Gamma Exposure Rates in the Steel Creek and Little Hell Landing Areas

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GAMMA EXPOSURE RATES
IN THE
STEEL CREEK AND LITTLE HELL LANDING AREAS

BY
W. I. MARTER

January 20, 1975

SUMMARY

Aeroradiographic and ground transect surveys in the summer of 1974 were conducted to determine the degree of offsite contamination in an area immediately below the Savannah River plant boundary. The results of these studies were published in report DP-1370, "Radioactivity From SRP Operations in a Downstream Savannah River Swamp: by W. L. Marter

It is recognized that mechanisms in the biosphere tend to cause non-homogenous distribution and redistribution of radionuclides released to the environment. To define these redistribution patterns as much as is practicable, a plan was developed to continually evaluate the off-site area. As part of this plan, a 1300-foot-long section of offsite swamp (42.9 acres) adjacent to the SRP boundary was surveyed in the latter half of October 1974 on a 10-foot grid pattern. The results of this survey show that 6.6 of the 42.9 acres surveyed in detail had exposure rates exceeding 57 $\mu\text{R/hr}$ ($\sim 500 \text{ mR/yr}$). The maximum exposure rate found at a single grid point was 120 $\mu\text{R/hr}$. Approximately 5.8 Ci of cesium-137 is deposited in the 42.9-acre 10-foot grid survey area.

A hypothetical person (none exists) residing continuously in the location of highest exposure rate when the swamp is not flooded (77% of the time each year) could receive an annual dose of about 809 mR. Previous surveys of this area indicated a maximum external annual dose of 357 mR under the same residency conditions. Even with the higher exposure rates detected in the 10-foot grid survey, the more probable incremental radiation dose (above background) to hunters and fishermen who spend a few hours to a few hundred hours in this section of swamp would range from less than 1 mR to a few tens of mR per year.

PREVIOUS SWAMP SURVEYS

During the 1960's, approximately 25 Ci of cesium-137 (^{137}Cs) and less than 1 Ci of cobalt-60 (^{60}Co) were deposited in a downstream Savannah River swamp⁽¹⁾, primarily as a result of releases of radioactivity from P and L reactor fuel storage basins to Steel Creek. The radioactivity in the swamp, mostly associated with sediments, was deposited during periods of swamp flooding which occurs an average 23 percent of the time each year. Aeroradiographic and ground transect surveys made in June 1974 and July-August 1974, respectively, revealed net gamma exposure rates (three feet above the ground) of 53 $\mu\text{R/hr}$ (464 mR/yr) maximum except for an exposure rate of 67 $\mu\text{R/hr}$ (590 mR/yr) on a small strip of land, several yards wide, between two sloughs containing standing water. This area was located in a swamp transect at River Mile 138.5, about one mile northwest of Little Hell Landing.

The swamp between the SRP boundary at Steel Creek and the SRP boundary at Lower Three Runs Creek is approximately five square miles in area. The area of the swamp containing radiation levels above natural background is 1.9 square miles (1235 acres). About 93 percent of the radioactivity is in the 3.5-mile-long section of swamp between the SRP boundary (at Steel Creek) and Little Hell Landing and about 20 percent is in a 1300-foot-long section (61.7 acres) just east of the SRP boundary at Steel Creek.

10-FOOT GRID SURVEY - OCTOBER 1974

A Barnwell County road (SC 493) and a boat launching ramp at the river, called Steel Creek Landing Road and Steel Creek Landing, respectively, are located in the 1300-foot long section of swamp adjacent to the SRP boundary near Steel Creek. As part of the program to evaluate radioactivity in the swamp, investigating surveys were conducted to gather information to guide future work. These surveys confirmed the need for a detailed ground survey of the swamp area where the aerial survey had indicated the spots of highest concentration of radioactivity should exist. A ground survey team was assigned to make a comprehensive survey of this section of swamp on a 10-foot grid pattern. The location of the grid survey is shown in Figure 1, an aerial photograph of the general area encompassing Steel Creek Landing.

The grid pattern for the radiation survey was laid out by a mapping team from the SRP Project Department. Wooden stakes were used to mark grid points at 100-foot intervals on a north-south line at the SRP boundary. This western-most line was designated by the letter "A" and 100-foot intervals along the line were identified with numbers, arbitrarily starting with "30" at the north end and increasing consecutively in a southerly direction. Similar grid lines were laid out east of and parallel to line A at 100-foot intervals and were assigned letter designations "B" through "P" ("I" and "O" omitted).

The radiation survey of the swamp was made in a series of "sweeps" through the swamp in a north-south direction by a team of 10 surveyors and a data recorder. The surveyors were each equipped with portable gamma scintillometers (Technical Associates, Model FS-11) which had been calibrated with a radium source. The surveyors formed an east-west line 10 feet apart and walked southward, stopping every 10 feet to make an exposure rate measurement and to record data. Thus, for each major 100-foot grid marked by wooden stakes, 100 exposure rate readings were recorded on a 10-foot grid. In order to expedite the overall survey, survey data were recorded only in those areas where general gross gamma exposure rates exceeded 30 μ R/hr. Approximately 19,000 measurements were recorded over a two-week period. The recorded data represented gross gamma exposure rates in reference to instrument response to a radium-226 calibration source and were uncorrected for natural background exposure rate. The large number of field measurements were coded and computer stored to facilitate correction, analysis, and mapping.

*This aerial photograph was taken on April 6, 1973 when the swamp was flooded during a period of high river flow (95.8 feet MSL at SRP boat dock). The river elevation at Steel Creek Landing was about 86 feet above mean sea level (MSL) at the time the photograph was taken. Water extends almost to the edge of the swamp margin and covers most of the unpaved end of the Steel Creek Landing Road to an elevation of about 86 feet MSL.

GROSS GAMMA ADJUSTMENT

The portable gamma scintillometers were calibrated to give uniform radiation response with a radium-226 source prior to the 10-foot grid swamp survey. The response of the NaI(Tl) detector is energy dependent with maximum response to gamma energy of about 0.3 MeV and decreasing in response as gamma energy increases. Cesium-137 emits a gamma photon with an energy of about 0.66 MeV; radium-226 in equilibrium with its daughters emits an effective mean gamma energy of about 0.78 MeV but is made up of a large number of discrete gamma energies ranging from 0.05 to 1.76 MeV. Scintillometers calibrated with radium will overrespond to the lower energy from cesium-137. To correct for this, radium calibrated thermoluminescent dosimeters (energy independent in response to a wide range of gamma radiation energies) were exposed for periods of five to seven days at three feet above the ground at each of the major 100-foot grid points in the swamp. The exposure rates at each grid point, as determined by TLD's, were plotted versus scintillometer readings at the same point. With these data, a formula for a least-squares fit line of regression was derived, including correction for natural background exposure rate. The equation was

$$\text{Net Exposure Rate} = 0.83X - 8.95$$

Where: X = scintillometer reading, $\mu\text{R/hr}$

Twelve different scintillometers were used during the survey. Accuracy of survey data were determined by measuring known exposure rates from a cesium-137 source with six of the instruments used in the survey. The deviation of gamma exposure rate response between survey instruments increases as exposure rate increases as shown in Table 1.

Table 1

<u>Exposure Rate, $\mu\text{R/hr}$</u>	<u>Standard Deviation (σ), %</u>
26.3	4.6
44.0	7.6
73.1	7.6
90.3	8.7
100.3	13.7
126.2	14.5
153.8	15.6

EFFECT OF SOIL MOISTURE CONTENT

The 10-foot grid survey of the swamp was made in the latter half of October 1974. The swamp was unusually dry because only 0.08 inch of rain fell during the entire month, none during the survey. The average rainfall in October at SRP (21 years of record) is 2.57 inches and only in two previous months (both in October) out of 252 (21 years) has the rainfall been less.

Table 2

Average Precipitation at SRP

<u>Month</u>	<u>Average Rainfall, in.</u>
January	4.1
February	4.3
March	5.1
April	3.5
May	3.8
June	4.5
July	4.8
August	4.7
September	3.8
October	2.6
November	2.2
December	3.6
Total	47

The effect of soil moisture on gamma exposure rates was determined by measurements in the swamp with TLD's, scintillometers, and ionization chambers before and after a rainfall early in November 1974. The shielding effect of water in saturated swamp soil reduced exposure rates approximately 10 percent. This was verified by laboratory tests. From the past history of rainfall, it appears unlikely that exposure rates measured in the October 1974 grid survey will ever be exceeded as a result of soil dryness. The survey data presented in the following section therefore represents the upper limit of exposure rates under present depth distribution (geometry) of the cesium deposits.

METHOD OF PRESENTING SURVEY DATA

The grid spacing used in the swamp survey was selected because FS-11 gamma scintillometer detectors have a circle of resolution of approximately 10 feet in diameter when measuring three feet above a plane source, i.e., an area of about 79 square feet. Each instrument reading, however, was taken to represent a 10-foot grid (100 ft²) to simplify the survey.

METHOD OF PRESENTING SURVEY DATA (CONTINUED)

Figure 2 is a map of the 10-foot grid survey area. The east-west scale is about 20 percent greater than the north-south scale in order to make the map compatible with computer printout sheets used in following figures. This map shows the SRP boundary, Steel Creek Landing Road (with elevations above mean sea level), Steel Creek Landing, the edge of the Savannah River, and the major 100-foot grid scale. This map, with computer printout overlays, is used to present results of the 10-foot grid survey.

THE SURVEY DATA

Figure 3 shows the computer printout of net gamma exposure rates in 5 $\mu\text{R/hr}$ increments at 18,696 points on the 10-foot grid survey area. The highest net exposure rate found was 120 $\mu\text{R/hr}$. Data from Figure 3 are summarized in the Appendix.

The areas in Figure 3 designated with the large letters "A" and "B", 4.1 and 2.9 acres, respectively, were reconnoitered and no gross exposure rates greater than 30 $\mu\text{R/hr}$ (net exposure rate of 16 $\mu\text{R/hr}$) were found; these areas were not surveyed on a 10-foot grid. The area designated "C" (11.5 acres) was impenetrable because of boggy conditions; however, a few survey readings in the edges of this area, along with data from the EG&G aeroradiographic survey of June 1974 lead to the conclusion that very little radioactivity is deposited in this area.

Figure 4 shows the same data as Figure 3 except exposure rates are shown in 20 $\mu\text{R/hr}$ increments. Areas that could not be surveyed because of water (0.3 acre) are shown by equal (=) signs. On the right side of this figure, the path of Boggy Gut Creek is clearly evident.

Figure 5 shows all survey points where exposure rates exceed 57 $\mu\text{R/hr}$ ($>500 \text{ mR/yr}$). This represents about 6.6 acres and is located in an area bordering the swamp margin which is generally depressed in elevation (a swale). If it is assumed that a person could reside in the swamp 77% of the time (flooded 23% of the time)(1), an exposure rate of 74 $\mu\text{R/hr}$ would cause an annual dose of 500 mR. Figure 6 shows grid points where exposure rates exceed 74 $\mu\text{R/hr}$. From Figure 6 it was determined that 110 grid points (0.25 acre) showed exposure rates that exceed 74 $\mu\text{R/hr}$.

Figures 7 through 12 are single character computer printouts showing net gamma exposure rates in 20 $\mu\text{R/hr}$ increments (Table 3).

THE SURVEY DATA (CONTINUED)

Table 3

<u>Figure Number</u>	<u>Exposure Rate Range, μR/hr</u>
7	0-20
8	20-40
9	40-60
10	60-80
11	80-100
12	100-120

AMOUNT OF RADIOACTIVITY DEPOSITED

Previous swamp ground transect surveys in July-August 1974⁽¹⁾ established a relationship between gross gamma exposure rates and measured radioactivity in swamp sediments. From this relationship, the amount of cesium-137 deposited in the 1300-foot-long section of swamp bordering the SRP boundary near Steel Creek was calculated. The results of these calculations are shown in Table 5.

Table 5

Radioactivity Deposited in Swamp

<u>Location</u>	<u>Acres</u>	<u>Curies</u>
Less than 500 mR/yr (100% occupancy)		
. Grid Area	36.4	4.4
. Area "A" (Figure 3)	4.1	0.2 max*
. Area "B" (Figure 3)	2.9	0.2 max*
. Area "C" (Figure 3)	11.5	0.6 max*
. Creeks	0.3	
Subtotal	55.2	5.5 max
Greater than 500 mR/yr (100% occupancy)		
. Grid Area	6.6	1.4
Grand Total	61.8	6.9 max

*An upper limit based on an assumed uniform gross gamma exposure rate of 30 μ R/hr.

The 1300-foot-long section of swamp bordering the SRP boundary is estimated to contain 6.9 Ci of cesium-137 based on the 10-foot grid survey. It was estimated that this section of swamp contains about 5 Ci of cesium-137 based on exposure rates measured in the June 1974 aeroradiographic survey. The 5 Ci estimated from the aeroradiographic survey is in fair agreement with the 6.9 Ci calculated from the 10-foot grid survey considering the nonhomogeneity of radioactivity deposition, the relatively small number of ground transect survey readings in this area in the July-August 1974 survey, and the broader areal resolution of the aeroradiographic survey.

LITTLE HELL LANDING SURVEY

On November 12, 1974, a reconnaissance survey was made (with portable scintillometers) of the swamp area between Little Hell Landing and River Mile 135.3 (Reference 1, Figure 12) to the west of the landing. The survey area ranged in width from about 1200 feet along the swamp margin to about 300 feet wide near the river. Highest exposure rates were detected in a swale bordering the swamp margin. In this swale, maximum net gamma exposure rates of about 35 $\mu\text{R/hr}$ (corrected) were detected at two locations. All other net exposure rates in the swale were less than 30 $\mu\text{R/hr}$. This indicates that the cesium-137 deposition at this location is less concentrated and is more homogeneously distributed than in the grid survey area adjacent to the SRP boundary.

CONCLUSIONS

A 10-foot grid ground survey of a 1300-foot-long section of the Savannah River Swamp below the SRP boundary near Steel Creek detected nonhomogeneities of radioactivity deposition not detected in the July-August 1974 ground transect survey and the June 1974 aeroradiographic survey. In scattered locations, representing about 0.25 acre of swamp, a hypothetical swamp resident who lived in the swamp for 77 percent of the time when the swamp is not flooded could receive gamma doses of 500 to 809 mR/year. Previous surveys indicated a maximum external gamma dose of 357 mR/yr under the same residency conditions. Residency in the swamp is unlikely. The more probable incremental radiation dose (above background) to hunters and fishermen who spend a few hours to several hundred hours in this section of swamp would range from less than 1 mR to a few tens of mR per year.

Nonhomogeneous radioactivity deposition likely occurs in the offsite swamp east of the area surveyed on a 10-foot grid pattern. However, the June 1974 aeroradiographic survey (Ref. 1, Figure 15) indicates that the cesium-137 deposition per unit area in other sections of the swamp is lower than in the grid-surveyed area; thus, the grid-survey area probably represents the location of highest gamma exposure rates.

A reconnaissance survey near Little Hell Landing in November 1974 lends support to this conclusion.

ACKNOWLEDGEMENTS

Mapping and layout of the grid survey area was performed by the SRP Project Department. Radiation surveys in the swamp were made by the SRP Health Physics Section. Computer programming for analysis and mapping of survey data was by R. E. Cooper of Environmental Analysis and Planning.

REFERENCES

1. W. L. Marter, "Radioactivity from SRP Operations in a Downstream Savannah River Swamp," DP-1370, September 1974.

APPENDIX

SURVEY DATA FROM FIGURE 3

<u>Exposure Rate</u> <u>μR/hr</u>	<u>Map</u> <u>Symbol</u>	<u>Number of</u> <u>Grid Points</u>	<u>Acres</u>	<u>Curies</u> <u>¹³⁷Cs</u>
0-5	0	254	0.5831	0.0083
5-10	1	288	0.6612	0.0187
10-15	2	288	0.6612	0.0281
15-20	3	746	1.7126	0.0970
20-25	4	2286	5.2479	0.3726
25-30	5	1362	3.1267	0.3105
30-35	6	1514	3.4757	0.3936
35-40	7	1357	3.1152	0.3976
40-45	8	3603	8.2713	1.1710
45-50	9	2269	5.2089	0.8123
50-55	A	1867	4.2860	0.7897
55-60	B	1381	3.1703	0.6284
60-65	C	673	1.5450	0.3284
65-70	D	579	1.3292	0.3011
70-75	E	116	0.2663	0.0679
75-80	F	17	0.0390	0.0105
80-85	G	21	0.0482	0.0137
85-90	H	11	0.0253	0.0075
90-95	J	49	0.1125	0.0350
95-100	K	8	0.0184	0.0062
100-105	L	0	-	-
105-110	M	2	0.0046	0.0017
110-115	N	1	0.0023	0.0009
115-120	P	1	0.0023	0.0009
TOTAL		18,696	42.9	5.8
Background	#	3	0.0069	-
Water	=	134	0.3076	-

FIGURE 1. Aerial Photograph Of Grid Survey Area

FIGURE 2. Master Grid Survey Map

FIGURE 4. Grid Survey - 0 to 120 $\mu R/hr$ - 20 $\mu R/hr$ Increments

FIGURE 5. Exposure Rates Greater Than 57.1 $\mu\text{R/hr}$ (≥ 500 mR/yr)

FIGURE 6. Exposure Rates Greater Than $74.1 \mu\text{R/hr}$ ($\geq 500 \text{ mR/yr}$ if occupied 77% of time)

FIGURE 7. Exposure Rates — 0 to 20 $\mu\text{R/hr}$

FIGURE 8. Exposure Rates - 20 to 40 μ R/hr

FIGURE 9. Exposure Rates - 40 to 60 μ R/hr

FIGURE 10. Exposure Rates — 60 to 80 $\mu\text{R/hr}$

FIGURE 11. Exposure Rates — 80 to 100 $\mu\text{R/hr}$

FIGURE 12. Exposure Rates — 100 to 120 $\mu\text{R/hr}$