RADIOACTIVITY IN THE ENVIRONS OF THE SAVANNAH RIVER PLANT JANUARY TO JULY - 1954

by

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ABSTRACT

There were significant increases in radioactivity in the environs of the Savannah River Plant during the period from January 1954 to July 1954. All of these increases were relatively small as compared to the maximum permissible concentration. Although fall-out from Pacific tests was the main contributor to the increased activity, some of the increase was due to normal Plant operations.

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RADIOACTIVITY IN THE ENVIRONS OF THE SAVANNAH RIVER PLANT JANUARY TO JULY - 1954

INTRODUCTION

Under a program established by the du Pont Company in June 1951, the Savannah River Plant site and the surrounding region are systematically monitored for radioactive contaminants. Operating experience at various AEC installations shows the need for this regional survey program. Most plants utilizing radioactive material or nuclear fission occasionally release quantities of radioactive wastes to effluent streams or to the atmosphere. The quantity of discharged radioactivity must be minute because of the severe toxicity of radioactive materials and the concentrating action of various organisms. The regional survey program provides detailed information which is useful both as a measure of the effectiveness of plant controls and as an authoritative record in the event of any future litigations.

This report, which covers the period from January 1954 to July 1954, is one of a series of reports dealing with the regional survey program at the Savannah River Plant. Previous issuances in this series include one research and development report(1) and several internal reports. During the six-month period covered by this report, the SRP Health Physics Section collected and analyzed more than three thousand samples from the Plant site and surrounding area.

SUMMARY

Radioactivity in vegetation increased significantly during March and had not returned to the normal background level by the end of June. The increase was more pronounced in trees and weeds on the plant site than in grain fields in the surrounding area. Fallout from Pacific tests was the main contributing factor, although some of the increase, particularly in the grain samples, was caused by the naturally occurring radioactive isotope K^{40}.

Radioactivity in the atmosphere also increased significantly during March and remained above normal levels through June. Measurements revealed significant increases in dosage rate, in particulate contamination of the atmosphere, in particulate fallout, and in rain water contamination. All of these increases can be attributed to fallout from Pacific tests.

Water and mud samples were collected from the Savannah River and from five streams which carry effluent to the river from Plant production areas. Plant operations made significant contributions to radioactivity in stream

water and stream mud, particularly in the 300 Area effluent system, which discharges into Upper Three Runs Creek.

Upper Three Runs Creek was the only stream that had any sampling locations with highly significant six-month means for radioactivity in the water, but significant increases in activity occurred in the water of all streams except the Savannah River. The increases in three streams can be accounted for by waste disposal from the plant. Fallout from Pacific tests appears to have been responsible for the increases in the other two streams.

Five streams, including the Savannah River, had sampling locations where the six-month mean for radioactivity in the mud was highly significant. The high activity in the Savannah River apparently was caused by a large quantity of K^{40} in the mica minerals of the mud. Significant changes in activity occurred in the mud of several streams. Highly significant increases occurred in Lower Three Runs Creek, probably because of Plant operations in R Area.

Radioactivity in public water supplies did not increase or decrease significantly during the six-month period.

The only zoological samples collected on a routine basis consisted of diatoms. A highly significant amount of uranium was found in diatoms collected from the 300 Area effluent. It also appears that the diatoms are concentrating the small amounts of uranium in Four Mile Creek and the Savannah River.

PROGRAM

Reports summarizing results of the regional survey program will be issued on a periodic basis. As activity contributions to the site by stack and stream effluents increase, the routine sampling program will be modified accordingly. Special studies will be made from time to time as conditions warrant.

DATA REPORTING

Survey data have been statistically analyzed to determine significant differences between monthly means and significant differences between mean values for different sampling locations. A single asterisk (*) indicates that the mean value is significant at the 95% confidence level, and a double asterisk (**) indicates that the mean value is significant at the 99% confidence level. Specific values for the least significant difference between means are identified by the term "L.S.D." In cases where calculations revealed no significant difference between means, the L.S.D.

is identified as "N.S.D." (no significant difference). Detailed information concerning statistical analysis methods appears in the Appendix.

Although the gross alpha content of all samples was determined, the results have not been included in this report, since all significant values for gross alpha activity were accounted for by uranium or plutonium analyses that are covered in the report.

SURVEY RESULTS

The text of this report consists of five major divisions, covering radioactivity in vegetation, radioactivity in the atmosphere, radioactive contamination in streams, radioactivity in public water supplies, and radioactivity in zoological specimens. Following the text are several maps showing the geographical distribution of sampling locations.

RADIOACTIVITY IN VEGETATION

Nearly four hundred samples were analyzed to determine the radioactivity due to nonvolatile beta emitters, and approximately one hundred samples were analyzed to determine the radioactivity due to K^{40}. These samples were collected from locations arranged roughly in three concentric circles: the inner perimeter (IP), within the project; the outer perimeter (OP), at the edge of the project; and the 25-mile radius (25MR), approximately 25 miles from the center of the project.

The results for each of the three sample groups are summarized in the following table. The maximum values refer to the maximum six-month mean (for an individual sampling location) in each group. The average values refer to the overall six-month mean for each group (i.e., the mean of all samples collected at all locations in the group during the six-month period).

Location	K^{40} Activity, 10^{-12} c/g (curies per gram)		Activity of Nonvolatile Beta Emitters, 10^{-12} c/g	
	Maximum	Average	Maximum	Average
Inner perimeter	20.6**	8.5	120**	57
Outer perimeter	20.3**	6.7	130**	61
25-mile radius	25.1	18.4	55*	44

The 25MR samples had a much higher average K^{40} activity than did the vegetation samples collected on the project. This difference in K^{40} activity can be attributed to the addition of potassium fertilizer to the crops from which the 25MR samples were collected. (The 25MR samples were collected from grain fields and the samples on the project from trees and weeds). Nonvolatile beta emitters were more concentrated in samples collected on the project. The nonvolatile beta activity in the 25MR samples probably was diluted by the rapid growth of the grain after fallout from Pacific tests, while the slow growth of the vegetation on the project apparently did not result in such a dilution.

The following table lists mean values by months for K^{40} activity and nonvolatile beta activity in each group of vegetation samples.

Month	K^{40} Activity, 10^{-12} c/g			Activity of Nonvolatile Beta Emitters, 10^{-12} c/g		
	IP	OP	25MR	IP	OP	25MR
January	3.7	6.9	18.3	14	12	28
February	5.3	8.3	27.1	11	15	28
March	12.9	11.8	25.8	139	134	75
April	11.1	10.3	14.9	63	67	39
May	9.8	10.2	8.8	54	61	47
June	8.2	11.6	15.1	59	67	48
L.S.D.*	3.5	2.5	6.8	25	19	17
L.S D.**	4.6	3.3	9.0	33	25	23

There was a sudden increase in the nonvolatile beta activity in vegetation during March, as a result of fallout from Pacific tests. This activity had not returned to the normal background level by the end of June. The increase in K^{40} activity in the vegetation during March is probably a seasonal change due to the accumulation of available soil potassium during the winter months.

RADIOACTIVITY IN THE ATMOSPHERE

Radioactivity in the atmosphere was measured by means of detachable ionization chambers, air filters, flypapers, and rain water analysis. The ionization chambers, which are located in all production areas, determine dosage rates per week in mrep (milliroentgen equivalent physical). The air filters, which are located at all 614 Buildings, remove suspended particles from a continuous air flow of 2.5 c.f.m. The flypapers, which are distributed around the production areas, collect particulate fallout from the atmosphere. (The number of particles collected on the air filters and flypapers was determined by radioautograph). Rain water samples were collected at all 614 Buildings. All rain water samples were analyzed for nonvolatile beta activity, and those samples collected during the period of heaviest fallout from the Pacific tests were also analyzed for iodine activity.

Ionization Chamber Readings

A total of 720 detachable ionization chamber readings were made during the six-month period. The monthly means of these measurements are shown in the following table.

Month	Dosage Rate, mrep/24 hours
January	0.54
February	0.56
March	0.73
April	0.87
May	0.85
June	0.83
L.S.D.*	0.06
L.S.D.**	0.08

There was a highly significant increase in the mean dosage rate during March, and the rate had not returned to the expected background level by June. It appears that this increase was due to the Pacific tests. There was no significant difference between ionization chamber readings made at different locations. The maximum weekly mean value was 6.93 mrep/week, for the period from April 26 to May 3.

Suspended Particles

A total of 152 air filter samples were collected during the six-month period. Listed below are mean values by months for the number of radioactive particles collected per 1000 cubic meters of air passing through the filters.

Month	Air Contamination particles/1000 meters^3
January	0
February	0
March	112
April	80
May	74
June	14
L.S D.*	56
L.S D.**	73

There was no particulate contamination in the atmosphere during January and February, but a highly significant number of particles were collected during March.

The number of particles then decreased each month through June. The decrease during June was highly significant. The radioactive particles in the atmosphere probably were due entirely to the Pacific tests. The maximum weekly mean was 268 particles per 1000 cubic meters, for the period from March 26 to April 2. This figure was almost equalled during the week ending May 14, when the weekly mean was 258 particles per 1000 cubic meters. There was no significant difference between the number of particles collected at different locations. The maximum value for an individual sample was 521 particles per 1000 cubic meters, for a sample collected at the Aiken Airport during the week ending May 14.

Particulate Fallout

During the six-month period, 216 flypapers were used for the determination of particulate fallout. Monthly means for the number of fallout particles per square foot are tabulated below.

Month	Fallout, particles/ft^2/week
January	0
February	0
March	7
April	16
May	11
June	13
L.S.D.*	4
L.S.D.**	5

There was no particulate fallout during January and February, but there were a highly significant number of particles during March. A highly significant increase in the number of particles occurred during April, and the fallout had not ceased by the end of June. All of the particulate fallout appeared to be due to the Pacific tests. The maximum weekly mean was 38 particles per square foot, for the week ending April 13. Another period of high fallout occurred during the week ending June 1, when the weekly mean was 37 particles per square foot.

Rain Water Contamination

During the six-month period, a total of 70 rain water samples were analyzed for nonvolatile beta activity. Monthly means for these analyses are shown in the following table.

Month	Activity of Nonvolatile Beta Emitters, 10^{-15} c/ml (curies per milliliter)
January	-
February	15
March	194
April	256
May	359
June	211
L.S.D.*	142
L.S D.**	188

There were highly significant variations in the activity of nonvolatile beta emitters in rain water during the six-month period. A significant increase occurred during March, and there had been no significant decrease by June. There was no significant difference between the activity in samples collected at different locations. The maximum weekly mean was 516×10^{-15} c/ml, for the week ending May 14. The maximum value for an individual sample was 1280×10^{-15} c/ml, for a sample collected at the Aiken Airport on March 19.

During the period from April 16 to May 14, a total of 22 rain water samples were analyzed for iodine activity. The mean for these samples was 115×10^{-15} c/ml. The maximum value for an individual sample was 448×10^{-15} c/ml, for a sample collected at the Talatha 614 Building on May 7, 1954.

RADIOACTIVE CONTAMINATION IN STREAMS

There are five streams on the Savannah River Plant site that carry effluent from Plant production areas to the Savannah River. Water samples and mud samples are collected from all of these streams at regular intervals. At least one sample is taken above the effluent discharge into each stream, so that any increase in activity due to effluent can be determined. The Savannah River is sampled below the mouth of each of the five streams and also at Augusta and near Allendale.

Stream Water

A total of 982 stream water samples were analyzed for uranium or plutonium activity, and 1000 samples were analyzed for nonvolatile beta activity. The results for each stream are summarized in the following table. The maximum values refer to the maximum six-month mean (for an individual sampling location) from each stream. The average values refer to the overall six-month mean for each stream (i.e., the mean of all samples collected from the stream during the six-month period).

Location	U or Pu Activity, 10^{-3} d/m/ml (disintegrations per minute per milliliter)		Activity of Nonvolatile Beta Emitters, 10^{-15} c/ml	
	Maximum	Average	Maximum	Average
Upper Three Runs Creek	310**	64	282**	52
Four Mile Creek	2	1	21	13
Pen Branch	1	1	17	15
Steel Creek	7	3	21	16
Lower Three Runs Creek	2	1	14	10
Savannah River	1	1	9	8

Only Upper Three Runs Creek had any sampling locations with highly significant six-month means for uranium or plutonium activity or for nonvolatile beta activity. Both the highly significant uranium or plutonium activity and the highly significant nonvolatile beta activity came from the 300 Area effluent. No other sampling locations in Upper Three Runs Creek had a significantly high mean activity for the six-month period.

The following table lists mean values by months for uranium or plutonium activity in water samples from each stream.

Month	U or Pu Activity, 10^{-3} d/m/ml					
	Upper Three Runs Creek	Four Mile Creek	Pen Branch	Steel Creek	Lower Three Runs Creek	Savannah River
January	36	2	1	1	1	1
February	33	1	1	1	1	1
March	128	1	1	1	1	1
April	53	1	1	1	1	1
May	36	1	1	1	1	1
June	79	1	1	10	2	-
L.S.D.*	N.S.D.	N.S.D.	N.S.D.	8	1	N.S.D.
L.S.D.**	N.S.D.	N.S.D.	N.S.D.	N.S.D.	1	N.S.D.

Steel Creek was the only stream that had a significant increase in uranium or plutonium activity. This increase was due entirely to the considerable activity in the water of this stream on June 29, when the mean for eight samples was 47 x 10^{-3} d/m/ml. Although the activity in Upper Three Runs Creek was higher than that in any other stream, it did not undergo any significant changes during the six-month period. The maximum uranium or plutonium activity in an individual sample was 1500 x 10^{-3} d/m/ml, in a sample collected on June 7 from the 300 Area effluent.

Tabulated below are mean values by months for the activity of nonvolatile beta emitters in water samples from each stream.

Month	Activity of Nonvolatile Beta Emitters, 10^{-15} c/ml					
	Upper Three Runs Creek	Four Mile Creek	Pen Branch	Steel Creek	Lower Three Runs Creek	Savannah River
January	18	9	8	8	8	8
February	10	8	8	8	8	8
March	55	8	8	13	9	8
April	26	9	8	18	9	8
May	27	31	31	16	8	8
June	151	12	10	25	17	-
L.S.D.*	111	12	20	10	5	N.S.D.
L.S.D.**	140	16	N.S.D	13	6	N.S.D.

There were significant changes in nonvolatile beta activity in all streams except the Savannah River. The maximum monthly mean was 151 x 10^{-15} c/ml, for Upper Three Runs Creek during June. The maximum value for an individual sample was 2800 x 10^{-15} c/ml, for a sample collected on June 28 from the 300 Area effluent. The activity of Upper Three Runs Creek generally exceeded that of the other streams, because of contributions from the 300 Area effluent. The significant increases in the activity of Steel Creek and Lower Three Runs Creek can be accounted for by discharge from the 100 Areas, but the significant increases in the activity of Four Mile Creek and Pen Branch cannot be accounted for by waste disposal from the Plant. It is interesting to note that the mean values for all samples collected on May 13 from these last two streams were 98 x 10^{-15} c/ml and 99 x 10^{-15}c/ml, respectively. It appears that these high values were due to fallout from the Pacific tests.

Stream Mud

A total of 740 stream mud samples were analyzed for uranium or plutonium activity, and 1000 samples were analyzed for nonvolatile beta activity. The results for each stream are summarized in the following table. The maximum values refer to the maximum six-month mean (for an individual sampling location) from each stream. The average values refer to the overall six-month mean for each stream (i.e., the mean of all samples collected from the stream during the six-month period).

Location	U or Pu Activity, d/m/g (disintegrations per minute per gram)		Activity of Nonvolatile Beta Emitters, 10^{-12} c/g	
	Maximum	Average	Maximum	Average
Upper Three Runs Creek	22	13	26**	12
Four Mile Creek	12**	4	22**	10
Pen Branch	12	4	12	9
Steel Creek	6**	4	11**	9
Lower Three Runs Creek	7**	4	19**	10
Savannah River	8	5	21**	17

Three streams had sampling locations with highly significant six-month means for uranium or plutonium activity. The highest six-month mean for an individual sampling location was 22 d/m/g, for a location in Upper Three Runs Creek, but this value was not significantly higher than the values for other sampling locations. Five streams had sampling locations with highly significant six-month means for nonvolatile beta activity. The Savannah River had the highest average nonvolatile beta activity, probably because of a large quantity of K^{40} in the mica minerals of the mud.

The following table lists mean values by months for uranium or plutonium activity in mud samples from each stream.

Month	U or Pu Activity, d/m/g					
	Upper Three Runs Creek	Four Mile Creek	Pen Branch	Steel Creek	Lower Three Runs Creek	Savannah River
January	13	3	-	-	2	7
February	30	4	1	3	3	4
March	11	4	3	3	2	4
April	8	3	8	4	3	6
May	11	5	1	4	4	5
June	18	5	3	7	6	-
L.S.D.*	14	N.S.D.	N.S.D.	N.S.D.	2	N.S.D.
L.S.D.**	N.S.D.	N.S.D.	N.S.D.	N.S.D.	3	N.S.D.

Upper Three Runs Creek had a significant increase during February but returned to a significantly lower level of activity during March. The maximum value for an individual sample was 252 d/m/g, for a sample collected on February 15 from Tims Branch, just above the point at which it reaches Upper Three Runs Creek. Lower Three Runs Creek had a significant increase during May and a highly significant increase during June, probably because of Plant operations in R Area.

Tabulated below are mean values by months for the activity of nonvolatile beta emitters in mud samples from each stream.

Month	Activity of Nonvolatile Beta Emitters, 10^{-12} c/g					
	Upper Three Runs Creek	Four Mile Creek	Pen Branch	Steel Creek	Lower Three Runs Creek	Savannah River
January	11	10	8	12	8	14
February	13	15	8	9	11	16
March	11	10	7	9	8	17
April	11	12	8	8	13	19
May	11	10	11	9	10	17
June	16	9	8	9	9	--
L.S.D.*	N.S.D.	2	N.S.D.	1	4	N.S.D.
L.S.D.**	N.S.D.	3	N.S.D.	N.S.D.	N.S.D.	N.S D.

Highly significant variations in activity occurred in Four Mile Creek, and significant variations in activity occurred in Steel Creek and Lower Three Runs Creek, but none of these variations indicate any general increase or decrease in activity. In general, the highest activity was in the Savannah River, apparently because of the high K^{40} content of the mica in the mud. The highest activity in any individual sample was 78×10^{-12} c/g, in a sample collected on February 15 from the 300 Area effluent.

RADIOACTIVITY IN PUBLIC WATER SUPPLIES

Samples from the water supplies of eleven surrounding towns were analyzed for radioactivity. A total of 66 samples were collected during the six-month period. The following table shows mean values by months for the activity of nonvolatile beta emitters in these samples.

Month	Activity of Nonvolatile Beta Emitters, 10^{-15} c/ml
January	8
February	8
March	8
April	8
May	8
June	8
L.S.D.*	N.S.D.
L.S.D.**	N.S.D.

There were no significant differences between these monthly means. The maximum value for an individual sample was 12.4×10^{-15} c/ml, for a sample collected at Augusta on April 5.

RADIOACTIVITY IN ZOOLOGICAL SPECIMENS

The only zoological samples collected on a routine basis consisted of diatoms. These samples were collected from the Savannah River (at points above and below the Plant) and also from Four Mile Creek and Tims Branch. Other types of zoological samples were collected only for special studies, or were obtained from the University of Georgia Biology Department, which is making a study of the area.

During the six-month period, a total of 56 diatom samples were collected and analyzed for uranium content. Six-month means for the various sampling locations are tabulated below.

Location		Uranium Content, µg/g (micrograms per gram)
1	Savannah River (above Plant)	8
2	" " " "	8
3	Savannah River (below Plant)	23
4	" " " "	25
5	Four Mile Creek	18
6	"	14
7	300 Area effluent	590
L.S.D.*		171
L.S.D.**		238

There were highly significant differences between the six-month means for the different sampling locations. The large amount of uranium in the diatoms from Location 7 came from the 300 Area effluent. It also appears that the diatoms are concentrating the small amounts of uranium in Four Mile Creek and the Savannah River.

During April 1954 a special study was made of zoological specimens from Steed's Pond. Steed's Pond is in the 300 Area effluent system, and approximately 350 pounds of uranium had been discharged through the pond up to the time of the study. The specimens removed included fish, bull-frogs, turtles and terrapins. The maximum nonvolatile beta activity in an individual specimen was 32×10^{-12} c/g in the intestinal tract of a snapper turtle, and the maximum uranium activity was 64 d/m/g in the gonads of a bullfrog. It is interesting to note that uranium was not concentrated in any of the fish flesh. A more detailed presentation of these results appears in an internal report issued at the conclusion of the study.

In addition to the samples indicated above, 28 zoological samples were collected at random. These samples included fish, turtles, quail, snakes, crawfish, salamanders, clams, terrapins and frogs. The maximum nonvolatile beta activity in an individual specimen was 268×10^{-12} c/g, in the flesh of a turtle collected on April 28 from Lower Three Runs Creek (at a point approximately two miles above the effluent discharge from R Area). The uranium or plutonium content of the random samples was insignificant.

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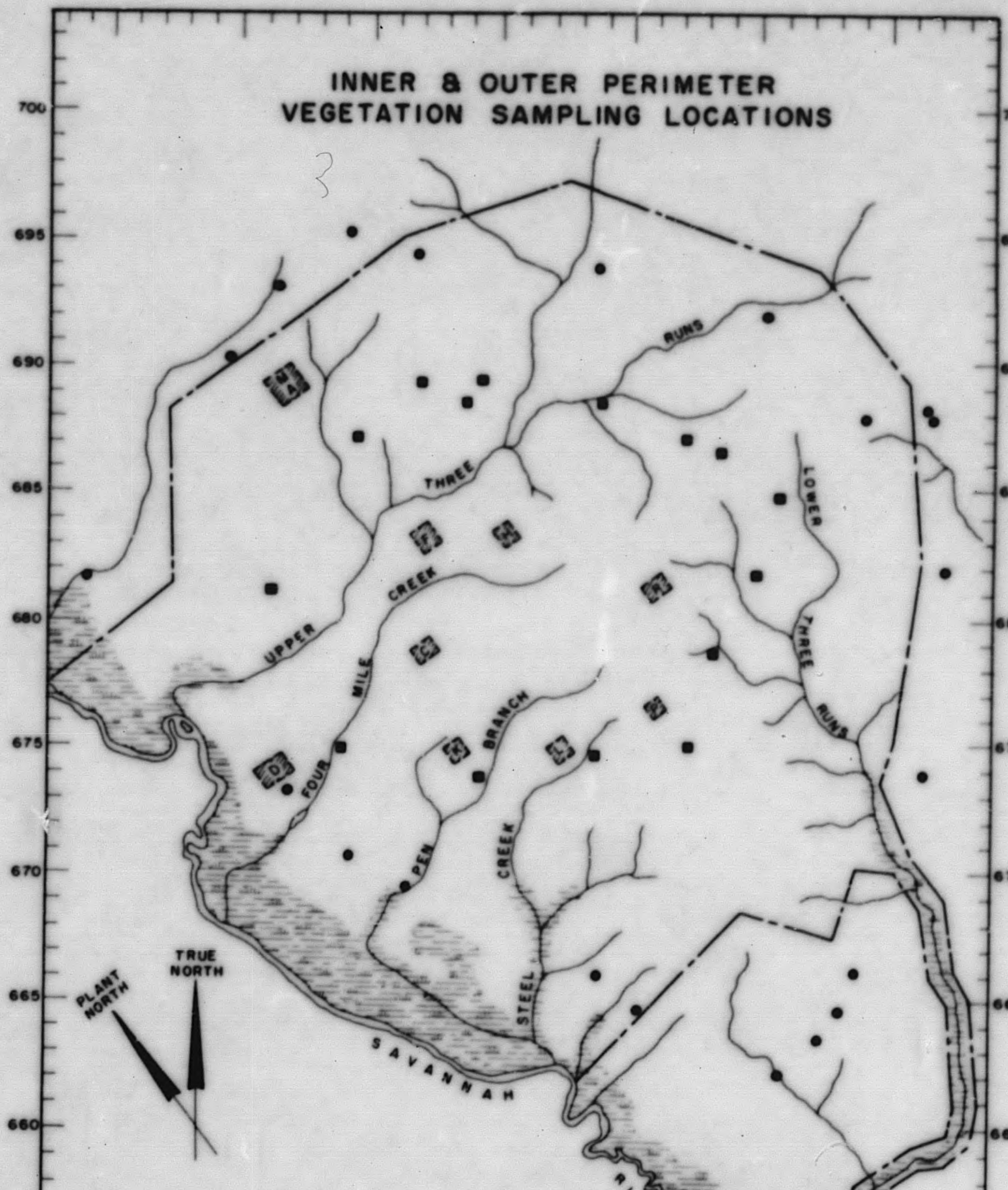
BIBLIOGRAPHY

1. Reinig, W. C., Gosline, R. E., Albenesius, E. L., and Williams, R. C. Natural Radioactive Contents of the Savannah River Plant. E. I. du Pont de Nemours & Co. DP-27, May 1, 1953. (This report summarizes and concludes the background activity survey of the Plant site and the surrounding region from the inception of the program to January 1953).

FIGURE 1


INNER & OUTER PERIMETER
VEGETATION SAMPLING LOCATIONS
UPPER THREE RUNS
LOWER THREE RUNS
FOUR MILE CREEK
PEN BRANCH
STEEL CREEK
SAVANNAH RIVER
PLANT NORTH
TRUE NORTH
MILES
0 1 2
I.P. VEG. LOCATIONS
O.P. VEG. LOCATIONS
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695
690
685
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425
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455

FIGURE 2

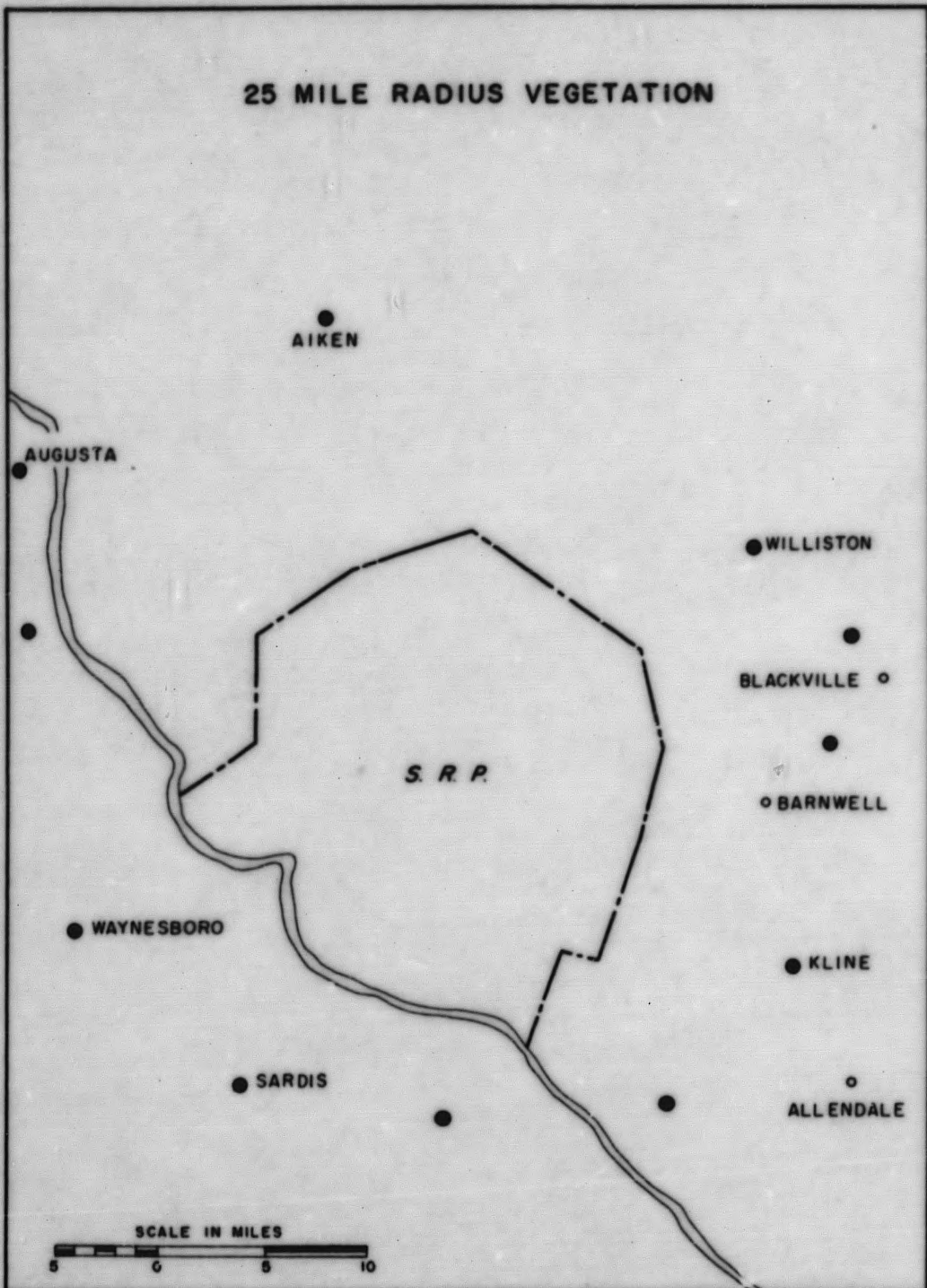
25 MILE RADIUS VEGETATION
AIKEN
AUGUSTA
WILLISTON
BLACKVILLE
BARNWELL
S. R. P.
WAYNESBORO
KLINE
SARDIS
ALLENDALE
SCALE IN MILES
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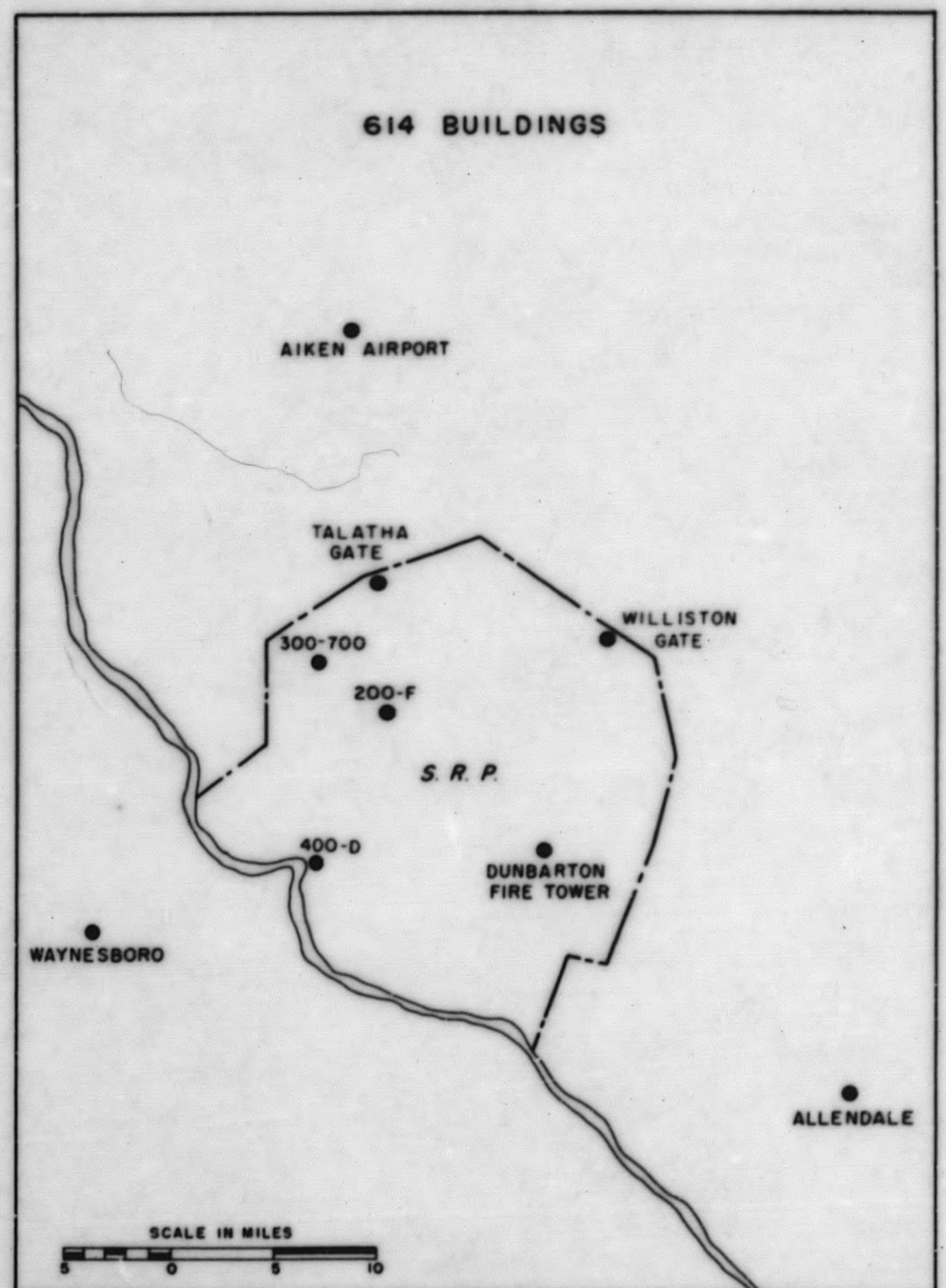
FIGURE 3


614 BUILDINGS
AIKEN AIRPORT
TALATHA GATE
WILLISTON GATE
300-700
200-F
S. R. P.
400-D
DUNBARTON FIRE TOWER
WAYNESBORO
ALLENDALE
SCALE IN MILES
5
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5
10

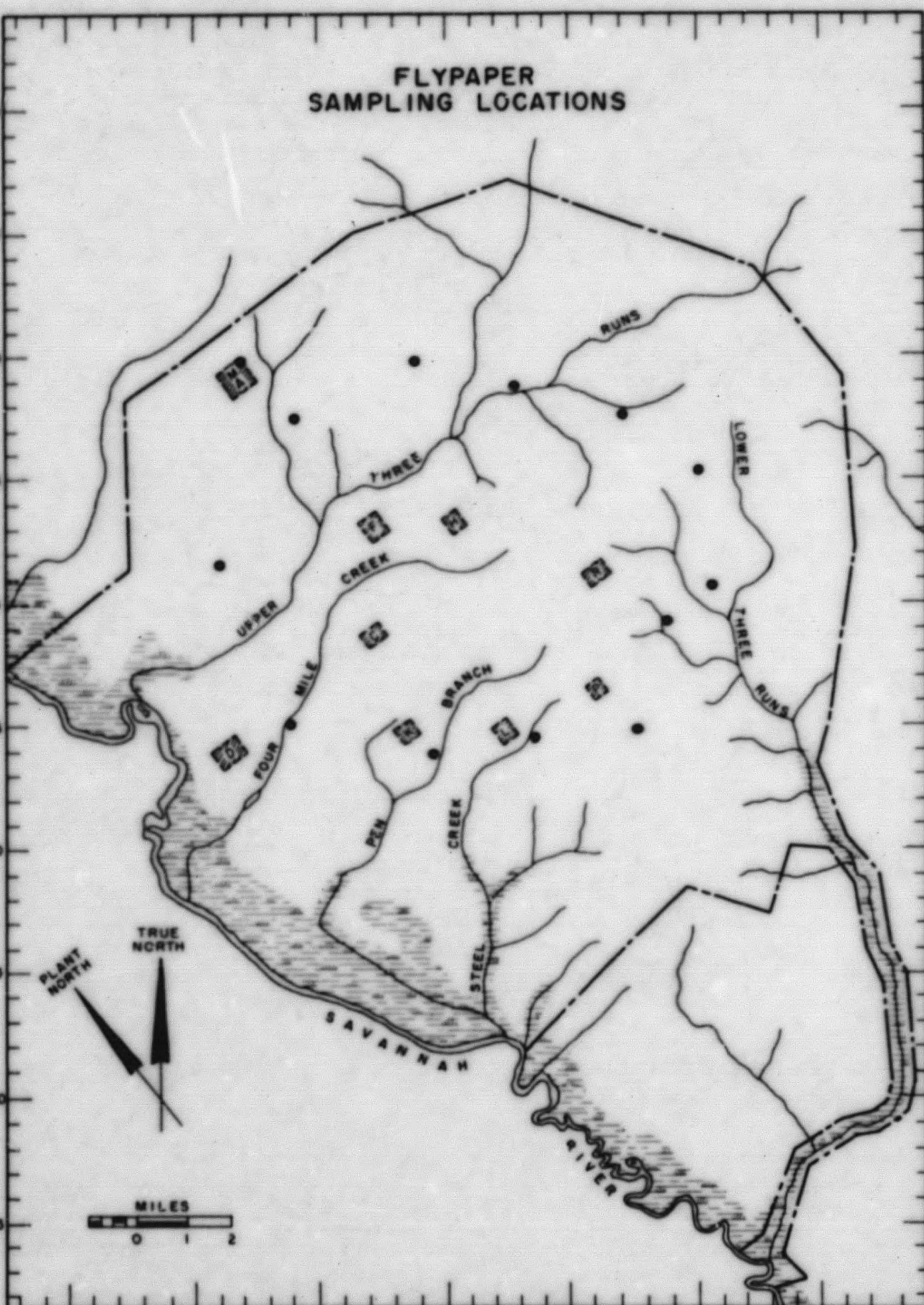
FLYPAPER
SAMPLING LOCATIONS
UPPER THREE RUNS
FOUR MILE CREEK
PEN BRANCH
STEEL CREEK
LOWER THREE RUNS
SAVANNAH RIVER
PLANT NORTH
TRUE NORTH
MILES
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FIGURE 5

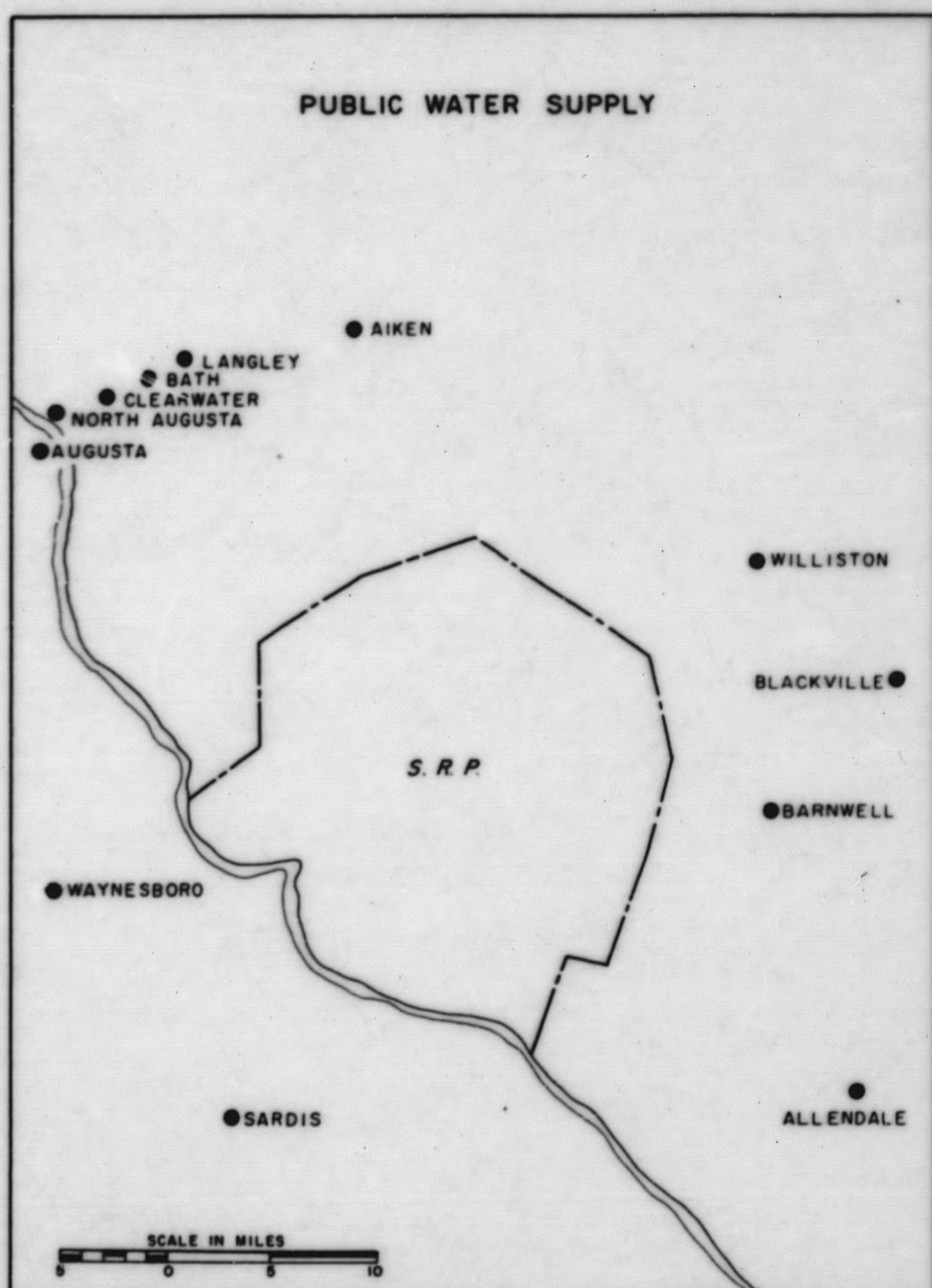
PUBLIC WATER SUPPLY
AIKEN
LANGLEY
BATH
CLEARWATER
NORTH AUGUSTA
AUGUSTA
WILLISTON
BLACKVILLE
S. R. P.
BARNWELL
WAYNESBORO
SARDIS
ALLENDALE
SCALE IN MILES
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FIGURE 6

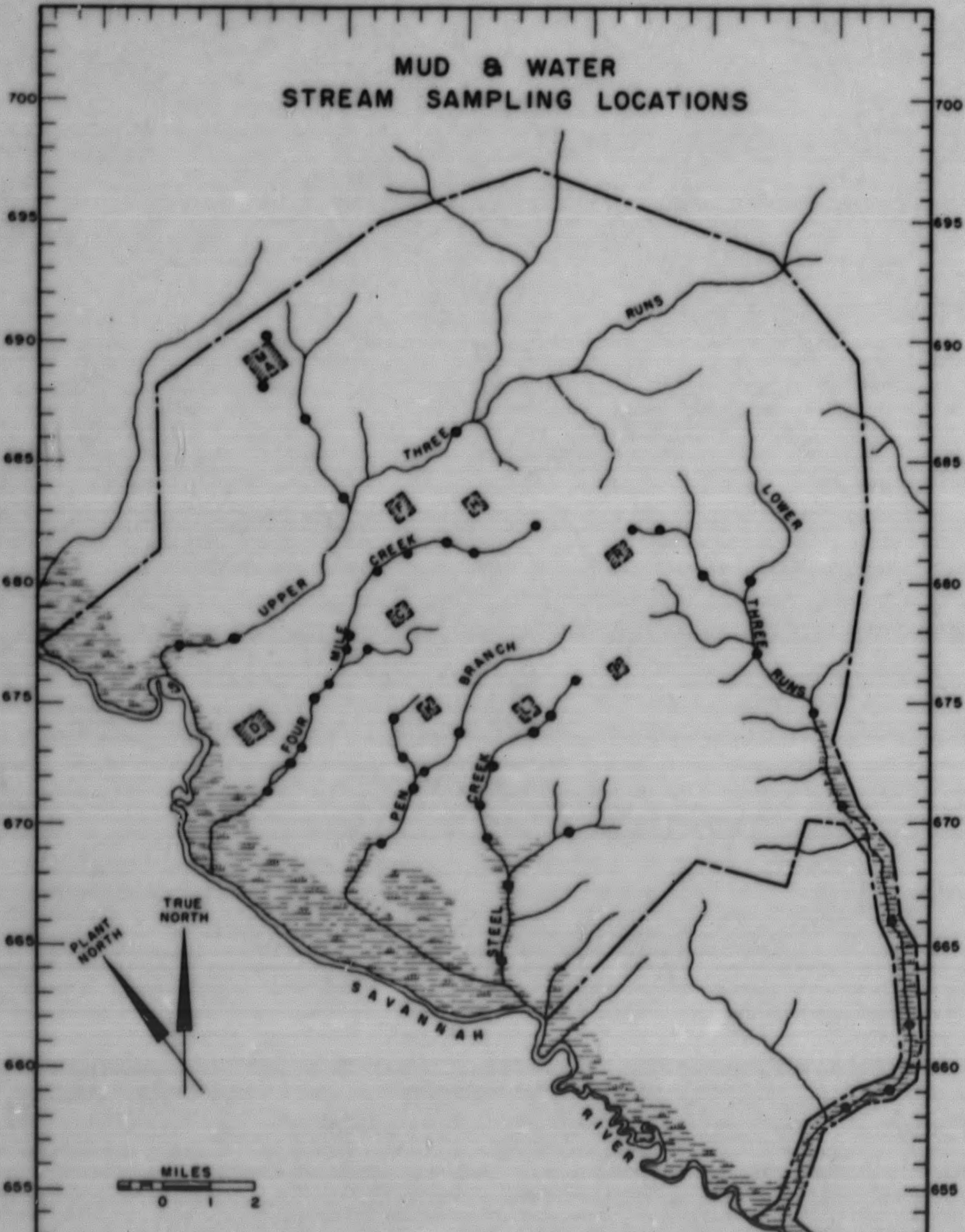
MUD & WATER
STREAM SAMPLING LOCATIONS
THREE
RUNS
UPPER
FOUR MILE CREEK
PEN
BRANCH
STEEL
CREEK
LOWER
THREE
RUNS
SAVANNAH
RIVER
PLANT NORTH
TRUE NORTH
MILES
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FIGURE 7

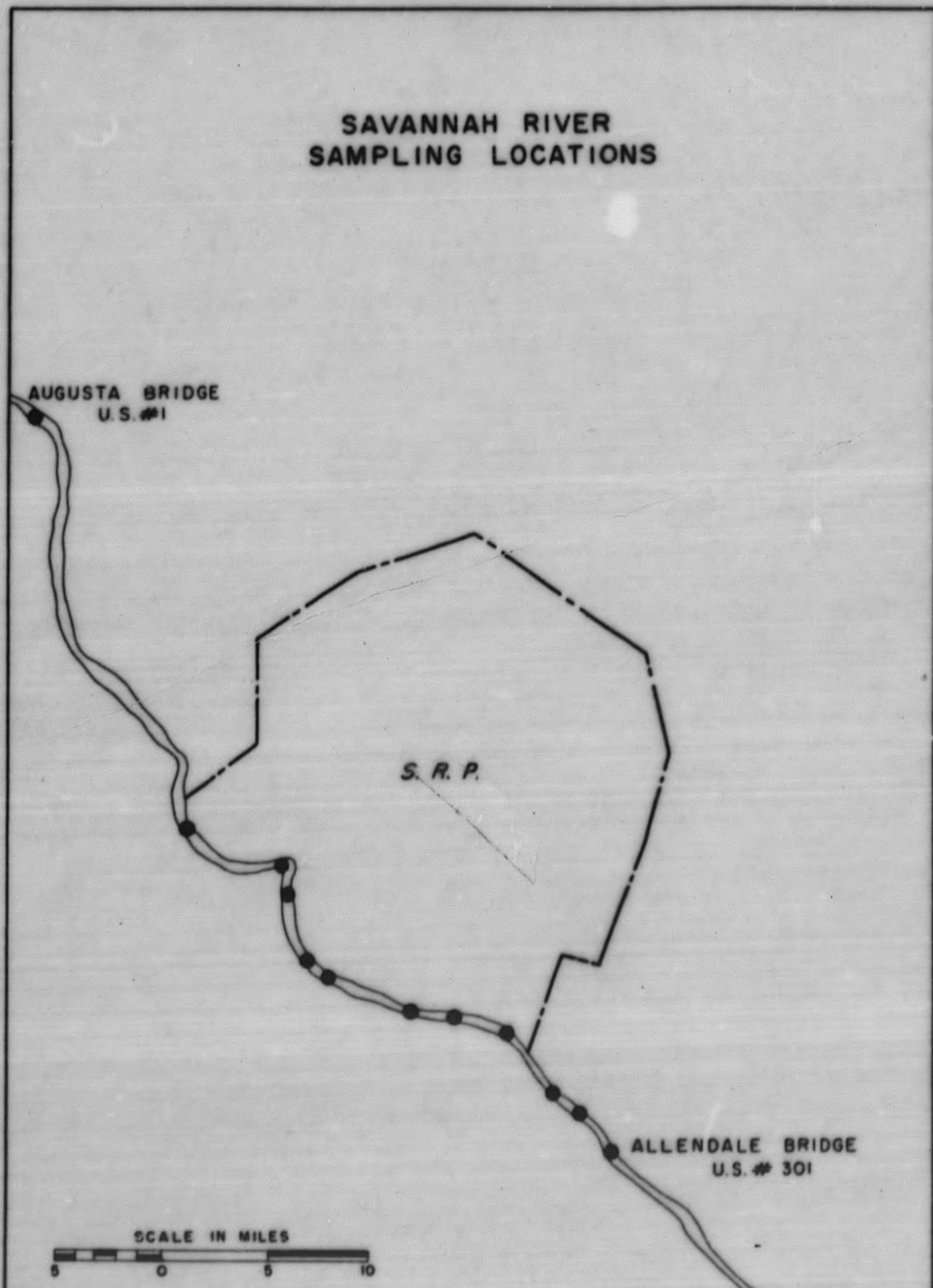
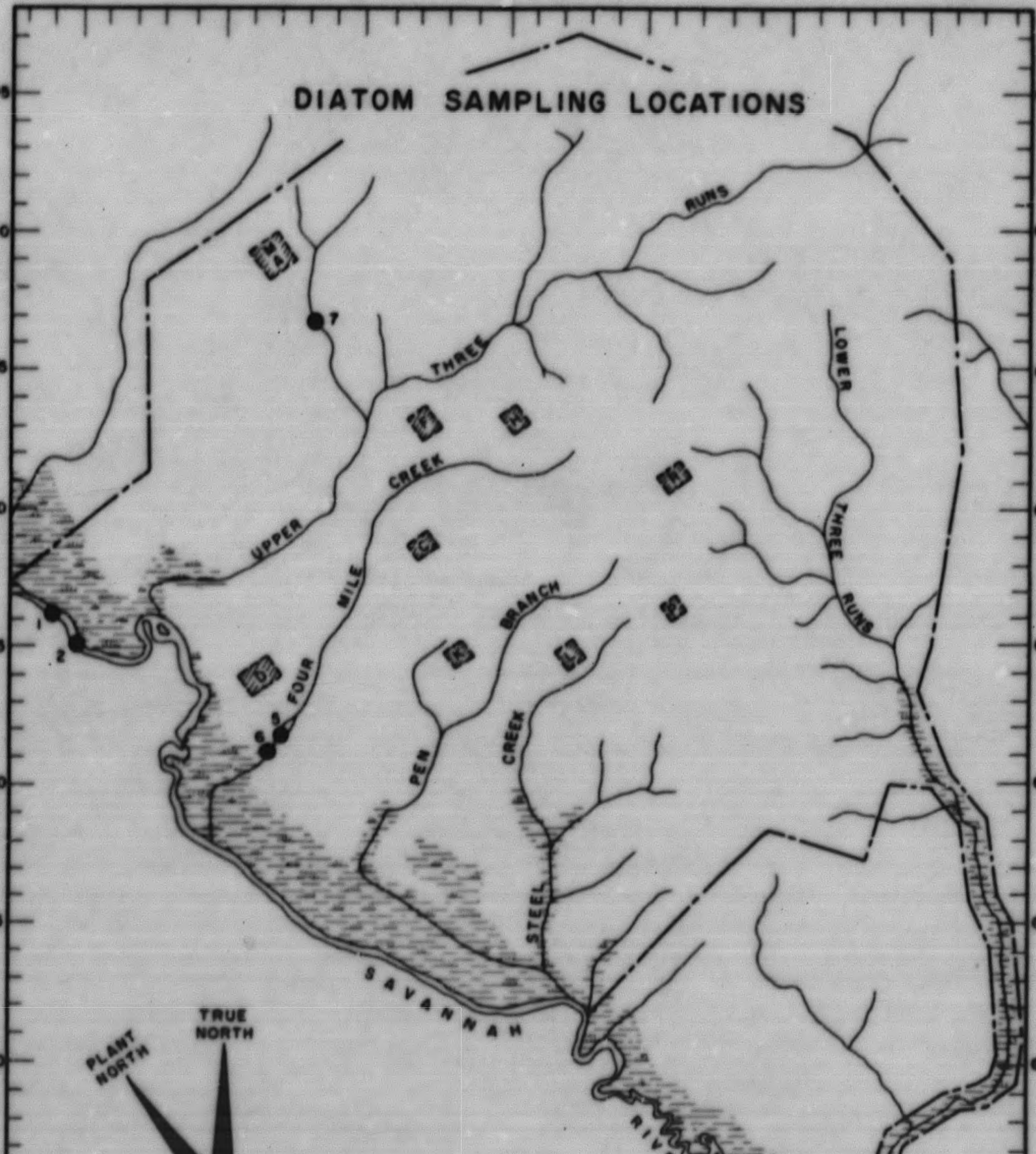

SAVANNAH RIVER
SAMPLING LOCATIONS
AUGUSTA BRIDGE
U.S. #1
S. R. P.
ALLENDALE BRIDGE
U.S. # 301
SCALE IN MILES
5
0
5
10

FIGURE 8


DIATOM SAMPLING LOCATIONS
UPPER THREE RUNS
CREEK
FOUR MILE
CREEK
PEN BRANCH
STEEL CREEK
LOWER THREE RUNS
SAVANNAH RIVER
PLANT NORTH
TRUE NORTH
0 1 2

APPENDIX

STATISTICAL ANALYSIS METHODS

Data were analyzed to determine significant differences between monthly means and significant differences between the means for different sampling locations. The error term employed was the "months X location" interaction. For a series of samples collected twice per month at four locations, the statistical analysis would be as follows:

First, the following arrangement of the data is made:

	Location					
	1	2	3	4		
January	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
February	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
March	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
April	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
May	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
June	X_1 X_2	X_1 X_2	X_1 X_2	X_1 X_2	SX_m	$\bar{X}_m$
	SX_L	SX_L	SX_L	SX_L		
	$\bar{X}_L$	$\bar{X}_L$	$\bar{X}_L$	$\bar{X}_L$		

X_1 or X_2 - individual samples

SX_m - sum of individual samples for each month

SX_L - sum of individual samples for each location

$\bar{X}_m$ - monthly mean

$\bar{X}_L$ - location mean

n - number of individual samples added to get the sum

After the data have been arranged as shown above, the following statistical analysis is made:

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
total	47	$SX^2 - \frac{(SX)^2}{n}$		
locations	3	$\frac{S(SX_L)^2}{n} - \frac{(SX)^2}{n}$	$\frac{\text{sum of squares}}{\text{degrees of freedom}}$	$\frac{\text{locations mean square}}{\text{error mean square}}$
months	5	$\frac{S(SX_m)^2}{n} - \frac{(SX)^2}{n}$		$\frac{\text{months mean square}}{\text{error mean square}}$
error	39	total S.S. -(locations S.S. + months S.S.)		

From the F-distribution table,* the values of F for 3 and 39 degrees of freedom are 2.84 at the 95% confidence level and 4.31 at the 99% confidence level. Therefore, when the F value determined for locations exceeds 2.84, there is a significant difference between the location means. This merely indicates a probability that if this same group of samples is collected 100 times, a true difference between the means will exist in 95 of these collections. Furthermore, when the F value determined for locations exceeds 4.31, there is a highly significant difference between the location means. This merely indicates a probability that if this same group of samples is collected 100 times, a true difference between the means will exist in 99 of these collections. The degrees of freedom and the F value for months are employed in a like manner to determine whether a significant difference exists between the monthly means.

Another statistical calculation is used to obtain the L.S.D., or least significant difference.

* George W. Snedecor. Statistical Methods. Fourth Edition. Ames, Iowa, Iowa State College Press, 1946.

From the t-distribution table, * the values of t for 39 degrees of freedom are 2.021 at the 95% confidence level and 2.704 at the 99% confidence level. To obtain the L.S.D., these values are substituted into the following equation:

$$\text{L.S.D. (at 95\% confidence level)} = t_{.05}\sqrt{\frac{2(\text{error mean square})}{n - 1}}$$

$$\text{L.S.D. (at 99\% confidence level)} = t_{.01}\sqrt{\frac{2(\text{error mean square})}{n - 1}}$$

n - number of individuals averaged to secure the mean. (In this problem, n has a value of 8 for the months and 12 for the locations).

The L.S.D. is merely a yardstick for measuring true differences with either a 95% or 99% probability of being right. For example, if the monthly means in the above problem were:

January	10	May	25
February	40	June	20
March	30	L.S.D.*	18
April	28	L.S.D.**	22

- then, it could be stated that there was a highly significant increase between January and February and a significant decrease between February and June.