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**Mercury Abatement Report
on the U.S. Department of Energy
Oak Ridge Y-12 Plant for Fiscal Year 1995**

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Energy Systems Environmental Restoration Program

**Mercury Abatement Report
on the U.S. Department of Energy
Oak Ridge Y-12 Plant for Fiscal Year 1995**

Date Issued—November 1995

Prepared by
The Oak Ridge Y-12 Plant
Oak Ridge, Tennessee

Prepared for the
U.S. Department of Energy
Office of Environmental Management
under budget and reporting code EW 20

Environmental Management Activities at the
OAK RIDGE Y-12 PLANT
Oak Ridge, Tennessee 37831-8169
managed by
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

PREFACE

The *Mercury Abatement Report on the U.S. Department of Energy Oak Ridge Y-12 Plant for Fiscal Year 1995* was prepared in accordance with the requirements under the National Pollutant Discharge Elimination System permit (TN0002968) issued (April 28, 1995) to the Oak Ridge Y-12 Plant. This work was performed under work breakdown structure 1.4.12.1.1.03.44 (activity data sheet 2303, "Upper East Fork Poplar Creek"). This permit requires annual reporting of activities and progress toward achieving compliance goals agreed to between DOE and the State of Tennessee related to mercury releases into Upper East Fork Poplar Creek. Publication of this document meets an annual milestone of November 28, 1995. The document compares scheduled and actual completion dates for several corrective actions; summarizes results of characterization efforts that both identified mercury sources for elimination and demonstrated achievement of source eliminations; and outlines the nature and schedules for future corrective actions and monitoring.

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ABBREVIATIONS

BMAP	Biological Monitoring and Abatement Program
BMP	best management practice
CMTS	Central Mercury Treatment System
EFPC	East Fork Poplar Creek
g/d	grams per day
gal/min	gallons per minute
lhgTU	Interim Mercury Treatment Unit
mg/d	milligrams per day
NPDES	National Pollutant Discharge Elimination System
RMPE	Reduction of Mercury in Plant Effluent
TSS	total suspended solids
Y-12 Plant	Oak Ridge Y-12 Plant

1. INTRODUCTION

This Annual Mercury Abatement Report for fiscal year 1995 summarizes the status of activities and the levels of mercury contamination in East Fork Poplar Creek (EFPC) resulting from activities at the U.S. Department of Energy's Oak Ridge Y-12 Plant. The report outlines the status of the on-going project activities in support of project compliance, the results of the ongoing sampling and characterization efforts, the biological monitoring activities, and our conclusions relative to the progress in demonstrating compliance with the National Pollutant Discharge Elimination (NPDES) permit.

Overall, the pace of mercury activities at the Y-12 Plant is ahead of the compliance schedules in the NPDES permit and new and exciting opportunities are being recognized for achieving additional mercury reductions. These opportunities were not felt to be achievable several years ago.

2. DESIGN/CONSTRUCTION/PROJECT SUMMARY

As part of the plan for achieving compliance with the permit limits for mercury, the activities discussed in the following sections have been completed or are ongoing.

2.1 SOURCE ELIMINATION FOR BUILDING 9201-2

The project was completed in July 1994 and resulted in the elimination of Outfall 49 and the reduction of mercury loading from Outfall 55. The NPDES compliance date for this activity was December 1, 1995.

2.2 INTERIM MERCURY TREATMENT UNIT IN BUILDING 9201-2

The Interim Mercury Treatment Unit (IHgTU) began operation in August 1994. Treated water from the IHgTU is discharged through Outfall 55A to Outfall 55. Approximately 4,000,000 gal of water have been treated. The operation of the unit in conjunction with the source elimination work in 9201-2 has resulted in a reduction of mercury loading from 9201-2 to EFPC from 3.25 g/d to <0.5 g/d.

Currently, the IHgTU treats 20 gal/min. A project is in the planning stages to upgrade the IHgTU to a permanent system called the East End Treatment System with the capacity to treat 30 gal/min. This project is scheduled to be completed in March 1996. Added capacity to allow additional mercury-contaminated water from Building 9202 to be treated will be provided if ongoing investigative work determines the need for this water to be treated.

2.3 SOURCE ELIMINATION FOR BUILDING 9201-5

The original scope of the project, which involved rerouting and/or replacement of mercury contaminated piping, was completed in January 1995. Additional scope, which consisted of consolidating the sump water from 9201-5 and 9201-4 into an existing underground tank, was completed in October 1995. Routing of the sump water to the tank provided isolation of the sump water from 9201-5 and 9201-4 and will allow monitoring of the remaining discharges from these buildings and verification of the pipe rerouting and replacement effort. The tank will serve as the interface point for the Central Mercury Treatment System (CMTS) to pick up the sump water when it becomes operational. The NPDES compliance date for this activity is June 1, 1996.

2.4 SOURCE ELIMINATION FOR BUILDING 9201-4

The project was completed in October 1995. Verification of the pipe rerouting and replacement is ongoing. The NPDES compliance date for this activity is September 1, 1996.

2.5 SOURCE ELIMINATION FOR BUILDING 9204-4

The project is scheduled for completion November 1995. In addition to the rerouting and replacement of piping in 9204-4, this project also will provide tanks and piping for the collection of sump water from the building. The collected sump water will be transported to the CMTS for treatment. The NPDES compliance date for this activity is January 1, 1997.

2.6 CENTRAL MERCURY TREATMENT SYSTEM

The CMTS will be installed in the Central Pollution Control Facility and will treat the sump waters from 9201-4, 9201-5, and 9204-4. Design of the CMTS was completed in October 1995, and construction is scheduled to begin in November 1995. The CMTS is tentatively scheduled to begin operation in January 1997. The NPDES compliance date for this activity is January 1, 1998.

2.7 MERCURY AIR STRIPPING TEST FACILITY AT OUTFALL 51

The Mercury Air Stripping Test Facility at Outfall 51 is a pilot operation designed to investigate the potential for removal of mercury from contaminated groundwater. Outfall 51 is a spring discharging to EFPC south of Building 9201-2. This outfall is permitted for groundwater flow and monitored weekly (report only) for mercury.

A portion of the flow from Outfall 51 is being collected, flowed through an air stripper, filtered, and discharged back to EFPC. The facility began operation August 1, 1995, and investigative efforts are planned to continue for 3 to 6 months.

Table 2.1. Status of mercury treatment and remediation activities.

ACTIVITY	COMPLIANCE COMPLETION DATE	ACTUAL/FORECAST COMPLETION DATE
Source Elimination—9201-2	12/1/95	7/30/94
Source Elimination—9201-5	6/1/96	1/31/95 - original scope 10/31/95 - added scope
Source Elimination—9201-4	9/1/96	10/31/95
Source Elimination—9204-4	1/1/97	11/31/95
Central Mercury Treatment System	1/1/98	1/31/97
East End Treatment System	1/1/98	3/31/96

3. CHARACTERIZATION OF MERCURY SOURCES

Point sources of mercury constitute almost all of the dry weather loading of mercury to upper EFPC. These sources include (1) Hg-contaminated shallow groundwater that is captured in basement sumps in several buildings and then pumped into the storm drain system, (2) Hg-contaminated natural spring flow into the creek via Outfall 51, and (3) Hg-contaminated piping both internal and external to several buildings through which water (mainly cooling water and condensate) passes en route to the creek. The nature of generic sources (1) and (3) is illustrated schematically in Figure 3.1. Virtually all of these sources supply mercury to the creek via one or more recognized outfalls (Figure 3.2). Characterization of these sources has been ongoing intermittently since 1982, with more comprehensive surveys conducted in the mid-1980s, 1990, and 1993-95. Generally only the results from the most recent surveys and other monitoring efforts will be presented and discussed here. Martin Marietta Energy Systems' reports, Y/TS-90, *Sources and Discharges of Mercury in Drainage Waters at the Oak Ridge Y-12 Plant*; and Y/ER-116, *Mercury Abatement at Y-12: A Progress Report*, provide detailed results from earlier characterization efforts.

3.1 BASEMENT SUMPS

The first semicomprehensive survey of mercury in basement sumps occurred in 1985 when all 16 sumps in 9201-4 and 9201-5 were sampled for total mercury analysis in September of that year (Table 3.1). The results from that time period, when combined with estimates of the pumping rates of each sump, suggested that the combined daily Hg loading from these sumps could constitute 5 to 10 g, thus representing a significant source of mercury to the creek when compared with recent Hg loading of 13 to 25 g/d at Station 17. These sumps were resampled comprehensively again in 1993, 1994, and 1995 (Table 3.1). Water meters (cumulative type) were installed concurrently on each sump to provide better flow estimates and efforts were begun to eliminate all other sources of flow except shallow groundwater. These efforts were largely completed by late 1994 or early 1995. As shown in Table 3.1, mercury concentrations in individual sumps have varied only slightly over the 10-year period. The exception to this general observation is Sump A in 9201-4, which declined sharply between September 1993 and August 1994. No explanation for this decline has been found. Although the latest Hg concentration and water flow information for this sump indicate only a trivial Hg loading (0.01 g/d), flow from this sump will still be routed to the CMTS (Figure 3.2). On the other hand, flow from Sumps B and H in 9201-5 (Figure 3.2) will not be routed to the CMTS because of their long monitoring record showing low Hg loading.

Based on the 1994-95 results, the combined loading from the sumps in 9201-4, 9201-5, and 9204-4 constitutes ~5 g/d. Thus, it is expected that routing flow from these sumps through the CMTS will reduce the Hg loading to the creek by a similar amount. As discussed in Chap. 6, it is not clear that this point source reduction will translate into an equivalent reduction at the Plant boundary (Station 17).

Figure 3.1. Foundation and equipment drains provide Hg source and pathway to surface water.

Figure 3.2. Schematic drawing of buildings, sumps, drain lines, outfalls, and surface water monitoring locations that are relevant to the Y-12 Plant's mercury abatement program. Note that this drawing is not to scale, nor is it a complete representation of all facilities.

Table 3.1. Results of sump water sampling in Buildings 9201-4, 9201-5, and 9204-4 and estimate of flow and mercury loading to the creek in 1995.

Building	Sump	Total Hg ($\mu\text{g/L}$)										Flow	Hg Load
		9/11/85	8/9/93	8/24/93	9/20/93	9/28/93	8/31/94	9/14/94	11/29/94	1/17/95	94-95 Mean	(gal/min)	(g/d)
9201-4	A	85	44	99	58	19	0.6	0.3	0.5	3.2	1.2	1.68	0.011
9201-4	B	164	440	400	370	370	300	290	220	160	243	0.04	0.053
9201-4	C	87	36	36	36	38	12	15	19	46	23	0.34	0.043
9201-4	D	80	39	45	39	33	50	41	30	34	39	0.49	0.103
9201-4	E	258	250	260	190	210	220	240	190	150	200	0.47	0.512
9201-4	F	156	190	250	190	95	190	230	81	370	218	0.66	0.783
9201-4	G	21	27	15	11	11	11	11	9.1	8.2	9.8	3.39	0.182
9201-4	H	56	50	35	93	26	22	25	20	17	21	0.1	0.011
9201-5	A	15	2	0.7	1	0.6	1.3	0.7	8.5	8.4	4.7	2.85	0.073
9201-5	B	<1	<0.2	0.3	0.2	<0.2	0.3	0.7	<0.2	<0.2	0.25	0.05	0.000
9201-5	C	88	130	110	90	92	140	130	81	83	109	2.18	1.289
9201-5	D	10	8	8.4	7.2	5.6	27	24	27	19	24	3.6	0.476
9201-5	E	33	72	64	61	66	75	90	52	88	76	1.3	0.540
9201-5	F	155	490	320	380	1000	460	460	460	210	398	0.33	0.715
9201-5	G	120	70	76	56	42	23	21	16	23	21	1	0.113
9201-5	H	8	1	1	<0.2	<0.2	2.3	1.4	1.4	1.1	1.6	6.48	0.055
9204-4	Elevator			230	62	120	37	21	43	43	36	0.04	0.008

3.2 OUTFALLS AND OTHER SURFACE WATER MONITORING SITES

Results from a 1993 comprehensive sampling and analysis of all outfalls (Figure 3.3) that were flowing during dry weather were used to prepare a "short list" of outfalls for further evaluation as mercury sources to the creek. These include Outfall 47/48, 49, 51, 55, 113, 150, 160, 169, and 200 (also known as North/South Pipe). To appear on this list an outfall generally must have exceeded 2.0 $\mu\text{g/L}$ in mercury concentration or 1.0 g/d in loading at least once during the 1993 survey. Outfall 150 has been retained on the list, even though it did not meet either the concentration or loading criteria in 1993, because it represents one of the largest water flows in the Y-12 Plant and because of its proximity to Building 9201-4. In addition to outfalls, other key surface water monitoring sites have been identified for continuing evaluation. These include Station 17 (9422-1), Station 8 (9422-3), 9422-15, and 9422-16. The monitoring site at 9422-16 has not shown Hg concentrations or loadings indicative of important Hg sources upstream. The site is included among the key sites for Hg because it represents flow from a large portion of the western area of the Y-12 Plant, including areas suspected, but not yet verified, to be potential Hg sources. The locations of these outfalls and monitoring sites are shown in Figure 3. 2.

3.2.1 Outfall 47/48

These outfalls, which are interconnected (Figure 3.2), receive dry weather flow from the Y-12 Plant Development Division complex (e.g., Building 9202) and wet weather flow from the northeastern corner of 9201-2. Historical mercury spills were recorded within this subbasin both at 9202 and 9201-2 (See Union Carbide report Y/EX-24, *Mercury at the Y-12 Plant*). As indicated in Figure 3.3, these outfalls approached or exceeded the concentration or loading criteria during the 1993 survey. Apparently in response to pipe reroutes, and perhaps the addition of tablet dechlorinators on several flows at 9202, mercury concentrations have declined over the summer of 1995. For example, monthly grab sample Hg concentrations at Outfall 47 (48 has been dry) over the period beginning June 20, 1995, and ending October 10, 1995, were 1.3, 0.6, 0.7, 0.4, and 0.4 $\mu\text{g/L}$. These values contrast with values ranging from 1.2 to 2.9 $\mu\text{g/L}$ observed during the summer and fall of 1993. Estimated dry weather loading from these outfalls now appears to be <0.1 g/d. As discussed subsequently, monthly (grab) and quarterly (24-h composite) monitoring of these outfalls will be continued through FY 1996 to ensure that the recent decline in Hg loading is permanent. Some adjustments in the final destination (storm or sanitary sewer) of discharges from 9202 are still in progress and could further alter the mercury loading at these outfalls.

3.2.2 Outfall 49

This outfall received process and sump water from the eastern section of Building 9201-2. In the 1980s and early 1990s water flow from this outfall ranged from 30 to 40 gal/min and mercury

Figure 3.3. Average flow, mercury concentration, and mercury loading for outfalls sampled four or more times between July and December 1993.

concentration ranged from 13 to 41 $\mu\text{g/L}$. Until 1994 when it was eliminated, this outfall was the strongest source of mercury in the eastern Y-12 Plant area (8 g/d in 1990) and once accounted for as much as 30% of the total outfall loading for the Y-12 Plant (Figure 3.4). Just before its elimination on July 15, 1994, all flow (e.g., cooling water, roof drains) to the outfall except from Sump E-22 had been routed through clean conduits to Outfall 55. Thus, the final monitoring results for Outfall 49 essentially reflect Hg loading from the E-22 sump ($\sim 15 \mu\text{g/L}$ and 0.025 g/d). The IHgTu has been used since 9/94 to remove mercury from both sump E-22 and O-12 in Building 9201-2.

3.2.3 Outfall 51

This outfall drains a large spring located just south of Building 9201-2 which actually covers a portion of the original spring throat. A video survey of the outfall in September 1995 revealed that the 15-inch concrete pipe that forms the outfall terminated in a box-shaped opening with water boiling up through the gravel floor. No other pipes or entrants to the opening were observed. The ground location of the subsurface opening corresponds closely with the edge of the original spring throat. The annual range of water flow rate from this spring has not been accurately determined, in part because the outfall floods (becomes embayed during stormflow in EFPC). Flow measurements from the 1993 comprehensive survey of outfalls showed a range from 66 to 130 gal/min. Mercury concentrations in the outfall have varied over a relative narrow range (3 to 8 $\mu\text{g/L}$) and there appears to be a slight inverse relationship between spring flow rate and mercury concentration. Mercury loading from this outfall has varied between about 2 and 3 g/d. Mercury in this outfall exhibits unique speciation among other outfalls at Y-12: up to 50% of the mercury is in the elemental form and thus is potentially air-strippable. This characteristic is the basis for research and development efforts directed at identifying cost-effective treatment.

3.2.4 Outfall 55

This outfall receives process and sump water from Building 9201-2. Flow rates have ranged from 40 to more than 100 gal/min. Until recently mercury concentrations averaged about 2 $\mu\text{g/L}$ while Hg loading ranged up to slightly over 1.0 g/d. The combination of strategic pipe replacement (source elimination) and sump water treatment (IHgTU) have significantly reduced the Hg concentration and loading at this outfall (Figure 3.5). Mercury concentrations have consistently been less than the laboratory reporting limit of 0.2 $\mu\text{g/L}$ since April 1995. Included among the data plotted on Figure 3.5 are grab sample results for the outfall during rainfall when roof drains were actively contributing flow to the outfall. Before pipe replacement, some roof drains were connected to Hg-contaminated pipes.

3.2.5 Outfall 113

This outfall receives process and cooling water from several buildings, including 9731, 9735, 9736, 9737 which house, or have housed, research and development laboratories. Dry weather flow from this outfall has been low (1 to 5 gal/min) or absent since 1993. Mercury concentrations

Figure 3.4. Temporal trend in mercury concentration and loading at Outfall 49. Note that dates are not plotted proportionally.

have most often been close to or less than the reporting limit of $0.2 \mu\text{g/L}$, but on two occasions in 1993 (9/14 and 10/29) the mercury concentration was high enough (7.3 and $2.3 \mu\text{g/L}$) to qualify for further evaluation. Subsequently, results (<0.2 to $0.5 \mu\text{g/L}$) for the outfall have not confirmed the need for further evaluation and none has been performed. The outfall will continue to be monitored on a monthly basis through 1996.

3.2.6 Outfall 150

Historically (1982–83) this outfall, which drains the area just east of 9201-4 (Figure 3.2), contributed 10 to 20 g/d of mercury to the creek. Water flow (currently about 400 gal/min, historically 900 gal/min) from this outfall is among the highest of any at the Y-12 Plant and thus even low mercury concentration can mean significant mercury loading. During the comprehensive survey conducted in 1993 mercury concentrations were all below the reporting limit of $0.2 \mu\text{g/g}$ except for the last sampling event (12/16/93) when the concentration was $0.25 \mu\text{g/L}$. The instantaneous loading at that time was thus ~ 0.5 g/d. All results from subsequent sampling through early October 1995 have been less than the reporting limit. It is not entirely clear why this outfall ceased to be a significant source of mercury between the 1980s and 1993. Possible explanations include the extensive pipe cleaning and relining performed in 1986 and rerouting of some sump discharges from 9201-4 to other outfalls (e.g., 160, 163).

Figure 3.5. Temporal trend in mercury concentrations measured in Outfall 55. Dates are plotted proportionally.

3.2.7 Outfall 160

This outfall drains the area immediately south of 9201-4 that includes the 2100U tank, the Central Pollution Control Facility, and several cooling towers (Figure 3.2). Flows have generally ranged from 5 to 50 gal/min. Historical (1982-3) mercury concentrations and loadings have ranged up to 60 $\mu\text{g/L}$ and 20 g/d, respectively. During the 1993 comprehensive survey mercury concentrations and loadings varied from 9 to 18 $\mu\text{g/L}$ and 0.6 to 2 g/d, respectively. A special dye study in 1995 of the destination outfall of sump discharges from 9201-4 revealed that only a very small portion of these discharges passed through the 2100U tank en route to Outfall 160. Instead,

most of the sump discharges bypassed the tank and entered the line leading to Outfall 163. The intermittent and small (< 3 gal/min) overflow from the 2100U tank typically exhibited mercury concentrations close to $200 \mu\text{g/L}$. As discussed elsewhere the 2100U tank has recently been tested and upgraded for use as a surge tank for the CMTS. Following this upgrade, all sump discharges ultimately destined for treatment in the CMTS were routed (late-October) to this tank. Thus, FY 96 monitoring of Outfall 160 will reflect the considerable contribution (estimated at 5 g/d) from 14 sumps. FY 96 monitoring will include monitoring both this outfall and the 2100U overflow.

3.2.8 Outfall 163

This outfall serves the area immediately west of 9201-4 and immediately east of 9201-5, as well as a large area north of both buildings (Figure 3.2). Access for flow measurement and sampling at the point where the outfall joins the main trunkline (extension of N/S Pipe) was not established until early 1995. Previous flow measurements and sampling were conducted upstream of at least one relatively large tributary inflow associated with the Y-12 Plant Steam Plant. Recent dry weather flows at the downstream point have been ~ 250 gal/min, whereas previous flows at the upstream point were in the range of 80 to 150 gal/min in 1993. Results of the 1993 survey show only limited variations in mercury concentrations (6.5 to $7.8 \mu\text{g/L}$), with loadings varying between 3.4 and 7 g/d. Results from FY 95 monitoring of this outfall show lower mercury concentrations (0.7 to $1.3 \mu\text{g/L}$) and loadings (1 to 2 g/d). This outfall has received most of the sump discharges from Buildings 9201-4 and 9201-5, and thus might be expected to show an average loading more in the range of 5 g/d. The discrepancy may be related to the fact that the monthly grab sampling has simply not coincided with discharge from any sump. This would have been more likely in 1995 because these sumps no longer received external sources of water due to pipe reroutes and thus were less active (pumped less frequently) than in 1993. As discussed above, before the November 1995 outfall monitoring, all Hg-contaminated sump discharges will have been directed to the 2100U and then to Outfall 160. Any residual mercury loading at Outfall 163 will then be due to sources (currently unidentified) other than sumps.

3.2.9 Outfall 169

This outfall serves the south side of Building 9201-5 and the area between and north of Buildings 9201-5 and 9204-4 (Figure 3.2). Sumps G and H in Building 9201-5, and the elevator sump in Building 9204-4 discharge to lines connected to this outfall. In the early 1980s mercury loadings approaching 60 g/d were measured immediately upstream of this outfall and were traced largely to sources at 9204-4 which were subsequently eliminated. Dry weather flows at this outfall have been in the 100 to 150 gal/min range. Mercury concentrations and loadings have ranged from 2 to $4 \mu\text{g/L}$ and 1 to 4 g/d, respectively. The most recent loadings values have varied between 2.5 to 2.8 g/d. At present it is difficult to attribute much of this loading to the three sumps (G and H in 9201-5 and elevator sump in 9204-4) connected to this outfall. Other sources of mercury feeding this outfall will probably have to be sought to account for the loading and to achieve further reduction.

3.2.10 Outfall 200 (North/South Pipe)

This surface water monitoring site represents the collected flow from several key mercury outfalls (150, 160, 163, 169) upstream, as well as all of the other drainage from the western area of the plant. Flow measurements conducted here during the 1993 outfall survey indicated dry weather flows in the range 900 to 1200 gal/min. A limited number of recent measurements indicate flows close to 800 gal/min. Mercury loadings determined at this site during the 1993 survey ranged from 6 to 13 g/d while recent loadings have been about 7 g/d. Accurate flow measurements have been difficult to obtain at this important site in the past without confined space entry for each measurement. Efforts are underway to obtain reliable continuous flow monitoring at this site in FY 96. Sampling frequency for mercury will also be increased, including during stormflow, to better assess the mass balance of mercury from the western area of the plant (see Chap. 6, Monitoring Plans for FY1996).

3.2.11 9422-3 (Station 8)

This surface water monitoring location is located just upstream from the Hg-contaminated outfalls associated with Buildings 9201-2 and 9202. Since at least November 1992, the site has produced high-quality stream flow data. Flow at the site is monitored by both the Y-12 Plant and the US Geological Survey [which publishes the data (USGS 03538231) annually in *USGS Water Resources Data-Tennessee*]. Daily or twice-daily grab samples for total mercury analysis have been collected at this site since 1989. In addition, dissolved and total mercury concentrations in samples collected over the duration of three storm events were measured in 1994-95 at this location.

As shown in Figure 3.6, flow at Station 8 contributed a variable percentage of the flow at Station 17 during the period January-August 1995. During dry weather the Station 8 contribution approaches, and frequently exceeds, 80%. Conversely, during stormflow events the Station 8 contribution may decrease to less than 50% due to direct surface runoff during rainfall from the eastern area of the Y-12 Plant.

Dry weather mercury loadings at Station 8, determined during the 1993 comprehensive outfall surveys, were very similar to those for the N/S Pipe and ranged from about 7 to 11 g/d. Combining the daily average flow data for this site with the daily Hg grab sample results allows calculation of daily mercury loadings. These results include both dry and stormflow conditions and thus are more representative of total loading for the site. Annual average mercury loadings ($\pm$ standard error) calculated in this manner were 16 ± 1.1 , 22 ± 1.7 , and 14 ± 1.6 for 1993, 1994 and the first seven months of 1995, respectively. Annual variations in Hg loading for this site will be influenced by variations in annual rainfall. Thus, the higher loading in 1994 is likely

Figure 3.6. Contribution (%) of daily average water flow at Station 8 to flow at Station 17.

due to the very wet spring period in 1994. Annual variations of Hg loadings can also be conveniently compared using probability, or cumulative frequency, plots. These plots allow determination of the percentage of observations (or time) that Hg loading was equal to, or less than, a given value. They also allow evaluation of whether daily grab sampling for mercury has been representative of all flows that occurred at a monitoring site (see evaluation for Station 17). Figure 3.7 compares the cumulative frequencies of Hg loading at Station 8 in 1993 and 1994 and demonstrates that the higher average 1994 Hg loadings were mainly due to higher frequencies of high Hg loadings. Data for calendar 1995 were incomplete at the time this report was prepared. The 1995 individual Hg loading data are displayed in Figure 3.8.

Average mercury loading at Station 8 may be expected to be slightly lower than at Station 17, the difference being equivalent to the additional mercury loading from the outfalls associated with Building 9201-2 (Outfalls 51, 55, and 49) and 9202 (Outfall 47/48) minus any mercury permanently retained in the streambed and Lake Reality. Before mid-1993, the outfall loading below Station 8 was ~7 g/d. With the loading reductions at Outfalls 55 and 49 in 1994 and Outfall 47/48 in 1995, the outfall loading downstream of Station 8 should have been reduced to ~3 g (i.e., the loading from Outfall 51 alone). As discussed subsequently, net long-term retention of mercury in Lake Reality appears to be small (<10% of the input). If the fractional retention has been constant since 1993, the annual difference in Station 8 and Station 17 loadings

Figure 3.7. Comparison of daily average mercury loading at Station 8 for 1993 and 1994 using cumulative frequency.

Figure 3.8. Daily mercury loading values for Station 8 for 1995 through August. Values are calculated as the product of mercury concentration (daily grab sample) and average daily flow.

should have revealed a change due to the source eliminations downstream of Station 8. However, the annual difference (2.7, 2.0, 2.8 g/d for 1993, 1994, and 1995 through August, respectively) have not shown a significant change. As discussed later, reconciling changes in outfall loading with changes at Station 17 is confounded by the presence of Lake Reality and the strong tendency of mercury to behave nonconservatively during stream transport. Sorption to solid surfaces and volatilization are two important mechanisms affecting mercury mass balance in this aquatic system. Figure 3.9 provides time plots of 3-month running average loadings for Station 8 for all average daily flows sampled and with daily flows greater than selected values (7, 10, 12, and 15 mg/d) excluded from the average. Use of a 3-month running average with flows > 15 mg/d excluded is prescribed by the NPDES permit for Station 17.

Three storm events have been intensively sampled at Station 8. Results for one of these events (10/9/94) are given in Table 3.2 and Figure 3.10. Discharge, total mercury and total suspended solids (TSS) were highly correlated, as expected. However, the highest TSS, mercury concentration and mercury loading occurred before the peak discharge, indicating a flushing effect. Concentrations and instantaneous loadings were substantially lower on the falling limbs of the main peak than at equivalent discharge values on the rising limb (e.g., Hg loading of 4600 g/d at 43 mg/d on the rising limb versus 550 g/d at 40 mg/d on the falling limb). This pattern supports the proposed conceptual model of Hg transport that permits temporary accumulation of mercury from dry weather discharges in the stream bed and then resuspends the "stored Hg" during stormflow. Dissolved mercury concentrations (0.33 to 0.59 $\mu\text{g/L}$) varied little over the storm and actually decreased slightly during the highest flow rates. Mercury transport during stormflow is dominated by the increased transport of suspended matter and thus the "quality" of the suspended matter will determine the Hg loading. Data for the concentration of mercury on suspended matter from this storm (Table 3.2) show a range from 72 to 342 $\mu\text{g/g}$. Based on the proposed conceptual model, lower suspended mercury concentrations might have been expected later in this storm if complete flushing of "stored Hg" occurred during the initial stormflow surge. Additional data will be required to fully validate or modify the conceptual model.

3.2.12 9422-15

This surface water monitoring site receives flow from the area between and north of Buildings 9201-5 and 9204-4. Flows ranged from 90 to 150 gal/min during the 1993 comprehensive outfall surveys. Flows during Hg sampling in 1995 have been ~110 gal/min, while mercury concentrations have ranged narrowly from 1.0 to 1.2 $\mu\text{g/L}$. Mercury loadings in 1995 have thus been ~0.5 g/d. This monitoring site contributes most of the water that passes Outfall 169 downstream, and thus the higher Hg loading at Outfall 169 must have a source or sources (in the range of 2 g/d) in the area immediately south of Building 9201-5. Limited upstream tracing in this area in 1995 did not identify any significant sources. More intensive efforts will be undertaken after the Hg-contaminated sumps in Building 9201-5 are rerouted to the 2100U tank.

Figure 3.9. Running average (3-month) mercury loadings (g/d) at Station 8 (9422-3) for all flows and with flows > 7, 10, 12, 15 mg/d excluded from the average.

Table 3.2. Stormflow results for Station 8 on October 9, 1994.

		Cumulative Rainfall	Stage Height	TSS	Total Hg	Dissolved Hg	Calculated Particulate Hg	Calculated Suspended Hg	Stream Discharge	Instantaneous Total Hg Loading	Instantaneous Dissolved Hg Loading
Location	Date/Time	(in.)	(ft)	(mg/L)	($\mu\text{g/L}$)	($\mu\text{g/L}$)	($\mu\text{g/L}$)	($\mu\text{g/g}$)	(mg/d)	(g/d)	(g/d)
Station 8	10/9/94 09:15	0	1.6	1.2	1	0.59	0.41	342	2.7	10.2	2.2
Station 8	10/9/94 10:00	0.04	1.67	9	1.2	0.55	0.65	72	3.9	17.7	2.5
Station 8	10/9/94 10:30	0.28	2.45	127	28	0.4	27.6	217	43.1	4574.0	42.4
Station 8	10/9/94 11:00	0.52	3.2	86	13	0.37	12.63	147	50.3	2478.4	18.2
Station 8	10/9/94 11:30	0.74	2.95	38	3.7	0.35	3.35	88	39.5	553.9	4.9
Station 8	10/9/94 12:00	0.76	2.15	22	5.1	0.6	4.5	205	12.5	241.6	11.6
Station 8	10/9/94 13:00	0.84	2.05	8	1.4	0.54	0.86	108	10.8	57.3	2.9
Station 8	10/9/94 14:00	1.07	2.42	18	2	0.33	1.67	93	22.8	172.8	2.5

Figure 3.10. Stormflow results for event sampled October 9, 1994. Discharge values plotted are 5-min averages. Concentration values plotted are for grab samples.

3.2.13 9422-16

This surface water monitoring site serves most of the Y-12 Plant west of Building 9201-5. Some tributary lines originate from, or near, Building 9204-4 and the area of former storage of empty mercury flasks. Dry weather flow at this site is strongly influenced by shallow groundwater infiltration from the eastern S-3 Pond plume, and by occasional treated wastewater discharges from the West End Treatment Facility and the Groundwater Treatment Facility. None of the latter sources of flow are significant sources of mercury. Flows ranged up to 110 gal/min during the 1993 comprehensive outfall surveys, but recent dry weather flows have typically been in the range of 30 to 40 gal/min. Mercury concentrations both during the 1993 surveys and recently have ranged narrowly between 0.2 to 0.5 $\mu\text{g/L}$, yielding an approximate dry weather loading of ~ 0.1 g/d. While neither the mercury concentration nor loading qualify this site for detailed evaluation/tracing of the mercury source(s) at present, the site will continue to be monitored in FY 96. Stormflow Hg loading from certain areas (flask storage area, scrap yards) served by this site are suspected and will be explored further if downstream stormflow monitoring results point to these areas as sources.

3.2.14 9422-1 (Station 17)

This site represents flow from essentially the entire Y-12 Plant site and is located on East Fork Poplar Creek at the plant boundary (220 Line). Flow and constituent monitoring began here in November 1988 after the closure of New Hope Pond. Initial flow monitoring suffered problems related to the ultrasonic water level measuring system. Flow data is available before November 1992 but is of unknown or variable quality and is not used here. The US Geological Survey began flow monitoring here (USGS 03538235) in November 1992 and publishes the daily average flow values annually in *USGS Water Resources Data—Tennessee*.

Mercury concentrations have been measured in daily, or twice-daily, grab samples from this site since it was established in 1988. Results of this monitoring through September 1995 are summarized in Figure 3.11 as monthly averages. The cumulative frequency of instantaneous flows sampled (flow at time of sampling) has corresponded very closely with the cumulative frequency of average daily flow at Station 17, verifying that the daily grab sampling program is providing representative samples for mercury loading calculations at this site. Figure 3.12 illustrates the good correspondence for 1994.

Sampling was twice-daily through January of 1992 and then daily beginning in February 1992. Short- (seasonal) and long-term temporal patterns are apparent in Figure 3.11. Regression of the

Figure 3.11. Monthly average mercury concentration at Station 17 (Jan.1989 through Sept. 1995).

Figure 3.12. Comparison of cumulative frequency of instantaneous flows sampled (daily grab) at Station 17 with the cumulative frequency of average daily flows.

Hg concentration data against time (Julian date) revealed a significant decline in concentration amounting to 10 to 15% per year since 1988. A moving average revealed an annual cycle in Hg concentration superimposed on the longer term decline. The annual cycle was apparently missed in 1994, an exceptionally wet year, but seems to be returning in 1995. The annual cycle is characterized by lower concentrations in the late winter through early summer, and higher concentrations in the summer through early winter months. This pattern is suggestive of the variable importance of groundwater inputs compared with Y-12 Plant effluents [i.e. the greater inputs of groundwater low in Hg content during the wetter months tend to dilute effluents (including the shallow groundwater in Hg-contaminated sumps) that are high in mercury].

The consistent decline in mercury concentration at Station 17 may have several explanations, including a response to any or all of the following: (1) corrective action directed at Hg reduction, (2) corrective action directed at another contaminant (e.g., residual chlorine) that may affect Hg releases, (3) corrective action that transferred Hg-contaminated water from the storm drain system to the sanitary sewer, (4) an increase in the proportion of flow of Hg-free water to EFPC, (5) shutdowns of Y-12 Plant processes that had been directing Hg-free water through Hg-contaminated conduits en route to the creek, and (6) corrective actions that simply replaced deteriorating infrastructures that allowed mercury to reach the creek (e.g., roads, roofs, and storm sewer replacement). With the exception of increased flows (4), all of the explanations may be correct.

Mercury loading at Station 17 is tracked using a variety of methods. For the purpose of compliance with the NPDES permit, a 3-month running average is used, with the exclusion of mercury values for days when average flow at Station 17 exceeds 15 mg/d. Running averages for all values and for days with average flows exceeding 7, 10, and 12 mg/d are plotted in Figure 3.13. The plot for flows < 7 mg/d is essentially equivalent to "dry weather" loading. The annual average daily loading ($\pm$ std. error) was 19 ± 1.4 , 24 ± 2.7 , and 17 ± 2.2 g/d for 1993, 1994, and 1995 through September, respectively, if no data are excluded from the averaging process. The annual average daily loading ($\pm$ std. error) was 18 ± 1.0 , 17 ± 0.7 , and 14 ± 0.7 g/d for the same periods if flows > 15 mg/d are excluded. Similarly, annual average dry weather loadings (flows > 7 mg/d excluded) were 14 ± 0.3 , 15 ± 0.4 , and 12 ± 0.5 g/d.

3.3 EFFECT OF LAKE REALITY ON DRY WEATHER HG LOADING AT STATION 17

As an impoundment of a free-flowing stream, Lake Reality may be expected to retain contaminants that have a high affinity for suspended matter that can settle in the lake. New Hope Pond, which preceded Lake Reality as a headwater impoundment of EFPC, retained an average of 50% of the mercury that entered it from upstream. During the first few years of operation of Lake Reality twice-daily grab samples were collected at the inlet to Lake Reality and at Station 17. Comparison of inlet and Station 17 mercury concentrations revealed that Lake Reality was not as efficient as New Hope Pond in trapping mercury and often showed higher concentrations of mercury at the outlet (Station 17) than in the inlet. Over this ~3-year period of intensive sampling

Figure 3.13. Running average (3-month) mercury loadings (g/d) at Station 17 (9422-1) for all flows and with flows > 7, 10, 12, and 15 mg/d excluded from the average.

(more than 700 Hg samples) inlet concentrations averaged $1.72 \mu\text{g/L}$, while Station 17 averaged $1.58 \mu\text{g/L}$. A paired t-test showed that this difference ($0.14 \mu\text{g/L}$) was statistically significant ($p=0.0001$). The difference represents $\sim 8\%$ of the inlet concentration.

The daily inlet sampling of Lake Reality was discontinued in January 1992 but was resumed again in September 1995 to provide current data to revisit this issue. In addition, a special study was undertaken to ascertain whether higher concentrations of mercury occurred at the actual lake outlet as well as at Station 17, and whether there was any diurnal trend in this pattern. Comparison of results for daily grabs from the lake inlet and Station 17 for the last two weeks of September 1995 and first week of October are given in Table 3.3 and depicted in Figure 3.14. Several rain events occurred over this interval and the event (0.06 in.) which occurred in the early morning hours of 9/26/95 and again on 10/5/95 (Hurricane Opal) produced the closest correspondence in Hg concentration between the lake inlet and Station 17. On most other days Station 17 values were typically 150% of the inlet concentrations.

Results from the diurnal study, conducted 9/25–26/95, are summarized in Table 3.4 and Figure 3.15. These results clearly demonstrate that under the dry weather conditions that prevailed during the study and the antecedent period (3 d with no rain) Lake Reality acted as a net source of mercury, on the order of $\sim 5 \text{ g/d}$.

These results prompted an effort to determine whether Lake Reality was almost filled with sediment and thus experiencing sediment resuspension and scour even under dry weather flow. Depth soundings performed over most of the lake showed no evidence that water depths, or sediment thickness, had changed significantly since 1991 when the last survey was conducted. In fact, there is very little sediment in the lake (average thickness = 5 in. , maximum thickness = 11 in.). These results do not support physical scouring of sediment in a nearly filled lake. Rather bioturbation resuspension due to activities of animals of the thin veneer of sediment that coats the lake liner even in the shallowest areas is the most probable explanation. The lake is now populated with abundant biota, including fish, turtles, water snakes, and often Canada geese.

3.4 EFFECT OF LAKE REALITY ON STORMFLOW HG LOADING AT STATION 17

Until very recently (October 1995), no sampling that was specifically focused on evaluating the “trap efficiency” of Lake Reality for TSS and mercury during stormflow had been undertaken. Engineering calculations performed in 1990 yielded an average “sediment” trap efficiency of 9.2% for the inlet channel and 13% for the lake. This calculation was based on a size distribution of source sediment that was composed of about equal portions of sand and silt with the balance (45%) as clay. As discussed in the previous section, the 3-year average concentrations of mercury at the lake inlet differed only slightly from the Station 17 averages, with a highly variable daily pattern of one monitoring site showing higher or lower concentrations. On the other hand, dry weather averages have often been higher at Station 17 than at the lake inlet, suggesting that the lake may behave as a temporary net source of mercury under non-stormflow conditions.

Table 3.3. Comparison of Hg daily grab samples—September and October 1995.

Time	RL Inlet	Station 17	Station 17
	Total Hg (ug/L)		Discharge (mg/d)
9/18/95	0.5	0.74	3.3
9/19/95	0.5	0.8	2.8
9/20/95	0.5	0.76	2.7
9/21/95	0.7	1.2	5
9/22/95	0.8	1.4	10.7
9/25/95	0.5	0.75	2.3
9/26/95	0.9	1	3.6
9/27/95	0.6	0.9	2.5
9/28/95	0.6	0.9	2.2
9/29/95	0.6	1	2.4
10/2/95	0.6	0.71	2.1
10/3/95	0.6	1.5	2.9
10/4/95	0.8	1	5.5
10/5/95	2.2	2.9	120
10/6/95	0.7	1	4.3

Figure 3.14. Comparison of mercury results for daily grab samples collected at the inlet to Lake Reality and at Station 17.

Table 3.4. Lake Reality Hg mass balance during a special dry weather study.

Time	Station 17 Discharge	Inlet Hg	Inlet Loading	Outlet Hg	Outlet Loading	Inlet/Outlet	Comments
	(mg/d)	(ug/L)	(g/d)	(ug/L)	(g/d)	(%)	
9/25/95 10:05	2.4	0.59	5.4	1.2	10.9	49.2	
9/25/95 13:05	2.5	0.66	6.2	1.2	11.4	55.0	
9/25/95 16:05	2.6	0.64	6.3	1.1	10.8	58.2	
9/25/95 16:05	2.6	0.64	6.3	1.1	10.8	58.2	Field Duplicate
9/25/95 19:15	2.6	0.76	7.5	1.1	10.8	69.1	
9/25/95 22:30	2.7	0.56	5.7	1.2	12.3	46.7	
9/26/95 1:15	2.7	0.63	6.4	1.2	12.3	52.5	Very light rain
9/26/95 4:05	2.7	0.7	7.2	1.3	13.3	53.8	
9/26/95 4:05	2.7	0.55	5.6	1.1	11.2	50.0	Field Duplicate
9/26/95 6:40	3.2	0.66	8.0	1.2	14.5	55.0	Light rain
9/26/95 10:25	3.3	0.69	8.6	1.2	15.0	57.5

Figure 3.15. Comparison of inlet and outlet mercury concentration at Lake Reality during a special study conducted September 25–26, 1995.

During the week beginning October 2, 1995, which included rainfall events from both passage of a regional front and Hurricane Opal, automatic sequential samplers were set up to collect grab samples at the inlet to Lake Reality and at Station 17 after each cumulative flow of 1.0 million gal. Thirty-four samples were collected at the lake inlet and 38 samples were collected at Station 17 over an ~4-d period with cumulative rain in excess of 2 in. Peak 5-min flows reached 150 mg/d. Sampling was terminated when the creek at each location had returned to prestorm flow rates. Samples were analyzed for total mercury and TSS, with the filter solids from TSS measurement archived for possible future analysis of mercury content.

Results from this intensive sampling effort were incomplete at the time this report was prepared. However, some preliminary conclusions can be drawn from the available results. Flow rate, total mercury, and TSS concentrations were correlated at both monitoring sites, reflecting the predominant occurrence of mercury in particulate (suspended) form and the increased carrying capacity of creek for suspended matter at higher flow rates (velocity). Peak mercury concentrations approached 10 $\mu\text{g/L}$, while peak TSS concentrations slightly exceeded 100 mg/L. Average values for TSS differed very little between the lake inlet (32.7 mg/L) and Station 17 (32.3 mg/L). Net retention of TSS by Reality Lake amounted to ~1.5% of the estimated inlet quantity (4200 kg). In contrast, average values for total mercury differed significantly between the lake inlet (4.4 $\mu\text{g/L}$) and Station 17 (2.5 $\mu\text{g/L}$). The estimated net retention (240 g) of mercury by Lake Reality amounted to ~42% of the inlet quantity (570 g). This apparent retention of mercury without a corresponding retention of suspended matter is anomalous, especially considering the good correlation between total mercury and total suspended matter observed at both monitoring locations.

Overall, the dry weather and stormflow Hg results presented above suggest that Reality Lake traps some mercury (in the range of 40%) during stormflow, but net long-term retention is diminished by resuspension and losses to the downstream creek during dry weather. Dry weather flow is sampled more frequently than stormflow, and thus the calculation of average mercury loading at Station 17 using a moving average (e.g. 90-d) will be biased toward dry weather loading. The role of Lake Reality as a sink or source for mercury will be investigated further in FY 96, including possibly an experimental period in which the lake is bypassed except during stormflow.

4. LONGITUDINAL DISTRIBUTION OF MERCURY AND MERCURY SPECIATION IN EAST FORK POPLAR CREEK

Reductions in mercury releases from the Y-12 Plant are expected to be observed to some degree over the entire length of EFPC, not just at Station 17. Accordingly, a semiannual monitoring effort was begun in July 1995 that is a companion to the bioaccumulation studies associated with the Biological Monitoring and Abatement Program (BMAP). This effort will gather data on concentrations and speciation of mercury in water at all of the BMAP bioaccumulation sites, plus a few additional sites. Similar longitudinal surveys were conducted on a monthly basis in 1990-91 and provided supporting data for the development of a site-specific criterion for mercury at Station 17 (Y/ER-126, *Site-Specific Water Quality Criterion for Total Mercury in East Fork Poplar Creek Downstream from the Oak Ridge Y-12 Plant*).

Complete results of the July 1995 survey are provided in Table 4.1 and selected results are presented in Figures 4.1 and 4.2. For comparison, these figures also provide results from July 1990. Some of these results are also discussed in the section on bioaccumulation. Results for total and dissolved mercury (Figure 4.1) show the spatial pattern that was first observed long ago (ORNL/TM-8894, *Mercury Contamination in East Fork Poplar Creek and Bear Creek*) and that suggests the presence of a mercury source in the headwaters of the creek. Dissolved mercury concentration decreased regularly with increasing distance from the N/S Pipe. The dry weather pattern, discussed earlier, of higher total mercury in the outlet of Lake Reality than the inlet was evident in both July 1990 and July 1995. Both total and dissolved mercury were slightly higher in 1990 than in 1995 in the upper creek sites, but this trend disappeared downstream of Lake Reality. Results for total methylmercury (MeHg), shown in Figure 4.2, illustrate the same significant increase between the inlet and outlet of Lake Reality. A corresponding increase in dissolved MeHg across the lake was not observed, indicating that the increase in total MeHg is due to particulate MeHg.

Table 4.1. Results of longitudinal sampling of water from EFPC conducted July 12, 1995.

Sampling Location	EFPC Distance Km	Time EDT	Temp °C	Conduct μ S	TSS mg/L	Diss. Hg μ g/L	Total Hg μ g/L	Diss. MeHg ng/L	Total MeHg ng/L	TVM ng/L	Diss. Hg %	Diss. MeHg %	MeHg %	Suspended Hg μ g/g	Suspended MeHg μ g/g
EFPC 2.1	2.1	08:17	22.0	390	6.3	0.03	0.16	0.32	0.55	0.33	16	58	0.34	21	0.036
EFPC 6.3	6.3	09:05	22.5	430	7.0	0.03	0.20	0.33	0.55	0.26	13	60	0.28	24	0.031
EFPC 13.8	13.8	09:25	22.5	372	5.8	0.03	0.25	0.30	0.46	0.14	11	65	0.18	38	0.028
EFPC 18.2	18.2	09:50	23.1	390	5.3	0.04	0.37	0.15	0.34	0.36	11	44	0.09	62	0.035
EFPC 20.8	20.8	10:00	24.0	403	6.8	0.05	0.40	0.092	0.42	0.65	12	22	0.11	51	0.048
NOAA	22.0	10:15	25.0	408	7.3	0.06	0.60	0.12	0.74	0.50	10	16	0.12	73	0.084
EFPC 23.4	23.4	10:35	26.1	403	17.7	0.10	1.8	0.079	1.6	0.56	5.8	4.9	0.09	95	0.086
LR-IN	23.5	11:05	26.1	408	1.7	0.23	0.77	0.069	0.23	1.5	30	30	0.03	301	0.090
EFPC 24.8	24.8	11:25	26.8	412	0.8	0.35	1.1	0.11	0.25	3.8	31	44	0.02	983	0.17
Station 8	25.0	11:40	25.0	428	1.9	0.39	1.1	0.095	0.20	8.4	34	47	0.02	394	0.057
N/S Pipe	26.0	11:55	24.5	405	0.8	1.1	1.4	0.38	0.40	4.0	74	95	0.03	453	0.025
Hind's Creek	N/A	10:02	22.0	335	20.0	0.010	0.007	0.040	0.090	0.025	142	44	1.3	*	0.002
Bear Creek	N/A	08:30	20.5	352	2.1	0.002	0.002	0.049	0.12	0.04	76	41	5.7	0.24	0.033

Diss. = dissolved.

TVM = total volatile mercury.

NOAA = National Oceanic and Atmospheric Administration.

LR-IN = Reality Lake Inlet

N/S = North/South

Figure 4.1. Results of longitudinal sampling and analysis of water for total and dissolved Hg from EFPC in July 1990 and July 1995.

Figure 4.2. Results of longitudinal sampling and analysis of water for total and dissolved methylmercury from EFPC in July 1990 and July 1995.

5. BIOLOGICAL MONITORING AND ABATEMENT PROGRAM MERCURY STUDIES

5.1 GOALS AND OBJECTIVES

The BMAP for EFPC has been monitoring mercury concentrations in fish in EFPC since spring of 1985. Coupled with work conducted by Oak Ridge National Laboratory Environmental Sciences Division in 1982 and Tennessee Valley Authority in 1984, it provides a nearly continuous 13-year record. The objectives of the monitoring are to track changes in mercury contamination over time and distance that can be used to assess and guide remedial actions and strategies concerning aqueous discharges at the Y-12 Plant, and to provide information to help the State of Tennessee implement oversight and regulation aimed at enhancing and protecting the resource value of EFPC.

5.2 METHODS

Redbreast sunfish are collected twice yearly at seven sites in EFPC (Figure 5.1), from its headwaters within the Y-12 Plant to where it becomes impounded by backwaters of Watts Bar Reservoir. Carp are also collected twice yearly from the middle reaches of the creek. At each site, eight sunfish of a size large enough to be taken by sport fishermen are collected, filleted, and scaled, and a sample of the fillet analyzed for total mercury. Four carp are collected at each of three sites (EFK 18.2, EFK 13.8, and EFK 6.3) twice yearly. In winter 1994, four largemouth bass were collected from Lake Reality to investigate whether mercury levels in large predatory fish were likely to exceed those typical of redbreast sunfish.

5.3 RESULTS

5.3.1 Downstream Profiles of Mercury Contamination

A summary of results of mercury monitoring in EFPC fish in FY 95 is presented in Tables 5.1 and 5.2. High mercury concentrations (~2 mg/kg) are found in fish from EFPC within the Y-12 Plant upstream from Lake Reality, where dissolved aqueous mercury concentrations are highest. Carp, which occur in abundance in the middle reaches of EFPC, contained mercury concentrations similar to sunfish. Surprisingly, largemouth bass from Lake Reality contained mercury concentrations that were no higher than those typical of redbreast sunfish, despite being higher on the food chain. It may be that bass in Lake Reality feed extensively on stonerollers, an herbivorous forage fish that does not accumulate methylmercury as effectively as carnivorous species. The downstream profiles of mercury concentrations in redbreast sunfish versus distance in EFPC below the Y-12 Plant are shown in Figure 5.2. In November 1994, a site was added between EFK 23.4 and EFK 18.2 to assess whether a maximum mean concentration of mercury in sunfish might occur intermediate between those sites. As can be seen in Figure 5.2, mean mercury concentrations in sunfish from the new site (EFK 20.8) were similar to those at the sites

Figure 5.1. Sampling sites for redbreast sunfish in EFPC in Oak Ridge, Tennessee. Sites are designated by distance (km) upstream from the mouth of EFPC.

Table 5.1. Concentrations of mercury (mean $\pm$ SE, mg/kg wet wt) in fillets of redbreast sunfish from EFPC, FY 1995. The second row (in parentheses) is range, the third row is the number of fish exceeding the FDA limit (1 mg/kg).

Site	Fall 1994	Spring 1995
EFK 24.8	2.18 $\pm$ 0.11 (1.80 - 2.70) 8/8	1.79 $\pm$ 0.17 (1.20 - 2.30) 8/8
Lake Reality	0.67 $\pm$ 0.05 (0.42 - 0.83) 0/8	1.25 $\pm$ 0.19 (0.67 - 2.00) 5/8
EFK 23.4	0.81 $\pm$ 0.06 (0.56 - 1.10) 1/8	0.84 $\pm$ 0.06 (0.61 - 1.10) 2/8
EFK 20.8	0.80 $\pm$ 0.09 (0.52 - 1.20) 2/8	N/A
EFK 18.2	1.05 $\pm$ 0.07 (0.86 - 1.30) 4/8	0.89 $\pm$ 0.09 (0.64 - 1.30) 3/8
EFK 13.8	0.86 $\pm$ 0.12 (0.45 - 1.40) 3/8	1.03 $\pm$ 0.09 (0.61 - 1.40) 4/8
EFK 6.3	0.93 $\pm$ 0.09 (0.56 - 1.30) 4/8	0.93 $\pm$ 0.08 (0.64 - 1.20) 4/8
EFK 2.1	0.59 $\pm$ 0.05 (0.43 - 0.80) 0/8	0.62 $\pm$ 0.07 (0.39 - 0.96) 1/8
Hinds Creek	0.16 $\pm$ 0.03 (0.06 - 0.29) 0/8	0.11 $\pm$ 0.01 (0.08 - 0.18) 0/8

Table 5.2. Concentrations of mercury (mean $\pm$ SE, mg/kg wet wt) in fillets of carp and largemouth bass from EFPC, FY 1995. The second row (in parentheses) is range, the third row is the number of fish exceeding the FDA limit (1 mg/kg).

Site	Fall 1994	Spring 1995
Lake Reality (Largemouth Bass)	0.86 $\pm$ 0.08 (0.73 - 1.10) 1/4	N/A
EFK 18.2 (Carp)	0.39 $\pm$ 0.02 (0.35 - 0.43) 0/4	0.48 $\pm$ 0.11 (0.21 - 0.73) 0/4
EFK 13.8 (Carp)	0.49 $\pm$ 0.12 (0.22 - 0.71) 0/4	0.73 $\pm$ 0.10 (0.52 - 0.91) 0/4
EFK 6.3 (Carp)	0.59 $\pm$ 0.06 (0.46 - 0.73) 0/4	0.83 $\pm$ 0.30 (0.26 - 1.40) 2/4

Figure 5.2. Mean concentration of mercury in redbreast sunfish ($n = 8$ fish per site) in EFPC versus distance upstream from its mouth.

above and below it. Mean mercury concentrations in sunfish are quite similar at all sites downstream from Lake Reality, despite decreasing concentrations of total mercury in water and sediments along the same gradient. Before the replacement of New Hope Pond with Lake Reality in 1988, total mercury concentrations in EFPC redbreast sunfish decreased in a regular, consistent pattern with increasing distance below the Y-12 Plant (Figure 5.3). This pattern was roughly proportional to dilution of the Y-12 Plant discharge with distance, and was interpreted as evidence of the importance of the aqueous discharge of mercury from the Y-12 Plant in determining the degree of mercury contamination in EFPC fish. The longitudinal pattern seen in Figure 5.2 has been typical since 1989 and is similar to that expected if mercury inputs to the headwaters were reduced.

5.3.2 Changes in Mercury Bioaccumulation over Time

Since BMAP monitoring started in 1985, mercury concentrations in fish at EFK 23.4 have decreased by ~50% (Figure 5.4). At sites farther downstream (Figure 5.5), mean mercury concentrations in redbreast sunfish have not changed appreciably over the past 10 years. In the lower portion of EFPC, mercury concentrations in sunfish have exhibited a statistically significant increasing trend over the study period (Figure 5.6). Although the response at EFK 23.4 is roughly that expected with reduced mercury discharges from the Y-12 Plant, that cannot be an explanation for the consistent pattern of increasing mercury concentrations in fish at downstream sites. If changes in mercury concentrations in fish and water at EFK 23.4 are compared over just the period of time subsequent to completion of Lake Reality, a distinctly different picture of the response to mercury discharge abatement (Figure 5.7) exists. In this case, no decrease in mercury contamination in fish is associated with the large reduction in mercury concentration and loading at EFK 23.4.

5.3.3 Implications for Reducing Mercury Contamination in Fish

Although the response of mercury contamination in fish has been disappointing, there are reasons to believe that the lack of response is due to offsetting changes in mercury transport and transformation in EFPC that are associated with biological responses to improved water quality. Since 1985, fish population density has increased at all sites in EFPC, but the greatest increases have occurred in the reaches within, and immediately below, the Y-12 Plant. Lake Reality and 2.5 km reach of EFPC upstream from Lake Reality now contain large populations of fish, whereas the same areas contained virtually no fish in the mid-to-late 1980's. Populations at EFK 23.4 and stream sites in the Y-12 Plant are 3 to 7 times greater than at comparable reference sites (Figure 5.8). Fish in these expanded populations have accumulated mercury, which is efficiently recycled within the biotic components of the stream ecosystem. Thus, although the concentration of mercury in fish and water has decreased at EFK 23.4 since 1985, the amount of mercury stored in fish populations at and above EFK 23.4 has increased many fold. This mercury must cycle (or spiral) its way downstream through EFPC in order for decreased mercury accumulation associated with source abatement to be fully manifest. That process may introduce a substantial time lag between actions and desired response in mercury remediation.

Figure 5.3. Mean concentration of mercury in redbreast sunfish ($n = 8$ fish per site) in EFPC versus distance upstream from its mouth, before Lake Reality.

Figure 5.4. Average mercury concentration in redbreast sunfish fillets, EFPC at the Y-12 Plant Boundary.

Figure 5.5. Average mercury concentration in redbreast sunfish fillets, EFPC, downstream from the Y-12 Plant.

Figure 5.6. Increase in mean mercury concentration in redbreast sunfish at sites in lower EFPC. Both regression lines are statistically significant ($P < 0.05$).

Figure 5.7. Mercury in water and fish in EFPC at the Y-12 Plant boundary since Lake Reality was completed.

Figure 5.8. Increase in fish population density in upper EFPC, 1985-1994.

6. MONITORING PLANS FOR FY 1996

Characterization of mercury loading from outfalls and key instream locations will be performed in FY 96 (1) to provide information on the effectiveness of specific corrective actions to reduce/eliminate mercury loading, (2) to define outfalls or Y-12 Plant areas where corrective actions are needed to help achieve the NPDES-imposed loading limit of 5 g/d, and (3) to provide mercury and mercury speciation data to support interpretation and application of BMAP data in establishing a future site-specific criterion for mercury in water. Sampling activities will be divided into four categories: monthly grabs, quarterly composites, storm sampling, and semiannual longitudinal sampling of EFPC. These activities are in addition to required and "best management practice" (BMP) sampling being performed under the auspices of the NPDES program. Table 6.1 summarizes information for all key monitoring locations for mercury, including NPDES sites (9422-1, Outfall 51, Outfall 55), BMP sites (RL Inlet, 9422-3), and Reduction of Mercury in Plant Effluent (RMPE) Project sites (Outfalls 21, 47/48, 113, 150, 160, 163, 169, N/S pipe, 9422-15 and 9422-16). Not included in Table 6.1 are several sites for which little or no data presently exist (e.g., overflow from Tank 2100U, building exits and manholes associated with 9202). Sampling at these Y-12 Plant locations in FY 96 is expected to be of limited duration. Locations of the BMAP sites is given elsewhere in this report. Sampling for mercury and mercury speciation at BMAP sites will occur in the November-December and May-June time periods.

6.1 MONTHLY PROGRAM

Sites for monthly grab sampling for mercury are indicated in the Table 6.1 column labeled "Hg Sample Frequency." These sites will be sampled on or near the 15th of each month. These samples should represent "dry weather" flow, and thus no rainfall should have occurred 24 h before commencing sampling, and sampling should be terminated if rainfall begins during the sampling event. Every effort should be made to obtain a reliable instantaneous water flow rate at the time of sampling. If the site has a functional and well-calibrated continuous flow device, instantaneous flow rate will be recorded from that device.

6.2 QUARTERLY PROGRAM

Sites for quarterly flow-proportional sampling are indicated in Table 6.1 under the column heading "Hg Sample Type." Composite samples for Hg analysis will be collected with Isco samplers interfaced with the respective flow devices at each location. A composite sampling event should consist of five successive 24-h samples, including at least 1 weekend day each quarter. Composite events will include stormwater from any rainfall that occurs during the 5-d period.

Table 6.1. Key mercury monitoring locations for FY 1996 and beyond. Flow given are "best estimates" from available data.

Location	Flow Frequency	Flow Device	Flow Quality	Dry Weather Flow (gal/min)	Hg Sample Type	Hg Sample Frequency	Program	Comments
Station 17 (9422-1)	Continuous	T-Flume, USGS Rated	Excellent	2100	Grab, Daily Comp	Daily	NPDES	Evaluate use of composite data
LR Inlet	Intermittent	Manning Eq	Poor	2100	Grab	Daily	BMAP	
Outfall 47/48	Intermittent	None	Poor	50	Grab, Qtr Comp	Monthly	RMPE	Install L 60° flume ¹
Outfall 51	Continuous	Manning Eq	Poor	100	Grab	Weekly	NPDES	Upgrade flow device
Outfall 55	Continuous	P-Flume	Excellent	75	Grab	Weekly	NPDES	
Station 8 (9422-3)	Continuous	T-Flume, USGS Rated	Excellent	1600	Grab	Daily	BMAP	
Outfall 113	Intermittent	Bucket gaged	Excellent	1	Grab	Monthly	RMPE	
N/S Pipe (200/201)	Continuous	Flume, (USGS Rated) ²	Currently poor	1300	Grab	Monthly	RMPE	
Outfall 150	Continuous	Manning Eq	Good	500	Grab, Qtr Comp	Monthly	RMPE	Install 2"45° T-flume
Outfall 160	Continuous	L 60° T-flume	Good	10	Grab, Qtr Comp	Monthly	RMPE	Install XL 60° T-flume
Outfall 163	Continuous	XL 60° T-flume	Good	400	Grab, Qtr Comp	Monthly	RMPE	
Outfall 169	Continuous	Manning Eq	Poor	150	Grab, Qtr Comp	Monthly	RMPE	Install 2"45° T-flume
9422-15 ³	Continuous	Manning Eq	Fair	100	Grab, Qtr Comp	Monthly	RMPE	Install 2"45° T-flume
9422-16	Continuous	Manning Eq	Fair	50	Grab	Monthly	RMPE	

¹ Use existing flume from Outfall 160 ² Flow/loading included in Outfall 169 ³ Flow quality better after USGS rating

USGS = United States Geological Survey

LR = Lake Reality

6.3 STORMWATER PROGRAM

Sites for stormwater sampling include 9422-1, RL Inlet, 9422-3, and N/S Pipe. Additional sites may be added if warranted by results from these four sites. A stormwater sampling event will be initiated when the forecast is favorable for rainfall from "frontal" activity. Such activity is more likely to generate significant and uniform rainfall over the Y-12 Plant site. Data for a minimum of four such storms is needed, but it is understood that more than four events may be initiated in order to obtain complete data for four events. Complete details for the sampling strategy for stormwater are given elsewhere (Y/ER-221, *Work and QA Plan for R&D in Support of the RMPE*). In summary, automated sequential samplers will be employed to collect a series of discrete samples over each storm hydrograph. Sample frequency during stormflow will be driven automatically by cumulative volume of flow, and thus sample frequency will increase as flow rate increases. The analyte list will always include total Hg, dissolved Hg, and total suspended solids but will be expanded to include other analytes and suspended particle-size analyses as appropriate to support numerical modeling of Hg transport.

6.4 LONGITUDINAL PROGRAM

Water samples will be collected semiannually at up to 12 locations along EFPC. Sampling will be contemporaneous with BMAP fish sampling and use the same sites, plus additional sites to better define gradients in mercury concentration and speciation. Constituents to be measured include total mercury, dissolved mercury, total methylmercury, total dissolved methyl mercury, dissolved gaseous mercury, and total suspended matter. Because Lockheed Martin Energy System's' analytical laboratories cannot presently achieve useful detection limits for total mercury in ambient stream water and has no capability to run methylmercury, analytical services for most of these analyses will be obtained externally through the Technical Services Office, which will employ only certified labs. Procedures will conform to the requirements of the Technical Services Office. Dissolved gaseous mercury and total suspended matter will be measured in a research laboratory at the Oak Ridge National Laboratory.

As stated in the NPDES permit, information is required "...to reach a site alternate criterion for chronic exposure to mercury on the Oak Ridge Reservation (ORR)." Efforts to define an empirical relationship between aqueous total mercury concentration and mercury concentration in sunfish in hard water streams similar to EFPC will use data from local reference and mercury contaminated streams in addition to EFPC. Because mercury or mercury speciation information is not available for the 'background' fish sampling sites both on and off the Oak Ridge Reservation, some of these sites (up to eight) will be added for semiannual sampling for mercury speciation.

7. SUMMARY OF CURRENT CONDITIONS AND CONCLUSIONS

Much progress has been made in the past 2 years toward the goal of reducing mercury releases to upper EFPC to environmentally acceptable levels. The strategies followed to achieve this recent progress have been similar to those found to be effective in the mid-1980s. These strategies begin with characterization and prioritization of sources. Comprehensive surveys in 1993 of all dry weather flows into the creek identified key sources and permitted estimates of achievable reductions. These formed the basis of the proposed corrective actions itemized in the NPDES permit. As discussed in this report, the schedule for completion of corrective actions has been accelerated to provide an opportunity to identify and complete any additional actions necessary to meet the NPDES permit goal of 5 g/d by December 31, 1998. In addition, certain recognized sources (e.g., Outfall 51) initially thought to be beyond cost-effective treatment have been aggressively investigated and promising treatment options pursued. Thus, corrective actions for these difficult sources could be implemented in advance of the December 31, 1998, date. In other cases (e.g., Outfall 47/48 reroute), corrective actions not directed at mercury reduction may have attenuated Hg releases.

Mercury concentrations in sunfish in EFPC at the Y-12 Plant boundary are considerably lower now than in the mid-1980s. However, the response of mercury contamination in fish at that site to recent reductions in aqueous mercury concentrations at that site has been disappointing. During the past 5 years, fish populations in EFPC upstream from that site have expanded greatly, creating a reservoir of biologically incorporated methylmercury that must cycle through the system for continued decreases in mercury concentrations in fish at the downstream site to be evident. Future reductions in aqueous mercury concentrations in upper EFPC are expected to eventually translate into decreased contamination in fish in and near the Y-12 Plant, but there is likely to be a substantial lag between changes in aqueous mercury and a biological response.

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