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CONCENTRATIONS, TOTAL STREAM LOADS, AND MASS TRANSPORT OF RADIONUCLIDES IN THE CLINCH AND TENNESSEE RIVERS

Supplement No. 1 to Status Report No. 5
on Clinch River Study

M. A. Churchill
J. S. Cragwall, Jr.
R. W. Andrew
S. Leary Jones

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HEALTH PHYSICS DIVISION

CONCENTRATIONS, TOTAL STREAM LOADS, AND MASS TRANSPORT OF RADIONUCLIDES IN THE CLINCH AND TENNESSEE RIVERS

Supplement No. 1 to Status Report No. 5 on Clinch River Study

By

M. A. Churchill
J. S. Cragwall, Jr.
R. W. Andrew
S. Leary Jones

Progress Report No. 4 (final) of Subcommittee on Water Sampling and Analysis. Presented at Meeting of Clinch River Study Steering Committee, December 15-16, 1964

AUGUST 1965

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PREFACE

The Subcommittee on Water Sampling and Analysis was established on September 22-23, 1960, by the appointment of the following members: M. A. Churchill (TVA), Chairman, J. S. Cragwall (USGS), A. G. Friend (USPHS), and S. L. Jones (TDPH). Following the transfer by the USPHS of Dr. Friend to Boston, R. W. Andrew (USPHS) was appointed to replace him.

Although this report includes a statement of the objectives of the Subcommittee, the method of study, detailed findings, and recommendations, some of the details of procedures used are omitted here since these have been included in previous Status Reports. Details of water sampling procedures at the established sampling stations are given in Status Report No. 1, pp. 22-23, and p. 73, Status Report No. 2, pp. 8-15, Status Report No. 3, pp. 10-11, and in Status Report No. 5, p. 16. Information concerning procedures used for radiological determinations is given in Status Report No. 1, p. 23, Status Report No. 2, pp. 16-17, Status Report No. 3, p. 12, and in Status Report No. 5, p. 16. (See references 2, 3, and 4, p 72.)

Results of stable chemical determinations for the sampling period November 1960-March 1961 are included in Status Report No. 2, pp. 29-33, and results for the period April 1961-June 1961 are included in Status Report No. 3, pp. 30-32. Analytical results on samples collected in the period July 1961 through November 1962 are available in Progress Report No. 3, Subcommittee on Water Sampling and Analysis, February 6, 1963. In addition, a statistical analysis of all the stable chemical data is included in Status Report No. 5, pp. 18-21. (See references 2, 3, and 4, p 72.)

Acknowledgements

Special acknowledgment is due R. W. Andrew for his initiative and painstaking thoroughness in re-examining and correcting the electronic computer program used to determine concentrations of three of the four radionuclides of primary interest. Acknowledgment is also due R. A. Buckingham formerly of TVA, for his valued assistance in preparing Subcommittee Progress Reports Nos. 1, 2, and 3. Similar acknowledgment is due W. R. Nicholas, TVA, for his assistance in preparing Progress Report No. 4 of the Subcommittee, which report, essentially unchanged, is reproduced here.

CONTENTS

Page

Purpose of Work 1

Method of Study 1

General 1
Sampling Stations 2
Period of Sampling 2
Sampling Procedures 2
Radiological Determinations 2
Stream Discharges 2
Mineral Analyses 2

Revision and Extension of Data Previously Reported 6

Lower Limits of Detection of Radionuclides 6

Strontium-90, Concentrations and Total Stream Loads 7

Mass Curves 19
Comparison with Load Measured by ORNL 22

Cesium-137, Concentrations and Total Stream Loads 22

Mass Curves 38
Comparison with Load Measured by ORNL 40

Cobalt-60, Concentrations and Total Stream Loads 40

Mass Curves 52
Comparison with Load Measured by ORNL 54

Ruthenium-106, Concentrations and Total Stream Loads 54

Mass Curves 67
Comparison with Load Measured by ORNL 67

Effects of Operation of Melton Hill Dam on Dispersion of Radionuclides 69

Recommendations 69

ILLUSTRATIONS

Figures | Page

1 Location of Water Sampling Stations 3

2 Mean River Discharges, Clinch River Study 4

3 Mean River Discharges, Clinch River Study 5

4 Mass Diagram, Strontium-90 20

5 Gross Beta Activity in Precipitation 23

6 Curies Passing White Oak Dam, Clinch River Study 24

7 Curies Passing White Oak Dam, Clinch River Study 25

8 Mass Diagram, Cesium-137 39

9 Mass Diagram, Cobalt-60 53

10 Mass Diagram, Ruthenium-106 68

Tables

1 Concentrations of Strontium-90, pc per liter 8

2 Concentrations of Cesium-137, pc per liter 26

3 Concentrations of Cobalt-60, pc per liter 41

4 Concentrations of Ruthenium-106, pc per liter 55

PROGRESS REPORT NO. 4 (FINAL)

Subcommittee on Water Sampling and Analysis

Clinch River Study

December 15-16, 1964

Purpose of Work

The basic purpose of the work of the Subcommittee on Water Sampling and Analysis is to collect and interpret such information concerning radionuclides suspended and/or dissolved in the waters of the surface streams downstream from Oak Ridge, Tennessee, as will assist the Clinch River Study Steering Committee in pursuing the basic purposes of the entire study, namely, "(1) to determine the fate of radioactive materials currently being discharged to the Clinch River, (2) to determine and understand the mechanisms of dispersion of radionuclides released to the river, (3) to evaluate the direct and indirect hazards of current disposal practices in the river, (4) to evaluate the over-all usefulness of the river for radioactive waste disposal purposes, and (5) to recommend long-term monitoring procedures."

Included as part of the work of the subcommittee is the determination of the mineral quality of the surface waters involved in the over-all study.

Method of Study

General--The general plan of the study involved systematic collection and analysis of water samples at selected sampling stations. Daily subsamples of water, the individual volumes of which at each station (except at Loudon) were proportioned to the volumes of daily streamflow passing that particular station, were composited weekly for analysis (monthly for most mineral analyses). Such analyses provided the mean flow-proportioned concentration of each radionuclide of interest passing each station each week. By combining this mean concentration with the total flow of water passing the station during each week, the total load, in curies, of each radionuclide passing the station was determined. The cumulative load of each radionuclide at each station was plotted progressively with time. The mass curves so produced reveal on comparison, one with another, the quantitative loss (by sedimentation, biological uptake, etc.) or gain (from fallout on the watershed) of this particular radionuclide between successive downstream stations.

The Centers Ferry sampler malfunctioned (See Progress Report No. 3, of the Subcommittee on Water Sampling and Analysis, page 27) during September through November 1961. This malfunction possibly affected the suspended-sediment results for all radionuclides. The degree to which the results are affected is dependent upon the proportion of a given radionuclide associated with the suspended solids.

Sampling Stations--Sampling stations used in the study are located as follows, and as shown in figure 1:

1. Clinch River at Oak Ridge water plant--Clinch River mile 41.5
2. White Oak Creek at White Oak Dam, mile 0.6
3. Clinch River at Gallaher Bridge--Clinch River mile 14.6
4. Clinch River above Centers Ferry--Clinch River mile 5.5
5. Tennessee River at Loudon, Tennessee--Tennessee River mile 591.8
6. Tennessee River at Watts Bar Dam--Tennessee River mile 529.9
7. Tennessee River at Chickamauga Dam--Tennessee River mile 471.0

Period of Sampling--Except for the station at Gallaher Bridge, sampling was begun in November 1960 and extended through November 1962. At Gallaher Bridge, sampling was begun on January 8, 1962, and was discontinued at the end of November 1962.

Sampling Procedures--Sampling procedures at each sampling station have been explained in detail in previous progress reports.

Radiological Determinations--The radionuclides of primary importance in the Clinch River Study, in the order named, are strontium-90, cesium-137, cobalt-60, and ruthenium-106. Consequently, determinations were made of concentrations and total loads of these radionuclides. All radiological determinations in this study have been made by the U. S. Public Health Service, Cincinnati, Ohio.

Details of sample preparation and analysis have been explained in previous progress reports.

Stream Discharges--The necessary data on streamflows at the five upstream sampling stations have been provided by the U. S. Geological Survey, through the cooperation of its Tennessee District. Discharges at Watts Bar and Chickamauga Dam have been supplied by TVA. (See plotted streamflow data in figures 2 and 3.)

Mineral Analyses--All mineral analyses were made in Nashville, Tennessee, by the staff of the Tennessee Stream Pollution Control Board. Methods used and results obtained have been included in previous progress reports.

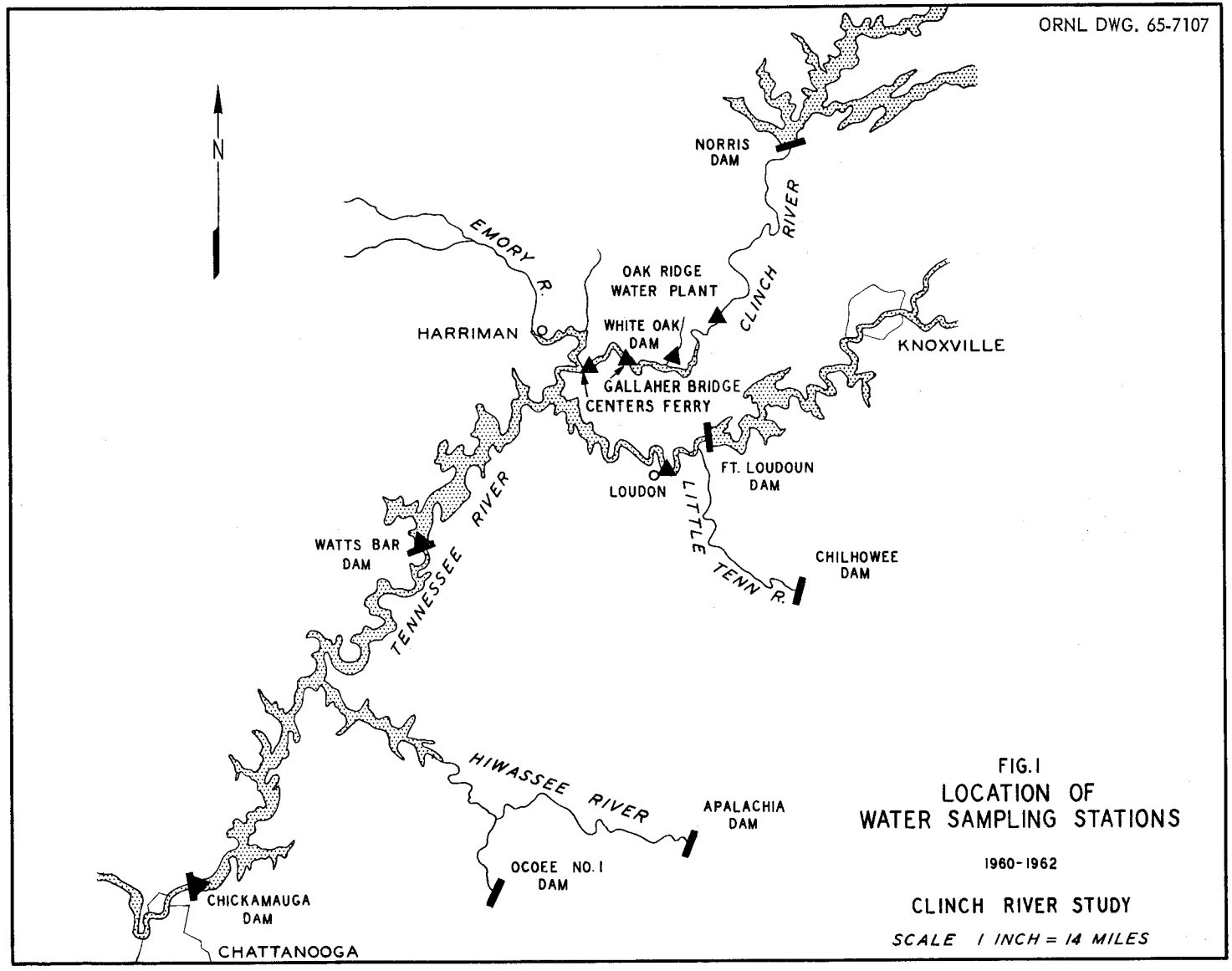


FIG. 1
LOCATION OF
WATER SAMPLING STATIONS

1960-1962

CLINCH RIVER STUDY

SCALE 1 INCH = 14 MILES

ORNL DWG. 65-7108

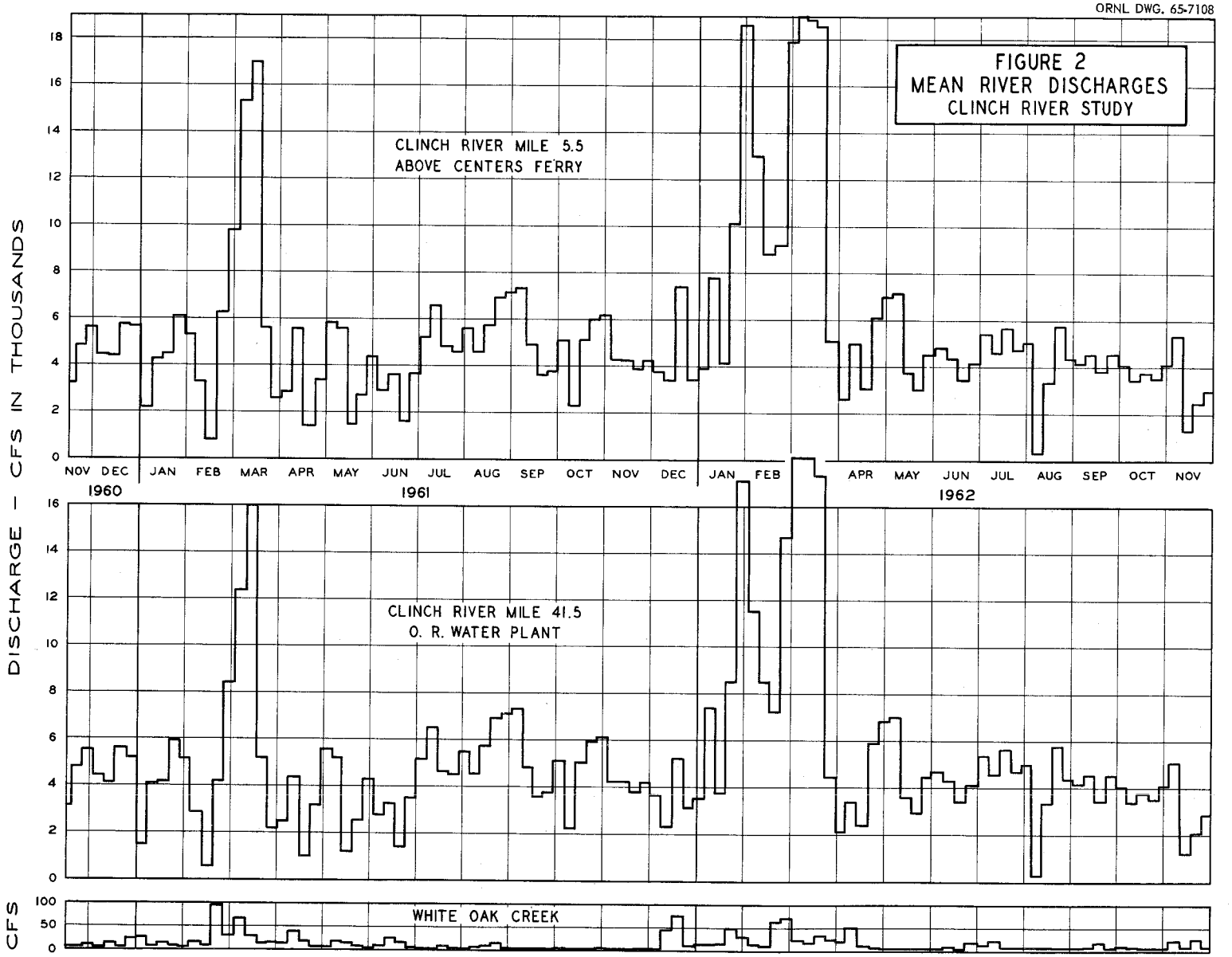
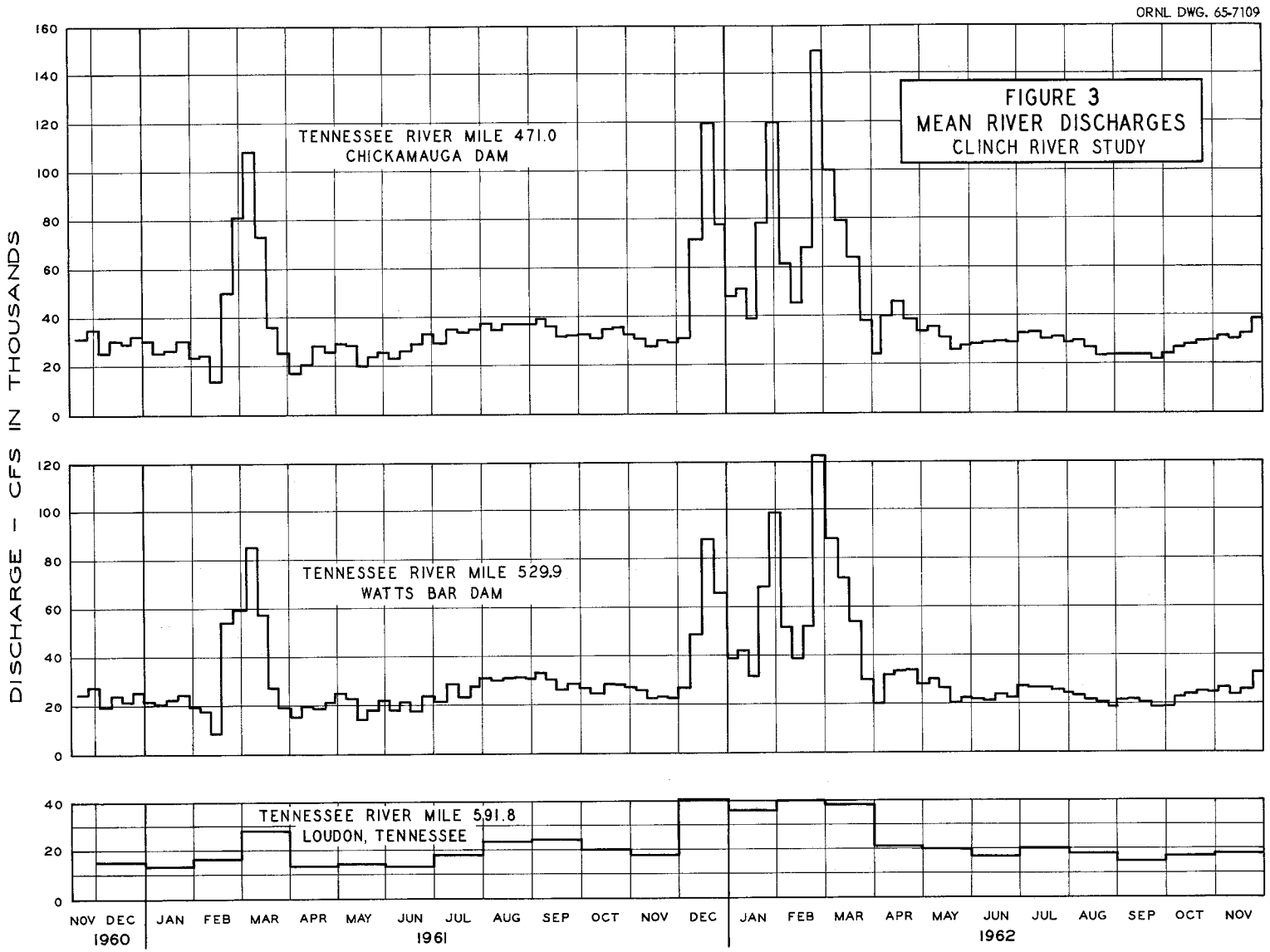


FIGURE 2
MEAN RIVER DISCHARGES
CLINCH RIVER STUDY


ORNL DWG. 65-7109
FIGURE 3
MEAN RIVER DISCHARGES
CLINCH RIVER STUDY
TENNESSEE RIVER MILE 471.0
CHICKAMAUGA DAM
TENNESSEE RIVER MILE 529.9
WATTS BAR DAM
TENNESSEE RIVER MILE 591.8
LOUDON, TENNESSEE
DISCHARGE – CFS IN THOUSANDS
160
140
120
100
80
60
40
20
0
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
1960
1961
1962

Revision and Extension of Data Previously Reported

Progress Report No. 3, issued February 6, 1963, reported results on the four radionuclides of interest to this study from the beginning of sampling in November 1960, well into the summer of 1962. However, due primarily to a reexamination and corrections made by personnel of the U. S. Public Health Service of the electronic computer program used to determine concentrations of cesium-137, cobalt-60, and ruthenium-106, many major changes were made in previously reported concentrations of these three radionuclides. The program in error systematically produced results that were 50 percent to 100 percent too high, for the samples of larger size (i.e., all samples except those for White Oak Creek). Correction and updating of the computer program produced the results reported here. In addition, a few changes have also been made in previously reported concentrations of strontium-90 as a result of further checking of the sample calculations. Consequently, this report includes tabulated and plotted data on all four radionuclides that supersede the data reported in Progress Report No. 3. In addition, the data on all four radionuclides at all seven stations have been extended through November 1962, i.e., to the end of the two-year sampling period. The tabulated radionuclide results are accurate to no more than two significant figures. The additional figures were tabulated for statistical reasons only.

All data reported as negative values were assumed to be zero when determining loads for the mass diagrams. This probably gives a slight positive bias to the results.

Lower Limits of Detection of Radionuclides

To assist in judging the reliability of the mass curves, information concerning the lower limits of detection of radionuclides was obtained from the U. S. Public Health Service. These data are shown in the following table. Some values below these lower limits of detection are reported in the tabulation of radionuclide concentrations and were used for calculating the cumulative loads shown in the mass diagrams.

Approximate Lower Limits of Detection*
Picocuries per liter

	Strontium-90	Cesium-137	Cobalt-60	Ruthenium-106
White Oak Creek (TS and SS)	1	11	9	45
White Oak Creek (DS)	1	67	44	190
Other Samples (TS and SS)	0.03	1	1	2
Other Samples (DS)	0.03	4	2	11

*Estimated on the basis of 2 sigma counting error associated with a blank determination (background only). The presence of any other radionuclide in a given sample would tend to raise slightly the lower limits for cesium-137, cobalt-60, and ruthenium-106.

Strontium-90, Concentrations and Total Stream Loads

Concentrations of strontium-90 found in all samples at all stations for the two-year sampling period (strontium-90 data ended November 10, 1962, at all stations except White Oak Dam and Loudon) are shown in table 1. Since some counting error is probable for every sample, the true activity level (as determined by counting) in the sample is thought to fall within the range indicated by the magnitude of the plus or minus value (95 percent confidence limits) included with each reported concentration. The plus and minus values infer the level of precision in counting rather than the accuracy of the result since some additional uncertainty arises as a consequence of the chemical separation processes involved.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the following tabulation:

Maximum and Mean Concentrations of Strontium-90

Station	Highest Concentration pc per liter	Period of Occurrence	Flow-Weighted Mean Concentration pc per liter
Clinch R. at Oak Ridge water plant	5.0	12/4-10/60	0.71
White Oak Creek at White Oak Dam	17,450	11/13-19/60	1,349
Clinch R. at Gallaher Bridge	11.67	4/29-5/5/62	4.5*
Clinch R. at Centers Ferry	42.6	12/25-31/60	4.2
Tennessee R. at Loudon, Tenn.	2.3	January 1961	**
Tennessee R. at Watts Bar Dam	16.4	12/25-31/60	1.6
Tennessee R. at Chickamauga Dam	14.1	1/15-21/61	1.6

*Record begun January 8, 1962
**Not applicable.

In this tabulation, the values in the last column were obtained by dividing the total cumulative stream load for the period of record by the corresponding total volume of streamflow. The mean concentration so obtained is not the same as the mean concentration over time. (In fact, it is impossible to determine the mean concentration on a time basis from the basic data.) At only the White Oak Creek station does the flow-weighted mean concentration exceed MPC values for drinking water.

Table 1

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960								
11/13-19	TS	1.2 ±0.03	17,450 ±450		21.6 ±0.57			
11/20-26	TS	0.92±0.2	75.6 ± 3.9		7.5 ±0.2		6.7*	1.5 ±0.08
11/27-12/3	TS	0.2 ±0.1	640 ± 6.6		14.3 ±0.4		4.8 ±0.18	0.9 ±0.02
12/4-10	TS	5.0 ±0.4	4,770 ± 20		5.0 ±0.33	1.4* for	6.7 ±0.4	4.3 ±0.14
12/11-17	TS	3.1 ±0.3	1,730 ± 15		24.1 ±0.3	December	0.7 ±0.04	5.9 ±0.57
12/18-24	TS	0.5 ±0.1	6,280 ± 22		1.5 ±0.1		2.1 ±0.1	3.6 ±0.25
12/25-31	TS	0.62±0.09	7,070 ± 74		42.6 ±1.6		16.4 ±1.30	1.4 ±0.1
1961								
1/1-7	TS	2.0 ±0.2	878 ± 8.8		13.3 ±0.32		1.98±0.009	1.7 ±0.16
1/8-14	TS	0.2 ±0.03	15,900 ± 26.2		6.3 ±0.2		4.8 ±0.3	5.6 ±0.9
1/15-21	TS	1.9 ±0.1	2,875 ± 13		4.6 ±0.1	2.3 ±0.1	12.0 ±0.6	14.1 ±0.4
1/22-28	TS	0.5 ±0.1	2,032 ± 14		3.88±0.2	for January	5.1 ±0.24	2.4 ±0.2
1/29-2/4	TS	0.3 ±0.04	6,700 ± 62		9.9 ±0.37		2.7 ±0.2	3.75±0.23
2/5-11	TS	0.8 ±0.1	3,400 ± 25		37.0 ±0.6		1.2*	2.0 ±0.25
2/12-18	TS	0.29±0.04	6,600 ± 53		30*	0.39±0.07	0.3 ±0.1	1.3 ±0.1
2/19-25	TS	0.6 ±0.1	1,350 ± 10		11.9 ±0.2	for February	0.6 ±0.1	1.7 ±0.05
2/26-3/4	TS	0.4 ±0.02	1,060 ± 8		4.1 ±0.1		2.2 ±0.2	2.8 ±0.2
3/5-11	TS	0.3 ±0.1	590 ± 7		2.9 ±0.1		1.0 ±0.04	1.5 ±0.1
3/12-18	TS	0.33±0.06	160 ± 5		1.8 ±0.1	SS Bkgd.**	0.9 ±0.1	0.8 ±0.1
3/19-25	TS	0.3 ±0.02	930 ± 80		2.5 ±0.1	DS 0.3 ±0.04	2.0 ±0.2	1.0 ±0.1
3/26-4/1	TS	0.2 ±0.02	1,000 ± 80		2.3 ±0.2	for March	0.9 ±0.1	0.3 ±0.1

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/2-8	TS 0.6 ±0.1	1,020 ± 25		5.3 ±0.1		0.7 ±0.05	1.3 ±0.1
4/9-15	TS 0.3 ±0.04	953 ±128		2.7 ±0.06	SS 0.05±0.009	1.5 ±0.2	1.5 ±0.07
4/16-22	TS 0.3 ±0.02	1,208 ± 50		4.7 ±0.08	DS 0.4 ±0.04	1.2 ±0.01	1.0 ±0.07
4/23-29	SS Bkgd.*	59.8 ± 0.09		0.1 ±0.01	for April	TS 1.3 ±0.09	TS 1.2 ±0.06
	DS 0.3 ±0.03	1,175 ±126		8.4 ±0.1			
4/30-5/6	SS Bkgd.	110.5 ± 1.2		0.1 ±0.01		Bkgd.	Bkgd.
	DS 0.3 ±0.03	2,225 ±130		2.8 ±0.07		0.8 ±0.04	1.2 ±0.1
5/7-13	SS Bkgd.	25.4 ± 0.8		0.1 ±0.01		0.1 ±0.01	0.1 ±0.1
	DS 0.3 ±0.03	1,462 ± 6		0.6 ±0.07		1.4 ±0.04	0.5 ±0.03
5/14-20	SS 0.1 ±0.02	18.8 ± 0.6		0.1 ±0.06	Bkgd.	Bkgd.	Bkgd.
	DS 0.3 ±0.02	1,400 ±100		4.5 ±0.1	0.3 ±0.03	1.4 ±0.03	1.6 ±0.07
5/21-27	SS Bkgd.	12.9 ± 0.5		0.1 ±0.01	for May	Bkgd.	Bkgd.
	DS 0.3 ±0.02	1,500 ±100		9.2 ±0.1		0.69±0.04	0.8 ±0.04
5/28-6/3	SS Bkgd.	30.0 ± 0.08		Bkgd.		Bkgd.	Bkgd.
	DS 0.5 ±0.03	2,000 ± 70		4.0 ±0.06		1.4 ±0.04	0.8 ±0.03
6/4-10	SS 0.1 ±0.01	71.8 ± 1.2		0.2 ±0.01		0.1 ±0.01	Bkgd.
	DS 0.16±0.03	1,400 ± 50		7.3 ±0.15		1.6 ±0.05	0.8 ±0.03
6/11-17	SS 0.2 ±0.02	130 ± 1.5		0.2 ±0.01	0.1 ±0.02	TS 1.80**	Bkgd.
	DS 0.4 ±0.03	1,800 ± 70		6.6 ±0.07	0.2 ±0.03		4.4 ±0.14
6/18-24	SS 1.23±0.07	80.2 ± 1.2		0.3 ±0.03	for June	Bkgd.	Bkgd.
	DS 0.3 ±0.02	1,679 ± 13		6.32±0.24		1.7 ±0.05	1.1 ±0.03

*Bkgd. indicates background.
**Value is estimated.

Blank spaces indicate data not available.
TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
6/25-7/1	SS	Bkgd.*	50.8 ± 1.0		0.3 ±0.03		Bkgd.	Bkgd.
	DS	0.2 ±0.02	1,627 ± 35.4		5.0 ±0.08		1.5**	1.5 ±0.07
7/2-8	SS	0.2 ±0.02	78.1 ± 1.1		2.5 ±0.04		Bkgd.	Bkgd.
	DS	0.2 ±0.02	2,280 ± 43		3.0 ±0.06		1.2 ±0.06	2.2 ±0.06
7/9-15	SS	0.2 ±0.02	218 ± 2		Bkgd.	0.2 ±0.05	0.4 ±0.02	Bkgd.
	DS	0.3 ±0.02	2,565 ± 40.6		1.3 ±0.04	1.96±0.1	2.0 ±0.06	0.8 ±0.04
7/16-22	SS	Bkgd.	50.3 ± 0.09		0.8 ±0.07	for July	Bkgd.	0.2 ±0.01
	DS	0.8 ±0.05	2,195 ± 53		3.0 ±0.1		1.6 ±0.04	2.0 ±0.07
7/23-29	SS	0.4 ±0.05	27.7 ± 1.8		0.21±0.06		Bkgd.	0.05**
	DS	0.36±0.04	1,920 ± 50		3.07±0.18		1.7 ±0.05	1.29±0.06
7/30-8/5	SS	0.11±0.03	23.6 ± 1.3		0.06±0.02		0.6 ±0.01	0.01±0.02
	DS	0.19±0.02	1,560 ± 36		2.1 ±0.07		0.8 ±0.05	0.49±0.05
8/6-12	SS	0.15±0.03	39.0 ± 2.7		0.13±0.12	0.02±0.01	0.04±0.02	Bkgd.
	DS	0.07±0.02	2,025 ± 41		0.6 ±0.04	0.2 ±0.02	1.2 ±0.07	1.9 ±0.07
8/13-19	SS	0.27±0.05	44.05± 1.94		0.06±0.04	for August	Bkgd.	0.02±0.02
	DS	0.15±0.14	1,651 ± 27.9		4.9 ±0.15		0.56±0.04	0.8±0.06
8/20-26	SS	0.07±0.04	64.3 ± 3.0		0.31±0.26		0.02±0.02	Bkgd.
	DS	0.13±0.11	1,275 ± 84		2.48±0.29		0.63±0.04	0.76±0.06
8/27-9/2	SS	0.08±0.06	18.8 ± 1.3		0.13±0.14		0.01±0.02	0.12±0.01
	DS	0.28±0.05	1,937 ± 35		2.89±0.14		1.1 ±0.07	0.37±0.04

*Bkgd. indicates background.
**Value is estimated.

Blank spaces indicate data not available.
SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0.14±0.04	17.8 ± 1.1		Bkgd.*		0.02±0.07	Bkgd.
	DS	0.38±0.05	1,738 ±100		1.51±0.06		0.57±0.05	0.5 ±0.05
9/10-16	SS	0.05±0.04	19.0 ± 1.2		0.22±0.01	0.04±0.02	Bkgd.	0.06±0.02
	DS	0.41±0.06	1,129 ± 89.1		2.22±0.22	0.07±0.05	1.07±0.08	0.9 ±0.06
9/17-23	SS	0.09±0.05	28.8 ± 1.58		0.17±0.15	for September	0.55±0.05	0.1 ±0.04
	DS	0.12±0.03	821.7 ± 6.93		2.0 ±0.3		0.07±0.02	0.52±0.04
9/24-30	SS	0.05±0.02	26.1 ± 1.24		0.35±0.15		0.04±0.02	0.23±0.03
	DS	0.36±0.06	1,435.5 ±147.5		1.6 ±0.17		0.32±0.03	0.05±0.05
10/1-7	SS	0.07±0.02	16.5 ± 1.2		0.23±0.03		0.08±0.02	Bkgd.
	DS	0.05±0.02	1,069.2 ±118.8		2.19±0.28		0.5 ±0.04	0.27±0.03
10/8-14	SS	0.05±0.04	10.9 ± 1.0		0.83±0.33	0.19±0.05	0.11±0.03	0.04±0.01
	DS	0.46±0.05	1,590 ±115		4.85±0.22	0.13±0.04	0.39±0.11	0.36±0.04
10/15-21	SS	0.21±0.04	17.2 ± 1.4		0.30±0.15	for October	0.31±0.02	0.03±0.02
	DS	0.46±0.70	1,810 ±195		2.41±0.32		0.5**	1.35±0.11
10/22-28	SS	0.14±0.09	9.3 ± 0.9		Bkgd.		0.15±0.06	0.05±0.02
	DS	0.4 ±0.04	1,530 ±116		1.41±0.17		1.03±0.07	0.98±0.12
10/29-11/4	SS	0.2 ±0.02	27.1 ± 1.46		0.33±0.23		0.03±0.02	Bkgd.
	DS	0.45±0.08	1,439 ±113		2.16±0.08		3.9 ±0.2	1.24±0.1

*Bkgd. indicates background.

**Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0.14±0.02	6.0 ± 2.34		2.0 ±0.03		TS 0.33±0.0	TS 0.94±0.12
	DS	0.4 ±0.06	1,538 ±197		6.0 ±0.5			
11/12-18	SS	0.1 ±0.03	11.4 ± 1.04		1.46±0.12	0.02±0.02	0.3 ±0.2	TS 0.7 ±0.1
	DS	0.56±0.05	1,640 ±235		6.0 ±0.44	0.33±0.07	0.4 ±0.05	
11/19-25	SS	0.09±0.04	253 ± 6.0		1.1*	for November	TS 0.5*	TS 0.9 ±0.01
	DS	0.6 ±0.02	1,560 ±145		1.9 ±0.3			
11/26-12/2	SS	Bkgd.**	20.4 ± 2.5		0.5 ±0.17		0.03±0.01	0.2 ±0.01
	DS	0.4 ±0.02	1,366 ± 89.1		2.6 ±0.09		0.4 ±0.07	0.7 ±0.06
12/3-9	SS	0.07±0.01	8.0 ± 0.73		0.2 ±0.04		0.06±0.04	0.04±0.02
	DS	0.4 ±0.07	1,564 ±102		2.8 ±0.1		0.54±0.07	1.0 ±0.01
12/10-16	SS	0.2 ±0.03	7.2 ± 0.9		0.87±0.03	0.06±0.03	0.03±0.02	0.07±0.02
	DS	0.35±0.01	782 ± 26.3		1.3 ±0.4	0.6 ±0.2	1.9 ±0.2	0.8 ±0.07
12/17-23	SS	0.16±0.04	3.89± 0.57		0.22±0.05	for December	0.08±0.02	0.04±0.03
	DS	0.4 ±0.1	454 ± 19.2		4.77±0.7		0.8 ±0.1	0.82±0.14
12/24-30	SS	0.06±0.03	Bkgd.		0.07±0.03		0.05±0.02	0.05±0.03
	DS	0.12±0.07	879 ± 19		2.29±0.32		0.67±0.05	0.06±0.02

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0.05±0.03	6.4 ± 1.2		0.03±0.02		0.07±0.02	Bkgd.*
	DS	0.5 ±0.08	816 ± 28		1.7 ±0.36		1.4 ±0.17	0.81±0.18
1/7-13	SS	0.07±0.06	5.21± 0.7	0.2 ±0.04	0.4 ±0.03	0.13±0.04	0.08±0.03	0.35±0.02
	DS	0.7 ±0.07	636 ± 14.3	1.6 ±0.3	0.79±0.07	0.5 ±0.02	0.71±0.10	0.7 ±0.1
1/14-20	SS	0.07±0.03	5.3 ± 2.4	0.9 ±0.07	0.06±0.06	for January	Bkgd.	0.04±0.02
	DS	0.4 ±0.01	719 ± 28.2	6.20±0.8	1.52±0.07		0.95±0.14	0.70±0.12
1/21-27	SS	0.1 ±0.03	10.28± 0.96	0.22±0.04	0.03±0.01		0.29±0.03	Bkgd.
	DS	0.53±0.13	714 ± 35.3	5.0 ±0.8	4.2 ±0.4		0.57±0.13	0.59±0.10
1/28-2/3	SS	0.1 ±0.04	6.87± 0.83	0.49±0.17	TS 1.6**		0.05±0.01	0.1 ±0.03
	DS	0.53±0.04	572 ± 17	1.01±0.54			0.6 ±0.1	1.34±0.22
2/4-10	SS	0.12±0.03	13.87± 1.54	0.02±0.02	TS 1.3**	0.46±0.23	0.06±0.02	0.03±0.02
	DS	0.4 ±0.01	1,129 ± 42	1.0 ±0.2		0.7 ±0.5	0.92±0.43	0.14±0.08
2/11-17	SS	0.03±0.02	6.6 ± 1.07	0.12±0.03	0.21±0.01	for February	0.03±0.02	Bkgd.
	DS	0.2 ±0.04	1,285 ± 56.6	1.54±0.71	1.21±0.34		0.8 ±0.3	0.6 ±0.2
2/18-24	SS	0.28±0.04	20.1 ± 1.2	0.13±0.03	0.09±0.02		0.11±0.02	0.03±0.02
	DS	0.8 ±0.02	577 ± 7.28	3.7 ±0.4	2.0 ±0.53		3.0 ±0.3	2.18±0.43
2/25-3/3	SS	0.22±0.05	8.5 ± 0.94	0.15±0.11	0.14±0.06		0.05±0.02	0.25±0.03
	DS	0.28±0.27	122.9 ± 5.35	2.5 ±0.3	7.5 ±0.2		1.48±0.21	5.4 ±0.4

*Bkgd. indicates background.

**Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	0.1 ±0.03	8.8 ± 0.9	0.08±0.03	0.2 ±0.04		Bkgd.*	0.04±0.02
	DS	0.9 ±0.2	636 ± 33.3	1.9 ±0.04	1.4 ±0.2		0.73±0.04	1.18±0.2
3/11-17	SS	0.84±0.03	TS 1,500**	0.16±0.06	0.1 ±0.05	0.05±0.02	0.05±0.03	0.03±0.01
	DS	0.6 ±0.01		1.1 ±0.1	0.85±0.12	0.37±0.04	0.23±0.06	0.3 ±0.04
3/18-24	SS	0.16±0.03	18.4 ± 1.22	0.09±0.04	0.15±0.03	for March	0.03±0.02	0.03**
	DS	0.6 ±0.07	1,101 ± 97.8	2.2 ±0.2	2.3 ±0.39		1.8 ±0.2	1.7 ±0.3
3/25-31	SS	0.04±0.02	4.28± 0.81	0.19±0.05	0.09±0.05		0.06±0.02	0.04±0.02
	DS	0.8 ±0.15	1,420 ±101	4.8 ±0.2	3.1 ±0.2		1.09±0.1	1.19±0.08
4/1-7	SS	0.08±0.03	5.08± 1.01	0.2**	0.09±0.02		0.05±0.02	0.09±0.02
	DS	0.6 ±0.1	1,600**	10.0 ±0.55	0.62±0.52		1.4 ±0.2	1.51±0.21
4/8-14	SS	0.2 ±0.05	6.85± 0.75	0.05±0.05	Bkgd.	0.05±0.04	0.05±0.02	0.02±0.01
	DS	1.05±0.25	527 ± 12	6.0 ±0.6	13.32±1.81	0.62±0.17	3.36±0.3	1.21±0.15
4/15-21	SS	0.04±0.02	12.1 ± 1.7	Bkgd.	0.12±0.05	for April	0.17±0.03	0.02**
	DS	0.4 ±0.04	1,368 ± 14	8.45±0.28	7.49±0.22		1.61±0.16	2.04±0.15
4/22-28	SS	0.05±0.02	10.4 ± 0.91	0.07±0.02	Bkgd.		0.04±0.02	0.03±0.01
	DS	1.57±0.10	2,000**	4.45±0.20	2.94±0.42		1.85±0.12	4.45±0.2
4/29-5/5	SS	0.04±0.01	18.75± 1.53	0.06±0.02	0.16±0.03		0.05±0.03	0.04±0.03
	DS	0.87±0.08	2,700**	11.61±0.46	1.99±0.42		4.15±0.14	1.11±0.07

*Bkgd. indicates background.

**Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	0.05±0.02	15.0 ± 1.06	0.83±0.03	0.11±0.02		0.04*	0.05*
	DS	0.51±0.09	2,852 ±178	2.17±0.37	1.85±0.36		1.34±0.07	1.07±0.14
5/13-19	SS	0.06±0.02	13.8 ± 1.4	0.09±0.02	0.09±0.02	0.05±0.02	Bkgd.**	0.06±0.02
	DS	0.54±0.11	2,700*	3.75±0.43	4.85±0.43	0.99±0.17 for May	2.35±0.31	1.02±0.13
5/20-26	SS	0.02±0.02	25.2 ± 1.44	0.11±0.03	0.11±0.07		0.05±0.02	0.29*
	DS	0.72±0.19	2,400 ±144	2.55±0.35	4.23±0.28		0.08±0.01	0.99±0.13
5/27-6/2	SS	0.06±0.02	21.8 ± 1.29	0.16±0.03	0.12±0.03		0.02±0.02	0.17*
	DS	0.62±0.16	1,900*	4.27±0.53	3.3 ±0.81		1.11±0.14	1.58±0.16
6/3-9	SS	0.07±0.03	2.85± 0.15	0.33±0.01	0.2*		0.05±0.02	0.06±0.02
	DS	0.87±0.13	1,579 ±122.5	8.5 ±0.65	4.9 ±0.53		1.23±0.16	1.26±0.25
6/10-16	SS	0.25±0.10	28.1 ± 3.23	0.22±0.04	0.21±0.07	0.04±0.02	Bkgd.	Bkgd.
	DS	0.4 ±0.08	1,258 ± 92.3	3.7 ±0.28	2.8 ±0.2	1.21±0.17 for June	1.8 ±0.18	1.55±0.20
6/17-23	SS	0.15±0.03	23.5 ± 1.23	0.14±0.03	0.68*		0.02±0.01	0.04±0.02
	DS	0.6 ±0.1	2,135 ±155.7	2.6 ±0.2	2.52±0.56		4.7 ±0.68	0.96±0.41
6/24-30	SS	Bkgd.	92.5 ± 2.48	0.24±0.04	0.99±0.07		0.11±0.03	0.05±0.03
	DS	1.2 ±0.1	1,700 ±112	2.43±0.38	3.17±0.44		1.4 ±0.2	1.5 ±0.3

*Value is estimated.

**Bkgd. indicates background.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	0.10±0.02	126 ± 3.11	0.27±0.07			0.04±0.02	0.06±0.02
	DS	0.6 ±0.09	1,450 ±128	3.2*			1.85±0.22	1.0 ±0.1
7/8-14	SS	0.12±0.03	13.4 ± 1.1	0.19±0.03		0.05±0.02	0.15±0.03	0.06±0.03
	DS	0.58±0.10	865 ± 70.4	7.05±0.61		1.18±0.16	1.4 ±0.16	1.1 ±0.1
7/15-21	SS	0.23±0.06	15.38± 1.03	0.05±0.02	0.03±0.02	for July	0.07±0.06	0.5 ±0.03
	DS	0.56±0.11	1,532 ± 83	2.02±0.14	1.62±0.13		1.12±0.11	1.02±0.16
7/22-28	SS		27.80± 1.58		for July 1-21			
	DS		1,004 ± 58.7					
7/29-8/4	SS		16.55± 1.43					
	DS		1,972 ±219					
8/5-11	SS		3.63± 0.65					
	DS		1,008 ± 80.2					
8/12-18	SS	0.05±0.02	13.62± 1.10	0.02±0.01	0.11*	Bkgd.**	0.07±0.04	0.12±0.05
	DS	0.65±0.12	1,115 ± 81.8	2.16±0.14	1.37±0.11	0.72±0.13	2.57±0.25	1.0 ±0.12
		for July 22-August 18		for July 22-August 18	for July 22-August 18	for August		
8/19-25	SS		16.81± 0.92					
	DS		1,985 ±124					
8/26-9/1	SS		10.90± 0.83					
	DS		1,400 ±183					

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/2-8	SS		16.95± 1.30					
	DS		985 ± 79					
9/9-15	SS	0.01±0.01	14 ± 0.64	0.03±0.01	0.01±0.01	0.02±0.02	0.10±0.02	0.10±0.03
	DS	0.75±0.09	1,002 ±193	2.14±0.14	1.94±0.14	0.55±0.08	1.45±0.15	1.15±0.11
9/16-22	SS	for Aug. 19-Sept. 15	22.28± 1.32	for August 19 -Sept. 15	for August 19-Sept. 15	for September		
	DS		1,133 ±168					
9/23-29	SS		16.10± 1.10					
	DS		1,573 ±214					
9/30-10/6	SS		14.60± 0.89					
	DS		997 ±198					
10/7-13	SS	0.20±0.06	9.38± 0.76	0.03±0.01	0.01±0.01		0.03±0.02	0.53±0.05
	DS	0.76±0.09	1,226 ± 97.2	1.93±0.14	2.29±0.26		0.88±0.09	1.13±0.12
10/14-20	SS	for Sept. 16-Oct. 13	2.66± 0.79	for Sept. 16-Oct. 13	for Sept. 16-Oct. 13	0.04±0.02		
	DS		986 ±161			0.38±0.08		
10/21-27	SS		0.50± 0.38			for October		
	DS		1,171.2 ± 72.4					

Blank spaces indicate data not available.
SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/28-11/3	SS		2.86± 0.45					
	DS		1,326 ±178					
11/4-10	SS	0.25±0.05	1.79± 0.42	0.03±0.01	0.04±0.01		0.03±0.02	0.14±0.03
	DS	0.94±0.13	500 ±124	4.36±0.28	2.36±0.25		0.01±0.01	1.11±0.12
		for Oct. 14-Nov. 10		for Oct. 14-Nov. 10	for Oct. 14-Nov. 10			
11/11-17	SS		1.46± 0.38			0.08±0.03		
	DS		848 ± 73.2			0.81±0.12		
						for November		
11/18-24	SS		7.69± 0.75					
	DS		236 ± 26.3					
11/25-12/1	SS		8.00± 1.60					
	DS		1,155 ±164.0					

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

To determine what portion of the total strontium-90 activity is associated, on the average, with the suspended solids, and what portion with the dissolved solids (meaning in solution and/or associated with very fine suspended particles not removed by the supercentrifuge), a simple average percentage was computed for each of the two portions from the determinations on all samples from each station, with results as shown in the following tabulation. Median values are also shown.

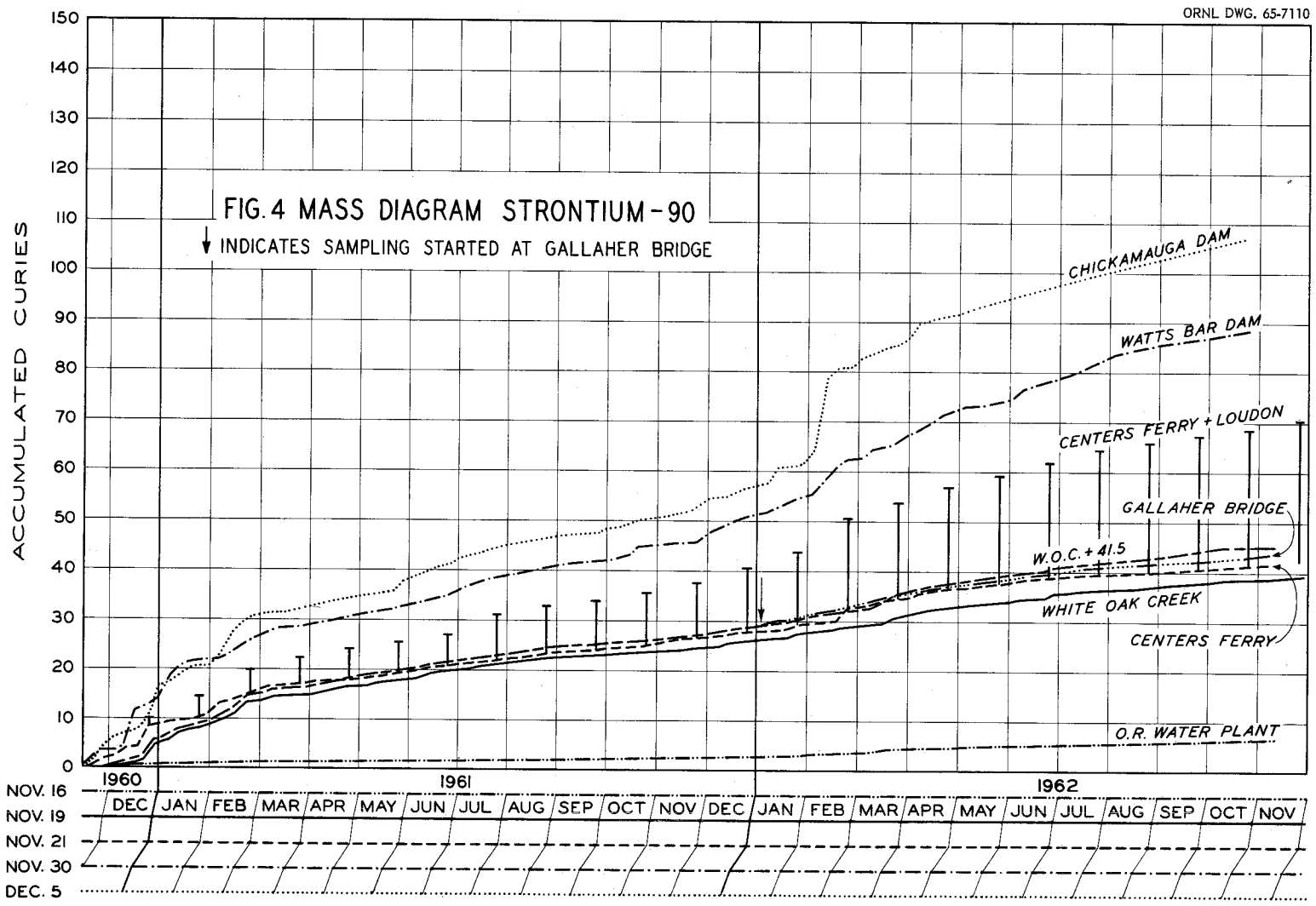
Distribution of Strontium-90 in Water Samples

Station	Percent Total Activity in			
	Suspended Solids		Dissolved Solids	
	Mean	Median	Mean	Median
Clinch River at Oak Ridge water plant	24	21	76	79
White Oak Creek at White Oak Dam	2	1	98	99
Clinch River at Gallaher Bridge	6	4	94	96
Clinch River at Centers Ferry	9	6	91	94
Tennessee River at Watts Bar Dam	9	6	91	94
Tennessee River at Chickamauga Dam	10	6	90	94

From these data it is quite apparent that from 90 to 98 percent of the strontium-90 activity is associated with the dissolved solids, or in other words, dissolved in the water itself. (The maximum size of sediment particles left in suspension by the supercentrifuge is estimated to be 0.7 microns.) The time of contact with the suspended solids in Clinch River appears to have some influence on the distribution of activity between suspended solids and dissolved solids since the percentage associated with the dissolved solids decreases from 98 percent at White Oak Dam to 94 percent at Gallaher Bridge, and to 91 percent at Centers Ferry. There is essentially no change, however, from Centers Ferry to Chickamauga Dam.

Mass Curves--Mass (cumulative) curves of strontium-90 loads at all stations except Loudon are shown in figure 4. The Loudon loads have been computed on the assumption that the concentrations found represent flow-weighted concentrations. These monthly loads are shown in figure 4 by the vertical bars extending up from the Centers Ferry load. In preparing all the mass curves in this report, the total activity in each sample was used in the computations; i.e., the total sample activity is determined as the sum of the activities in both the suspended and dissolved solids.

To permit comparison of the total cumulative loads, at successive stations, an estimate of the "normal" time of water travel from station to station was made and lagged time scales were used for plotting the loads accordingly. For example, water flowing out of the mouth of White Oak Creek would be expected to arrive at the Centers Ferry station


ORNL DWG. 65-7110
FIG. 4 MASS DIAGRAM STRONTIUM-90
INDICATES SAMPLING STARTED AT GALLAHER BRIDGE
ACCUMULATED CURIES
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
CHICKAMAUGA DAM
WATTS BAR DAM
CENTERS FERRY + LOUDON
GALLAHER BRIDGE
W.O.C. + 41.5
WHITE OAK CREEK
CENTERS FERRY
O.R. WATER PLANT
1960
1961
1962
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
NOV. 16
NOV. 19
NOV. 21
NOV. 30
DEC. 5

(Clinch River mile 5.5) two days later, and to arrive at Watts Bar Dam nine days later, and at Chickamauga Dam after five more days. Naturally, these times are not constant but vary with streamflows, pool levels, and to some extent with the season of the year. A constant time of travel has been assumed, however, as detailed above, and the plotted data seem to support, over all, the estimated times reasonably well.

The rate of discharge of strontium-90 to Clinch River during the first three months of the sampling period was approximately 4.5 curies per month but at the end of February 1961 the rate was abruptly reduced to approximately 1.2 curies per month, a rate that was maintained quite uniformly throughout the remainder of the two-year sampling period.

The strontium-90 load measured for the Clinch River at the Oak Ridge water plant is also shown in figure 4. The rate of accumulation was quite steady throughout the two-year period, at about 0.29 curies per month, or at about 91 microcuries per square mile per month.

Combining the sum of the two loads, White Oak Creek and Clinch River at Oak Ridge water plant, produces a third curve, also shown in the figure. The curve representing the sum of these two loads exceeds, at the end of sampling, the load measured at Centers Ferry by approximately 13 percent. There is also a slight loss indicated between the stations at Gallaher Bridge and Centers Ferry during the 11 months of record at Gallaher Bridge. Since about 9 percent of the total strontium-90 activity at the Centers Ferry station is associated with the suspended solids, the apparent explanation for part of this loss is sedimentation in the embayment of Clinch River.

Although the daily Loudon samples were not proportioned to streamflow, if it is assumed that they were, a sizable load presumably derived from fallout is shown as flowing down the Tennessee River from the 12,220 square miles of drainage area above this station. The accumulated load, with the above assumption, was found to be about 28 curies representing a contribution, averaged over the 24 months of record, of 96 microcuries per square mile per month.

Additional gains are indicated from the 1,550 square mile drainage area between Centers Ferry plus Loudon and Watts Bar Dam. This gain was 21 curies representing a contribution of approximately 590 microcuries per square mile per month. On the assumption that the Loudon load is not correct (and since the samples were not flow-proportioned, it undoubtedly is not), if the Centers Ferry load is subtracted from the Watts Bar load the contribution per square mile from the intervening area is determined to be 151 microcuries per square mile per month.

There is a large increase in the load at Chickamauga Dam during late February 1962, presumably from fallout following numerous bomb tests (Russian and some American) during the months of September, October, and November 1961. The total accumulated increase between Watts Bar and Chickamauga Dams in the two-year period was approximately 19 curies, representing a contribution of 227 microcuries per square mile per month.

Downstream from the Centers Ferry station, there was a measured gain in the total load from station to station. However, this cannot be interpreted to mean that all the strontium-90 originating at Oak Ridge is transported past Chattanooga, Tennessee. All that can be said on this point, with a reasonable degree of confidence, is that a large percentage of the Oak Ridge load does pass Chattanooga. That quantity of strontium-90 lost from solution and suspension during the two-year sampling period was apparently more than offset by contributions to the river system from fallout. In fact, the two-year load at Chattanooga is over two and one-half times the load passing White Oak Dam.

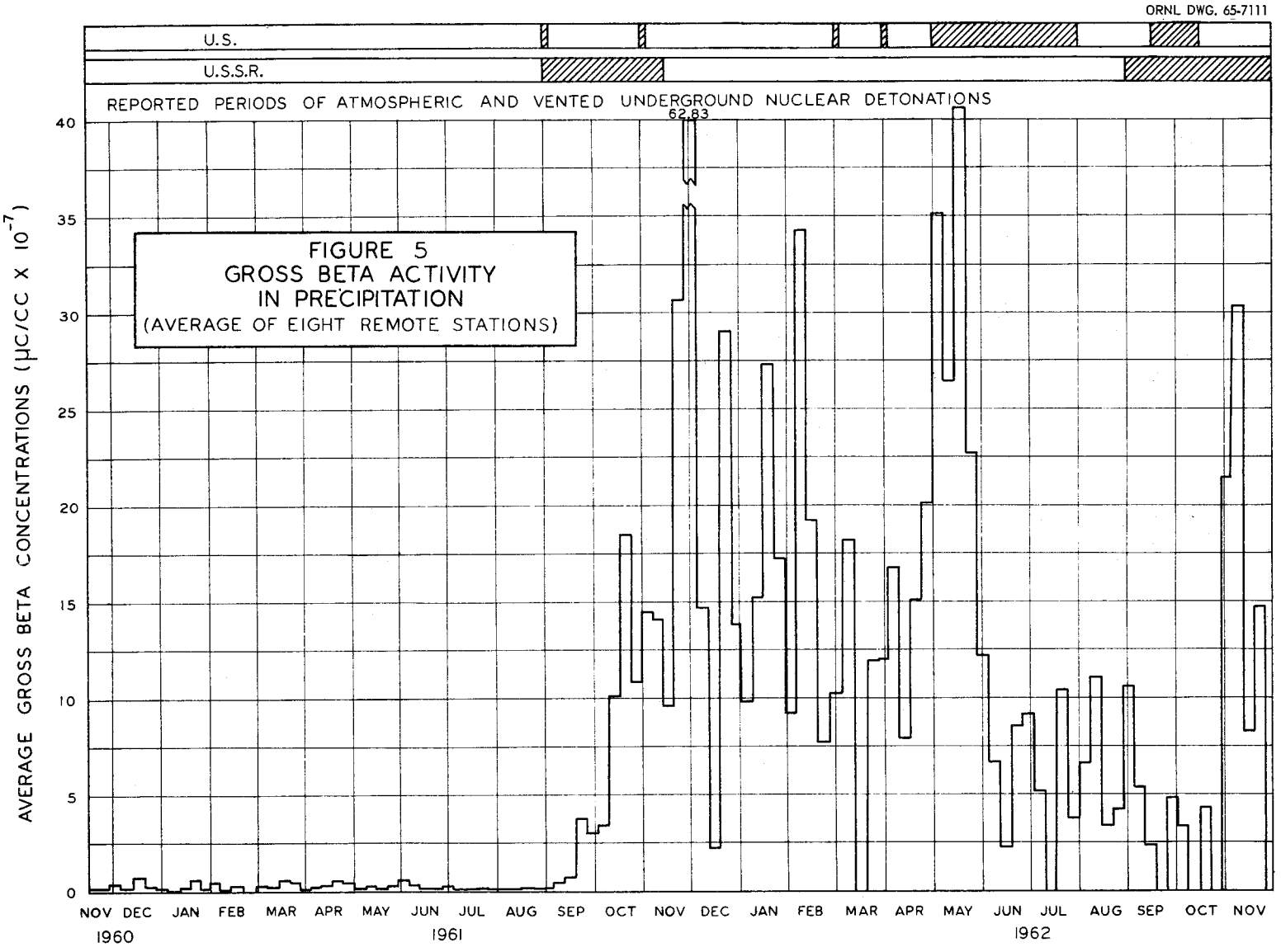
Periods of 1961 and 1962 in which fairly frequent nuclear bomb detonations occurred in both the United States and in the USSR, together with the resultant effects on gross beta concentrations at eight remote (remote from Oak Ridge) precipitation stations are shown in figure 5. (These data were supplied by the Applied Health Physics Section.) The stations were located at Norris, Fort Loudon, Douglas, Cherokee, Watts Bar, Great Falls, and Dale Hollow Dams, and at Berea, Kentucky.

The abrupt increases in the strontium-90 loads during February 1962 at Loudon, Watts Bar Dam, and at Chickamauga Dam would appear to reflect relatively large volumes of runoff containing strontium-90.

Comparison with Load Measured by ORNL--To determine how strontium-90 loads at White Oak Dam, as measured in this study, compare with the same loads measured by the Oak Ridge National Laboratory, these two sets of data were plotted by months in figure 6. Reported loads for several of the individual months are greatly different but for the two years of record, the total load as determined by ORNL was only about 12 percent less than that measured in the Clinch River Study.

Cesium-137, Concentrations and Total Stream Loads

Concentrations of cesium-137 found in all samples at all stations for the two-year period of record are shown in table 2. However, because of extreme difficulty in analyzing the gamma spectrum to identify the activity due strictly to cesium-137 when there is a high concentration of ruthenium-106 present, the data reported here on cesium-137 must be considered only very approximate. Cumulative loads may be reasonably correct (due to tendency for positive and negative errors to balance out), but no great confidence can be placed in any of the cesium-137 data. In retrospect it can be said that the cesium should have been separated chemically or by other means from the samples before any radiological determinations were made.


ORNL DWG. 65-7111
U.S.
U.S.S.R.
REPORTED PERIODS OF ATMOSPHERIC AND VENTED UNDERGROUND NUCLEAR DETONATIONS
62.83
FIGURE 5
GROSS BETA ACTIVITY
IN PRECIPITATION
(AVERAGE OF EIGHT REMOTE STATIONS)
AVERAGE GROSS BETA CONCENTRATIONS (μC/CC X 10^-7)
0
5
10
15
20
25
30
35
40
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
1960
1961
1962

ORNL DWG. 65-7112

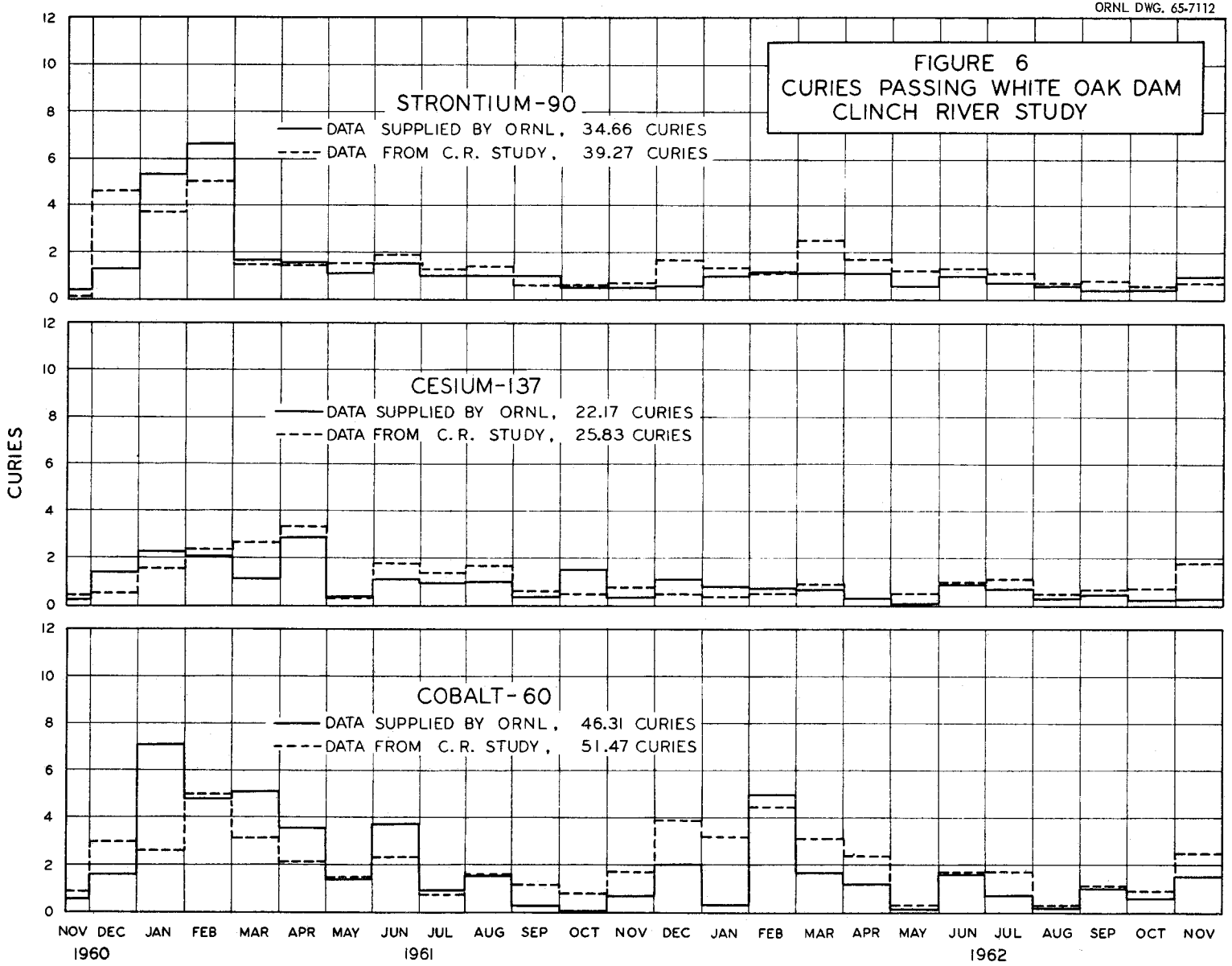


FIGURE 6
CURIES PASSING WHITE OAK DAM
CLINCH RIVER STUDY

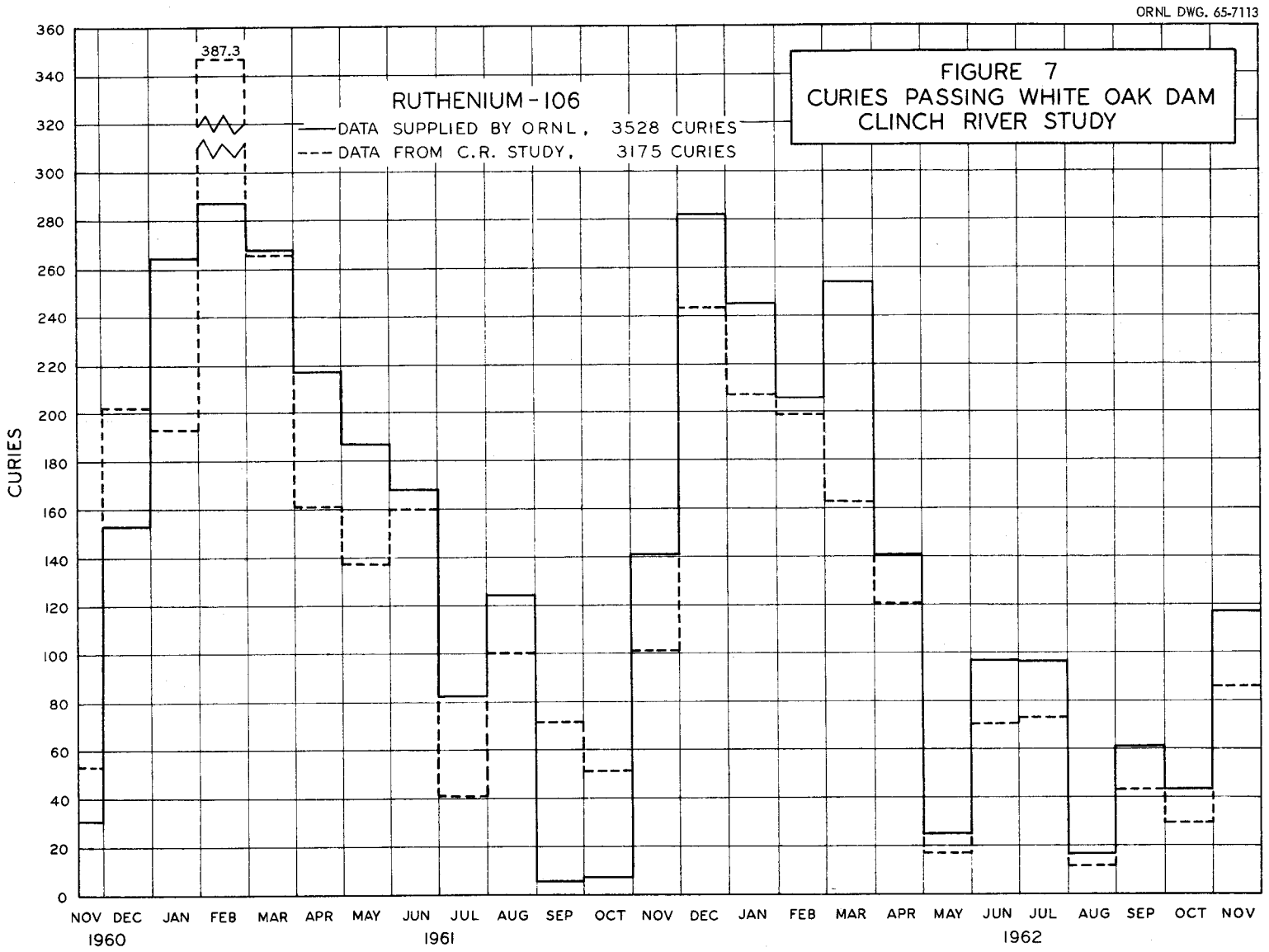

ORNL DWG. 65-7113
FIGURE 7
CURIES PASSING WHITE OAK DAM
CLINCH RIVER STUDY
RUTHENIUM-106
DATA SUPPLIED BY ORNL, 3528 CURIES
DATA FROM C.R. STUDY, 3175 CURIES
387.3
CURIES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
1960
1961
1962

Table 2

CONCENTRATIONS OF CESIUM-137, pc per liter

Date		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960								
11/13-19	TS	1	978		6			
11/20-26	TS	1	-36		11			1
11/27-12/3	TS	1	4,225		6*		2	1
12/4-10	TS	2	778		4		1	0
12/11-17	TS	0	190		-7	10	1	6
12/18-24	TS	1	316		4	for December	1	2
12/25-31	TS	0	74		22		0	2
1961								
1/1-7	TS	1	696		6		0	0
1/8-14	TS	0	688		1	1	-1	0
1/15-21	TS	2	1,383		7	for January	0	0
1/22-28	TS	0	180		3		0	0
1/29-2/4	TS	3	666		1		-2	0
2/5-11	TS	1	2,978		-4		0*	0
2/12-18	TS	2	824		8	34	1	1
2/19-25	TS	5	787		3*	for February	0	0
2/26-3/4	TS	3*	366		4		2	2
3/5-11	TS	2	523		6		2	0
3/12-18	TS	1	2,082		10	SS 1	1	3
3/19-25	TS	5	2,742		6	DS 1	4	2
3/26-4/1	TS	5	1,500*		17	for March	2	4
4/2-8	TS	2	329		4		7	1
4/9-15	TS	0	4,292		1		0	0
4/16-22	TS	0	462		0	SS 0	0	0
4/23-29	SS	0*	832		5	DS 3	TS 0	TS 0
	DS	0	740		0*	for April		

*Value is estimated.
Blank spaces indicate data not available. TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/30-5/6	SS	0	667		3		0	1
	DS	0	43		0*		0	1
5/7-13	SS	0	377		2	0	0	0
	DS	0	0*		0*	0	1	0
						for May		
5/14-20	SS	0*	184		1		0	0
	DS	0	0		0		0	0
5/21-27	SS	0	341		5		0	0
	DS	0	38		1		0	0*
5/28-6/3	SS	0	632		6		0	0
	DS	0	0		0		0	0
6/4-10	SS	0	1,180*		6	0	0	0
	DS	0	0		1	0	0	0
						for June		
6/11-17	SS	0	1,052		7		0	0
	DS	0	-70		0		0	1
6/18-24	SS	1	747		16		0	0
	DS	0	1,310*		-3		0	0
6/25-7/1	SS	1	4,365		13		0	0
	DS	0	426		0		0	0

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/2-8	SS	6	703		1		0	0
	DS	0	87		0		0	0
7/9-15	SS	0	966		3	0	0	0
	DS	0	5,443		0	0	0	0
7/16-22	SS	0	731		4	for July	0	0
	DS	0	1,019*		0		0	0
7/23-29	SS	0	1,190		6		0	0
	DS	0	-65		1		0	0
7/30-8/5	SS	0	1,585		2		0	0
	DS	0	1,178		1		0	0
8/6-12	SS	0	2,188		8	1	0	0
	DS	0	1,492		5	6	0	0
8/13-19	SS	3	1,445		0	for August	0	0
	DS	3	-253		0		0	0
8/20-26	SS	0	1,061		4		0	0
	DS	0	-221		0		0	0
8/27-9/2	SS	0	484		1		0	0
	DS	2	1,341*		0		0	3

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0	TS 1,880*		1		0	2*
	DS	0			0		0	0
9/10-16	SS	0	TS 1,290*		2	0	0	0
	DS	0			0	-2	0	0
9/17-23	SS	0	TS 1,320*		2	for September	0	0
	DS	0			0		0	0
9/24-30	SS	0	TS 1,145*		19		0	0
	DS	0			1		0	0*
10/1-7	SS	0	636		12		0	0
	DS	0	-265		2		0	0
10/8-14	SS	0	571		49	0	0	0
	DS	2	25		6	0	0	1
10/15-21	SS	0	985		29	for October	0	0
	DS	0	315*		0		0	1
10/22-28	SS	0	1,860*		18		0	0
	DS	0	131		1		1	0
10/29-11/4	SS	0	1,156		30		0	0
	DS	0	885		4		0	0

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0	106		116		TS 0	TS 0
	DS	0	1,578		8			
11/12-18	SS	0	823		94	0	0	TS 0
	DS	0	2,330		2	0*	0	
11/19-25	SS	0	159		75*	for November	TS 0*	TS 0
	DS	-2	553		1			
11/26-12/2	SS	0	349		39		0	0
	DS	0	223		1		0	0
12/3-9	SS	0	379		3		0	0
	DS	0	595		2		0	0
12/10-16	SS	0	321		5	0	0	0
	DS	0	0*		-6	0	-2	0
12/17-23	SS	0	96		5	for December	0	1
	DS	-1	0*		0*		-3	-1
12/24-30	SS	0	70		2		0	0
	DS	-1	380*		-6		18	-3

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0	88		1		0	0
	DS	-4	275*		-8		-2	-1
1/7-13	SS	0	71	1	1	0	0	0
	DS	-4	320*	-2	1	-1	-5	-3
1/14-20	SS	0	153	2	2	for January	0	0
	DS	-4	194	-2	-6		0*	0*
1/21-27	SS	0	288	6	2		0	0
	DS	0*	0*	-1	0*		-2	-3
1/28-2/3	SS	0	286	8	TS 1*		0	0
	DS	0*	0*	1			-3	1
2/4-10	SS	-1	308	4	TS 1*		0	0
	DS	0*	170*	-1			0*	-1
2/11-17	SS	0	153	5	3	0	0	0
	DS	-1	430*	-1	-2	-1	0*	0*
2/18-24	SS	-1	590	7	2	for February	0	0
	DS	-9	0*	0	3*		-2	1
2/25-3/3	SS	0	350	5	4		0	0
	DS	0	0*	-2	-2		-4	1*

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	2	301	4	7		0	1
	DS	0	120*	0	1		3*	-4
3/11-17	SS	1	TS 630*	4	6	0	0	1*
	DS	0		-1	0	-1	5	0
3/18-24	SS	1	450	-6	5	for March	3*	0
	DS	-2	75	-4	-1		-1	-1
3/25-31	SS	0	98	5	12		1	0
	DS	-2	197	-3	-3		-1	0
4/1-7	SS	0	141	0	7		0	0
	DS	0	59	4	-2		-2	0
4/8-14	SS	2	203	TS 3*	5	1	0	0*
	DS	-1	0*		1	-1	-2	-3
4/15-21	SS	1	323	5	5	for April	1	0
	DS	0	15*	1	0		0	-2
4/22-28	SS	1	388	2	4		1	0
	DS	0	200*	-1	0		1	-1
4/29-5/5	SS	0	530*	1	2		0	0
	DS	0	288	0	0		0	1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	1	742	2	2		0	0
	DS	-1	202	0	0		0	-2
5/13-19	SS	0	595	4	3	0	0	0
	DS	-1	395*	-1	0	0	0	0
5/20-26	SS	0	973	5	5	for May	0	0
	DS	0*	225*	-2	-2		-1	0
5/27-6/2	SS	0*	1,283	8	7		0	0
	DS	0*	1	0	-1		-1	-1
6/3-9	SS	0	977	9	11		1	0
	DS	-1	425*	0	5		0	-1
6/10-16	SS	0	927	12	5	0	0	0
	DS	-3	250	1	1	-1	-1	-2
6/17-23	SS	0	929	9	22*	for June	0	0
	DS	-1	1,370*	0	-1		0	-1
6/24-30	SS	1	1,070	16	34		0	0
	DS	0	0*	0	1		-1	-1
7/1-7	SS	1	816	15	TS 16*		0	0
	DS	-1	410*	0*			0	-1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/8-14	SS	1	613	18	TS 10*		0	0
	DS	0	370	-1			0	0
7/15-21	SS	0	1,194	8	0	0	0	0
	DS	0	38	1	4	1	-1	0
7/22-28	SS	0*	1,129	3	4*	for July	0*	0
	DS	0	538	0	0		0	-1
7/29-8/4	SS	1	955	1	TS 3*		0	0
	DS	0	68	0			0	0
8/5-11	SS	2	781	TS 24*	TS 49*		0	0
	DS	0	295*				0	1
8/12-18	SS	1	1,124	4	5	0	0	0
	DS	2	155*	0	0	0	0	-3
8/19-25	SS	1	1,210	3	3	for August	0	0*
	DS	1	27	0	1		1	1
8/26-9/1	SS	1	904	3	3		0	0*
	DS	-1	59	0	0		1	0*
9/2-8	SS	0	966	2	5		0	0
	DS	0	73	0	1		1	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/9-15	SS	1	720	6	3		0	0
	DS	0	240*	-5	1		0	0
9/16-22	SS	1	610	8	1	0	0	0
	DS	0	0*	-9	8	0	1	0
9/23-29	SS	0	766	4	3	for September	0	0
	DS	0	970*	0	5		0	0
9/30-10/6	SS	0	710	4	4		2	0
	DS	0	570*	2	0		1	0
10/7-13	SS	1	1,000	4	4		0	0
	DS	0	730	0	4		1	1
10/14-20	SS	0	493	9	5	0	0	0
	DS	0	115	2	0	1	0	-1
10/21-27	SS	0*	280	12	2	for October	0	0
	DS	1	695*	0	1		3	0
10/28-11/3	SS	0	308	11	2		0	0
	DS	1	1,820*	2	1		0	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/4-10	SS	0	282	11	1		0	0
	DS	-1	884	6	1		2	3
11/11-17	SS	1	88	13	3	0	0	2*
	DS	0	2,660*	1	4	0	1*	0
11/18-24	SS	0*	410	9	4	for November	1	0
	DS	-3	656	12	0*		-1	0
11/25-12/1	SS	0	359	8	1			0
	DS	0		2	3			0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the following tabulation:

Station	Sample Showing Highest Concentration Cesium-137	
	Concentration	Period of Occurrence
	pc per liter	
Clinch R. at Oak Ridge water plant	6	Jul. 2-8, 1961, and Aug. 13-19, 1961
White Oak Creek at White Oak Dam	6,409	Jul. 9-15, 1961
Clinch R. at Gallaher Bridge	21	Nov. 18-24, 1962
Clinch R. at Centers Ferry	35*	Jun. 24-30, 1962
Tennessee R. at Loudon, Tenn.	34	Feb. 5-11, 1961
Tennessee R. at Watts Bar Dam	18	Dec. 24-30, 1961
Tennessee R. at Chickamauga Dam	6	Dec. 11-17, 1960

*Omitting high values during period September 10 through December 2, 1961, when sampling equipment was not functioning properly.

Since even the maximum concentrations at all stations are far below MPC values for drinking water used by the general population, mean concentrations at the various stations were not computed.

To determine what portion of the total cesium-137 activity is associated, on the average, with the suspended solids, and what portion with the dissolved solids (including, of course, those very fine suspended solids not removed by the supercentrifuge), a simple average percentage was computed for each of the two portions from the determinations made on all samples from each station, with results as shown in the following tabulation. Median concentrations are also indicated.

Distribution of Cesium-137 in Water Samples

Station	Percent Total Activity in Suspended Solids		Percent Total Activity in Dissolved Solids	
	Mean	Median	Mean	Median
Clinch R. at Oak Ridge water plant	82	100	18	0
White Oak Creek at White Oak Dam	69	79	31	21
Clinch River at Gallaher Bridge	92	100	8	0
Clinch River at Centers Ferry	86	100	14	0
Tennessee River at Watts Bar Dam	30	0	70	100
Tennessee River at Chickamauga Dam	19	0	81	100

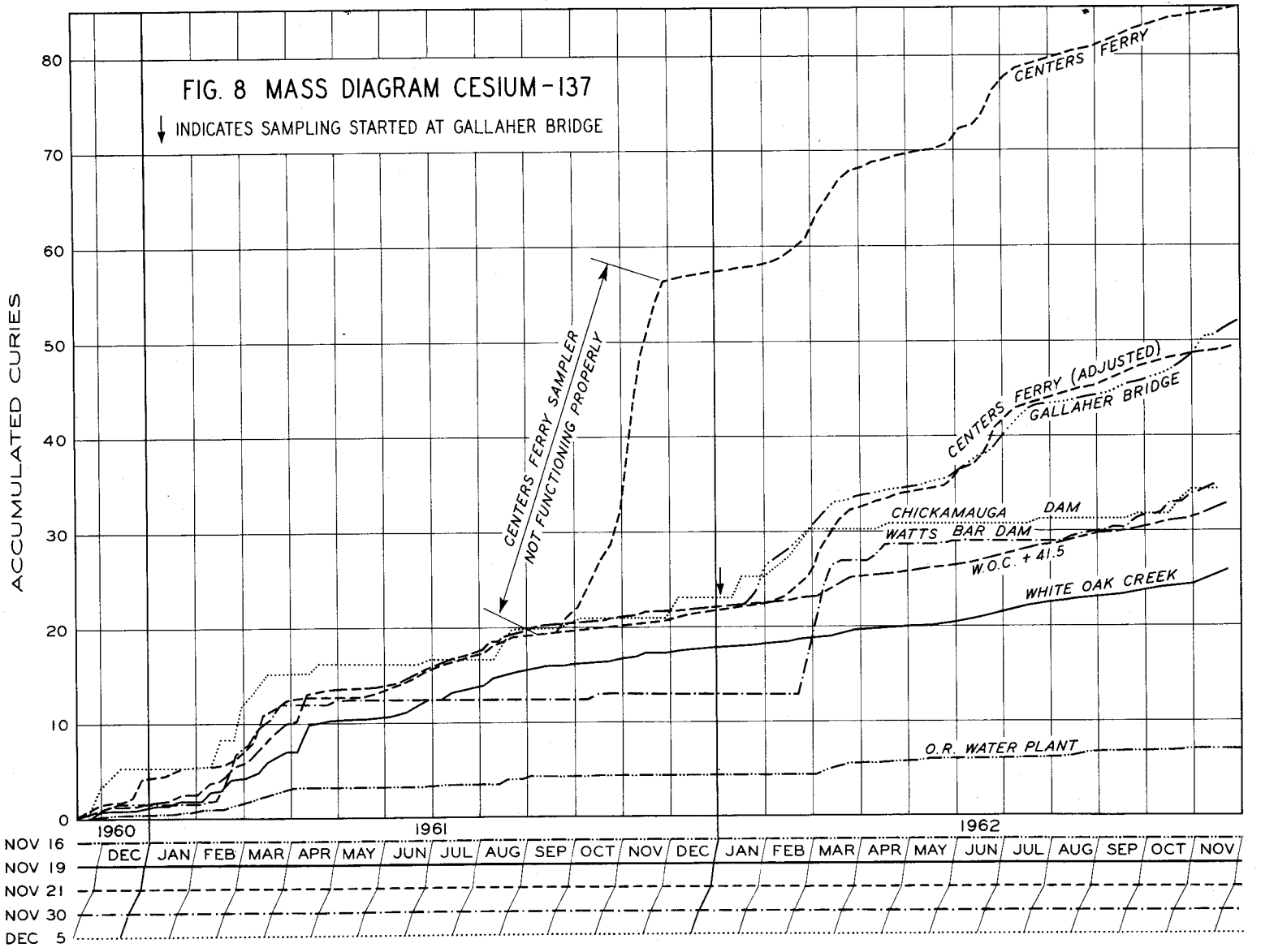
In marked contrast with strontium-90, the great bulk (69 to 92 percent) of the cesium-137 load is associated with the suspended solids in the water samples collected from White Oak Creek and from Clinch River. The Tennessee River samples, however, show 70 to 81 percent of the load to be in solution and/or associated with the very fine solids not removed by the supercentrifuge. This indicates that practically all the Clinch River sediment has settled by the time the Watts Bar Dam and Chickamauga Dam stations are reached and that only the very fine particulate matter and its contained activity remains.

Mass Curves--Mass curves of cesium-137 loads at all stations except Loudon, are shown in figure 8. In spite of a basic lack of accuracy in all cesium-137 determinations, the agreement shown in the discussion under "Comparison with Load Measured by ORNL," page 40, indicates the mass curve for White Oak Creek probably is reasonably accurate. The rate of discharge of cesium-137 to Clinch River was quite variable for the period November 1960 to April 1961, but thereafter, through November 1962, the rate of discharge was reasonably steady at about 0.8 curie per month.

The outstanding feature of all these curves that immediately catches the eye is the extremely great load shown for Centers Ferry in the fall of 1961. Due to a malfunctioning of the sampling equipment here during this period, as explained in detail in Progress Report No. 3, the reported load is undoubtedly incorrect. If the curve value for December 1, 1961, is adjusted to about 21 curies (the value obtained by extending the curve established prior to about October 1), and the load thereafter accumulated from this value, the entire mass curve for this station appears more reasonable, and is very similar to that for Gallaher Bridge.

Although there is considerable question about the accuracy of all cesium-137 determinations, still there is an indicated increase in the cesium-137 loads during 1962 between White Oak Creek and Gallaher Bridge that is quite substantial. Such an increase might be attributed to lack of accuracy were it not for the fact that when the Centers Ferry load is plotted in the lower position as discussed above, the Gallaher Bridge and Centers Ferry loads check each other amazingly well. This increase cannot logically be attributed to scouring of silt from the riverbed in the reach between White Oak Creek and Centers Ferry since the load seems to have increased more or less continuously throughout the year, and not just during the high river flows of January, February, and March 1962. Although limited accuracy in analysis of the cesium-137 samples casts serious doubts into the situation, and although a careful field investigation of this situation has previously been made by P. H. Carrigan and R. J. Pickering, still the indication of a sizable increase in the Clinch River load of this radionuclide at some point(s) below the mouth of White Oak Creek is sufficiently definite to warrant a "second look" by personnel familiar with the possibilities of seepage from disposal pits, and with all other possible sources of this radionuclide.

ORNL DWG. 65-7114



Because of the very limited accuracy of analysis, particularly in the dilute samples collected from the Tennessee River, no detailed discussion of the mass curves for Watts Bar and Chickamauga Dams is warranted.

Comparison with Load Measured by ORNL--The data for cesium-137 plotted in figure 6 indicate reasonable agreement during most months of record between the loads as determined by the Oak Ridge National Laboratory and as determined in the Clinch River Study. The total load for the two-year period as determined by ORNL (22.17 curies) was about 14 percent less than that determined in the Clinch River Study (25.83 curies).

Cobalt-60, Concentrations and Total Stream Loads

Concentrations of cobalt-60 found in all samples at all stations for the two-year period of record are shown in table 3.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including activity in both suspended and dissolved solids) are shown below:

Station	Sample Showing Highest Concentration Cobalt-60	
	Concentration	Period of Occurrence
	pc per liter	
Clinch River at Oak Ridge water plant	5	Jul. 22-28, 1962
White Oak Creek at White Oak Dam	5,095	Nov. 12-18, 1961
Clinch River at Gallaher Bridge	18	Nov. 18-24, 1962
Clinch River at Centers Ferry	52	Jun. 11-17, 1961
Tennessee River at Loudon, Tenn.	1	*
Tennessee River at Watts Bar Dam	3	**
Tennessee River at Chickamauga Dam	3	Feb. 18-24, 1962, Jun. 17-23, 1962, and Aug. 12-18, 1962

*This value occurred in several samples throughout the sampling period.

**This value occurred five times, March to October 1962, inclusive.

Table 3

CONCENTRATIONS OF COBALT-60, pc per liter

Date		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960								
11/13-19	TS	0	2,302		4			
11/20-26	TS	0	4,679		8		1*	0
11/27-12/3	TS	0	3,734		8		1	0
12/4-10	TS	2	2,521		3		1	1
12/11-17	TS	0	3,156		6	0	1	0
12/18-24	TS	0	3,147		12	for December	1	0
12/25-31	TS	1	3,391		12		1	0
1961								
1/1-7	TS	0	2,022		19		1	1
1/8-14	TS	0	2,246		2		1	1
1/15-21	TS	0	3,656		3	0	2	2
1/22-28	TS	0	2,533		3	for January	1	2
1/29-2/4	TS	0	3,611		2		1	2
2/5-11	TS	0	3,817		34		1*	1
2/12-18	TS	0	2,765		28	1	0	1
2/19-25	TS	0	1,784		5*	for February	2	1
2/26-3/4	TS	0*	1,418		4		1	1
3/5-11	TS	0	1,046		2		0	0
3/12-18	TS	0	1,526		4	SS 0	0	0
3/19-25	TS	0	1,861		2	DS 0	0	0
3/26-4/1	TS	0	1,657		3	for March	0	0
4/2-8	TS	0	1,612		13		0	0
4/9-15	TS	0	1,566		4	SS 0	0	0
4/16-22	TS	0	1,521		10	DS 0	1	0
						for April		

*Value is estimated.

Blank spaces indicate data not available. TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/23-29	SS	0*	157		1			
	DS	0	852		1*		TS 1	TS 0
4/30-5/6	SS	0	254		0		0	0
	DS	0	102		1		0	0
5/7-13	SS	0	182		0	0	0	0
	DS	0	1,578		7	0	1	0
5/14-20	SS	0*	9		0	for May	0	0
	DS	0	1,921		4		0	1
5/21-27	SS	0	69		2		0	0
	DS	0	1,303		8		0	0*
5/28-6/3	SS	0	147		1		0	0
	DS	0	928		2		1	0
6/4-10	SS	0	940*		1	0	0	0
	DS	0	1,893		2	0	0	0
6/11-17	SS	0	302		3	for June	0	0
	DS	0	2,037		49		0	1
6/18-24	SS	0	240		3		0	0
	DS	0	1,831		15		0	0
6/25-7/1	SS	0	201		2		0	0
	DS	0	1,051		6		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/2-8	SS	0	125		1		0	0
	DS	0	791		0		0	1
7/9-15	SS	0	210		0	0	0	0
	DS	0	2,104		1	0	1	1
7/16-22	SS	0	1,191		4	for July	0	0
	DS	0	0*		4		1	1
7/23-29	SS	0	151		1		0	0
	DS	0	541		2		0	0
7/30-8/5	SS	0	1,018		0		0	0
	DS	0	1,163		0		0	0
8/6-12	SS	0	344		0		0	0
	DS	0	1,767		0		0	0
8/13-19	SS	0	407		0	0	0	0
	DS	0	1,192		0	0	0	0
8/20-26	SS	0	248		1	for August	0	0
	DS	0	1,119		4		0	0
8/27-9/2	SS	0	111		0		0	0
	DS	0	2,625*		1		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0	TS 3,155*		0		0	0*
	DS	0			0		0	0
9/10-16	SS	0	TS 2,490*		0	0	0	0
	DS	0			0	0	0	1
9/17-23	SS	0	TS 2,644*		0	for September	0	0
	DS	0			0		0	0
9/24-30	SS	0	TS 2,061*		2		0	0
	DS	0			0		0	0*
10/1-7	SS	0	112		1		0	0
	DS	0	1,044		1		0	0
10/8-14	SS	0	115		5	0	0	0
	DS	0	747		2	0	0	0
10/15-21	SS	0	123		4	for October	0	0
	DS	0	1,175*		0		0	0
10/22-28	SS	0	3,175*		2		0	0
	DS	0	417		1		0	0
10/29-11/4	SS	0	215		4		0	1
	DS	0	3,694		4		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0	68		16		TS 0	TS 0
	DS	0	3,097		6			
11/12-18	SS	0	286		12	0	0	TS 0
	DS	0	4,809		3	0*	1	
11/19-25	SS	0	103		5*	for November	TS 0*	TS 0
	DS	0	3,293		7			
11/26-12/2	SS	0	139		7		0	0
	DS	0	2,230		2		1	1
12/3-9	SS	0	102		0		0	0
	DS	0	3,734		9		1	0
12/10-16	SS	0	130		1	0	0	0
	DS	0	2,208		14	0	2	0
12/17-23	SS	0	53		1	for December	0	0
	DS	0	730		16		0	1
12/24-30	SS	0	45		1		0	0
	DS	0	1,771		6		1	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0	74		0		0	0
	DS	0	1,699		5		0	0
1/7-13	SS	0	87	0	0		0	0
	DS	0	1,875*	1	6		1	0
1/14-20	SS	0	66	1	0	0	0	0
	DS	1	1,659	9	1	0	0	1
1/21-27	SS	0	175	1	1	for January	0	0
	DS	0	1,602	8	20		1	0
1/28-2/3	SS	0	134	1	TS 10*		0	0
	DS	0	773	1			0	0
2/4-10	SS	0	1,584	4	TS 12*		0	0
	DS	0	3,499	5			-1	1
2/11-17	SS	0	371	2	2	0	0	0
	DS	1	2,608	2	5	1	1*	2*
2/18-24	SS	0	326	2	1	for February	0	0
	DS	1	1,129	10	4		2	3
2/25-3/3	SS	0	242	1	1		0	0
	DS	0	844	6	3		3	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	0	173	1	1		0	0
	DS	1	1,216	3	1		0	1
3/11-17	SS	0	TS 1,675*	0	1	0	0	0*
	DS	1		1	0	1	1	0
3/18-24	SS	0	248	-2	1	for March	0*	0
	DS	0	796	0	3		2	2
3/25-31	SS	0	60	2	1		0	0
	DS	1	1,468	6	1		1	1
4/1-7	SS	0	94	0	1		0	0
	DS	1	1,483	13	1		3	2
4/8-14	SS	0	129	3	2	0	0	0*
	DS	0	1,384	3*	13	1	1	1
4/15-21	SS	0	122	2	1	for April	1	0
	DS	1	1,108	7	5		1	1
4/22-28	SS	0	90	1	1		1	0
	DS	3	1,026	1	1		2	1
4/29-5/5	SS	0	0*	0	1		0	0
	DS	2	1,420	1	0		3	1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	0	150	1	0		0	0
	DS	0	692	1	1		2	0
5/13-19	SS	0	74	1	0	0	0	0
	DS	1	198	1	2	1	0	0
5/20-26	SS	0	136	1	1	for May	0	0
	DS	0*	40	2	1		0	1
5/27-6/2	SS	0*	187	0	1		0	0
	DS	0*	423	1	0		1	0
6/3-9	SS	0	436	2	3		0	0
	DS	0	1,931	4	7		0	1
6/10-16	SS	0	584	3	2	0	0	0
	DS	0	2,540	6	5	0	0	0
6/17-23	SS	0	258	2	8*	for June	0	0
	DS	0	910	2	3		2	3
6/24-30	SS	0	575	4	6		0	0
	DS	1	1,392	4	6		2	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	0	534	4	TS 8*		0	0
	DS	1	1,359	4*			1	0
7/8-14	SS	0	392	4	TS 2*	0	0	0
	DS	1	1,822	5		1	3	1
7/15-21	SS	0	173	2	0	for July	0	0
	DS	1	56	0	0		2	0
7/22-28	SS	0*	352	1	0*		0*	0
	DS	5	1,821	4	0		1	0
7/29-8/4	SS	0	310	0	0		0	0
	DS	1	1,482	1	1*		1	1
8/5-11	SS	0	38	TS 20*	TS 16*		0	0
	DS	1	992				0	1
8/12-18	SS	0	196	1	1	0	0	0
	DS	1	97	2	1	1	0	3
8/19-25	SS	0	186	0	0	for August	0	0*
	DS	1	10	0	0		1	1
8/26-9/1	SS	0	141	0	1		0	0*
	DS	1	33	1	1		2	1*

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/2-8	SS	0	126	0	0		0	0
	DS	1	17	1	2		0	0
9/9-15	SS	0	177	1	1	0	0	0
	DS	0	774	4	2	1	0	0
9/16-22	SS	0	270	2	3	for September	0	0
	DS	1	2,198	9	10		0	1
9/23-29	SS	0	201	0	1		0	0
	DS	2	1,788	0	4		1	0
9/30-10/6	SS	0	204	1	1		0	0
	DS	0	1,767	5	2		2	0
10/7-13	SS	0	225	2	1		0	0
	DS	1	2,151	6	8		3	0
10/14-20	SS	1	42	1	1	0	0	0
	DS	2	590	2	3	1 for October	1	0

SS = suspended solids.

DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/21-27	SS	0*	10	2	0		0	0
	DS	0	1,087	3	2		1	1
10/28-11/3	SS	0	36	2	0		0	0
	DS	2	1,299	2	2		0	0
11/4-10	SS	0	13	2	0		0	0
	DS	1	2,123	8	4		2	1
11/11-17	SS	0	0	2	0	0	0	0*
	DS	0	1,603	14	11	1 for November	2*	0
11/18-24	SS	0*	227	3	1		0	0
	DS	1	1,981	15	15		2	1
11/25-12/1	SS	0	79	2	0		0*	0
	DS	2		6	3		0*	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Even the maximum concentrations of cobalt-60 found at all stations are far below MPC values. Consequently, mean concentrations were not computed.

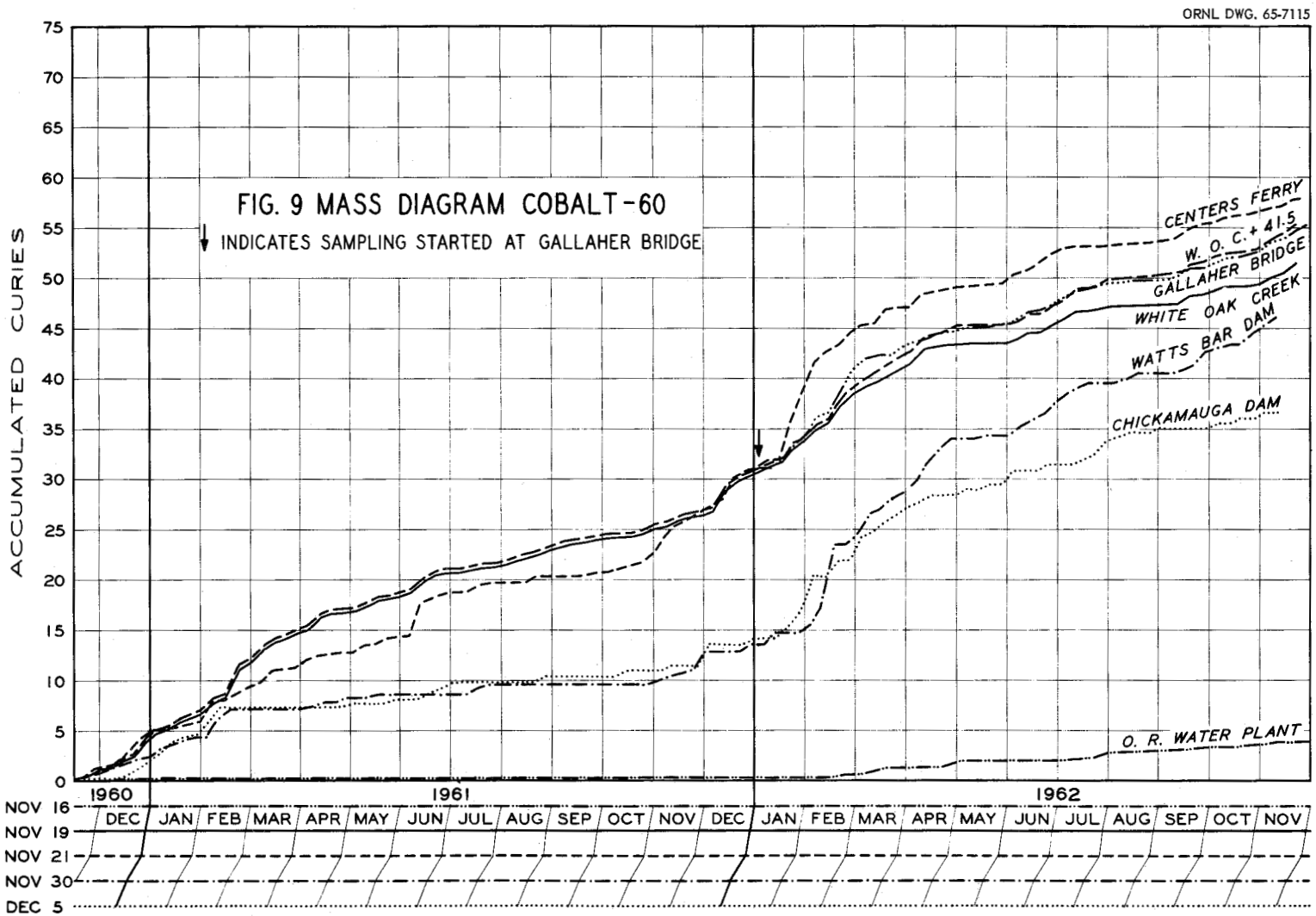
The distribution of cobalt-60 activity between the suspended and dissolved solids in the samples is summarized in the following tabulation. Percentages are arithmetic averages of all samples. Median percentages are also indicated.

Distribution of Cobalt-60 in Water Samples

Station	Percent Total Activity in			
	Suspended Solids		Dissolved Solids	
	Mean	Median	Mean	Median
Clinch River at Oak Ridge water plant	5	0	95	100
White Oak Creek at White Oak Dam	19	12	81	88
Clinch River at Gallaher Bridge	27	25	73	75
Clinch River at Centers Ferry	30	25	70	75
Tennessee River at Watts Bar Dam	2	0	98	100
Tennessee River at Chickamauga Dam	3	0	97	100

These data indicate 70 to 98 percent of the total cobalt-60 present in the water phase is actually in solution. In White Oak Creek and in Clinch River, approximately 20 to 30 percent of the cobalt-60 present is associated with the suspended solids, but in the Tennessee River the percentage drops to only 2 or 3 percent. This would seem to indicate loss of sediment (and the associated activity) from the water phase in a downriver direction.

Mass Curves--Mass curves of cobalt-60 loads at all stations are shown in figure 9. The curves for White Oak Dam, Gallaher Bridge, and Centers Ferry plot reasonably close together throughout the period of record. Thus there seems to have been no significant loss of this radionuclide in Clinch River. Actually there was an apparent gain in load at Centers Ferry during January and February 1962. However, because of malfunctioning of the sampling equipment at the Centers Ferry station, the reported load at this station might be incorrect. If the curve value for December 1, 1961, is adjusted to about 22 curies (the value obtained by extending the curve established prior to about October 1), and the load thereafter accumulated from this value, the mass curve for this station would fall slightly below the curve for Gallaher Bridge.


ORNL DWG. 65-7115
FIG. 9 MASS DIAGRAM COBALT-60
INDICATES SAMPLING STARTED AT GALLAHER BRIDGE
ACCUMULATED CURIES
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
CENTERS FERRY
W. O. C. + 41.5
GALLAHER BRIDGE
WHITE OAK CREEK
WATTS BAR DAM
CHICKAMAUGA DAM
O. R. WATER PLANT
1960
1961
1962
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
NOV 16
NOV 19
NOV 21
NOV 30
DEC 5

The total load for the two-year sampling period would be about 53 curies. The curves could then be interpreted as showing a very slight loss of cobalt-60 in Clinch River due to sedimentation.

Curves for both Watts Bar and Chickamauga Dams indicate a cumulative loss from the load measured at both White Oak Dam and at Centers Ferry. However, most of this loss is indicated to have occurred during the spring and summer of 1961. From November 1961 through November 1962, the curves for White Oak Creek and Chickamauga Dam are surprisingly parallel. Thus during this period the only effect discernible in the river system was dilution, since the load going in at White Oak Dam arrived later, undiminished, at Chattanooga.

Comparison with Load Measured by ORNL--The data for cobalt-60 plotted in figure 6 indicate serious disagreement in measured loads at White Oak Dam for many of the individual months, but over all the total load during the two-year period was found to be 46.31 curies by ORNL and 51.47 curies by the subcommittee. These values represent a difference of about 10 percent.

Ruthenium-106, Concentrations and Total Stream Loads

Concentrations of ruthenium-106 found in all samples for the period of available record at all stations are shown in table 4.

A factor not noted in earlier progress reports, which could affect reported concentrations to some extent, is the presence of ruthenium-103 (half life = 40 days) and possibly other fission products from weapons fallout, in the samples. Since the mean storage time of the samples prior to counting was approximately 60 to 80 days, measurable quantities of the ruthenium-103 could have been present if the samples contained relatively fresh fallout material. Unfortunately the age and quantities of fallout entering the river cannot be estimated from the available data. Any ruthenium-103 present in the samples would be reported as ruthenium-106 since the respective radionuclides are not distinguishable by the methods used in the study. However, the quantities of ruthenium-103 present are believed to be relatively insignificant in relation to the amounts of ruthenium-106 released via White Oak Creek.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the tabulation on page 66. Flow-weighted mean concentrations are also shown.

In only White Oak Creek do the maximum concentrations exceed MPC values for drinking water. Mean concentrations at all sampling stations except White Oak Creek at the dam, are far below MPC values for drinking water.

Table 4

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960								
11/13-19	TS	10	140,424		234			
11/20-26	TS	47	268,169		337			269
11/27-12/3	TS	2	252,368		772		62	38
12/4-10	TS	223	184,714		187		51	74
12/11-17	TS	16	244,604		683	3	77	152
12/18-24	TS	2	192,009		845	for December	59	73
12/25-31	TS	218	217,883		812		117	61
1961								
1/1-7	TS	4	141,791		1,434		96	86
1/8-14	TS	1	171,891		123		174	62
1/15-21	TS	3	294,412		415	0	168	133
1/22-28	TS	1	188,843		384	for January	90	117
1/29-2/4	TS	10	218,938		189		121	88
2/5-11	TS	2	292,517		2,480		100*	97
2/12-18	TS	5	208,479		2,633	2	55	76
2/19-25	TS	7	145,070		415*	for February	112	46
2/26-3/4	TS	10*	87,955		384		192	144
3/5-11	TS	11	98,092		406		91	82
3/12-18	TS	3	125,074		312	SS 0	165	64
3/19-25	TS	2	157,283		347	DS 49	77	38
3/26-4/1	TS	0	144,464		222	for March	66	46

*Value is estimated.

Blank spaces indicate data not available.

TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961	Clinch River at Oak Ridge Water Plant		White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/2-8	TS	13	119,620		1,344		61	52
4/9-15	TS	13	106,627		548		56	42
4/16-22	TS	8	121,368		1,263	SS 0	106	38
4/23-29	SS	0*	8,781		117	DS 62 for April	TS 131	TS 46
	DS	123	108,972		260*			
4/30-5/6	SS	14	13,657		39		2	1
	DS	32	15,769		195		84	74
5/7-13	SS	0	9,981		56		2	2
	DS	14	187,918		704		119	30
5/14-20	SS	9*	2,909		32	0	2	8
	DS	20	173,094		392	6 for May	83	107
5/21-27	SS	2	11,004		115		2	5
	DS	6	74,265		523		70	110*
5/28-6/3	SS	1	8,389		91		1	0
	DS	27	76,363		220		83	121
6/4-10	SS	4	76,650*		42		6	4
	DS	12	159,271		215		91	54
6/11-17	SS	3	11,899		219	0	0	2
	DS	11	145,841		646	19 for June	87	61

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
6/18-24	SS	4	4,789		304		1	2
	DS	29	123,519		1,154		67	56
6/25-7/1	SS	2	3,386		230		0	1
	DS	7	55,609		740		55	36
7/2-8	SS	24	3,063		3		10	3
	DS	60	67,066		8		120	80
7/9-15	SS	0	3,013		19	1	3	3
	DS	3	88,547		58	3	95	59
7/16-22	SS	0	5,841		50	for July	1	3
	DS	7	68,000*		475		64	59
7/23-29	SS	2	1,966		38		3	2
	DS	169	54,769		190		55	29
7/30-8/5	SS	0	3,680		0		6	0
	DS	16	104,740		185		41	36
8/6-12	SS	1	4,756		0		0	0
	DS	0	153,758		148		25	45
8/13-19	SS	1	4,411		0	1	0	0
	DS	185	75,093		5	2	84	18
						for August		

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
8/20-26	SS	1	5,615		13		0	0
	DS	3	90,162		385		20	6
8/27-9/2	SS	9	2,030		7		2	2
	DS	1	180,500*		128		26	39
9/3-9	SS	1	TS 197,800*		2		3	1*
	DS	7			10		41	19
9/10-16	SS	1	TS 154,600*		4	1	1	1
	DS	4			7	64	23	33
9/17-23	SS	5	TS 159,750*		5	for September	2	2
	DS	19			6		13	14
9/24-30	SS	1	TS 125,950*		26		0	2
	DS	1			6		7	8*
10/1-7	SS	2	1,331		21		0	1
	DS	5	62,173		26		0	4
10/8-14	SS	1	570		115		2	1
	DS	2	52,204		155		6	3
10/15-21	SS	1	1,076		51	0	1	2
	DS	4	128,700*		42	8	3	1
						for October		

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/22-28	SS	-1	224,100*		27		1	2
	DS	3	21,361		18		17	8
10/29-11/4	SS	2	5,704		58		0	1
	DS	0	209,186		324		10	16
11/5-11	SS	1	1,536		390		TS 5	TS 9
	DS	129	238,627		292			
11/12-18	SS	1	8,313		367	2	1	TS 88
	DS	8	282,698		212	145*	75	
11/19-25	SS	4	2,544		135*	for November	TS 60*	TS 85
	DS	12	199,997		424			
11/26-12/2	SS	4	3,478		320		3	6
	DS	7	138,438		183		54	32
12/3-9	SS	4	3,356		38		6	3
	DS	8	225,385		620		63	42
12/10-16	SS	8	4,576		37	4	0	2
	DS	60	134,500		805	292	73	53
12/17-23	SS	11	1,685		24	for December	5	4
	DS	30	52,830		975		125	80
12/24-30	SS	5	1,298		23		3	6
	DS	24	114,025		404		39	69

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	4	1,707		13		14	5
	DS	38	128,816		353		45	33
1/7-13	SS	9	1,913	12	13		6	3
	DS	75	120,000*	182	399		83	53
1/14-20	SS	5	1,585	50	12	8	8	2
	DS	71	108,171	719	376	2	136	210
1/21-27	SS	7	3,890	37	24	for January	3	1
	DS	50	103,473	512	542		81	90
1/28-2/3	SS	9	3,026	29	TS 235*		5	5
	DS	3	70,115	213			81	55
2/4-10	SS	6	1,955	21	TS 200*		4	6
	DS	-1	94,595	138			21	42
2/11-17	SS	8	1,960	18	24	8	7	4
	DS	1	93,361	130	121	5	18*	40*
2/18-24	SS	24	3,772	52	23	for February	7	8
	DS	8	85,337	482	289		50	53
2/25-3/3	SS	27	2,110	34	20		10	3
	DS	-23	54,187	273	189		104	53

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	10	2,270	17	21		4	3
	DS	6	79,094	127	60		26	30
3/11-17	SS	11	TS 87,600*	18	10	4	7	4*
	DS	3		73	58	64	57	88
3/18-24	SS	15	3,298	18	25	for March	10*	4
	DS	4	44,402	80	171		25	33
3/25-31	SS	10	1,259	52	13		13	6
	DS	-1	85,423	238	174		52	23
4/1-7	SS	12	1,772	14	41		9	9
	DS	9	81,578	635	97		30	33
4/8-14	SS	31	3,320	86	64		6	12*
	DS	34	72,501	200*	680		41	32
4/15-21	SS	6	1,971	78	42	1	6	7
	DS	-3	52,418	284	376	32	75	47
4/22-28	SS	5	1,698	24	16	for April	15	7
	DS	27	62,902	87	78		51	61
4/29-5/5	SS	4	1,700*	13	11		1	5
	DS	41	81,897	66	40		65	41

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	3	1,900	22	11		3	5
	DS	-2	40,756	53	36		26	22
5/13-19	SS	4	882	17	13	1	2	3
	DS	3	13,735	22	45	2	33	4
5/20-26	SS	4	817	12	10	for May	4	1
	DS	4*	36,860	27	14		18	8
5/27-6/2	SS	TS 5*	2,153	17	12		2	4
	DS		23,237	23	14		9	11
6/3-9	SS	3	7,850	31	53		4	5
	DS	-1	108,784	140	276		11	9
6/10-16	SS	5	8,553	52	42	5	0	0
	DS	2	132,388	215	342	8	7	4
6/17-23	SS	7	3,982	39	320*	for June	1	1
	DS	-1	56,020	72	148		7	1
6/24-30	SS	4	17,146	69	110		1	2
	DS	-1	46,056	204	247		16	12

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962	Clinch River at Oak Ridge Water Plant		White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry		Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	1	13,168	83	TS	250*		2	4
	DS	-1	64,164	170*				21	16
7/8-14	SS	3	6,397	88	TS	225*		3	1
	DS	0	92,971	223				21	13
7/15-21	SS	2	790	25		130*	2	5	1
	DS	3	3,260	32		15	3	30	18
7/22-28	SS	0*	3,538	22		100*	for July	2*	1
	DS	15	91,380	118		28		25	15
7/29-8/4	SS	3	3,714	9	TS	80*		2	3
	DS	8	74,957	78				17	33
8/5-11	SS	5	1,811	TS 98*	TS	65*		2	3
	DS	5	46,233					13	28
8/12-18	SS	2	665	17		24	0	4	1
	DS	4	3,111	65		-5	4	-5	19
8/19-25	SS	4	1,105	6		4	for August	1	0*
	DS	9	1,206	4		14		18	18

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
8/26-9/1	SS	2	350	3	3		2	0*
	DS	7	1,107	4	8		8	7*
9/2-8	SS	4	338	5	5		1	0
	DS	0	1,127	21	5		0	1
9/9-15	SS	3	1,800	11	9	1	1	2
	DS	-1	34,130	91	54	6	12	2
9/16-22	SS	4	3,740	39	70	for September	1	1
	DS	21	89,381	363	436		11	0
9/23-29	SS	4	1,870	8	10		2	1
	DS	3	77,720	101	136		8	8
9/30-10/6	SS	4	2,798	21	17		3	1
	DS	13	61,193	168	103		33	0
10/7-13	SS	4	2,644	27	30	0	4	5
	DS	6	72,965	197	298	3	22	4
						for October		

*Value is estimated.

SS = suspended solids.

DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/14-20	SS	12	524	23	20		4	2
	DS	5	22,192	38	75		25	21
10/21-27	SS	4*	440	20	7		2	4
	DS	11	38,291	53	41		75	32
10/28-11/3	SS	0	940	25	7		1	2
	DS	8	49,971	46	63		23	23
11/4-10	SS	6	1,058	47	11	5	6	3
	DS	2	73,832	247	155	6	15	11
						for November		
11/11-17	SS	10	417	74	20		2	2*
	DS	7	60,470	462	391		23*	5
11/18-24	SS	0*	4,035	57	24		3	2
	DS	17	67,577	655	686		25	6
11/25-12/1	SS	6	1,388	43	13		TS 30*	4
	DS	7		149	129			26

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Maximum and Mean Concentrations of Ruthenium-106

Station	Highest Concentration	Period of Occurrence	Flow-Weighted Mean Concentration
	pc per liter		pc per liter
Clinch R. at Oak Ridge water plant	223	Dec. 4-10, 1960	23
White Oak Creek at White Oak Dam	294,412	Jan 15-21, 1961	109,800
Clinch R. at Gallaher Bridge	769	Jan. 14-20, 1962	345*
Clinch R. at Centers Ferry	2,633	Feb. 12-18, 1961	317
Tenn. R. at Loudon, Tenn.	296	December 1961	**
Tenn. R. at Watts Bar Dam	192	Feb. 26-Mar. 4, 1961	63
Tenn. R. at Chickamauga Dam	269	Nov. 20-26, 1960	51

*Record begun January 8, 1962.

**Not applicable.

The distribution of ruthenium-106 activity between the suspended and dissolved solids in the samples is summarized in the following tabulation. Percentages are arithmetic averages of all samples. Median percentages are also indicated.

Distribution of Ruthenium-106 in Water Samples

Station	Percent Total Activity in			
	Suspended Solids		Dissolved Solids	
	Mean	Median	Mean	Median
Clinch River at Oak Ridge water plant	44	29	56	71
White Oak Creek at White Oak Dam	6	4	94	96
Clinch River at Gallaher Bridge	21	17	79	83
Clinch River at Centers Ferry	21	16	79	84
Tennessee River at Watts Bar Dam	11	7	89	93
Tennessee River at Chickamauga Dam	15	8	85	92

From these data it is apparent that from 79 to 94 percent of the ruthenium-106 activity is associated with the dissolved solids, or in other words, dissolved in the water itself. Neither the time of contact with the suspended solids, nor sedimentation, appear to have any significant influence on the distribution of activity between suspended solids and dissolved solids since the percentage associated with the dissolved solids decreases from 94 percent at White Oak Dam to 79 percent at Centers Ferry, then goes back up to 89 percent at Watts Bar, and back down to 85 percent at Chickamauga Dam.

Mass Curves--Cumulative curves of ruthenium-106 loads at all stations except Loudon are shown in figure 10.

During the first year of sampling, the mass curves for all stations below White Oak Creek agree quite closely with that for White Oak Creek; then, beginning in the fall of 1961 and continuing through March 1962, the downriver curves diverge to some extent. From March through November 1962, the curves remain essentially parallel to each other. The divergence in early 1962 appears to reflect the effect of fallout from weapons testing. (See figure 5, page 23.)

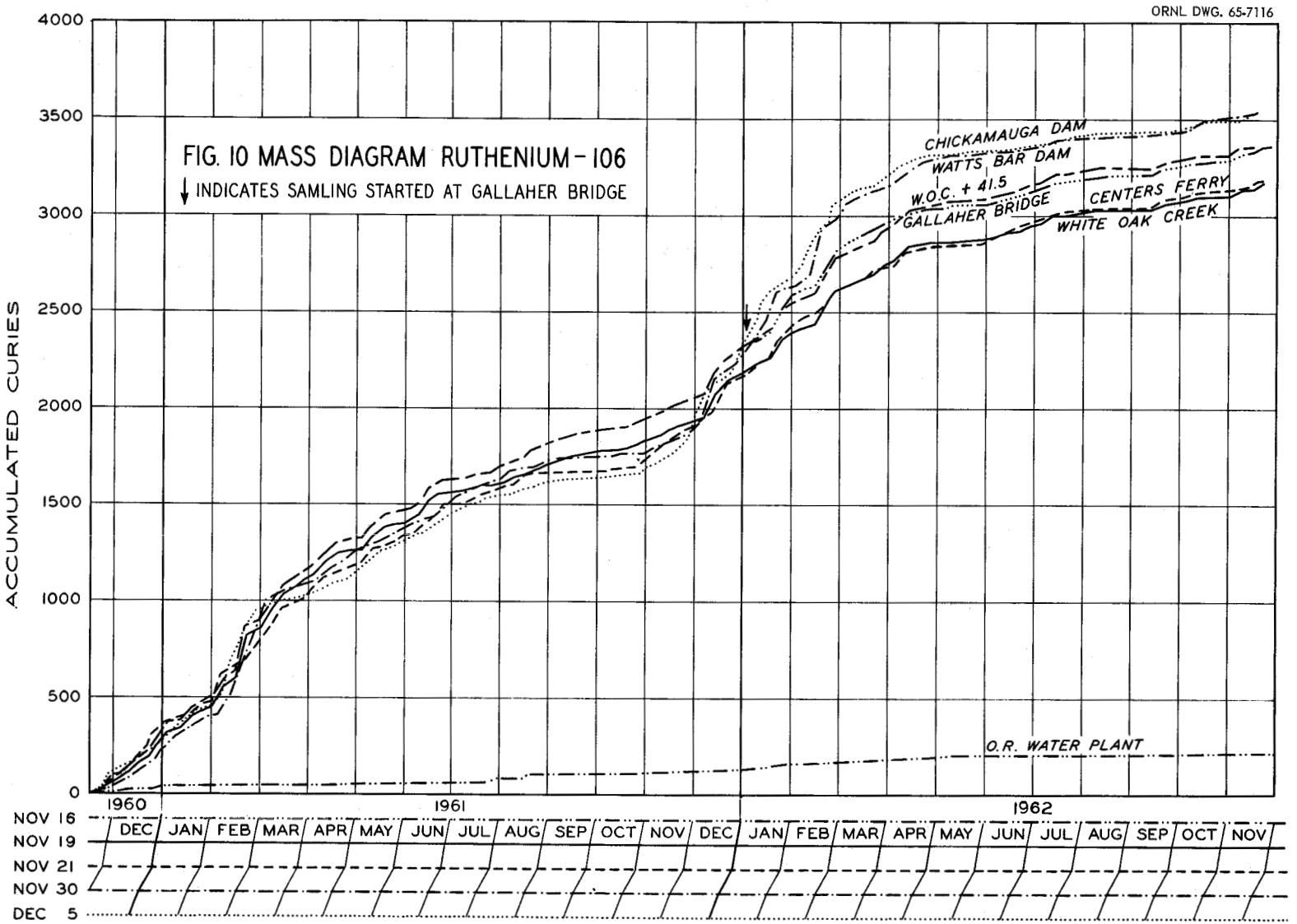
Throughout the two-year period the curve for Centers Ferry is practically identical to the one for White Oak Creek. Likewise, during the last 11 months of record the curve for White Oak Creek plus the Oak Ridge water plant is nearly identical to that for Gallaher Bridge. Throughout the entire period of record, the curves for Watts Bar Dam and Chickamauga Dam are essentially the same.

Based on the rather amazing agreement between the cumulative loads measured at all stations below White Oak Dam with the load measured at White Oak Dam, it can be definitely concluded that during the two-year sampling period essentially all the ruthenium-106 discharged from Oak Ridge passed through the river system to Chattanooga in the water phase. That ruthenium-106 which is found in bottom sediments between Oak Ridge and Chattanooga must represent the continued accumulation over the years of a very small percentage of the annual load discharged at Oak Ridge.

The good agreement in the cumulative loads measured at the successive stations indicates considerable confidence can be placed in the methods used throughout the study in sampling and compositing.

Comparison with Loads Measured by ORNL--As with the other radionuclides, comparison of monthly loads at White Oak Dam as measured by the subcommittee and by ORNL, indicates several rather serious disagreements, as shown in figure 7, page 25. However, comparison of cumulative loads measured over longer periods indicates better agreement, as might be expected.

The first 12-month period (December 1960 through November 1961) shows a total discharge of about 1,900 curies of ruthenium-106 at White Oak Dam as measured by the subcommittee, while the second 12-month period


ORNL DWG. 65-7116
FIG. 10 MASS DIAGRAM RUTHENIUM-106
↓ INDICATES SAMLING STARTED AT GALLAHER BRIDGE
ACCUMULATED CURIES
4000
3500
3000
2500
2000
1500
1000
500
0
CHICKAMAUGA DAM
WATTS BAR DAM
W.O.C. + 41.5
GALLAHER BRIDGE
CENTERS FERRY
WHITE OAK CREEK
O.R. WATER PLANT
1960
1961
1962
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
NOV 16
NOV 19
NOV 21
NOV 30
DEC 5

(December 1961 through November 1962) shows a total discharge of about 1,300 curies. Data supplied by the Oak Ridge National Laboratory show a total discharge of 1,906 curies at White Oak Dam during the first 12-month period and a total discharge of 1,586 curies for the second 12-month period. Thus in comparing the total loads reported in this study with those reported by ORNL, the total loads for the first 12-month period are found to be identical. On the other hand, the difference of nearly 300 curies during the last 12-month period represents a disagreement of approximately 22 percent. If the White Oak Creek load for the last 12 months of record as measured by the subcommittee, were increased by 300 curies, it would equal almost exactly that measured for Chickamauga Dam. This probably indicates a negative bias in the White Oak Creek values reported by the subcommittee for the last 12-month period. (See figure 10, page 68.)

Effects of Operation of Melton Hill Dam on Dispersion of Radionuclides

The operation of Melton Hill Dam at mile 23.1 on Clinch River will change the hydraulic pattern of releases of radioactive waters from White Oak Creek into Clinch River. The potential effects of this altered hydraulic pattern on the dispersion of radioactive waters originating at the Oak Ridge National Laboratory have been investigated cooperatively in the field by personnel of the U. S. Geological Survey and of the Oak Ridge National Laboratory.

From results of these dispersion studies that have been and are being reported separately, the subcommittee concludes that although the time versus concentration pattern of radionuclides will be altered drastically in the Clinch River embayment of Watts Bar Reservoir, the pattern of dispersion in the Tennessee River will not be altered sufficiently from that observed during the two-year study reported here to justify reactivation of the network of sampling stations.

Recommendations

Recommendations 1, 2, and 3 concern the monitoring program which the subcommittee feels must be continued indefinitely at and below Oak Ridge. Recommendations 4, 5, and 6 concern improvements that should be made in studies of the type reported here, should such a study be reinitiated in the future at and below Oak Ridge, or put into operation by others at some other location for similar purposes.

1. (a) Continuous monitoring and proportional sampling should be continued at White Oak Dam, and weekly composite samples should be examined for concentrations of strontium-90, cesium-137, cobalt-60, and ruthenium-106. Arrangements should be made to keep this station rated since knowledge of continuous streamflow rates at this station is essential.

(b) Proportional sampling should be initiated very soon and continued indefinitely on the power discharge of Melton Hill Dam. Weekly composite samples should be examined for radionuclide activity.

(c) Proportional sampling should be initiated very soon and continued indefinitely at or near the present location of the water intake in Clinch River of the Oak Ridge Gaseous Diffusion Plant. Volumes of river water, proportioned to the instantaneous rate of river discharge at the intake site, should be added to the composite sample at intervals of not more than 15 minutes. Such samples, composited weekly, should be examined for the radionuclides of importance unless sample results at White Oak Dam, or at Melton Hill Dam, indicate need for more frequent examination.

(d) If at any time in the future it becomes reasonably possible for any significant load of radionuclides to enter Clinch River downstream from the monitoring station at the water intake of the Oak Ridge Gaseous Diffusion Plant, either the station should be moved far enough downstream to intercept such additional inflow, or an additional downstream monitoring station should be established.

2. Since the Oak Ridge National Laboratory and the Public Health Service will both be monitoring Clinch River below White Oak Creek, these two agencies, and any others that may collect radiological samples here, should compare results obtained on regularly scheduled split samples. This is essential to prevent differences in technique, equipment, etc., from introducing disagreement in routine sampling results.

3. The Public Health Service should be supplied with part of each weekly composite sample collected at the water intake of the Oak Ridge Gaseous Diffusion Plant. The Public Health Service should be requested in a letter from the Chairman of the Clinch River Study Steering Committee, to utilize these samples in the radiological determinations made on water samples collected at this station in its Water Pollution Surveillance System.

4. If any detailed study of this nature is made in the future, it would be extremely helpful in determining cesium-137 activity levels if this radionuclide were extracted from the sample by the best chemical separation technique available, prior to counting. In any situation where the gamma spectrum of a radionuclide of importance is seriously masked by some other radionuclide, chemical separation, as well as gamma spectrometry, should be used. The most sensitive, yet accurate, technique and

equipment available should be applied to the determination of the concentration of each radionuclide. It would be helpful if a few "dry runs" were made at all proposed sampling stations prior to the initiation of routine sampling, to determine the volumes of samples needed at the various stations to provide sufficient activity, after concentration, for accurate measurements.

5. It is recommended for any future study of this nature that the actual, and relative concentrations of radionuclides in the suspended and dissolved solids be determined as carefully as possible in a limited number of special samples collected at such times as would permit detection of the influences, if any, on relative concentrations, of such factors as water chemistry, streamflows, particle sizes, time of flow below Oak Ridge, water temperature, and possibly other variables. To provide needed information on precision and reproducibility of results, more effort than in the present study should be directed toward duplicate processing of " whole samples," and in processing duplicate samples (twice the needed volume, mixed and split).

6. If a network of sampling stations is needed for future studies of this general nature, a companion network of precipitation stations would be desirable to provide information on the fallout contribution to the radionuclide load.

Respectfully submitted,

SUBCOMMITTEE ON WATER SAMPLING AND ANALYSIS

M. A. Churchill, Chairman
J. S. Cragwall, Jr.
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