CHAPTER 12.1

RADIONUCLIDES IN SEDIMENTS

ABSTRACT

This chapter discusses radionuclide concentrations measured in sediment samples collected on or in the vicinity of the Savannah River Site (SRS). We reviewed the history of sediment monitoring at the SRS and evaluated these data with regard to their potential usefulness for dose reconstruction.

We compiled and examined sediment data to determine their potential value in source term verification, model validation, and direct exposure assessment. Uranium data collected from Steed's Pond, which received liquid effluents from the M-Area via Tim's Branch, may be useful for source term verification and model validation of uranium releases from the M-Area. However, the potential usefulness of the Steed's Pond data, which are limited in number, is bounded by spatial resolution. Results of measurements of long-lived radionuclides (uranium, plutonium, and ^{137}Cs) in streambeds do not appear useful because samples do not represent the entire streambed and demonstrate no spatial trends because of the complex sediment deposition processes involved. Appendix K further discusses potential uses for environmental monitoring data.

INTRODUCTION

Long-lived contaminants, deposited by releases to air and SRS streams, tend to accumulate in bottom sediments. Deposits may be in distinct layers, for example, after discrete release events; thus, they preserve the temporal history of liquid releases to a stream, pond, or river. Deposition patterns often show concentrations decreasing as a function of distance from the source of contamination, thus, revealing spatial trends and defining the extent of contamination.

This chapter summarizes reported information regarding radionuclide concentrations in sediments on or in the vicinity of the SRS. We examined several sets of routine semiannual and annual environmental monitoring reports, prepared by the SRS contractor and spanning the years 1953 through 1992. See Chapter 7, Table 7-1 for a complete description of the various monitoring report series.

Data usefulness was considered in terms of the following:

- The contaminant is a key contaminant (i.e., screened in Task 3 of Phase I of the dose reconstruction to potentially contribute significantly to dose)
- The contaminant was monitored during the period of interest (i.e., 1951 through 1990)
- Contaminant concentrations were above detection limits
- The results demonstrate expected trends (spatially and temporally)
  - Concentrations were generally higher close to the source
  - Concentrations in sediment cores are often present in discrete layers.

Data that are available for sediments include gross alpha activity; nonvolatile beta activity; and concentrations of gamma-emitting radionuclides, uranium and plutonium. Appendix A details analytical and counting procedures for sediment samples. We provide the summary results for the onsite streams and Savannah River locations in this chapter.

MEASUREMENT OF CONTAMINANTS IN SEDIMENTS

Routine sediment monitoring began in 1951 with the collection of stream sediments for use in establishing background levels of radioactivity at 13 locations along the inner perimeter and 17 locations along the outer perimeter of the SRS (Reinig et al. 1953; Reinig 1952). The sampling locations included stations on the Upper Three Runs Effluent System (including Tim's Branch), Four Mile Creek, Steel Creek, Pen Branch, Indian Graves Branch, Lower Three Runs, and the Savannah River. Sample collection methods are not detailed, although Reinig (1952) states that "approximately 1000 boring samples were analyzed," implying that a soil-coring device of unspecified diameter was used. Samples from the 1951 survey varied in weight from 0.7 to 2.5 grams (g). The samples were analyzed for gross alpha and gross beta activity and plotted as activity versus location. This sampling, analysis, and reporting regime continued in 1953 following the start up of the plant (Albenesius 1954). Table 12.1-1 summarizes general features about the sediment sampling program at the SRS through 1991, including the cessation of a routine sediment sampling program from 1963 through 1977.

Table 12.1-1. Sediment Sampling Summary at SRS[a]

Years	Site monitoring areas	No. of samples	Measured
1951-1953	At mouth of Upper Three Runs, Four Mile Creek, Steel Creek, Pen Branch, Indian Grove Branch. Lower Three Runs	30	Gross alpha; gross beta
1954	Same as above but sampling along stream length	46	Alpha (U+Pu); nonvolatile beta
1955-1961	TNX effluent ditch added to above; Table 12.1-2 and Figures 12.1-1, 12.1-2, 12.1-3 summarize locations and data	48	Alpha (U+Pu); nonvolatile beta
1963-1977	*No routine sediment monitoring program; resumed in 1977*		
1977-1991	Routine sediment monitoring resumed in site streams and in Savannah River	15	Gamma-emitting radionuclides, ^{238}Pu, ^{239}Pu, ^{90}Sr
1967, 1981, 1984	Special study: Steed's Pond receiving M-Area effluent	6-15	Uranium
1974-1976	Special study: Savannah River swamp		^{137}Cs, ^{238}Pu, ^{239}Pu, ^{90}Sr

[a] From annual environmental monitoring reports (see Table 7-1).

In 1954, the number of locations sampled for sediment increased to 46 along the five major stream systems that carry waste into the Savannah River (Upper Three Runs, Four Mile Creek, Steel Creek, Pen Branch, and Lower Three Runs); Tim's Branch (which carries plant waste into Upper Three Runs); and the Savannah River. The sampling design was changed from perimeter sampling to sampling along the length of each stream system (Horton 1954, 1955). Approximately 80% of the weekly samples were analyzed for alpha activity (uranium and plutonium) using tri-n-butyl phosphate (TBP) extraction and scintillation counting (see

Appendix A). All of the samples were analyzed for nonvolatile beta activity. The maximum and average uranium or plutonium activity for each 6-month period and stream location was reported in the semiannual environmental monitoring reports as disintegrations per minute per gram.

In 1955, the sampling network was changed to include the TNX effluent ditch, which empties effluent directly into the Savannah River (Alexander and Horton 1956; Horton and Mealing 1956). Approximately 70% of the weekly samples were analyzed for uranium or plutonium activity. All were analyzed for nonvolatile gross beta activity. A similar sampling strategy continued through 1960 (Mealing et al. 1958, Harvey et al. 1959a, 1959b, and Du Pont 1959, 1960), but results of TBP extraction and scintillation counting were reported as gross alpha activity (curies per gram) instead of uranium and plutonium activity. The sampling designs for 1955 through 1960 are outlined in Table 12.1-2, Figures 12.1-1 and 12.1-2 show water and sediment sampling locations from 1954 to 1958 and from 1959 to 1960, respectively.

Marter and Boulogne (1961) provide some information on sediment sample collection methods. This document states that stream mud samples, taken at all river and stream locations, were generally collected close to the bank and "bear no relation to localized 'silt out'."

In 1961, the sediment sampling program consisted of weekly samples collected from 16 stream locations and weekly and monthly samples collected from 7 river locations (as shown in Figure 12.1-3). Monthly sediment samples from five river locations (2, 3, 5, 8, and 9) and weekly samples from two river locations (10 and 11) and two stream locations (3 and 4) were analyzed for TBP extractable alpha activity.

Table 12.1-2. Sediment Sampling Design (1955–1960)

Sampling area	Number of sampling locations					
	1955	1956	1957	1958	1959	1960
Tim's Branch	5	4	3	4	4	3
Upper Three Runs	4	4	4	4	4	4
Four Mile Creek	7	7	7	7	5	5
Pen Branch	3	3	3	3	2	2
Steel Creek	5	4	4	4	3	3
Lower Three Runs	3	3	3	4	5 [c]	5[c]
TNX Effluent	1	1	1	–	–	–
Savannah River	10	10	10	11	11	11
Collection frequency	Weekly[a]	Weekly	Monthly[b]	Monthly[b]	Monthly[b]	Weekly[d]
Total number of samples analyzed for nonvolatile beta	2209	1350	475	520	520	1166
Total number of samples analyzed for uranium and plutonium	1446	1036	339	454	454	1166

[a] Sediments collected biweekly at 8 of 10 locations along the Savannah River beginning in July 1955.

[b] Sediments collected monthly, except samples were collected weekly at one location on the Savannah River, where it intersects Highway 301.

[c] Includes three sample locations at Par Pond.

[d] Sediments collected monthly on the Savannah River, except at two locations, where samples collected weekly.

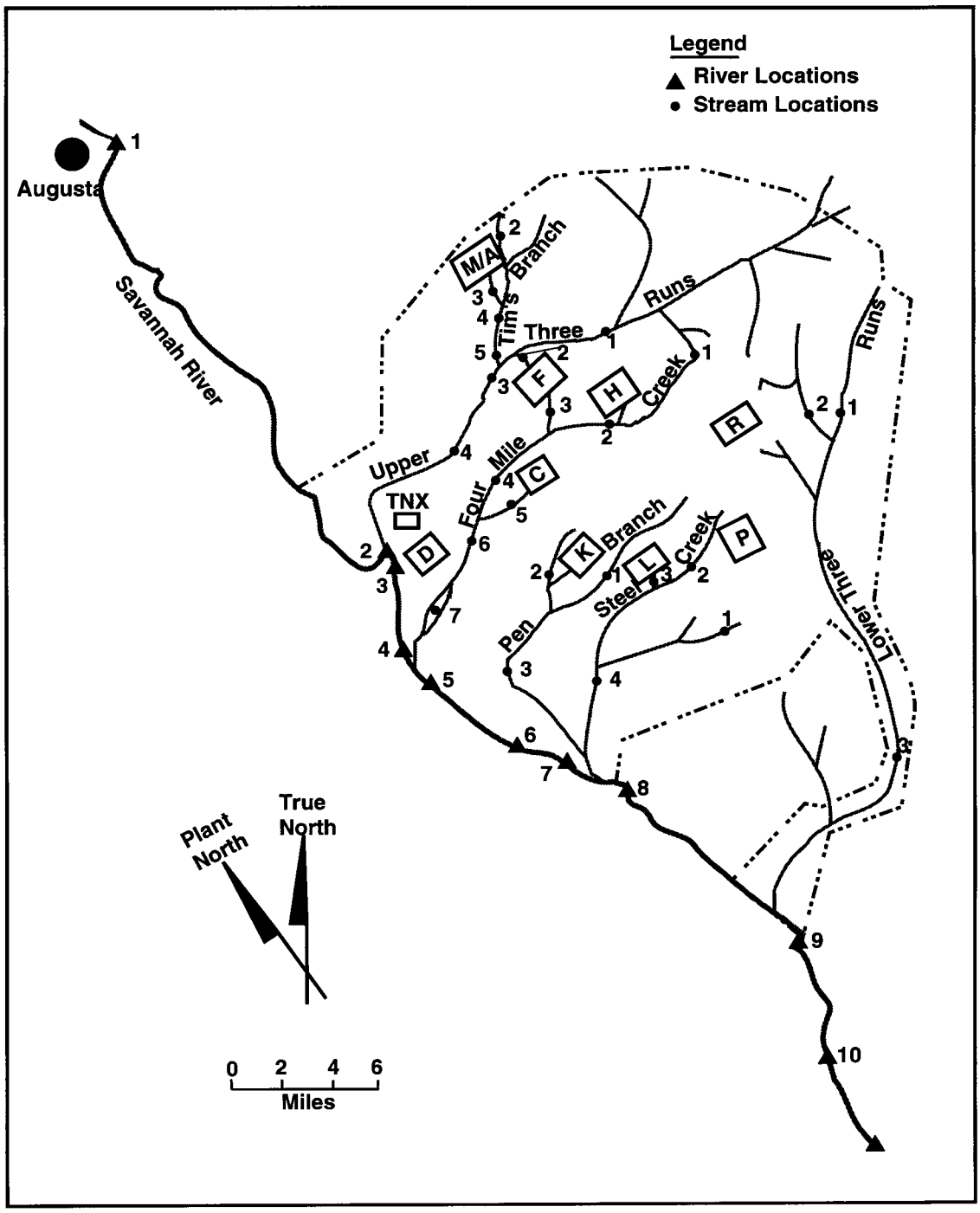

Figure 12.1-1. Map of SRS routine stream and river sampling locations used in the sediment sampling programs from 1954 through 1958.

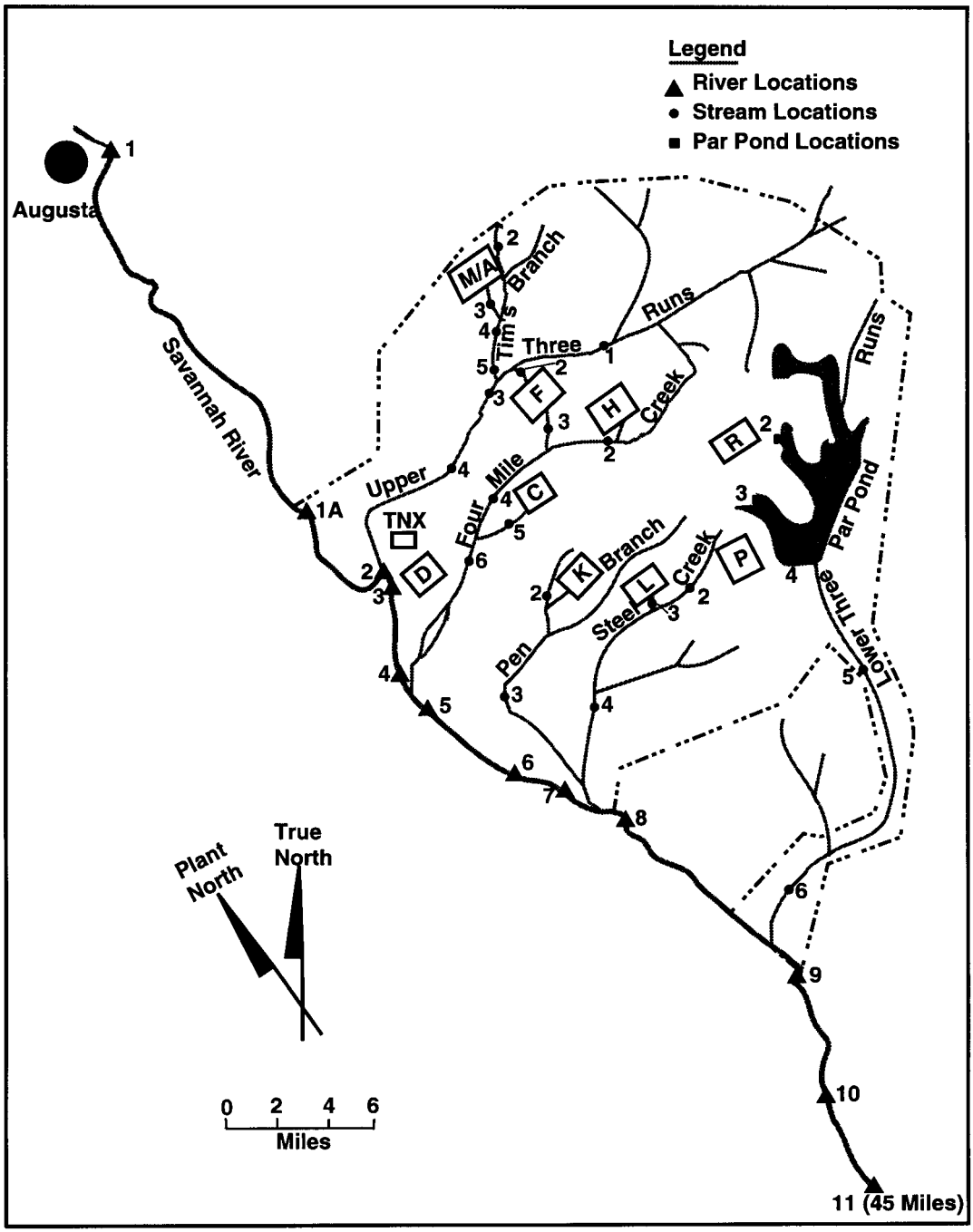

Figure 12.1-2. Map of SRS routine stream and river sampling locations used in 1959 and 1960 sediment sampling programs.

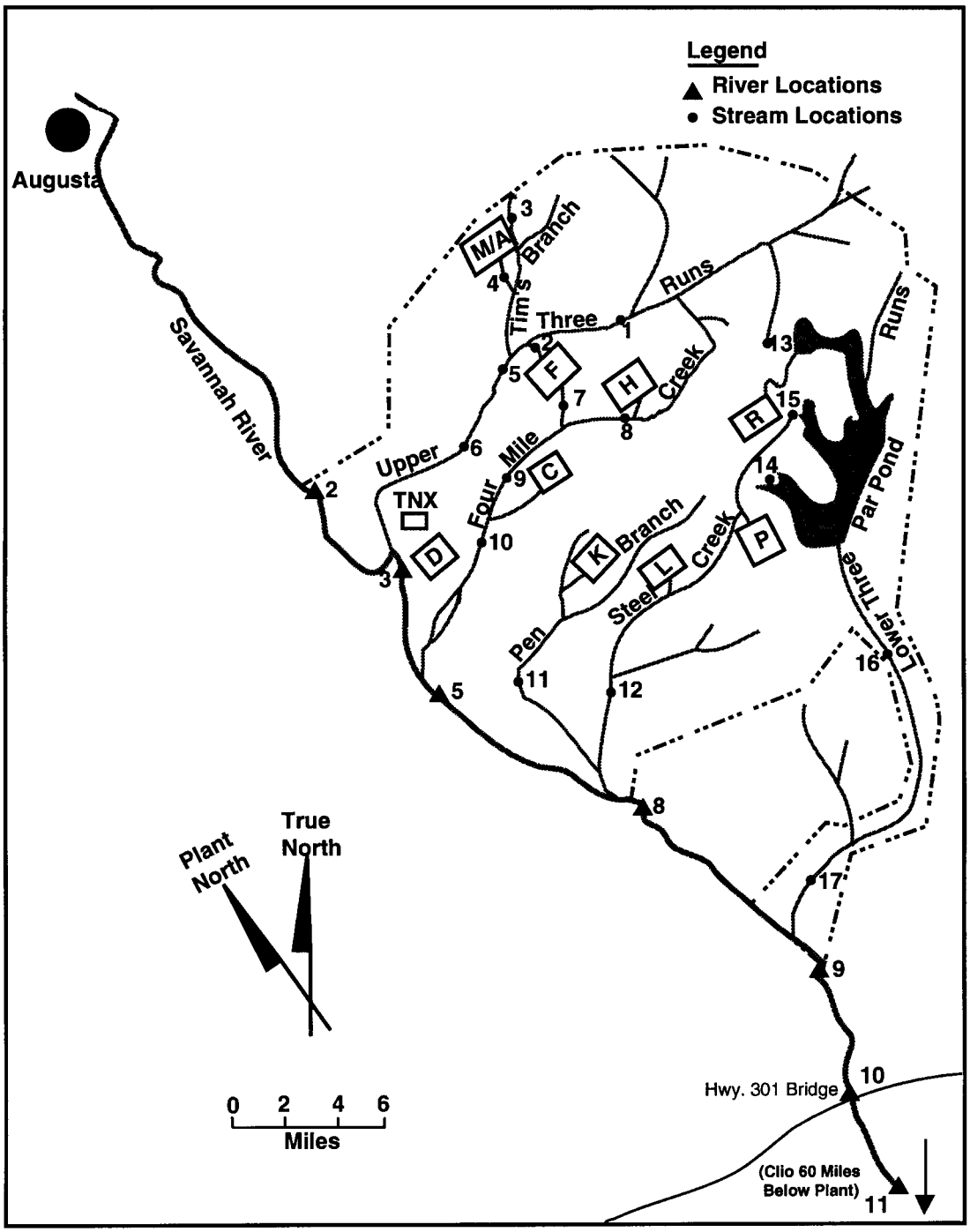

Figure 12.1-3. Map of SRS routine stream and river sampling locations used in 1961 and 1962 sediment sampling programs.

In 1963, it was proposed that all routine sediment sampling be eliminated on the basis that "the information gained with present methods is meaningless" (Johnson 1963). Routine sediment sampling was discontinued from 1963 through the mid-1970s. Collection of sediments was resumed in 1974 (Ashley and Zeigler 1976). Ten sediments cores, 25 cm deep, were collected from each of 10 trails transecting the Savannah River swamp, where radioactive materials from

Savannah River Plant (SRP) releases in 1960s were deposited in about 1.7 mi^2 of offsite swamp downstream from the SRP. The cores were divided into two increments (from 0 to 7.6 cm and from 7.6 to 25 cm), which were composited by increment from each location (trail) for plutonium analysis. In addition, 12 sediment samples were collected in the Savannah River, starting above the Site and continuing to the Savannah, Georgia harbor. Samples were analyzed for gamma-emitting radionuclides (^{137}Cs in particular), ^{238}Pu, and ^{239}Pu. In 1976, samples were also analyzed for ^{90}Sr (Ashley and Zeigler 1977).

Sediment collections in the Site streams resumed in 1977 to obtain an estimate of the maximum accumulation of radioactivity released from the Site (Ashley and Zeigler 1978). The 1977 and subsequent annual reports state that stream sediment sampling locations were designed to obtain an estimate of the maximum accumulation and are, therefore, not representative of the entire stream bed. The sampling approach called for collecting approximately the top 8 cm of sediment in areas where fine sediment accumulates. The sediments in the Savannah River continued to be sampled, although sediment sampling in the Savannah River swamp was reduced in frequency in 1978 because the results of these surveys showed no significant changes in radiological conditions. At that time it was decided to conduct comprehensive surveys of the swamp every 5 years, including sediment, vegetation, animals, fish, and thermoluminescent dosimeter (TLD) measurements unless additional surveys were warranted by changes in the annual TLD radiation measurements (Ashley and Zeigler 1979).

Several nonroutine sediment sampling studies have been conducted over the years. Three studies that may be of particular importance to the dose reconstruction are the surveys of Steed's Pond sediments for uranium conducted in 1967, 1981, and 1984 (Ashley and Zeigler 1982, Zeigler et al. 1986). Before 1985, when an advanced liquid waste treatment facility was put into operation, untreated liquid effluents containing uranium were released to Tim's Branch via a drainage ditch. Tim's Branch flowed into Steed's Pond, which acted as a settling basin and accumulated uranium in the sediments. Steed's Pond originally had an area of approximately 14 acres and had a spillway that partially collapsed in the early 1960s. The spillway was only partially removed, as evidenced by the retention of a few acres of water. The first survey was conducted on the sediments that were exposed. At that time, six 18-in. sediment cores were collected, separated into 6-in. segments, and analyzed for uranium. In the early 1970s the spillway was repaired and the pond returned to a surface area of about 11 acres.

The spillway was opened in January 1981, and the pond was drained for turtle studies. While the pond was drained, six 6-in. sediment cores were collected and analyzed for uranium. In August 1984, the spillway collapsed and the pond was drained completely. Fifteen 24-in. sediment cores were collected. In addition, 15 samples were taken between Steed Pond and the M-Area effluent ditch. The samples were divided into increments of 0–6 in., 6–12 in., and 12–24 in., and they were analyzed for uranium as well as for chromium, copper, lead, nickel, sodium, aluminum, ammonia, chlorine, nitrate, and thorium. The uranium concentrations in the 1985 sediment samples were analyzed using more sophisticated radiochemical techniques than TBP extraction.

The Savannah River Environmental Laboratory (SREL) did extensive research on the behavior of ^{137}Cs within the Steel Creek flood plain. This research, which is summarized in Carlton et al. (1992), addresses the availability of cesium in the sediments for plant uptake and its subsequent transfer through the food chain.

Measurements of Uranium in Sediments

Greater than 97% of the gross alpha activity released from SRS facilities occurred from the M-Area (Evans et al. 1992). Essentially all of the alpha activity in the process effluent in the M-Area has been identified as depleted uranium. Most of this activity was released between 1966 and 1969 during the development of a new uranium/aluminum bonding process for fuel and target assemblies. Because the effluent from the M-Area was released into Tim's Branch, the dose reconstruction should focus on uranium data collected from sediments of this stream.

Steed's Pond acted as a settling basin for Tim's Branch, as evidenced by the accumulation of sediment of about 3 ft of sediment in the vicinity of the Steed's Pond spillway. Water entering the pond had a residence time of about 3 days (Evans et al. 1992). The first survey for uranium, conducted in February 1967, indicated that the top 6 in. of sediment contained greater than 90% of the uranium activity detected in the cores (Ashley and Zeigler 1982). The uranium concentrations in the upper 6 in. ranged from 20 to 531 pCi g^{-1}. Concentrations in the second 6-in. increment had decreased to about one-eighth the surface value. The uranium concentration was near background concentrations (approximately 5 pCi g^{-1}) between 12 and 24 in.

In 1981, the six 6-in. cores collected from Steed's Pond had an average uranium concentration of 170 to 700 pCi g^{-1}, about twice as great as the 1967 results. Evans et al. (1992) attributes this increase to additional uranium released to the effluent since 1966. Approximately 10 Ci of uranium was released to Tim's Branch from 1954 through 1966. An additional 15 Ci was released from 1966 through 1981.

The 1984 sediment sampling of Steed's Pond was more extensive than previous studies. Figures 12.1-4 and 12.1-5 show that uranium activity was generally higher in the sediments of Steed's Pond than in sediments above the pond, and that most of the uranium is in the upper 6 in. of sediment. However, in the 1984 survey, it was estimated that 54% of the uranium was in the upper 6 in., compared to 90% in the 1967 survey (Evans et al. 1992). This decrease may be attributed to an increase in sediment deposition in the pond after the spillway was repaired in the early 1970s. Most of the cores show a pattern of highest concentration in the first 6 in. and decreasing concentrations as a function of sediment depth. However in four of the cores, the highest uranium concentration occurred in the segment below 6 in. Evans et al. (1992) states that some of the processes that could be involved in determining depth distributions include deposition, erosion, and redeposition; size sorting during deposition; changes in the flow regime; flood events; manmade changes; changes in water level in a pond; biological processes; alterations in water chemistry; and unplanned releases.

There also appears to be a pattern of increasing uranium concentrations in cores as a function of distance from the pond inlet (Figure 12.1-4). That is, the lowest numbered samples, collected near the inlet, have the lowest concentrations of uranium. In contrast, the highest numbered samples, collected near the spillway, have the highest concentrations of uranium. This makes sense since the deepest part of the pond, where the heaviest deposition of sediments is most likely to occur, is near the spillway.

Comparisons of the 1967 and 1981 results from Steed's Pond sediment studies cannot be made with the 1984 results because more sensitive and more accurate nonradiological methods were used to measure the uranium concentrations in sediments in the 1984 study.

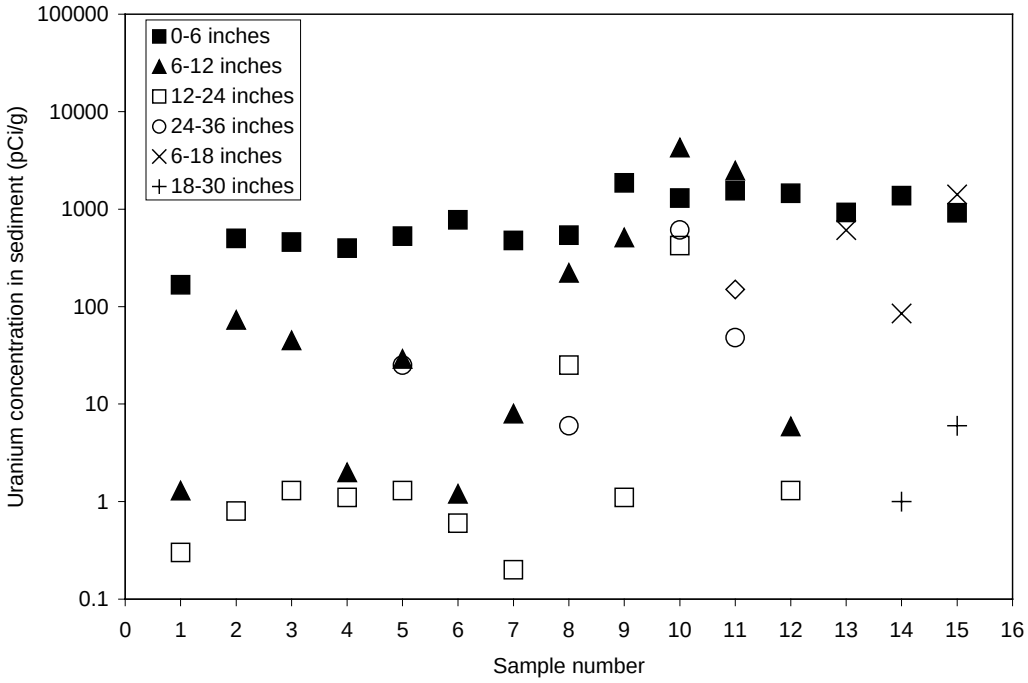

Figure 12.1-4. Uranium in Steed's Pond sediment cores collected in 1984. Link to tabulated figure data

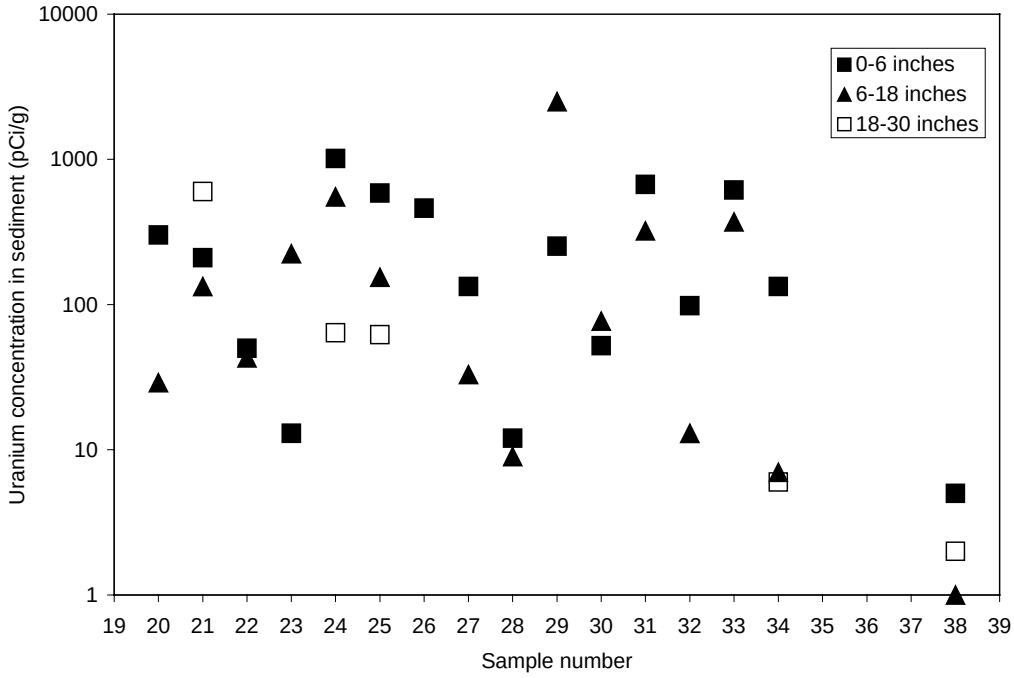

Figure 12.1-5. Uranium in Tim's Branch sediment cores, collected above Steed's Pond in 1984. Link to tabulated figure data

Measurements of Plutonium in Sediments

Carlton et al. (1992) states that fallout deposited on the Savannah River watershed has been estimated at 55 Ci with a $^{238}Pu/^{239,240}Pu$ ratio of 0.04 to 0.18. Approximately 1.5 Ci was deposited directly on water impoundments and 1.2 Ci was deposited within the boundaries of the SRS. Atmospheric plutonium releases from SRS operations, including unidentified alpha, have totaled about 3.8 Ci, and direct releases to streams have totaled 0.6 Ci. About 90% of the liquid releases containing plutonium and unidentified alpha has been released from F-Area and H-Areas into the Four Mile Creek watershed. For this reason, this stream has received more study. An examination of $^{238}Pu/^{239,240}Pu$ ratios in sediments (Table 12.1-3) collected from Site streams shows that Four Mile Creek has an elevated ratio, indicating that the source of plutonium in this stream is plutonium effluent from Site operations (Alberts et al. 1986). Steel Creek, which received cooling water from L- and P-Reactors, and Pen Branch, which received cooling water from K-Reactor, also showed elevated $^{238}Pu/^{239,240}Pu$ ratios in sediments. Upper Three Runs and Lower Three Runs show ratios similar to that of the Savannah River upstream of the SRS, indicating little contribution from Site operations. The isotopic ratios do not indicate whether the source of the plutonium is from atmospheric or liquid releases; however, it is most likely that the source of plutonium in Four Mile Creek is liquid effluent.

Table 12.1-3. Sediment Sample Plutonium Isotopic Ratios[a]

Sampling location	$^{238}Pu/^{239,240}Pu$
Upper Three Runs (Treadway Bridge)	0.141
Four Mile Creek (Road A)	3.29
Steel Creek (Road A)	2.64
Pen Branch (Road A)	1.84
Lower Three Runs (Road S-3-17	0.167
Savannah River (Jackson)	0.189

[a] Source: Alberts et al. (1986).

Tables 12.1-4 and 12.1-5 present a summary of routine monitoring for plutonium in stream sediments from 1977 through 1986. Previous data (1955 through 1962) are not presented because the sampling and analysis design for that period is not comparable to the design used since 1977. The swamp locations represent discharge areas for the streams. The data shown indicate no spatial or temporal trends. Many of the results are near or below the detection limit. Only concentrations measured at Four Mile Creek at Road A are consistently above the detection limit. Thus, it appears from routine measurements that, in general, plutonium releases from the SRS were small, are subject to various deposition processes, and result in concentrations in sediments that are, with a few exceptions, indistinguishable from background concentrations. In addition, the samples collected are probably not representative of the entire streambed making temporal and spatial trend analysis improbable. Concentrations in sediment of the Savannah River collected above the SRS during the same time period ranged from 0.0001 to 0.008 pCi g^{-1}.

Table 12.1-4. Concentration of Plutonium (pCi g^{-1}) in Sediments at Stream Locations at the SRS (1977 through 1991)

Year	Four Mile Creek at Road A7	Steel Creek at Road B	Steel Creek-Pen Branch Mouth
^{238}Pu			
1977	1.17	0.016	<0.001
1978	0.39	0.04	<0.003
1979	0.2	0.053	0.002
1980	0.31	0.017	<.001
1981	.008	0.043	0.002
1982	NA[a]	NA	NA
1983	0.3	0.05	0.003
1984	0.2	0.006	0.0006
1985	1.3	0.006	0.0004
1986	0.36	0.0008	0.0008
1987	0.074	0.043	0.05
1988	0.4	0.009	0.035
1989	0.02	0.021	0.049
1990	0.78	0.09	0.05
1991	0.078	0.0015	0.013
$^{239,240}Pu$			
1977	0.97	0.007	0.001
1978	0.29	0.03	<0.003
1979	0.074	0.044	0.004
1980	0.092	0.001	<0.001
1981	0.004	0.039	0.001
1982	NA	NA	NA
1983	0.11	0.15	0.002
1984	0.07	0.007	0.003
1985	0.38	0.008	0.0008
1986	0.016	0.004	0.002
1987	0.046	0.046	0.04
1988	0.15	0.012	0.036
1989	0.054	0.093	0.014
1990	0.23	0.007	0.004
1991	0.032	0.0043	0.026

[a] NA = No analysis.

Table 12.1-5. Concentration of Plutonium (pCi g^{-1}) in Sediments at Stream Discharge Locations at the SRS (1977 through 1991)

Year	Upper Three Runs Mouth	Four Mile Creek Swamp	Pen Branch Swamp	Steel Creek Swamp	Lower Three Runs Mouth
^{238}Pu					
1977	0.003	0.24	0.003	0.132	0.007
1978	0.006	0.12	0.02	0.09	0.04
1979	<0.001	0.02	0.022	0.006	0.001
1980	0.004	0.085	0.02	0.004	0.002
1981	0.001	0.003	<0.001	NA[a]	0.001
1982	NA	NA	NA	NA	NA
1983	0.002	0.08	0.003	0.03	0.005
1984	0.004	0.003	0.005	0.01	0.0005
1985	0.0003	0.006	0.019	0.2	0.0007
1986	0.003	0.002	0.0002	0.022	0.0005
1987	<0.003	0.003	0.024	0.012	0.02
1988	0.034	0.007	0.021	0.079	0.264
1989	0.061	0.015	0.07	0.005	<MD[b]
1990	0.006	0.007	0.02	0.002	0.04
1991	0.0052	0.0019	0.01	0.0029	0.0011
$^{239,240}Pu$					
1977	0.014	0.092	0.004	0.04	0.011
1978	0.02	0.07	0.04	0.05	0.04
1979	<0.001	0.012	0.021	0.046	0.003
1980	0.029	0.035	0.044	<0.001	0.008
1981	0.004	0.002	<0.001	NA	0.003
1982	NA	NA	NA	NA	NA
1983	0.007	0.11	0.02	0.04	0.001
1984	0.002	0.002	0.008	0.01	0.002
1985	0.001	0.006	0.032	0.12	0.001
1986	0.009	0.001	0.0004	0.015	0.0012
1987	0.012	0.002	0.018	0.01	0.02
1988	0.052	0.007	0.024	0.18	0.014
1989	0.02	0.006	0.019	0.003	<MD[b]
1990	0.007	0.003	0.002	0.0002	0.001
1991	0.0065	0.003	0.028	0.0071	0.0017

[a] NA = No analysis.
[b] <MD = Less than minimum detectable concentration.

Measurements of Gamma-Emitting and Other Radionuclides in Sediments

Stream and river samples collected routinely after 1975 were analyzed for gamma-emitting radionuclides and ^{90}Sr. Concentrations in river sediments were within the range typically detected from worldwide fallout. However, concentrations of ^{137}Cs often reflected contributions from Site releases, particularly along Four Mile Creek. However, no temporal or spatial trends were observed because of the complex sediment deposition processes involved and the fact that samples are probably not representative of the entire streambed.

ELECTRONICALLY COMPILED SEDIMENT DATA

Sediment sampling data were reported beginning in 1951 for at the inner and outer perimeter of the SRS along streams and the Savannah River. Samples were analyzed for gross alpha and gross beta activities. Later, samples were analyzed for specific radionuclides. The long-lived radionuclides, especially uranium and plutonium, are of particular interest to the dose reconstruction because they persist in sediments over long periods of time.

The various data summarized in this chapter are electronically compiled in a Microsoft Excel® workbook. This workbook contains the figures depicted in this chapter as well as the tabulated data that were used to produce the figures. In the workbook, each figure is represented in a chart. There is a separate worksheet that contains the tabulated data for each chart, or in some cases, for each group of charts. The following hyperlink allows readers of the electronic version of this document to directly access the workbook described above if the source application (Microsoft Excel®) is installed on the reader's computer: Ch12-Figure_data.xls.

USEFULNESS AND LIMITATIONS OF THE SEDIMENT DATA FOR DOSE RECONSTRUCTION

There are a number of factors that impact how the sediment data may be used during subsequent phases of the dose reconstruction project. These factors include the availability of sufficient original monitoring data sets to verify reported summary data and to evaluate spatial and temporal trends, as well as the ability to distinguish between Site releases of contaminants and other sources of the same contaminants in the environment (i.e., establish appropriate background concentrations).

Based on the information provided in the semiannual monitoring reports, it appears that surface water and sediment monitoring before 1958 was limited primarily to gross analyses. Because fallout was relatively high during this time period, nonvolatile beta data, especially for the Savannah River where concentrations were low, may be of limited value (i.e., SRS contributions may be masked by the presence of fallout).

The majority of alpha activity released via surface water effluents from the Site occurred from the M-Area. Essentially all of the alpha activity in the process effluent in the M-Area has been identified as depleted uranium. Steed's Pond received surface water from Tim's Branch, which received effluent from the M-Area. Thus, the sediment cores collected from Steed's Pond in 1967, 1981, and 1984 may provide uranium data useful for source term verification or model

validation. The small number of samples collected limits the usefulness of the data and may be insufficient to estimate the total activity of uranium in the pond.

Plutonium is a radioactive material that is typically of great concern to the public. However, the SRS did not conduct routine plutonium monitoring in surface water in the 1950s, 1960s, or 1970s. Uranium or plutonium alpha measurements were made in surface water from roughly 1954 to 1957. Also in the 1950s and 1960s, sediments from some of the Site streams and the river were analyzed for uranium/plutonium alpha. Routine plutonium measurements were initiated in Savannah River sediments in 1975. However, the sampling method as explained in Ashley and Zeigler (1978) and described above would not provide insight into historical releases of plutonium. As noted previously, routine sediment samples are probably unrepresentative of the entire streambed. The data may only be useful in that they confirm the sources of plutonium in specific streambeds. Routine ^{137}Cs measurements are, like those of plutonium, probably only useful for confirming the sources of the ^{137}Cs in specific streambeds.

In general, sediment sampling variability arises from the nature of the sample, the adequacy of the sampling population in representing the total population, and the bias resulting from the methods of sampling and analysis. The variations because of the heterogeneity of the sampled material (e.g., differing amounts of solid and suspended materials) frequently exceed the deviations that result from the analytical method. Characterizing variability because of sample heterogeneity and sampling methodology is extremely difficult, and it was not assessed as part of the historical SRS environmental monitoring program. Statistically speaking, increasing the number of samples collected can serve to increase the confidence that one has in the data, as the mean and range of values are generally better defined. As discussed previously, the number and locations of samples collected do not provide enough information to adequately characterize the streambeds at the SRS. At best, the data can serve to confirm that specific radionuclides were released into the streams and the Savannah River.

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