FINAL

APPENDIX E – Summary and Evaluation of the Alternative Lake Linganore Sediment TMDL

INTRODUCTION

In 2003, the EPA approved the document *Total Maximum Daily Loads of Phosphorus and Sediments for Lake Linganore, Frederick County, MD.* Lake Linganore is located in the northeastern portion of the Lower Monocacy River watershed. It is an impoundment within the Eagle Head development, near the city of Frederick in Frederick County, Maryland. The impoundment is part of the Linganore Creek subwatershed, a tributary of the Lower Monocacy River (MDE 2003).

In 1996 Lake Linganore was identified as impaired by both phosphorus and sediments. The phosphorus listing was based on water quality data, whereas the basis for the sediment listing was not explicitly stated. It has been determined that the sediment listing was a best professional judgment determination based on land use analysis.

Maryland does not have a numeric standard that could serve as a TMDL endpoint for sediment TMDLs in impoundments. In the absence of an applicable numeric criterion, Maryland has adopted a pragmatic approach for developing TMDLs for sediment in impoundments. Given the propensity of phosphorus to bind to sediments, reductions in phosphorous loads are expected to result in sediment load reductions (i.e., 0.5:1 sediment to phosphorous ratio). Consequently, whenever a phosphorus TMDL is developed for an impoundment/reservoir with a sediment listing, the Department evaluates whether the TMDL will also result in sediment conditions that preserve impoundment/reservoir capacity, thereby meeting the sediment requirement for the waterbody's specific designated use.

The Lake Linganore TMDL for phosphorus was based on two widely accepted empirical methods: the Vollenweider Relationship and Carlson's Trophic State Index. The results of this analysis required a 90% reduction in phosphorus loads in order to attain water quality standards within the impoundment. The sediment TMDL for this report was calculated based on a 0.5:1 ratio of sediment reduction to phosphorus reduction. Therefore, the net sediment reduction associated with a 90% phosphorus reduction is equivalent to a 45% reduction (0.9*0.5 = 0.45). This reduction was determined to significantly extend the impoundment's capacity, thus meeting the sediment conditions protective of Lake Linganore's designated use (Use IV-P: Recreational Trout Waters and Public Water Supply).

The Lower Monocacy River watershed 1996 sediment listing refers to the entire MD 8-digit watershed, which inherently includes the Lake Linganore drainage basin. In order to maintain consistency with the 2003 Lake Linganore Sediment TMDL and to ensure that the 2003 Lake Linganore sediment TMDL is also protective of the tributary streams draining to the impoundment, the Lake Linganore watershed was analyzed separately applying the same analytical approach as was used to develop a TMDL protective of aquatic health within the remainder of the Lower Monocacy River watershed. Since this

analysis indicated that the 2003 Lake Linganore sediment TMDL is more environmentally conservative than the alternative TMDL estimated within this appendix, the 2003 Lake Linganore sediment TMDL will be applied in the Lower Monocacy River TMDL analysis and will be presented as an upstream load.

SETTING AND WATER QUALITY DESCRIPTION

General Setting

Location

Lake Linganore is an impoundment located near the city of Frederick in Frederick County, Maryland (See Figure 1 of main report). The impoundment, which is owned by the Lake Linganore Association, lies on Linganore Creek, a tributary of the Lower Monocacy River. An earthen dam was installed in 1972 to create the lake for the purpose of water supply and for recreational use.

Geology/Soils

The watershed lies in the Piedmont physiographic province, and the soils immediately surrounding the lake are of the Manor-Linganore-Montalto association. The Montalto soils are deep, well drained, and fine textured while the Manor and Linganore soils are generally shallow to very shallow, excessively drained, immature, or skeletal. They form in material weathered from schistose, schist or phyllite, and igneous rocks. The outer watershed area is comprised of soils of the Duffield-Hagerstown association. These soils are well drained and developed from limestone (USDA 1960).

Land Use

Land Use Methodology

For a detailed description of the methodology used to assess the Lake Linganore watershed land use, please see Section 2.1.1 of the main report.

Lake Linganore Land Use Distribution

The land use distribution in the Lake Linganore watershed consists of nearly equal amounts of crop (31%), forest (31%), and urban (27%) land uses. Pasture (11%) makes up the remainder of the land use distribution. A land use map is provided in Figure 2 of the main report and a summary of the watershed land use areas is presented in Table E-1.

Table E-1: Land Use Percentage Distribution for the Lake Linganore Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	26.4	N/A[1]	
	Hay	6,485.9	12.0	
	High Till	5,013.0	9.3	
	Low Till	5,138.5	9.5	
	Nursery	229.6	0.4	31.3
Extractive	Extractive	1.2	N/A[1]	N/A[1]
Forest	Forest	16,545.9	30.7	
	Harvested Forest	167.1	0.3	31.0
Pasture	Natural Grass	153.9	0.3	
	Pasture	5,803.9	10.8	
	Trampled Pasture	30.4	0.1	11.1
Urban	Urban: Barren	171.4	0.3	
	Urban: Imp	1,286.8	2.4	
	Urban: perv	12,872.8	23.9	26.6
	Total	53,926.8	100.0	100.0

Note: [1] Percentage of total land area is minimal.

Source Assessment

For a detailed description of the methodology used to estimate the current nonpoint and point source baseline loadings within the Lake Linganore watershed, please see Sections 2.2.1-2.2.3 of the main report.

Summary of Baseline Loads

Table E-2 summarizes the Lake Linganore baseline sediment loads, which are reported in ton/yr and presented in terms of nonpoint and point source loadings.

Table E-2: Lake Linganore Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{LL}	+	NPDES Stormwater BL_{LL}	+	Process Water BL_{LL}
21,767.9	=	18,776.0	+	2,989.6	+	2.3

Table E-3 presents a breakdown of baseline loads generated within the Lake Linganore watershed, detailing loads per land use. The majority of the sediment load is from crop land (74.9%). The next largest sediment sources are urban land (13.7%), pasture (6.2%), and forest (5.1%).

Table E-3: Detailed Baseline Sediment Budget Loads Generated Within the Lake Linganore Watershed

General Land Use	Description	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	64.7	0.3	
	Hay	2,706.1	12.4	
	High Till	8,024.7	36.9	
	Low Till	4,954.6	22.8	
	Nursery	563.1	2.6	74.9
Extractive	Extractive	2.6	N/A[1]	N/A[1]
Forest	Forest	1,020.1	4.7	
	Harvested Forest	96.0	0.4	5.1
Pasture	Natural Grass	37.1	0.2	
	Pasture	1,240.1	5.7	
	Trampled Pasture	66.9	0.3	6.2
Urban	Urban: Barren	393.0	1.8	
	Urban: Imp	1,070.1	4.9	
	Urban: perv	1,526.5	7.0	13.7
N/A	Process Load	2.3	N/A	N/A
	Total	21,767.9	100.0	100.0

Note: [1] Percentage of total sediment load is minimal.

Water Quality Characterization

For a detailed description of the MBSS data (i.e., the individual MBSS parameters used in this analysis and how these data were collected) used to assess the Lake Linganore watershed, please see Section 2.3 of the main report.

Lake Linganore Watershed MBSS Monitoring Stations

A total of 10 water quality monitoring stations were used to characterize the Lake Linganore watershed, all of which were biological/physical habitat monitoring stations from the MBSS program. The stations are presented in Figure 4 of the main report and listed in Table E-4. Observed values of the SSDI selected MBSS parameters along with total BIBI and FIBI scores for each monitoring station are presented in Table E-5.

Table E-4: Monitoring Stations in the Lake Linganore Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude	Longitude
LMON-107-R-2003	MD DNR	MBSS	Bens Branch, unnamed tributary 1	39.419	-77.253
LMON-108-R-2003	MD DNR	MBSS	Weldon Creek	39.4742	-77.115
LMON-109-R-2003	MD DNR	MBSS	Talbot Branch, unnamed tributary 1	39.449	-77.152
LMON-113-R-2003	MD DNR	MBSS	South Fork Linganore Creek, unnamed tributary 1	39.4338	-77.117
LMON-118-R-2003	MD DNR	MBSS	Lake Linganore, unnamed tributary 1	39.3942	-77.302
LMON-123-R-2003	MD DNR	MBSS	Town Branch, unnamed tributary 1	39.4817	-77.262
LMON-127-R-2003	MD DNR	MBSS	Long Branch, unnamed tributary 1	39.394	-77.322
LMON-142-R-2003	MD DNR	MBSS	Linganore Lake, unnamed tributary	39.4212	-77.336
LMON-328-R-2003	MD DNR	MBSS	North Fork Linganore Creek	39.4627	-77.196
LMON-337-R-2003	MD DNR	MBSS	Bens Branch	39.4163	-77.286

Table E-5: Lake Linganore MBSS Data

Site	FIBI	BIBI	Epifaunal Substrate	Percent Embeddedness	Instream Habitat	Bank Stability	Benthic Tolerant Species
LMON-107-R-2003	3.67	2.5	16	30	16	14.5	5.29
LMON-108-R-2003	3.33	3.25	10	35	15	20	4.85
LMON-109-R-2003	4	2.5	17	25	16	17.67	5.46
LMON-113-R-2003	3.67	2.25	8	40	6	12.2	5.07
LMON-118-R-2003	3	2	5	55	7	14	5.88
LMON-123-R-2003	2	2.25	11	40	9	14.8	5
LMON-127-R-2003	NS	3.5	NS	NS	NS	NS	5.19
LMON-142-R-2003	1	2.5	6	20	6	16.2	2.83
LMON-328-R-2003	4.33	2.75	6	60	16	14.53	5.75
LMON-337-R-2003	4.67	2.75	13	35	16	8.8	5.32

Note: NS = No Sample

Water Quality Impairment

For a detailed description of the SSDI methodology used to determine whether or not aquatic health within the Lake Linagnore watershed is impacted by elevated sediment loads, please see Section 2.4 of the main report. This section thoroughly describes the MBSS parameters used to calculate the SSDI, why these parameters were chosen, and how they were combined/analyzed to calculate the SSDI.

The Lake Linganore watershed average BIBIs, FIBIs, and corresponding SSDIs are listed in Table E-6. The BIBIs and FIBIs indicate that the watershed is exhibiting a negative deviation from reference conditions. Both the benthic and fish based SSDIs indicate that sediment is a stressor to the aquatic community.

Table E-6: Lake Linganore IBI and SSDI Values

Site	BIBI	Benthic SSDI	FIBI	Fish SSDI
LMON-107-R-2003	2.5	3.5	3.67	4.33
LMON-108-R-2003	3.25	3.5	3.33	3.0
LMON-109-R-2003	2.5	3.5	4.0	5.0
LMON-113-R-2003	2.25	2.5	3.67	1.67
LMON-118-R-2003	2.0	1.5	3.0	1.0
LMON-123-R-2003	2.25	3.0	2.0	2.33
LMON-127-R-2003	3.5	3.0	NS	NS
LMON-142-R-2003	2.5	3.5	1.0	2.33
LMON-328-R-2003	2.75	1.5	4.33	2.33
LMON-337-R-2003	2.75	2.0	4.67	3.67
Average	**2.63 ± 0.24**	**2.70 ± 0.41**	**3.30 ± 0.64**	**2.85 ± 0.70**

Note: NS = No Sample

TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

For a detailed description regarding the general methodology used to calculate the alternative Lake Linganore sediment TMDL, please refer to Sections 4.1-4.4 and Section 4.7 within the main report. These sections thoroughly describe the following components of the alternative Lake Linganore sediment TMDL analysis: the CBP PV watershed model, the reference watershed approach, the forest normalized sediment load, the sediment loading threshold and its calculation, the formula for calculating the TMDL, and the incorporation of critical conditions, seasonality, and a margin of safety.

TMDL Loading Caps

The average annual alternative Lake Linganore TMDL of TSS is considered the maximum allowable long-term average annual load the watershed can receive and still meet water quality standards. The alternative Lake Linganore sediment TMDL was set at a load 3.3 times the all forested condition. In order to arrive at the TMDL, equal

reductions were applied to the predominant controllable sources (i.e., significant contributors of sediment to the stream system) in the TMDL analysis segment. This approach aims to achieve water quality standards in the most effective, efficient, and equitable manner. Predominant sources typically include urban land, high till crops, low till crops, hay, pasture, and harvested forest, but additional sources might need to be controlled in order to ensure that the water quality standards are attained. The Lake Linganore watershed baseline load and alternative Lake Linganore sediment TMDL are presented in Table E-7.

Table E-7: Lake Linganore Watershed Sediment Baseline Load and Alternative Lake Linganore Sediment TMDL

Baseline Load (ton/yr)	Alternative TMDL (ton/yr)	Reduction (%)
21,767.9	11,133.6	48.8

Load Allocations Between Point and Nonpoint Sources

Table E-8 summarizes the alternative Lake Linganore sediment TMDL results derived by applying the reductions equally to the predominant controllable sediment sources. The source categories in the table represent aggregates of multiple sources (e.g. crop source is an aggregate of high till, low till, hay, animal feeding operations, and nursery sources). The alternative Lake Linganore sediment TMDL of 11,133.6 ton/year is equivalent to a 48.8% overall reduction.

Table E-8: Alternative Lake Linganore Sediment TMDL Reductions by Source Category

Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source	Crop	16,313.2	**LA**	7,875.4	51.7
	Extractive	2.6		2.6	0.0
	Forest	1,116.1		1,116.1	0.0
	Pasture	1,344.1		700.1	47.9
Point Source	Urban	2,989.6	**WLA**	1,437.1	51.9
	Permits	2.3		2.3	0.0
Total		**21,767.9**		**11,133.6**	**48.8**

Summary of Alternative Lake Linganore Sediment Total Maximum Daily Loads

The average annual alternative Lake Linganore sediment TMDL is summarized in Table E-9. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, and MOS.

Table E-9: Average Annual Alternative Lake Linganore TMDL of Sediment/TSS Summary (ton/yr)

Alternative TMDL (ton/yr)	=	Nonpoint Source BL_{LL}	+	NPDES Stormwater BL_{LL}	+	Process Water BL_{LL}	+	MOS
11,133.6	=	9,694.2	+	1,437.7	+	2.3	+	Implicit

COMPARISON

The analysis presented in this appendix indicates that the 2003 Lake Linganore sediment TMDL is more environmentally conservative than the alternative Lake Linganore sediment TMDL and is thus not only preserving the impoundment's capacity, but is also protective of the aquatic health within the tributary streams draining to the impoundment. Therefore, the 2003 Lake Linganore sediment TMDL will be applied in the Lower Monocacy River TMDL analysis and will be presented as an upstream load.

Table E-11 compares the 2003 Lake Linganore sediment TMDL to the alternative Lake Linganore sediment TMDL estimated in this appendix.

Table E-11: Comparison of the 2003 Lake Linganore Sediment TMDL to the Alternative Lake Linganore Sediment TMDL

2003 Lake Linganore Sediment TMDL (ton/yr)	Alternative Lake Linganore TMDL (ton/yr)
7,073.0	11,133.6