WSRC-TR--91-583

DE92 017933

RADIOLOGICAL IMPACT OF PAR POND DRAWDOWN FROM LIQUID EFFLUENT PATHWAYS (U)

by

W. H. Carlton, et al.

Westinghouse Savannah River Company
Savannah River Laboratory
Aiken, South Carolina 29808

A technical report proposed for publication

DISCLAIMER

WESTINGHOUSE SAVANNAH RIVER COMPANY
INTER-OFFICE MEMORANDUM

WSRC-TR-91-583

October 25, 1991

TO: Distribution

FROM: D.M. Hamby, 773A (5-3042)

RADIOLOGICAL IMPACT OF PAR POND DRAWDOWN FROM LIQUID EFFLUENT PATHWAYS

SUMMARY

The water level of Par Pond has been lowered over the past several months to reduce the effects in the event of catastrophic dam failure while assessing the condition of the dam and determining if repairs are necessary. In lowering the level of Par Pond, 60 billion liters of water containing low levels of tritium and cesium-137 were discharged to several onsite streams. SRS surface streams flow to the Savannah River. An assessment was made to determine the total amount of tritium and Cs-137 discharged and to estimate the consequences to downstream Savannah River users.

It is estimated that a total of 160 curies of tritium were displaced from Par Pond to the Savannah River between June 28, 1991 and September 19, 1991. This release could hypothetically result in a maximum individual dose of 3.2×10^{-4} mrem and a total (80-km and drinking water populations) population dose of 1.4×10^{-2} person-rem. Likewise, a maximum individual dose of 5.0×10^{-2} mrem and a total population dose of 1.7×10^{-1} person-rem are predicted as a result of an estimated 0.21 curies of Cs-137 being discharged from Par Pond to the Savannah River.

INTRODUCTION

Beginning in late June, water from Par Pond was pumped to onsite surface streams to lower its level and reduce the threat of catastrophic dam failure to individuals and property below the dam along Lower Three Runs Creek. Displacement of large quantities of water ceased in mid-September when the pond surface was lowered to about 182 feet (msl). During higher than normal discharges, a total of 60 billion liters of water was withdrawn from Par Pond and discharged to onsite streams.

The radiological impact to persons using the Savannah River as a source of drinking water, aquatic foods, and recreation is assessed in this report. Data on pumping and siphoning rates, Savannah River flow rates, tritium and cesium concentrations in displaced water,

discharge rate by outfall location, etc. were utilized to estimate tritium and Cs-137 source terms and the pathway-specific radiation doses to a hypothetical maximum individual and the river-user populations.

The dosimetric models are normally used to estimate dose based on annual releases, uptakes, and exposures. Using the models for shorter-term assessments, on the order of months, may necessitate the use of some overly conservative assumptions. These assumptions are addressed later in this report.

DISCUSSION

Savannah River Flow Rates

In order to estimate concentrations of H-3 and Cs-137 in the Savannah River at downstream receptor locations, an average flow rate during the period (i.e., dilution volume) was determined. During the time that the level of Par Pond was being reduced, river flow data at Highway 301 indicate that there were three periods of distinctly different flow rates.

Because of either heavy rains, discharge rates at Thurmond Dam, or both, the average Savannah River flow rate varied during the drawdown period. River flow data show that flow rates during July were consistently 12,000 cfs while August flow rates averaged 19,000 cfs and the average flow rate from September 1st through September 19th was 8,000 cfs. Given these differences and the various discharge rates, the dose assessment will be conducted assuming a fractionate release, utilizing data appropriate for each of three release periods (the months of July, August, and September).

Savannah River "effective" flow rates at the Beaufort-Jasper and Port Wentworth water treatment facilities were determined using data from Hayes and Marter (1991). Based on that report, the "effective" flow rates are 40.3% and 26.8% greater than the Highway 301 flow rate. This increase in flow is to account for measured dilution through additional inflow of surface water between Highway 301 and the treatment facility intakes. An "effective" flow rate for the Savannah River estuary is estimated by increasing the Port Wentworth flow rate by 10%.

Estimation of the Total Amount of Water Discharged from Par Pond

Daily reports from the Power Engineering Department were utilized to estimate the total volume of Par Pond water discharged to various outfalls on the SRS. For the dose assessment that follows, it is assumed that this water flows directly to the Savannah River with no loss of radioactive constituents except via radioactive decay. Calculational estimates of tritium and cesium-137 concentrations in Lower Three Runs will be given for comparison with measured concentration data. The chronology of drawdown is shown in Table 1.

Discharges from Par Pond were routed to various streams to keep impacts from erosion to a minimum. Discharge rates to these locations varied but were recorded daily by Power Engineering. According to these daily reports, of the 60 billion liters discharged, 55% went over Par Pond dam to Lower Three Runs, 27% was directed to Steel Creek (L-Lake), 11% was pumped to Pen Branch, and 7% was discharged into Fourmile Branch.

Variability in discharge rates during the three months of drawdown resulted in 16% of the total discharge being released in July, 64% in August, and 20% in September. A total of

almost 33 billion liters were discharged over the dam into Lower Three Runs; 1% in July, 62% in August, and 37% in September (Riggsbee 1991).

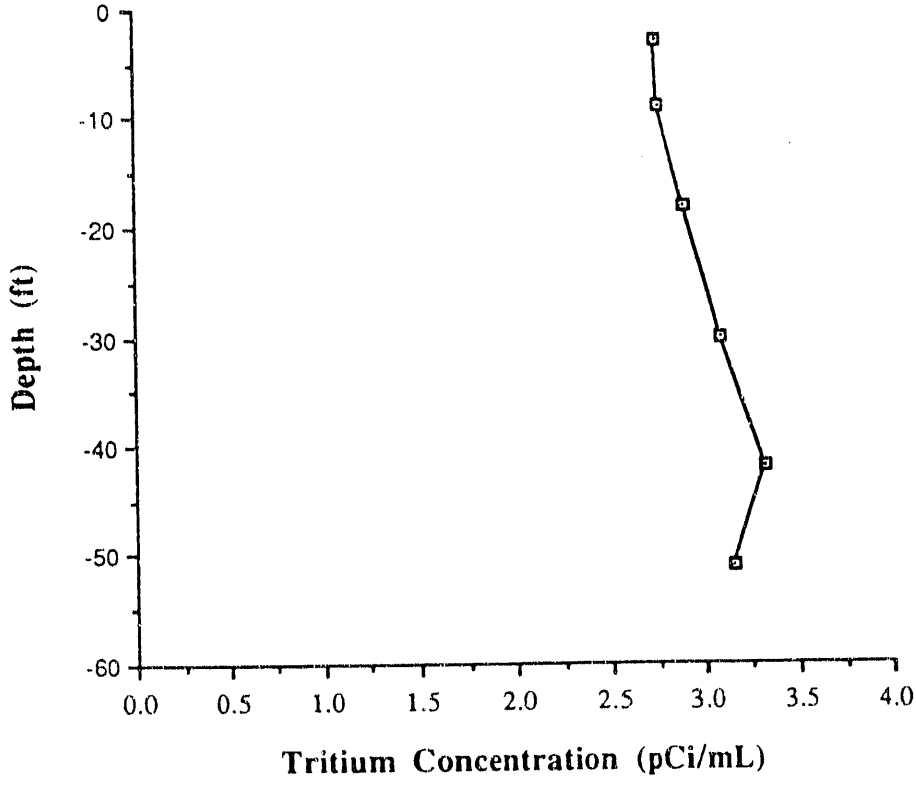
Table 1. Par Pond Drawdown Chronology.

Date	Event
June 28	681-6G Pumphouse routes water to Steel Creek, Four-Mile Branch, and Pen Branch via the P-, L-, C-, and K-Area water lines.
July 8	4" Siphons started over dam discharging to Lower Three Runs.
July 27	Tractor pumps added to increase discharge over Par Pond dam.
August 5	Large (32 & 36 inch) siphons discharging water over the dam.
August 20	681-6G pumphouse shut-down so that all discharge water is now going over the dam to Lower Three Runs.
September 19	Drawdown ceases except what is required to maintain Par Pond level between 181' and 182' msl.

Estimation of the Tritium Source Term to the Savannah River

Before the drawdown began, tritium concentrations in Par Pond (see Figure 1) were measured to be approximately 3.0 pCi/mL at all depths (Hayes 1991a). During drawdown, however, large amounts of rain fell resulting in a dilution of tritium in Par Pond. Rainwater was assumed to have a tritium concentration equal the average onsite tritium concentration measured in rainwater over the past three years (1.4 pCi/L). A 3-year average was used since an average during the drawdown period was unavailable. The average tritium concentration of water discharged from Par Pond was determined considering the volume of water initially in the pond and the volumetric increase due to rain and runoff.

Figure 1. Tritium concentration profile in Par Pond, June 25, 1991.



A total tritium source term of 160 curies was added to the Savannah River during the Par Pond drawdown assuming all water discharged to SRS surface streams contained a tritium concentration of 2.7 pCi HTO/mL. With the discharge rates given above, the tritium source terms for the three periods of the dose assessment were calculated to be 26, 102, and 32 curies, respectively.

The total volume of Par Pond at its normal level (200 ft. msl) has been estimated to be approximately 66 billion liters. Between June 28th and September 19th an estimated 60 billion liters of water was removed from Par Pond by various routes. At the pond's current level (approx. 182 ft msl) it contains about 21 billion liters. This would indicate that rain and runoff collected in Par Pond during the drawdown period totals approximately 15 billion liters.

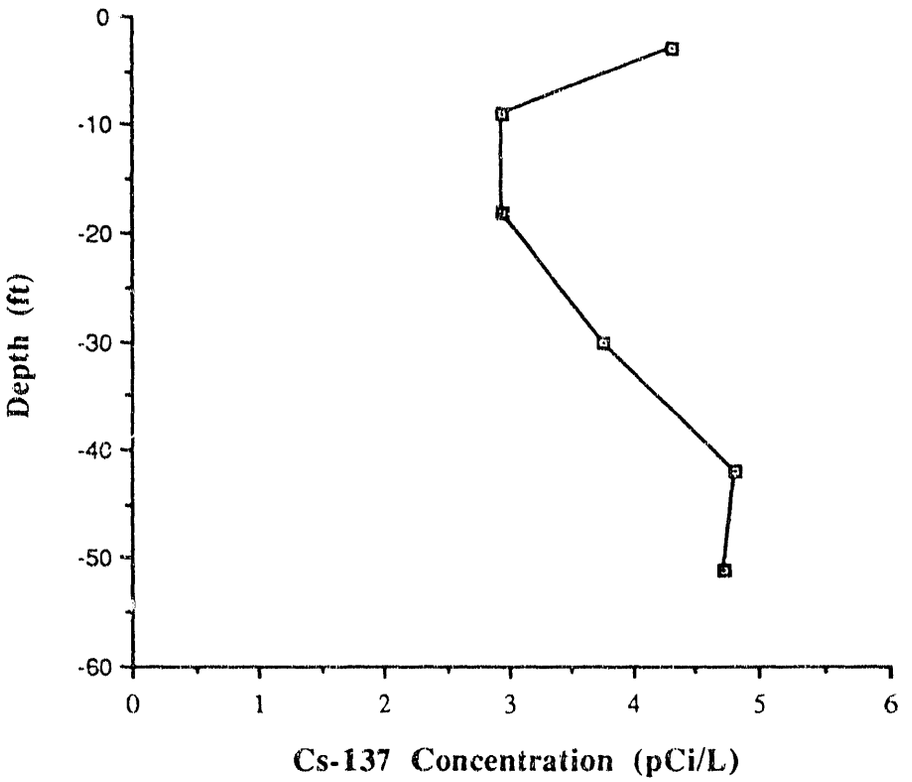
An estimate, therefore, of the average tritium concentration in water discharged from Par Pond is approximated using the following expression:

$$C = \frac{(66 \times 10^9\ \text{L})\,(3.0\ \frac{\text{pCi}}{\text{mL}}) + (15 \times 10^9\ \text{L})\,(1.4\ \frac{\text{pCi}}{\text{mL}})}{(66 \times 10^9\ \text{L} + 15 \times 10^9\ \text{L})} = 2.7\ \frac{\text{pCi}}{\text{mL}} \qquad (1)$$

Estimation of the Cesium-137 Source Term to the Savannah River

Measurements in Par Pond prior to drawdown, shown in Figure 2 (Hayes 1991a), indicate that cesium concentrations vary with depth, ranging from about 3 to 4 pCi/L in the shallower depths (<30 feet) and 4 to 5 pCi/L at greater depths (>30 feet).

Figure 2. Cesium-137 concentration profile in Par Pond, June 25, 1991.



Discharge water was typically withdrawn from the shallower depths of Par Pond with an average concentration of approximately 3.5 pCi/L. The inflow of runoff due to rain was assumed to have no significant affect on the cesium concentration since an equilibrium is maintained between the pond's water and cesium-bearing sediment.

Given a total discharge of 6×10^{10} L and an average concentration of 3.5 pCi/L, 0.21 curies of Cs-137 are assumed to have been displaced from Par Pond to the Savannah River during the course of drawdown. With the monthly discharge flows given earlier, the Cs-137 source terms for the three periods of the dose assessment were estimated to be 0.034, 0.134, and 0.042 curies, respectively.

Calculated and Measured Tritium and Cesium-137 Concentrations in Lower Three Runs and the Savannah River

The validity of the source term estimate is checked by comparing predicted concentrations of tritium and cesium in Lower Three Runs and the Savannah River with measured values. Background concentrations measured in the Savannah River upstream of the SRS are approximately 0.2 pCi HTO/mL and 0.01 pCi Cs-137/L. Concentrations of HTO and Cs-137 in Lower Three Runs and the Savannah River shown below are estimates considering only discharged activity and total flow; background and/or sediment desoprtion has not been considered.

Concentrations in Lower Three Runs are estimated assuming creek flow rates of 40, 280, and 220 cfs (18000, 125000, and 100,000 gal/min) during the three release periods. Figure 3 shows flow rates in Lower Three Runs at Patterson's Mill for the period of drawdown. Fractionating the release as specified above, 1.2, 55, and 33 curies of tritium and 0.0017, 0.074 and 0.044 curies of Cs-137 are assumed to be discharged from Par Pond to Lower Three Runs. Estimated concentrations of tritium and cesium during the months of July, August, and September are shown in Table 2.

Table 2. Estimated tritium and cesium-137 concentrations in Lower Three Runs and the Savannah River.

Assessment Period	6/28 - 7/31	8/1 - 8/31	9/1 - 9/19
<u>Lower Three Runs (L3Rs) Concentrations at Patterson's Mill</u>			
Estimated L3Rs Flow	40 cfs	280 cfs	220 cfs
HTO Released	1.2 Ci	55 Ci	33 Ci
Calculated HTO Conc.	0.36 pCi/mL	2.6 pCi/mL	3.1 pCi/mL
Cs-137 Released	0.0017 Ci	0.074 Ci	0.044 Ci
Calculated Cs-137 Conc.	0.51 pCi/L	3.5 pCi/L	4.1 pCi/L
<u>Savannah River Concentrations at Highway 301</u>			
Average River Flow	12,000 cfs	19,000 cfs	8,000 cfs
HTO Released	26 Ci	102 Ci	32 Ci
Calculated HTO Conc.	0.026 pCi/mL	0.071 pCi/mL	0.082 pCi/mL
Cs-137 Released	0.034 Ci	0.13 Ci	0.042 Ci
Calculated Cs-137 Conc.	0.034 pCi/L	0.090 pCi/L	0.11 pCi/L

Measured concentrations at three sampling locations on Lower Three Runs are provided in Figures 4 and 5 for tritium and cesium-137, respectively. Estimated tritium

LOWER THREE RUNS FLOW AT PATTERSONS MILL

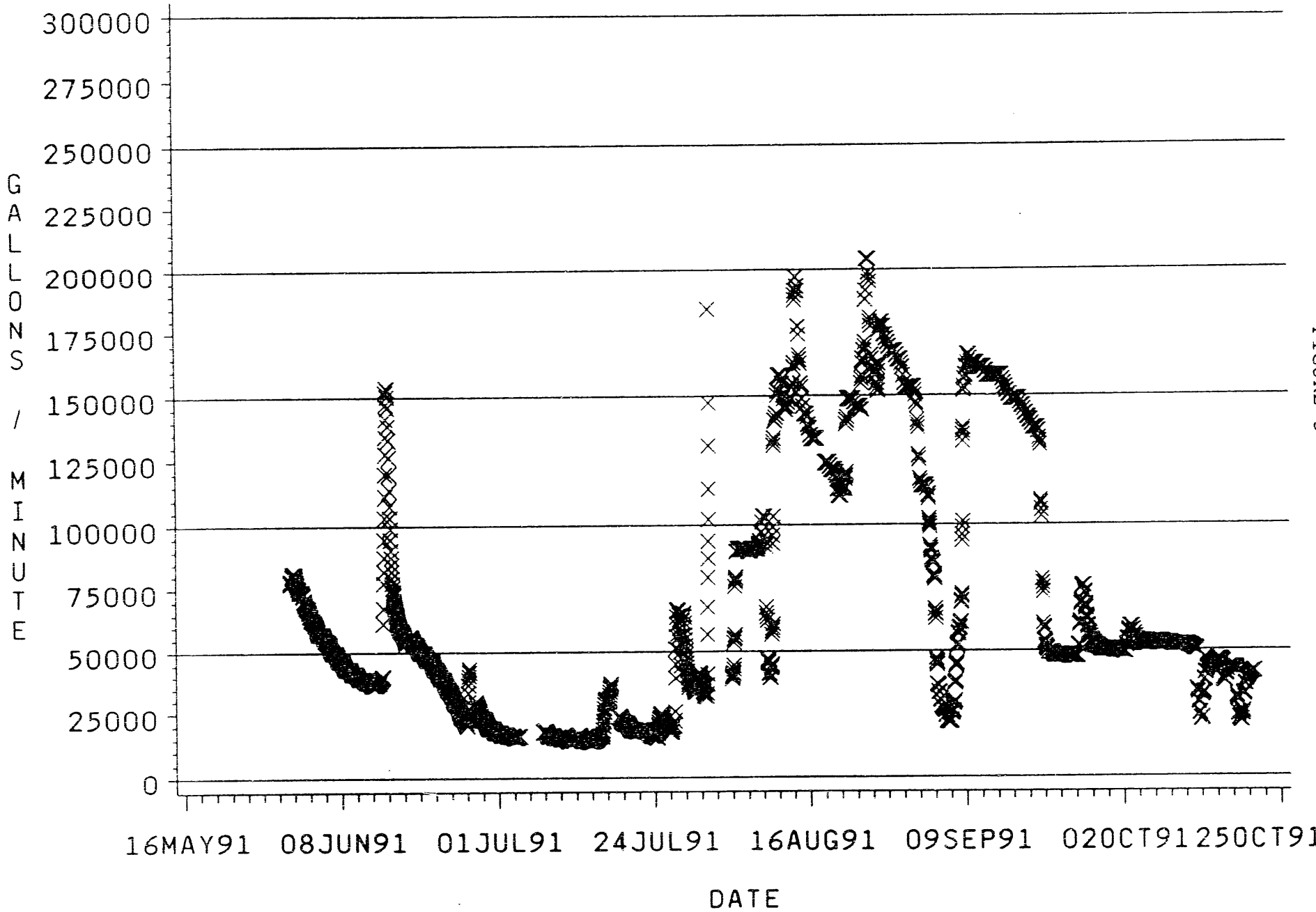
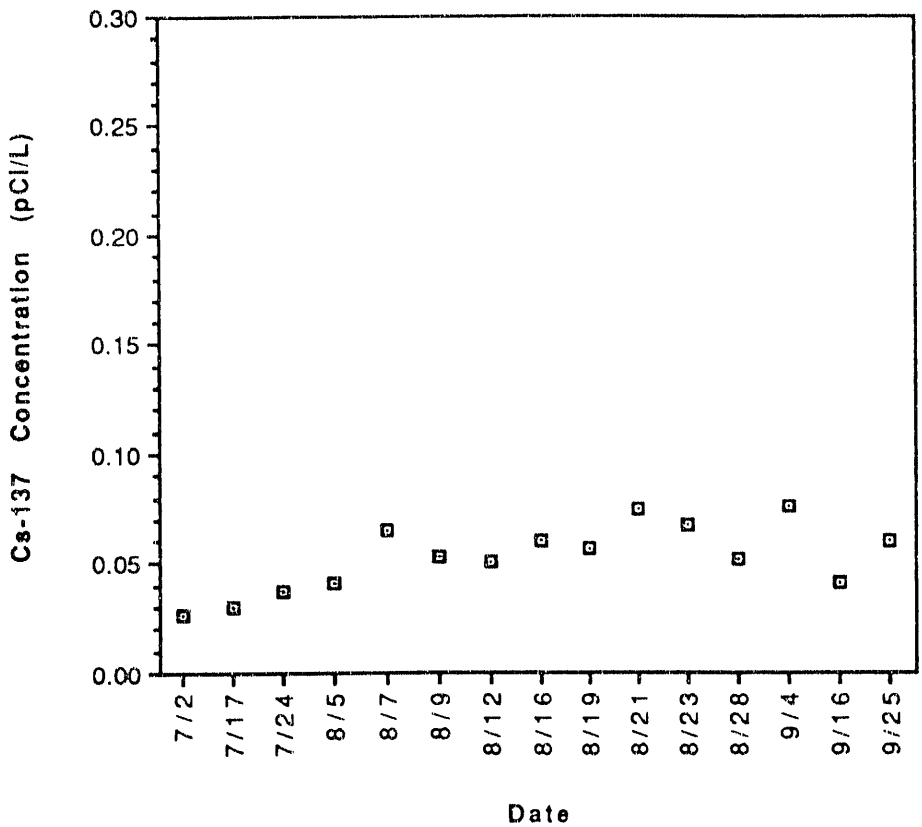


FIGURE 3

concentrations in the creek are within the range of measured values shown in Figure 4. Predicted cesium concentrations are generally a factor of 2 or 3 higher than the measured values of Figure 5. As evident in Figure 5, cesium concentrations decrease in Lower Three Runs as a function of distance from the Par Pond dam. This indicates that some fraction of the cesium is being absorbed in the sediments and that the Cs-137 source term assumption is conservative.

Measured concentrations of Cs-137 in the Savannah River (at Highway 301) averaged approximately 0.04 pCi/L during July and 0.06 pCi/L during August and September (see Figure 6). The estimated cesium concentrations shown in Table 2 are generally within a factor of 2 of these measurements. Predicted concentrations are conservatively higher than the measured values since the methodology used to estimate downstream concentrations does not consider removal (except radiological decay), resuspension, and/or additional dilution.

Figure 6. Cs-137 concentrations in the Savannah River at Highway 301.



Offsite Dose via Liquid Pathways

The dosimetry models of the NRC Regulatory Guide 1.109 (USNRC 1977) were used to estimate the radiation dose received by users of the Savannah River for drinking water, recreation, and aquatic foods consumption. The LADTAP XL spreadsheet was utilized for these calculations (Hamby 1991a). Concentrations of tritium and cesium-137 in the

FIGURE 4

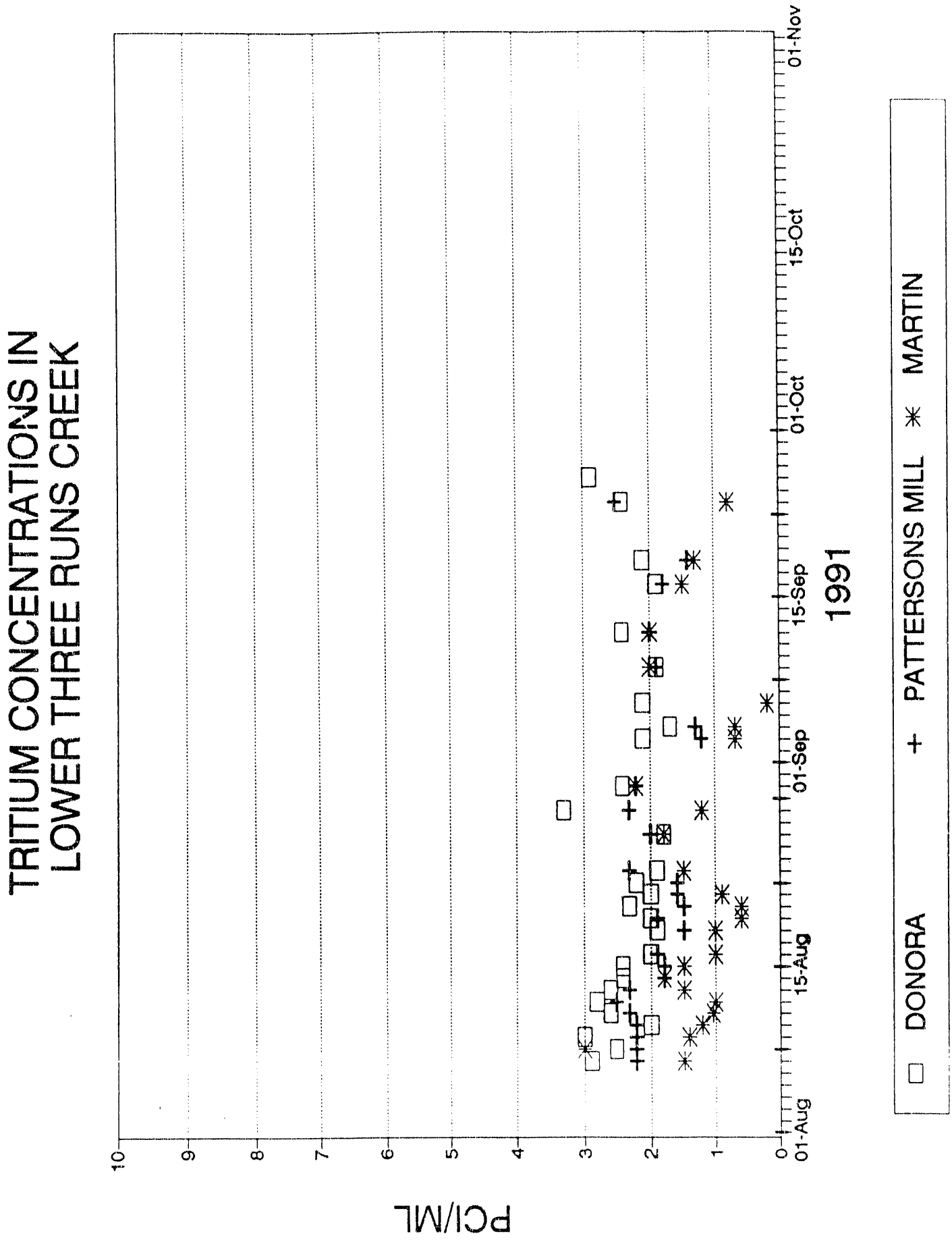
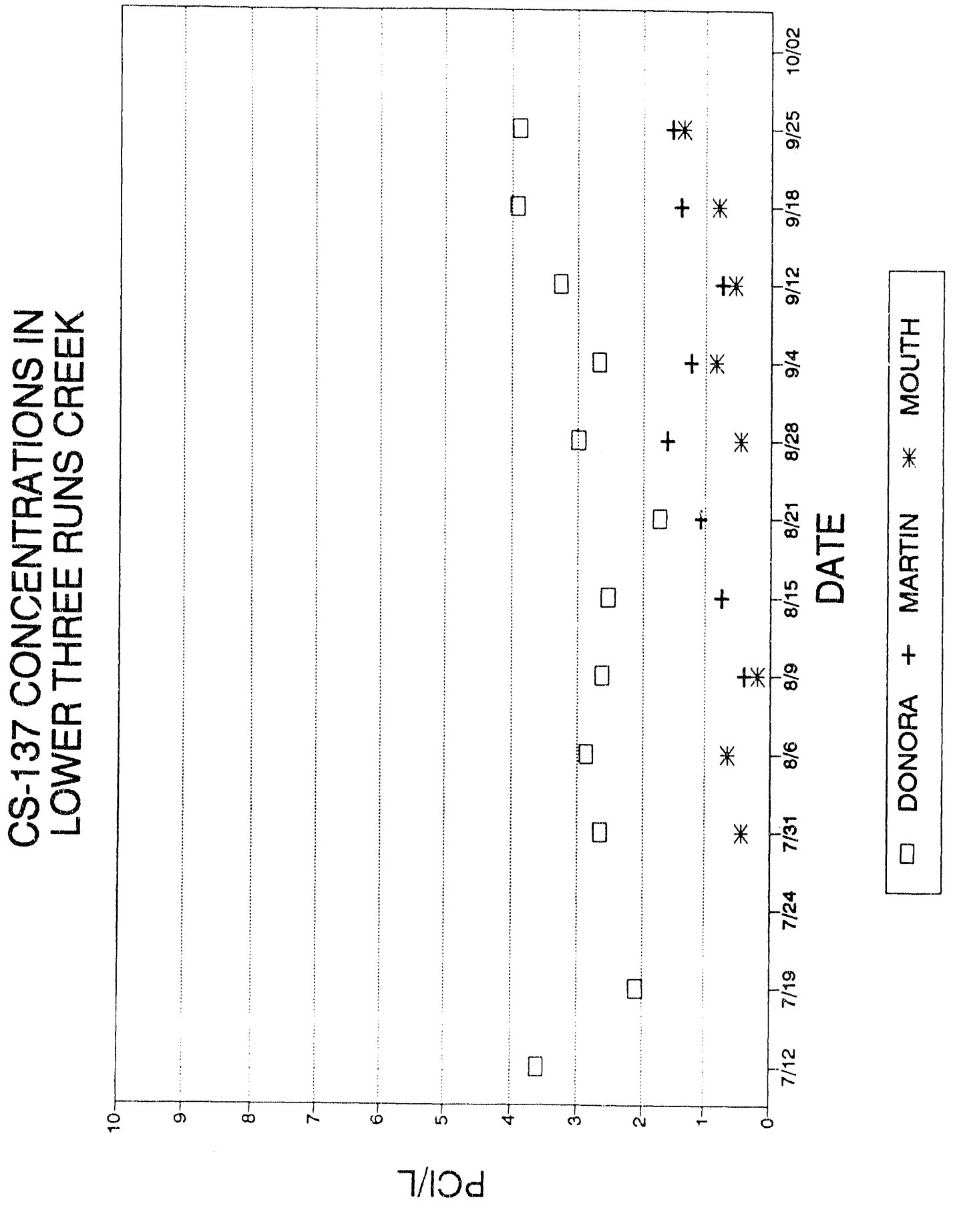
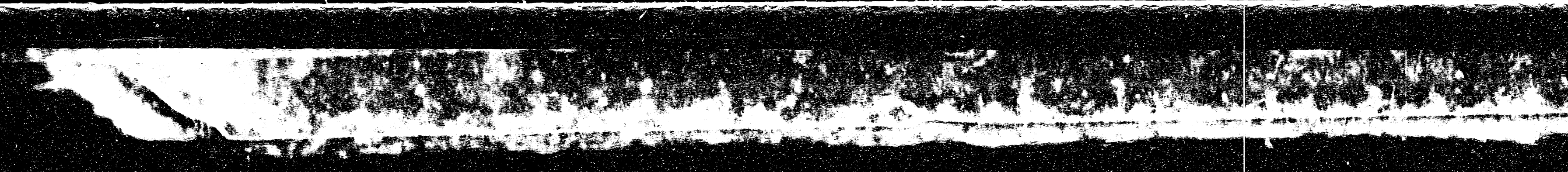

TRITIUM CONCENTRATIONS IN
LOWER THREE RUNS CREEK
PCI/ML
10
9
8
7
6
5
4
3
2
1
0
01-Aug
15-Aug
01-Sep
15-Sep
01-Oct
15-Oct
01-Nov
1991
DONORA
PATTERSONS MILL
MARTIN

FIGURE 5


CS-137 CONCENTRATIONS IN
LOWER THREE RUNS CREEK
PCI/L
10
9
8
7
6
5
4
3
2
1
0
7/12
7/19
7/24
7/31
8/6
8/9
8/15
8/21
8/28
9/4
9/12
9/18
9/25
10/02
DATE
DONORA
MARTIN
MOUTH



Savannah River were determined using a simple volumetric dilution model. As stated above, three distinct river flow scenarios were used for the dose assessment to model doses received during the months of July, August, and September. A summation of these doses is the total dose predicted for the maximum individual and the population groups using the Savannah River.

Dose estimates using the NRC models are normally made for annual, chronic releases. Since the releases modeled here are assumed to occur over three one month intervals, several assumptions need to be made. First, it has been assumed that water, fish, and invertebrate consumption rates are constant throughout the year, i.e., an individual drinking 370 liters of water per year will drink approximately 31 liters per month, 7 liters per week, 1 liter per day, etc. This assumption will not result in significant over- or under-predictions for assessments where consumption is averaged over one month.

Secondly, since the drawdown occurred during the later part of summer, it is assumed that all of the individual or population recreational use of the Savannah River occurred during July, August, and September. For example, annual boating usage for the maximum individual is normally assumed to be 21 hours per year; in this assessment the maximum individual boats 7 hours in each of the three months. Dose predictions via the shoreline, swimming, and boating pathways will be slightly more conservative (than for an annual dose prediction) since it assumed that all recreational activities are taking place during the release time.

Also, cesium in fish and invertebrates is assumed to reach equilibrium in a relatively short time so that the concentration of cesium in aquatic species can be estimated using river concentrations. This assumption is most likely very conservative since the turnover rate of Cs-137 in fish is on the order of two months (Gallegos and Whicker 1971). Tritium is known to reach equilibrium in fish in a matter of hours (Morgan et al. 1973).

A summary of the Savannah River flow rates and release amounts is given in Table 3. The amounts released are assumed to enter the Savannah River over a one month period and undergo dilution based on an average flow rate estimated for the assessment period.

Table 3. Estimated tritium and cesium-137 displaced to the Savannah River from drawdown activities at Par Pond.

Assessment Period	River Flow Rate (cfs)	Released Activity for Period (Ci) Tritium	Cs-137
June 28 - July 31	12,000	26	0.034
August 1 - August 31	19,000	102	0.13
September 1 - September 19	8,000	32	0.042
TOTAL Activity Released		160	0.21

Estimates of dose to the maximum individual at the site boundary appear in Table 4. The hypothetical maximum individual at the SRS resides full-time at a location where complete mixing is assumed to have occurred. This individual drinks ordinary amounts (1 L/day) of river water and eats large amounts of Savannah River fish. He also participates in shoreline, swimming, and boating activities as specified above. A breakdown of the relative contribution of each pathway dose is given in Table 5. The tritium dose received while swimming results from an assumed intake via skin absorption.

Table 4. Dose to the maximum individual from tritium and cesium-137 entering the Savannah River during drawdown activities at Par Pond.

Assessment Period	Effective Dose Equivalent (mrem) Tritium	Cs-137
July	6.0×10^{-5}	9.5×10^{-3}
August	1.5×10^{-4}	2.3×10^{-2}
September	1.1×10^{-4}	1.7×10^{-2}
TOTAL Dose	**3.2×10^{-4}**	**5.0×10^{-2}**

Table 5. Pathway contributions to dose (maximum individual).

Pathway	Percent of Max. Individual Dose Tritium	Cs-137
Fish Ingestion	4.3	96.7
Water Ingestion	95.4	0.6
Shoreline	0	2.7
Swimming	0.3	<0.1
Boating	0	<0.1

Tables 6 and 7 show the predictions of maximum dose to individuals using the Beaufort-Jasper and Port Wentworth domestic drinking-water supplies, respectively. The maximum individuals at Beaufort-Jasper and Port Wentworth receive their dose solely from the consumption of maximum amounts (2 L/day) of untreated river water.

Table 6. Dose to the downstream drinking-water maximum individual of Beaufort-Jasper.

Assessment Period	Effective Dose Equivalent (mrem) Tritium	Cs-137
July	8.1×10^{-5}	8.2×10^{-5}
August	1.9×10^{-4}	2.0×10^{-4}
September	1.5×10^{-4}	1.5×10^{-4}
TOTAL Dose	**4.2×10^{-4}**	**4.3×10^{-4}**

Table 7. Dose to the downstream drinking-water maximum individual of Port Wentworth.

Assessment Period	Effective Dose Equivalent (mrem) Tritium	Cs-137
July	8.8×10^{-5}	9.2×10^{-5}
August	2.1×10^{-4}	2.2×10^{-4}
September	1.6×10^{-4}	1.7×10^{-4}
TOTAL Dose	**4.6×10^{-4}**	**4.8×10^{-4}**

Fish and other aquatic species of Savannah River origin are harvested throughout the year from the Savannah River and its estuary. For the purpose of estimating a dose to the population within 80 kilometers of the SRS, it has been assumed that enough fish and invertebrates to support the 555,100 person population are harvested during each month of the assessment period. This population also participates in recreational activities in and along the Savannah River. Table 8 contains population dose estimates, in units of person-rem, resulting from the predicted releases of tritium and cesium from the Par Pond drawdown. Relative contributions to the 80-km population dose by pathway are shown in Table 9.

Table 8. Dose to the 80-km population.

Assessment Period	Effective Dose Equivalent (person-rem) Tritium	Cs-137
July	2.2×10^{-5}	2.9×10^{-2}
August	5.4×10^{-5}	7.0×10^{-2}
September	4.1×10^{-5}	5.4×10^{-2}
TOTAL Dose	$\mathbf{1.2 \times 10^{-4}}$	$\mathbf{1.5 \times 10^{-1}}$

Table 9. Pathway contributions to dose (80-km population).

Pathway	Percent of Population Dose Tritium	Cs-137
Sport Fish	23	57
Commercial Fish	2	4
Invertebrates	60	1
Shoreline	0	38
Swimming	15	<0.1
Boating	0	<0.1

Population doses to the consumers of water from the Beaufort-Jasper and Port Wentworth treatment facilities are presented in Tables 10 and 11. These doses are, again, solely from the consumption of Savannah River water. Removal of some fraction of cesium during the treatment process is not considered in the dose estimation.

Table 10. Dose to the downstream drinking-water population of Beaufort-Jasper.

Assessment Period	Effective Dose Equivalent (person-rem) Tritium	Cs-137
July	2.0×10^{-3}	2.1×10^{-3}
August	5.0×10^{-3}	5.1×10^{-3}
September	3.8×10^{-3}	3.9×10^{-3}
TOTAL Dose	$\mathbf{1.1 \times 10^{-2}}$	$\mathbf{1.1 \times 10^{-2}}$

Table 11. Dose to the downstream drinking-water population of Port Wentworth.

Assessment Period	Effective Dose Equivalent (person-rem) Tritium	Cs-137
July	6.8×10^{-4}	6.8×10^{-4}
August	1.6×10^{-3}	1.7×10^{-3}
September	1.2×10^{-3}	1.3×10^{-3}
TOTAL Dose	$\mathbf{3.5 \times 10^{-3}}$	$\mathbf{3.7 \times 10^{-3}}$

The radiation dose to the total population using the Savannah River is given in Table 13. Pathways considered include fish and invertebrate consumption; shoreline, swimming, and boating activities; and drinking water consumption. The irrigation pathway is not considered since their is no use of the Savannah River for crop irrigation known to exist (Hamby 1991b).

Table 13. Total population dose.

Assessment Period	Effective Dose Equivalent (person-rem) Tritium	Cs-137
July	2.7×10^{-3}	3.2×10^{-2}
August	6.7×10^{-3}	7.7×10^{-2}
September	5.0×10^{-3}	5.9×10^{-2}
TOTAL Dose	$\mathbf{1.4 \times 10^{-2}}$	$\mathbf{1.7 \times 10^{-1}}$

REFERENCES

Gallegos, A.F. and Whicker, F.W., "Radiocesium Retention by Rainbow Trout as Affected by Temperature and Weight", Proceedings of the Third National Symposium on Radioecology, Oak Ridge, TN, CONF-710501-P1, pp. 361-371, May 10-12, 1971.

Hamby, D.M., "LADTAP XL: An Improved Electronic Spreadsheet Version of LADTAP II", WSRC-RP-91-975, Westinghouse Savannah River Laboratory, Aiken, SC, 1991a.

Hamby, D.M., "Land and Water Use Characteristics in the Vicinity of the Savannah River Site", WSRC-RP-91-17, Westinghouse Savannah River Laboratory, Aiken, SC, March 1991b.

Hayes, D.W., "Inventory and Concentration of Cs-137 and Tritium in Par Pond and Lower Three Runs Creek System", SRL-ETS-910327, Westinghouse Savannah River Laboratory, Aiken, SC, July 15, 1991a.

Hayes, D.W. and Marter, W.L., "Historical River Flow Rates for Dose Calculations", SRL-ETS-910257, Westinghouse Savannah River Laboratory, Aiken, SC, June 10, 1991.

Morgan, T.J., Landolt, R.R., and Hamelink, J., "Behavior of Tritium in Fish Following Chronic Exposure", in Tritium, Moghissi, A.A. and Carter, M.W. (eds), Phoenix, Messinger Graphics, pg. 378, 1973.

Riggsbee, J.H., memo to D.M. Hamby, "Par Pond Flow to Lower Three Runs Creek", SSP-PED-910143, October 16, 1991.

US Nuclear Regulatory Commission, "Calculation of Annual Dose to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", Reg. Guide 1.109, Revision 1, October 1977.

END

DATE
FILMED
9/01/92