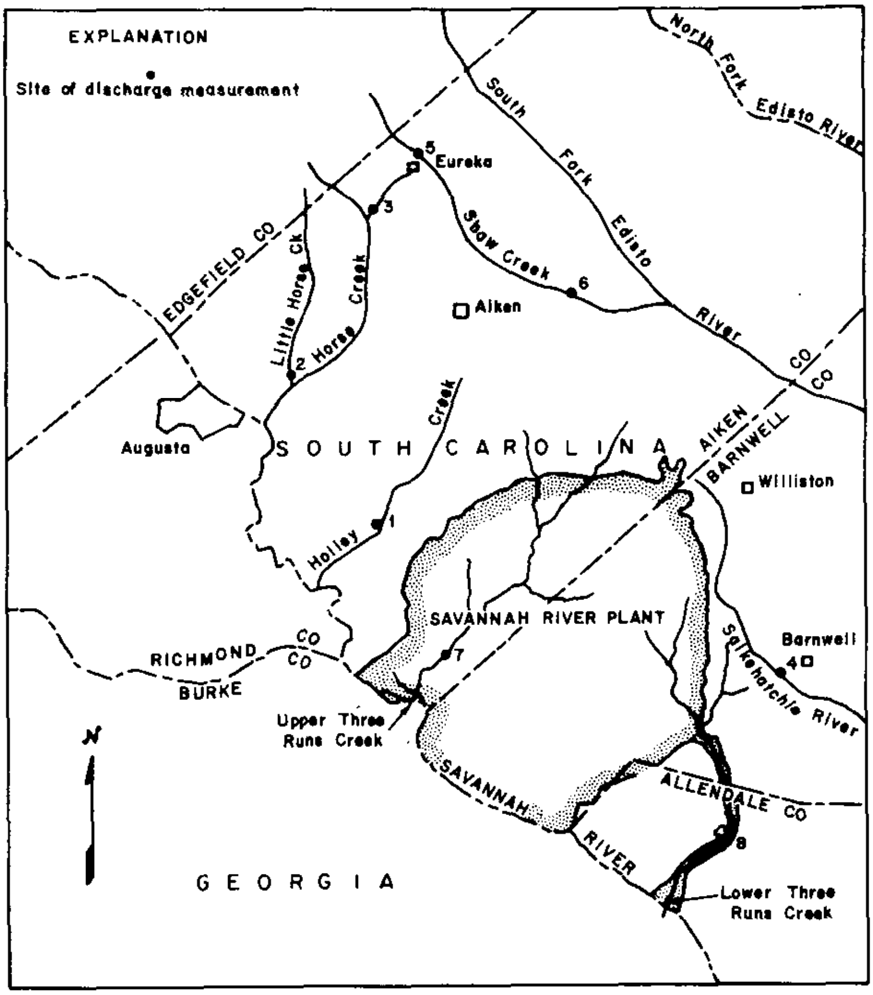


FIGURE II-44. Locations of Stream Discharge Measurements

TABLE II-21

Chemical Analysis of Surface Water in SRP Area[17]

Location (Fig. II-45)	ppm													
	SiO_2	Total Iron	Calcium	Magnesium	Potassium plus Sodium	HCO_3^-	SO_4^{2-}	Cl^-	F^-	NO_3^-	Dissolved Solids	Hardness, $CaCO_3$	Specific Conductance (25°C), μmho	pH
1	6.7	0.14	0.6	0.4	2.4	3	1.7	2.5	0.1	0.5	17	3	15.5	6.4
2	5.4	0.14	1.0	0.5	2.2	4	1.4	2.5	0.1	1.0	18	5	21.2	6.3
3	4.9	0.06	0.6	0.3	2.2	3	1.0	2.1	0.1	0.9	13	3	14.7	6.4
4	8.9	0.05	8.8	0.6	2.0	27	1.1	3.4	0.1	0.5	48	24	63.6	7.3
5	6.3	0.20	1.3	0.7	4.8	7	1.2	5.1	0.1	2.7	28	6	34.8	6.8
6	6.6	0.31	0.8	0.5	3.6	5	1.5	3.6	0.1	1.2	23	4	24.5	6.8
7	2.0	0.30	0.5	3.0	2.0	35	0.8	0.8	-	0.5	12	13	25.0	6.5
8	1.4	0.30	3.0	7.0	10	17	3.0	1.3	-	0.5	50	37	60.0	6.9

of water to wells or springs is called an aquifer. Geologic formations that are adjacent to but less permeable than aquifers are called confining beds because they tend to restrict or retard the movement of ground water.

Within the zone of saturation, ground water occurs under either water-table or artesian conditions. Under water-table conditions, the ground water is not confined, and the upper surface of the saturated zone is free to rise and fall. Under artesian conditions, the ground water is confined between an upper and lower confining bed, and the piezometric surface of the aquifer is above the top of the aquifer. The piezometric surface is an imaginary surface that indicates the level to which the confined water rises in wells.

The results of detailed studies on the site reveal how the geology and hydrology of the plantsite affects ground water movement. Differences in the piezometric head (water pressure) measurements show the direction that ground water flow will take. Figure II-45 shows the vertical distribution of hydrostatic head in ground water near H Area, measured with six piezometers near the H-Area waste tank farm and four other piezometers outside H Area. Downward percolation of water from the water table is indicated by decline to minimum head in the Congaree formation. In the two piezometers (1E, 1D, Figure II-45) above the tan clay, the decline is probably fairly uniform with depth. Across the tan clay (1D to 1C), the decline is relatively abrupt (about 12 ft of head decline in 18 ft of depth). The tan clay, maximum 12 ft thick, is sufficiently impermeable to divert some of the water laterally to creeks, the nearest being several thousand feet away.

Within the fairly permeable sands of the McBean formation, the head declines only 2 ft in $\sim$50 ft of geologic material (1C to 1B). The green clay shown on Figure II-45 is one of the more significant hydrologic units in the region; it is only 6 to 10 ft thick in H Area (although somewhat thicker elsewhere), and its importance is easily missed if only drilling information is available. The 80-ft decline in piezometric head (1B to 3B, 1A) across the green clay indicates that the clay is continuous over a large area and has low permeability. Thus the green clay also diverts water laterally to creeks that have eroded down into the McBean. These points of discharge are farther from H Area than the discharges from the Barnwell formation.

Ground water in the Congaree zone below the green clay also discharges into Upper Three Runs. This formation has the lowest hydrostatic head. The Ellenton formation has a head $\sim$7 ft higher than the Congaree, thus indicating the Ellenton is not receiving water from the Congaree formation.

Head is uniform in the three Tuscaloosa piezometers (P3C, P3B, P3A), lower than that in the Ellenton formation (DRB7WW), but higher than those in the Congaree. Both the recharge and discharge regions of the Tuscaloosa are principally off the plantsite, and they control its water level within the plantsite.

Piezometric contours for the Tuscaloosa formation (Figure II-46) indicate that the Tuscaloosa water flows from the Aiken plateau in a curved path to the Savannah River valley. This lateral flow through the very permeable formation supports the Tuscaloosa water level on the plantsite. Recharge by vertical percolation from above probably does not occur at SRP.

Any contamination entering ground water from H Area would be transported both downward and laterally, especially laterally at each clay barrier. Because water heads in the Tuscaloosa and Ellenton formations are higher than in the Congaree, such contamination would be discharged into Upper Three Runs before it could enter the Tuscaloosa.

LOCAL CLIMATE AND METEOROLOGY

The climate in the SRP area is tempered with mild winters and long summers. Augusta temperatures average 48°F in the winter, 85°F in summer, and 65°F annually. The average relative humidity is 70%. The average annual rainfall at SRP is 47 in. The recorded maximum annual precipitation in Augusta occurred in 1929 (73.82 in.); the minimum occurred in 1933 (28.05 in.).

Basic meteorological data needed to characterize atmospheric dispersion are wind speed and direction, horizontal wind direction variability, and vertical wind direction variability (standard deviations of these quantities), vertical temperature profiles, and vertical mixed depth. Empirically derived relationships are then necessary to relate the above parameters to atmospheric transport and dispersion.

Meteorological data applicable to the SRP are obtained at the WJBF-TV tower located near Beech Island, S. C., about 25 km northwest of the center of SRP. A 2-yr data base[18] was compiled from March 1966 until March 1968; the data consisted of measurements of wind speed, azimuthal and vertical wind direction, and temperatures. These data were taken from instruments at various elevations up to 1200 ft at about 3-min intervals. Data taken over a period of this length are assumed adequate to apply to any given year without serious error. A new system of seven additional towers is being erected on SRP to provide additional data.

When estimating dispersion, it is important to consider the meteorological conditions as they occur jointly. Using techniques similar to those described in DP-1163,[18] the SRP 3-min data from the 1966-1968 data base were reduced to averaged parameters which characterized dispersion properties over each 15-min period. An annual average mixing depth was imposed to normalize estimated dispersion with long-term measurements both onsite and offsite. A more-detailed discussion of methods for estimating environmental effects is presented in Appendix F.

To confirm the earlier assumption that the 1966-1968 data base could be used to estimate effects of releases in any given year, a second 2-yr data base was constructed for the period of 1974 and 1975. This data base was collected at 5-sec intervals between ground level and 1100 ft above ground level at the WJBF-TV tower. The results from using this new data base confirm the earlier assumption that a 2-yr data base can be used to calculate the effects of releases from other years without significant error.

Storms

The probability and magnitude of severe storms have been analyzed to determine their effects on waste management facilities. Two types of major storms, hurricanes and tornadoes, occur in South Carolina. The following sections describe these storms and discuss their frequency of occurrence.

Hurricanes

Fully mature tropical cyclones, called hurricanes in the Atlantic and typhoons in the Pacific, are large rotating storms of extraordinary violence. They are born over the warm waters of all the tropical oceans. Although hurricanes are neither the largest nor the most intense atmospheric storms, their considerable size and great intensity make them the most dangerous and destructive of all storms. The greatest damage and loss of life arise from storm surges that inundate low-lying coastal areas with wind-driven seawater in which all floating objects act as battering rams, from flooding caused by heavy rains, and from winds that frequently exceed 150 mph.

Tropical cyclones that do not mature into hurricanes are called tropical storms (winds <75 mph). A summary of all Atlantic-born tropical storms and hurricanes for the years 1959 to 1975 is listed in Table II-22 (data assembled by the National Hurricane Center, Miami, Fla.). Many of these storms did not strike land and thus caused little damage.

Thirty-eight hurricanes affected (caused damage to) South Carolina in the 275 years of record for an average frequency of 1 every 7 years.[19] The hurricanes that affect South Carolina occur predominantly in the months of August and September (Table II-23). Records during the 1700s and 1800s are not complete or totally accurate because of the lack of communications and a systematic method of identifying and tracking hurricanes at that time.[19]

The occurrence of a hurricane along the coastal region does not generally mean that the Savannah River Plant will be subjected to winds of hurricane force. SRP is 100 miles inland, and the high winds associated with hurricanes tend to diminish as the storms move over land. Winds of 75 mph were measured by anemometers mounted at 200 ft only once during the history of SRP, during passage of Hurricane Gracie to the north of the plantsite on September 29, 1959 (Figure II-47).

Tornadoes

Tornadoes are normally characterized as violently rotating columns of air in contact with the ground. Most tornadic winds rotate in a counterclockwise direction. The wind speeds often reach high speed within a relatively small storm. A distinguishing feature of a tornado is that the vortex is nearly always visible as a funnel-shaped pendant which appears to hang from a heavy cumulonimbus cloud. A tornado is usually accompanied by heavy rain and hail, and often by lightning and thunder. Although a few tornadoes destroy large areas, a typical tornado is on the ground for only one or two minutes and lightly damages an area 50 yards wide by one mile long. The translational speed averages 30 mph. In the extreme cases, the path may be one mile wide and 300 miles long leaving great destruction. The maximum recorded duration is over 7 hours. Less than 5% of all tornadoes which occur throughout the United States have wind speeds in excess of 200 mph. Tornadoes with wind speed of this magnitude may have several vortices rotating about a common axis. The maximum number of vortices observed in a single storm is 7. Generally the wind speed varies in intensity during the lifetime of a tornado and reaches the maximum wind speed and damage capability for 15% of their life cycle. Although tornadoes with wind speeds in excess of 200 mph comprise only 5% of all tornadoes, they are responsible for 97% of the fatalities.

The Savannah River Plant is in an area where occasional tornadoes are to be expected. National Weather Service records from 1916 to 1975 show that at least 300 tornadoes have occurred in South Carolina. In 1975, 12 tornadoes struck South Carolina and 22 struck in Georgia. More-accurate records of wind speeds and damage area have been kept since 1959. The Fugita-Pearson scale for assessing tornado wind speed and damage has been in use by the National Weather Service since 1971. Most tornadoes occur in South Carolina and Georgia during the period February through June and August to September (Table II-24) and travel in a southwest to northeast direction. The combined area of Georgia and South Carolina is struck by an average of 24.6 tornadoes per year.[20]

Tornado data from 1969 to 1975 show that Georgia and South Carolina may have extreme tornadoes with a maximum wind speed up to 260 mph. Tornadoes with winds up to 318 mph have been observed in the Midwest but not in the Southeast. The probability of a tornado with winds in excess of 250 mph striking a point within the SRP, is estimated to be less than 10^{-5} per year. During the 24-yr history of SRP, there has been no tornado damage to any production facility. On two occasions, light damage has occurred (displacement of light sheet metal roofing, window breakage, tree breakage, etc.). Several other tornado funnels have been sighted in unpopulated areas on the plantsite but investigations showed no damage; thus, the sighted funnels did not touch the ground. Investigation of tornadoes occurring near SRP in 1975-1976 showed damage from tornadic wind speeds varying from 100 to 175 mph.

TABLE II-24

Month of Tornado Occurrence, % of Total/Yr

	Georgia	*South Carolina*
January	9	1
February	8	5
March	18	12
April	33	24
May	7	19
June	5	13
July	2	2
August	4	9
September	3	8
October	<1	2
November	5	2
December	5	3