Memorandum

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PROJECT: **ERC413**

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Appendix B: Development of the Rock Creek Mercury Model

Introduction

Limno-Tech, Inc. (LTI) has developed and applied a model to assist in the determination of the Mercury TMDL for the District of Columbia portion of the Rock Creek watershed. This memorandum documents the technical approach and model results for a representative three-year period. A description of the SWMM model applied in Rock Creek is provided along with a discussion of model inputs and relevant assumptions used in the Rock Creek Mercury Model of Rock Creek.

Technical Approach

The technical approach to model development and application was centered on (1) developing a model that had appropriate complexity given the modeling issues to be addressed and the availability of data to support model development; and (2) utilizing other locally developed models to the fullest extent possible. Given this approach, the SWMM model was selected for the simulation of mercury in Rock Creek. SWMM has process and transport capabilities that are consistent with the needs of a model to support development of TMDLs for mercury in Rock Creek. In addition, SWMM has been successfully applied recently in Rock Creek for other studies, including a bacteria TMDL and the development of a Long Term Control Plan (LTCP) for CSOs in the District of Columbia.

The Rock Creek Mercury Model

The SWMM model for mercury is similar to the models developed for the zinc, lead, and copper TMDLs for Rock Creek in the District of Columbia documented in Appendix A of the TMDL Report. The only difference is the model inputs for mercury loads developed for this application.

Model Inputs

To calculate the mercury TMDL, three sources are taken into consideration: point sources, upstream sources, and nonpoint sources. The point sources in the watershed are the CSO and storm water outfall locations. For CSO and storm water inputs to the model, the DC WASA July

2002 LTCP models were used (DC WASA 2002). Storm water and combined sewer flows for current conditions were determined by running these models. The hourly output of these models was used as input for the Rock Creek Mercury Model. For mercury, the concentration for CSOs was estimated as the highest value collected at the Piney Branch CSO. The concentration of total mercury in storm water was determined by averaging all of the storm water data collected in 1994, 1995, and 2003 (Figure 1) above the detection limit. The CSO and storm water values for mercury are presented in Table 1. Modeled flow times these concentrations produced hourly loads for the Rock Creek Mercury Model.

Table 1: Mercury Concentrations for Storm Water and CSOs.

Constituent	CSO Concentration	Storm water Concentration
Mercury (ug/L)	0.4	0.19

There are additional storm water sources within the Rock Creek watershed that do not flow through the storm water or CSO system of the District of Columbia. The majority of these flows come from parkland along Rock Creek its tributaries. To determine the flows from these areas, the simple method was used (MWCOG 1987). A widely used flow estimation approach, application of the simple method combines rainfall, drainage area, and runoff coefficients to estimate the flow. Then mercury concentrations for storm water (given in Table 1) were used to generate load inputs.

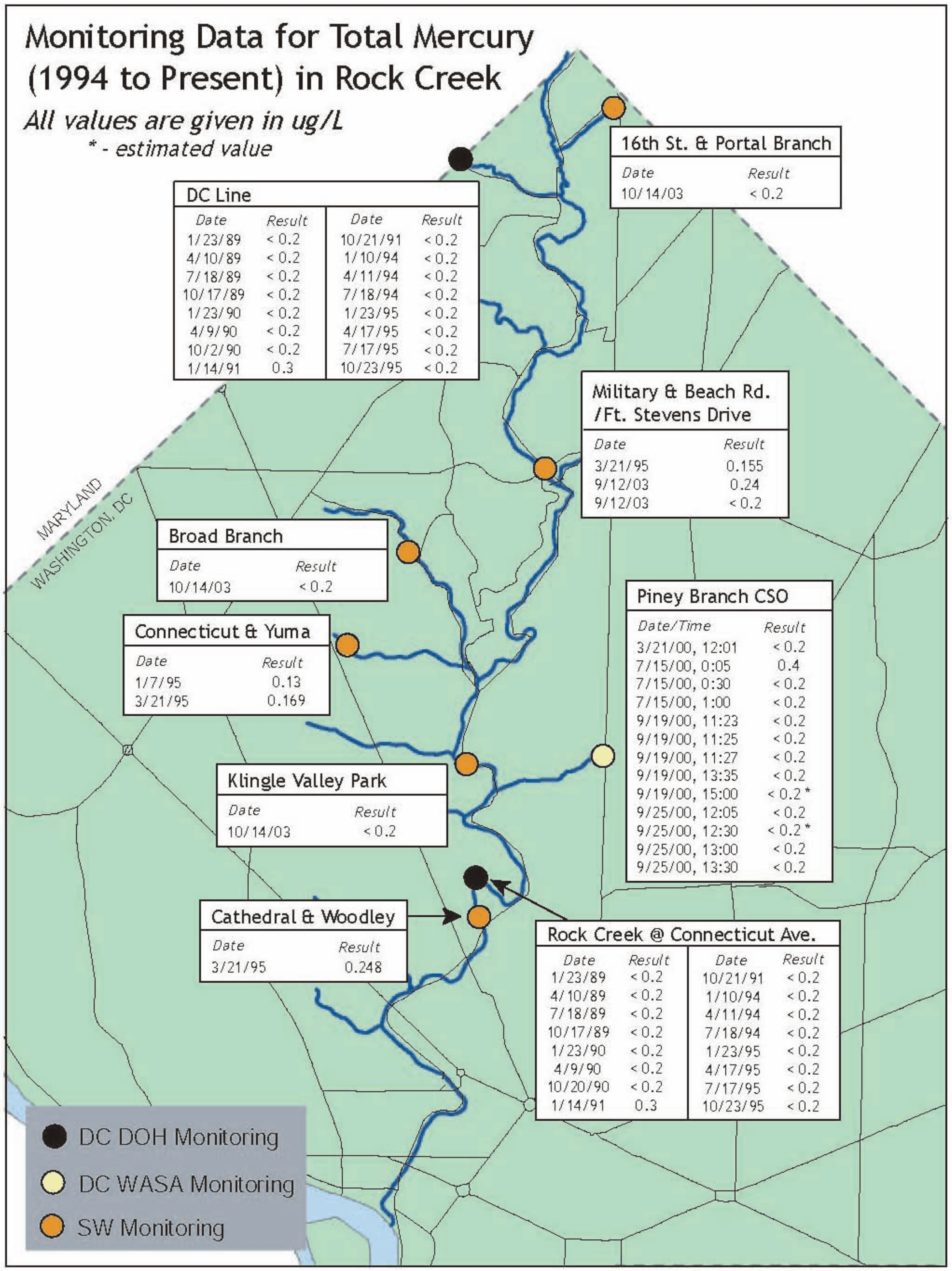

Figure 1: Total Mercury Data in Rock Creek

Upstream data was also needed for the model to account for all flows and loads from Maryland into the District of Columbia for Rock Creek. Flow for the upstream dataset was based on the USGS gage at Sherrill Drive (USGS 01648000). Flow from Sherrill Drive was adjusted to represent flow at the boundary of Maryland and the District of Columbia using areal weighting based on watershed area.

The absence of sufficient monitoring data at the upstream boundary of the model necessitated the need for further research into values of mercury at the Maryland/DC boundary. DC DOH has sampled for mercury at the DC line, but except for a sample of 0.3 ug/L taken on 1/14/1991, all reported values are under the reporting limit of 0.2 ug/L (Figure 1). To estimate the concentrations of mercury present at the boundary, atmospheric modeling done by SAI for the US EPA was used (Myers, 2003). SAI utilized REMSAD (Regional Modeling System for Aerosols and Depostion), a three-dimensional atmospheric grid model, to estimate the mercury deposition in a 36 km^2 area that covered the District of Columbia and portions of Maryland and Virginia. The total annual mercury deposition for the grid was estimated to be 49.4 $g/km^2/yr$. Multiplying this value by area of the Rock Creek watershed in Maryland (157 km^2) provides a deposition value of 7.76 kg/yr (17.1 lb/yr). If it is assumed that atmospheric deposition is the major source of mercury in the watershed, the value of the upstream load can be determined using the watershed yield.

Watershed yield is the fraction of deposition to the watershed that is transmitted to the surrounding river, lake, or estuary (Mason, 2000). Dr. Mason from the University of Maryland has studied the behavior of mercury in the Chesapeake watershed and in 1998, Dr. Mason published an article that examined the transport of mercury and methyl mercury through an urban watershed. The transport of mercury in the Northeast Branch and the Northwest Branch of the Anacostia River watershed were described in this article (Mason, 1998). The article focused on determining the amount of atmospheric deposition retained in the watershed. Dr. Mason calculated at watershed yield for the Northeast and Northwest Branches of the Anacostia (Mason, 1998). Although no watershed yield has been calculated for Rock Creek watershed the Northwest branch watershed has similar characteristics as the Maryland portion of the Rock Creek watershed. Since the watersheds are similar and are located adjacent to each other, the watershed yield for Northwest Branch was used in Rock Creek. The watershed yield in Northwest Branch ranges between 38 and 84 percent (Mason, 1998). The highest value of yield calculated, 84 percent, was used to be conservative as it will produce a higher load. Using the given deposition of 17.1 lb/yr, an upstream loading of 14.36 lb/yr was calculated.

The SWMM model constructed for the mercury TMDL requires daily mercury concentrations at the upstream boundary. To convert the annual loading of 14.36 lb/yr to daily mercury concentrations, research done by Nicole Lawson was used (2001). In her research, Ms. Lawson showed that total mercury concentrations increased as flow increased. This relationship between flow and total mercury was particularly strong in rivers with a local urbanized area. This relationship between total mercury and flow is consistent with the tendency of mercury to bind strongly to particulate matter. Typically, higher values of particulate matter are seen as flow increases. Combining this relationship and the total load leads to the following set of equations:

$$Load_i = Q_i C_i$$

$$Total\ Annual\ Load = \sum_{i=1}^{n} Load_i$$

$$C_i = \alpha Q_i$$

where: Q_i = daily flow at the upstream boundary
C_i = daily mercury concentration at the upstream boundary
$Load_i$ = daily mercury load
α = proportionality constant
n = 365 or 366 days in one year

The daily flows and total load were known, therefore the set of equations can be solved simultaneously, and the total mercury concentration for each day was determined. As a check, the mercury concentrations calculated were compared with literature values and the data collected by DC DOH at the Maryland/DC boundary. The lowest mercury concentration calculated at the DC/MD boundary of Rock Creek by this method was 0.005 ug/L. Data collected by Robert Mason for the NW Branch of the Anacostia River included an average base- flow concentration of 0.00445 ug/L (Mason, 1998). The highest mercury concentration calculated using this approach was 0.47 ug/L. DC DOH has recorded a value of 0.3 ug/L at the DC/MD boundary, so the calculated value appears to be reasonable.

Water Quality Standards for Mercury

Three numeric criteria for mercury apply in Rock Creek. Class C, protection and propagation of fish, shellfish, and wildlife, criteria include two numeric criteria. The Criteria Maximum Concentration (CMC) is the acute criterion that estimates the highest concentration of a pollutant in surface water to which an aquatic community can be briefly exposed without resulting in an unacceptable effect. The Criteria Continuous Concentration (CCC) is the chronic criterion that estimates the highest concentration of a pollutant in surface water to which an aquatic community can be indefinitely exposed without resulting in an unacceptable effect. A Class D criteria for protection of human health related to consumption of fish and shellfish, is also applicable for mercury. The Class C and Class D water quality standards for the District of Columbia are presented in Table 2.

Table 2: District of Columbia Mercury Criteria

	Class C		**Class D 30 Days**
	CMC One Hour	**CCC Four Days**	
Total Recoverable Mercury (ug/L)	2.4	0.012	0.15

Model Application

The representative three-year period from 1988 to 1990 used in developing the LTCP, the Anacostia River and tributary TMDLs, and other Rock Creek tributary TMDLs was used when applying the model for the mercury TMDL. This time period includes a wet year, a dry year and an average year. The SWMM Model was run using mercury loading inputs developed in an earlier section of this memorandum. Following completion of the three-year model simulation, the results were processed to compared the model output to the water quality standards for mercury. The results of the three-year simulation for total mercury at Segment 7 (a representative segment near the Massachusetts Avenue Bridge) of the Rock Creek model are presented in Figure 2.

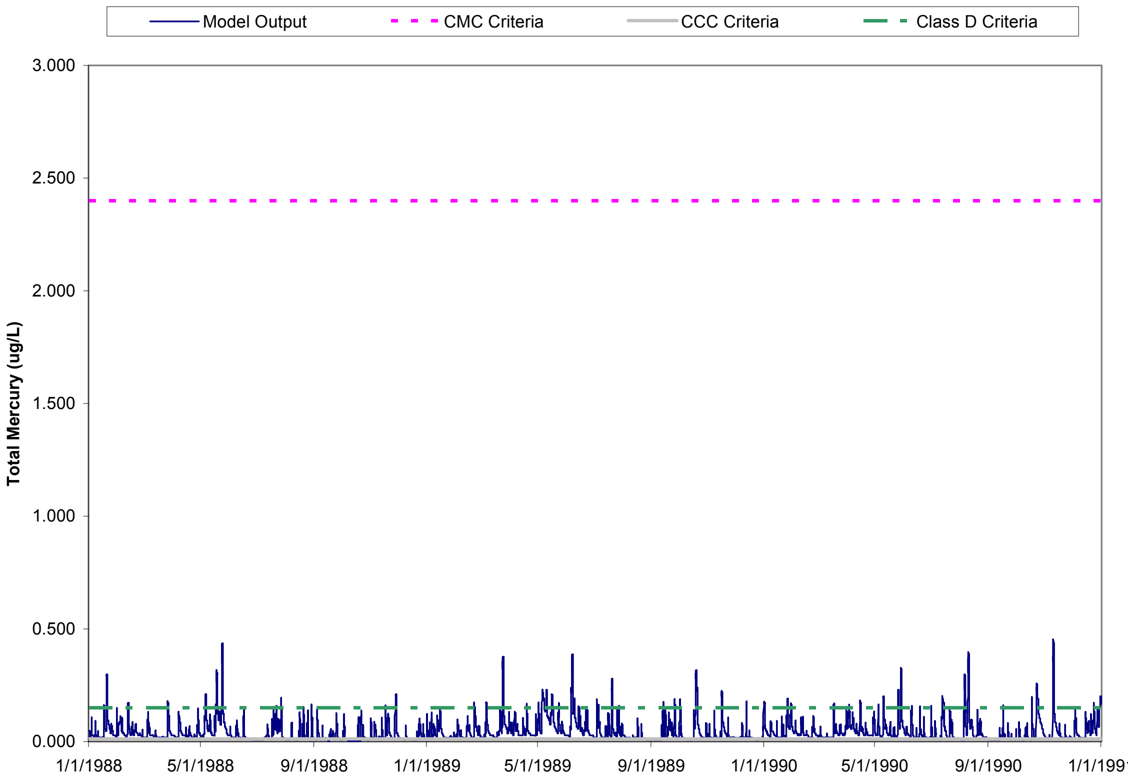

Figure 2: Three-year Model Results for Total Mercury

From this figure and the model output for other segments, it was determined that the mercury levels never exceed the CMC criteria during the three-year simulation.

To investigate whether the model will exceed the CCC (chronic) criteria or Class D standard under existing conditions, the results for total mercury at segment 7 during a shorter but illustrative six-month period were plotted. These model results are presented as Figure 3.

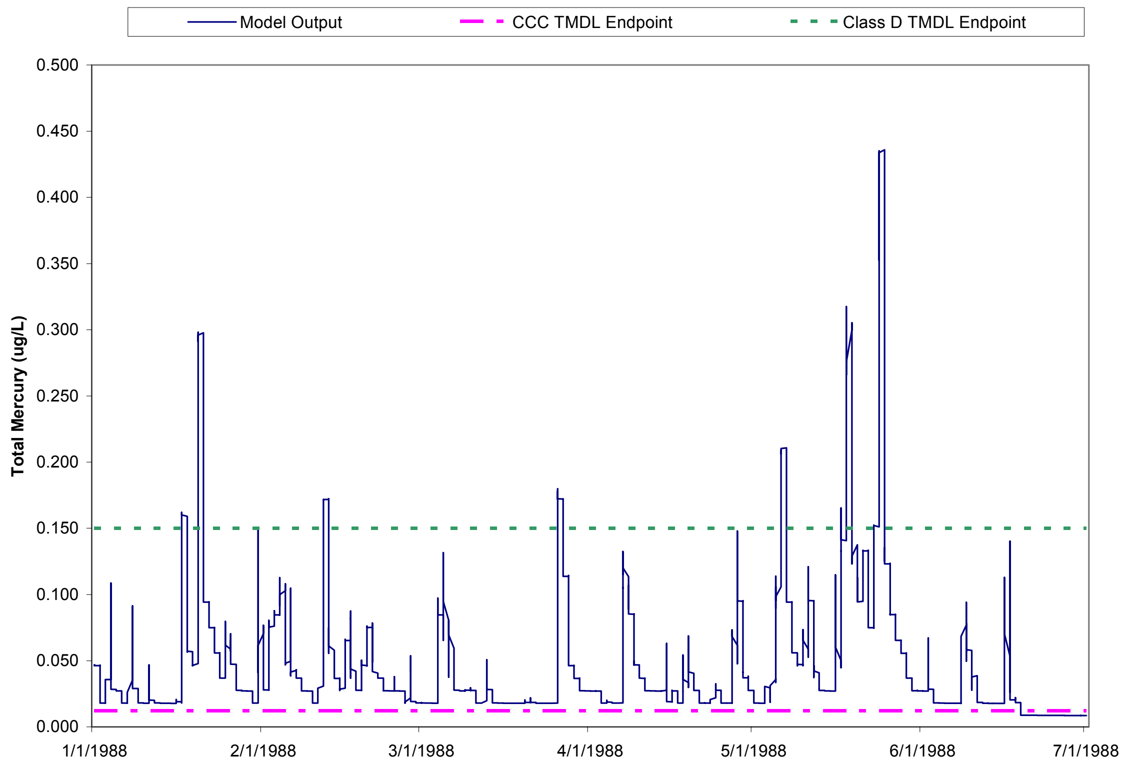

Figure 3: Six-Month Model Results for Total Mercury

Examining Figure 3, the model predicts that the chronic standard (CCC) for total mercury is almost continually exceeded in Rock Creek at segment 7. This is also true at other segments. The Class D standard in exceeded occasionally in this segment. Therefore, load reductions are needed for mercury in Rock Creek. To meet the chronic standard during the entire three-year model simulation, the following load reductions were needed:

- CSO loads were reduced to match the load reductions specified under the LTCP. Through the provisions in the LTCP, the mercury load will be reduced by 90 percent.
- All storm water loads (piped and parkland runoff) were reduced by 85 percent. This was needed to prevent violations in the downstream segments of the model.
- Upstream loads were reduced by 97 percent. This was needed to prevent violations in the upstream segments of the model.

A five percent margin of safety was used and the TMDL model simulations were compared to a chronic standard of 0.0120 ug/L and a class D standard of 0.15 ug/L. The results were not compared to the acute standard as the existing condition for total mercury does not exceed this standard (Figure 2). The model results for total mercury after the load reductions are presented in Tables 3 and 4.

Table 3: Maximum 4-day Average Total Mercury Concentrations (ug/L) After Load Reductions

Month/Year	**1**	**7**	**12**	**17**	**18**	**40**
January-88	0.0042	0.0042	0.0041	0.0041	0.0040	0.0025
February-88	0.0028	0.0028	0.0028	0.0028	0.0028	0.0025
March-88	0.0031	0.0031	0.0031	0.0031	0.0030	0.0025
April-88	0.0011	0.0011	0.0010	0.0010	0.0009	0.0000
May-88	0.0043	0.0043	0.0041	0.0040	0.0039	0.0025
June-88	0.0019	0.0019	0.0017	0.0016	0.0015	0.0000
July-88	0.0029	0.0028	0.0025	0.0024	0.0022	0.0000
August-88	0.0027	0.0027	0.0025	0.0025	0.0023	0.0000
September-88	0.0017	0.0017	0.0016	0.0015	0.0014	0.0000
October-88	0.0034	0.0033	0.0031	0.0031	0.0028	0.0000
November-88	0.0037	0.0037	0.0036	0.0036	0.0035	0.0025
December-88	0.0037	0.0037	0.0036	0.0036	0.0035	0.0025
January-89	0.0027	0.0026	0.0024	0.0024	0.0022	0.0000
February-89	0.0017	0.0017	0.0015	0.0016	0.0014	0.0000
March-89	0.0035	0.0035	0.0034	0.0034	0.0033	0.0025
April-89	0.0021	0.0021	0.0019	0.0019	0.0017	0.0000
May-89	0.0066	0.0064	0.0063	0.0063	0.0060	0.0050
June-89	0.0078	0.0079	0.0078	0.0079	0.0078	0.0074
July-89	0.0048	0.0047	0.0045	0.0045	0.0043	0.0025
August-89	0.0016	0.0015	0.0014	0.0013	0.0012	0.0000
September-89	0.0045	0.0044	0.0039	0.0039	0.0038	0.0025
October-89	0.0067	0.0067	0.0066	0.0066	0.0065	0.0050
November-89	0.0034	0.0033	0.0033	0.0032	0.0031	0.0025
December-89	0.0026	0.0025	0.0024	0.0023	0.0022	0.0000
January-90	0.0037	0.0038	0.0036	0.0037	0.0036	0.0025
February-90	0.0029	0.0029	0.0029	0.0029	0.0029	0.0025
March-90	0.0017	0.0017	0.0016	0.0015	0.0014	0.0000
April-90	0.0035	0.0035	0.0034	0.0034	0.0033	0.0025
May-90	0.0056	0.0057	0.0056	0.0056	0.0056	0.0050
June-90	0.0031	0.0031	0.0030	0.0030	0.0030	0.0025
July-90	0.0066	0.0066	0.0065	0.0065	0.0064	0.0050
August-90	0.0044	0.0043	0.0042	0.0042	0.0040	0.0025
September-90	0.0019	0.0019	0.0017	0.0017	0.0015	0.0000
October-90	0.0057	0.0058	0.0057	0.0058	0.0057	0.0050
November-90	0.0029	0.0029	0.0028	0.0028	0.0028	0.0025
December-90	0.0033	0.0033	0.0033	0.0033	0.0033	0.0025

Table 4: Max 30-day Average Total Mercury (ug/L)

Month/Year	1	7	12	17	18	40
January-88	0.001	0.001	0.001	0.001	0.001	0.000
February-88	0.001	0.001	0.001	0.001	0.001	0.001
March-88	0.001	0.001	0.001	0.001	0.001	0.000
April-88	0.001	0.001	0.001	0.001	0.001	0.000
May-88	0.002	0.002	0.002	0.002	0.002	0.001
June-88	0.002	0.002	0.002	0.002	0.001	0.001
July-88	0.001	0.001	0.001	0.001	0.001	0.000
August-88	0.001	0.001	0.001	0.001	0.001	0.000
September-88	0.001	0.001	0.001	0.001	0.001	0.000
October-88	0.001	0.001	0.001	0.001	0.001	0.000
November-88	0.001	0.001	0.001	0.001	0.001	0.000
December-88	0.001	0.001	0.001	0.001	0.001	0.000
January-89	0.001	0.001	0.001	0.001	0.001	0.000
February-89	0.001	0.001	0.001	0.001	0.001	0.000
March-89	0.001	0.001	0.001	0.001	0.001	0.001
April-89	0.001	0.001	0.001	0.001	0.001	0.001
May-89	0.002	0.002	0.002	0.002	0.002	0.001
June-89	0.002	0.002	0.002	0.002	0.002	0.001
July-89	0.002	0.002	0.002	0.002	0.002	0.001
August-89	0.002	0.002	0.002	0.002	0.001	0.001
September-89	0.002	0.002	0.001	0.001	0.001	0.000
October-89	0.002	0.002	0.002	0.002	0.002	0.001
November-89	0.002	0.002	0.002	0.002	0.002	0.001
December-89	0.001	0.001	0.001	0.001	0.001	0.000
January-90	0.002	0.002	0.002	0.002	0.002	0.001
February-90	0.001	0.001	0.001	0.001	0.001	0.001
March-90	0.001	0.001	0.001	0.001	0.001	0.000
April-90	0.001	0.001	0.001	0.001	0.001	0.000
May-90	0.002	0.002	0.002	0.002	0.002	0.001
June-90	0.002	0.002	0.002	0.002	0.001	0.001
July-90	0.002	0.002	0.002	0.002	0.001	0.001
August-90	0.002	0.002	0.002	0.002	0.002	0.001
September-90	0.001	0.001	0.001	0.001	0.001	0.001
October-90	0.001	0.001	0.001	0.001	0.001	0.001
November-90	0.002	0.001	0.001	0.001	0.001	0.001
December-90	0.001	0.001	0.001	0.001	0.001	0.000

Conclusions

With the upstream loads, storm water loads, and CSO loads reduced, the instream mercury concentrations are less than the CMC, CCC, and Class D standards in all segments.

References

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