Appendix A

Christina Basin Nutrient and Bacteria TMDLs

Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland

September 2006

U.S. Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, Pennsylvania

Errata

4/30/2007

The2005 and 2006 Total Maximum Daily Load of Nutrients and Low Dissolved Oxygen Under High-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, *established April 8, 2005, and revised September 26, 2006, by EPA was not intended to modify wasteload allocations (WLAs)established in the* Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, *to the two WWTPs discharging to the West Branch Christina River in Maryland. The two WWTPs are:*

Highlands WWTP MD0065145
Meadowview WWTP MD0022641

The corrected portions of summary tables are shown in italics below.

Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	*96.5*	26.2	*72.8%*
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
C01	*57.781*	53.686	*110.467*	*57.781*	2.634	7.566	0.537	*67.718*	*38.9%*
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	*52.996*	2.650	*52.996*	2.650	0.0%	0.0%
C01	MD0065145	0.0500	*3.785*	0.189	*3.785*	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

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Executive Summary

Revisions to
Nutrient and Low dissolved Oxygen TMDL
Under High-Flow Conditions for
Christina River Watershed
Pennsylvania, Delaware, and Maryland

The Clean Water Act (CWA) requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the states where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint and natural background sources, including a margin of safety (MOS), which may be discharged to a water quality-limited waterbody without violating water quality standards.

TMDLs are defined as the summation of the point source WLAs plus the summation of the nonpoint source LAs plus a MOS and are often shown as:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The TMDL is a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards. The TMDL is a scientifically-based strategy that considers current and foreseeable conditions, the best available data, and accounts for uncertainty with the inclusion of a MOS value.

The TMDLs are to achieve and maintain the States' existing water quality standards and must meet the following eight regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDLs are designed to implement the applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual Wasteload Allocations (WLAs) and Load Allocations (LAs).
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a MOS.
7. There is reasonable assurance that the proposed TMDLs can be met.
8. The TMDLs have been subject to public participation.

As interstate TMDLs, both Pennsylvania and Maryland have the responsibility of meeting downstream Delaware's water quality standards.

The Pennsylvania Department of Environment Protection (PADEP) identified waterbodies within Pennsylvania's portion of the Christina River Watershed as impaired by nutrients, organic enrichment, or low dissolved oxygen, which are addressed in this TMDL Report. The Delaware Department of Natural Resources and Environmental Control (DNREC) identified waterbodies

within Delaware's portion of the Christina River Basin as impaired by nutrients or low dissolved oxygen. Maryland's Department of the Environment (MDE) has not identified waterbodies within the Christina River Watershed as impaired.

Both PADEP and DNREC have designated the primary contact recreation (swimming) and protection of aquatic life (fishing) uses for waterbodies in the Christina River Basin. Applicable use designations and dissolved oxygen (DO) criteria are shown in Table 1-5 and a summary of nutrient criteria is shown in Table 1-6.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the U.S. Geological Survey (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of nutrients.

Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	68.7	26.2	61.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
B01	31.559	362.174	393.733	31.559	170.416	36.023	10.865	248.863	36.8%
B02	0.000	114.369	114.369	0.000	65.191	0.000	3.431	68.622	40.0%
B03	2.167	89.226	91.393	2.167	67.779	8.510	4.015	82.471	9.8%
B04	0.000	5.369	5.369	0.000	5.101	0.000	0.268	5.369	0.0%
B05	558.690	77.512	636.202	558.690	34.049	10.133	2.325	605.197	4.9%
B06	0.156	123.362	123.518	0.156	80.940	1.095	4.318	86.509	30.0%
B09	0.078	252.455	252.533	0.078	97.148	99.515	10.351	207.092	18.0%
B10	3.721	252.455	256.176	3.721	179.343	17.320	10.351	210.735	17.7%
B17	1.013	83.890	84.903	1.013	43.626	30.491	3.901	79.031	6.9%
B18	0.000	103.795	103.795	0.000	98.605	0.000	5.190	103.795	0.0%
B19	0.946	64.711	65.657	0.946	61.475	0.000	3.236	65.657	0.0%
B32	0.000	29.001	29.001	0.000	24.796	0.000	1.305	26.101	10.0%
B33	1.799	95.092	96.891	1.799	80.541	0.763	4.279	87.382	9.8%
B34	11.443	33.958	45.401	4.107	32.260	0.000	1.698	38.065	16.2%
Total Phosphorus									
B01	6.360	6.920	13.280	6.360	3.256	0.688	0.208	10.512	20.8%
B02	0.000	2.185	2.185	0.000	1.245	0.000	0.066	1.311	40.0%
B03	0.540	16.229	16.769	0.540	12.328	1.548	0.730	15.146	9.7%
B04	0.000	0.988	0.988	0.000	0.939	0.000	0.049	0.988	0.0%
B05	35.524	14.615	50.139	35.524	6.420	1.911	0.438	44.293	11.7%
B06	0.040	25.254	25.294	0.040	16.570	0.224	0.884	17.718	30.0%
B09	0.020	3.849	3.869	0.020	1.481	1.517	0.158	3.176	17.9%
B10	0.429	3.848	4.277	0.429	2.734	0.264	0.158	3.585	16.2%
B17	0.221	7.508	7.729	0.221	3.904	2.729	0.349	7.203	6.8%
B18	0.000	8.586	8.586	0.000	8.157	0.000	0.429	8.586	0.0%
B19	0.189	2.376	2.565	0.189	2.257	0.000	0.119	2.565	0.0%
B32	0.000	2.147	2.147	0.000	1.836	0.000	0.097	1.933	10.0%
B33	0.115	1.729	1.844	0.115	1.465	0.014	0.078	1.672	9.3%
B34	1.966	2.843	4.809	0.730	2.701	0.000	0.142	3.573	25.7%

WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B01	PA0036412	0.0550	2.682	0.559	2.682	0.559	0.0%	0.0%
B01	PA0044776	0.6000	28.799	5.781	28.799	5.781	0.0%	0.0%
B01	PA0057339	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B03	PA0052728	0.0004	0.036	0.015	0.036	0.015	0.0%	0.0%
B03	PA0055697	0.0490	2.131	0.525	2.131	0.525	0.0%	0.0%
B05	PA0011568-001	0.6400	14.045	1.029	14.045	1.029	0.0%	0.0%
B05	PA0011568-016	0.5045	23.868	0.811	23.868	0.811	0.0%	0.0%
B05	PA0026859	3.8500	466.237	29.508	466.237	29.508	0.0%	0.0%
B05	PA0036897	0.3900	54.54	4.176	54.54	4.176	0.0%	0.0%
B06	PA0053228	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B06	PA0053236	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B09	PA0054691	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0050458	0.0351	1.724	0.188	1.724	0.188	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B10	PA0050547	0.0375	1.841	0.201	1.841	0.201	0.0%	0.0%
B10	PA0055492	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0057827	0.0050	0.078	0.02	0.078	0.02	0.0%	0.0%
B17	PA0053082	0.0206	1.013	0.221	1.013	0.221	0.0%	0.0%
B19	DE0021768	0.0250	0.947	0.189	0.947	0.189	0.0%	0.0%
B33	PA0012416	0.1400	1.643	0.075	1.643	0.075	0.0%	0.0%
B33	PA0052990	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B33	PA0056073	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B34	(DE CSO)	See Table 4-11						

TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
R01	3.677	126.926	130.603	3.677	54.709	5.581	3.173	67.140	48.6%
R02	49.825	104.678	154.503	49.825	49.722	0.000	2.617	102.164	33.9%
R03	6.807	120.151	126.958	6.807	57.071	0.000	3.004	66.882	47.3%
R04	2.197	39.984	42.181	2.197	18.992	0.000	1.000	22.189	47.4%
R05	0.568	34.713	35.281	0.568	16.489	0.000	0.868	17.925	49.2%
R06	0.078	67.015	67.093	0.078	63.664	0.000	3.351	67.093	0.0%
R07	0.000	3.012	3.012	0.000	2.861	0.000	0.151	3.012	0.0%
R08	0.318	23.882	24.200	0.318	22.688	0.000	1.194	24.200	0.0%
R09	0.000	7.346	7.346	0.000	6.979	0.000	0.367	7.346	0.0%
Total Phosphorus									
R01	0.914	2.277	3.191	0.914	0.982	0.100	0.057	2.053	35.7%
R02	7.506	45.473	52.979	7.506	4.320	0.000	0.227	12.053	77.2%
R03	1.606	2.845	4.451	1.606	1.352	0.000	0.071	3.029	31.9%
R04	1.699	6.407	8.106	1.699	1.887	0.000	0.099	3.685	54.5%
R05	0.114	4.249	4.363	0.114	4.037	0.000	0.212	4.363	0.0%
R06	0.020	1.269	1.289	0.020	1.206	0.000	0.063	1.289	0.0%
R07	0.000	0.424	0.424	0.000	0.403	0.000	0.021	0.424	0.0%
R08	0.133	1.383	1.516	0.133	1.314	0.000	0.069	1.516	0.0%
R09	0.000	0.360	0.360	0.000	0.342	0.000	0.018	0.360	0.0%

WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R01	PA0050679	0.2500	0.321	0.134	0.321	0.134	0.0%	0.0%
R01	PA0057720-001	0.0720	3.240	0.732	3.240	0.732	0.0%	0.0%
R01	PA0057720-002	0.0900	0.116	0.048	0.116	0.048	0.0%	0.0%
R02	PA0024058	1.1000	49.825	7.506	49.825	7.506	0.0%	0.0%
R03	PA0055107	0.1500	6.807	1.606	6.807	1.606	0.0%	0.0%
R04	DE0000451	2.1700	1.972	1.643	1.972	1.643	0.0%	0.0%
R04	DE0050067	0.0015	0.225	0.056	0.225	0.056	0.0%	0.0%
R05	DE0021709	0.0150	0.568	0.114	0.568	0.114	0.0%	0.0%
R06	PA0055425	0.0005	0.078	0.020	0.078	0.020	0.0%	0.0%
R08	DE0000230	0.3500	0.318	0.133	0.318	0.133	0.0%	0.0%

TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
W01	0.981	157.038	158.019	0.981	74.593	0.000	3.926	79.500	49.7%
W02	15.503	133.766	149.269	15.503	47.807	9.378	3.010	75.697	49.3%
W03	0.000	87.269	87.269	0.000	41.453	0.000	2.182	43.635	50.0%
W04	0.000	83.361	83.361	0.000	38.121	1.476	2.084	41.681	50.0%
W06	59.718	168.665	228.383	59.718	50.433	29.683	4.217	144.051	36.9%
W07	8.868	29.463	38.331	8.868	13.994	0.000	0.737	23.599	38.4%
W08	1.164	129.466	130.630	1.164	61.496	0.000	3.237	65.897	49.6%
W09	0.113	79.504	79.617	0.113	37.764	0.000	1.988	39.865	49.9%
W10	0.000	32.949	32.949	0.000	15.651	0.000	0.824	16.475	50.0%
W11	0.000	39.714	39.714	0.000	37.728	0.000	1.986	39.714	0.0%
W12	0.027	52.612	52.639	0.027	49.981	0.000	2.631	52.639	0.0%
W13	0.000	12.866	12.866	0.000	12.223	0.000	0.643	12.866	0.0%
W14	0.000	13.572	13.572	0.000	12.893	0.000	0.679	13.572	0.0%
W15	0.000	34.796	34.796	0.000	33.056	0.000	1.740	34.796	0.0%
W16	0.000	39.019	39.019	0.000	37.068	0.000	1.951	39.019	0.0%
W17	0.000	84.250	84.250	0.000	80.038	0.000	4.213	84.250	0.0%
Total Phosphorus									
W01	0.214	1.921	2.135	0.214	0.821	0.000	0.043	1.078	49.5%
W02	2.676	1.418	4.094	2.676	0.507	0.100	0.032	3.315	19.0%
W03	0.000	16.736	16.736	0.000	7.155	0.000	0.377	7.532	55.0%
W04	0.000	1.170	1.170	0.000	0.482	0.019	0.026	0.527	55.0%
W06	6.493	2.203	8.696	6.493	0.330	0.194	0.028	7.044	19.0%
W07	0.105	1.890	1.995	0.105	0.808	0.000	0.043	0.955	52.1%
W08	0.084	59.994	60.078	0.084	15.958	0.000	0.840	16.882	71.9%
W09	0.046	15.519	15.565	0.046	6.635	0.000	0.349	7.030	54.8%
W10	0.000	4.907	4.907	0.000	2.098	0.000	0.110	2.208	55.0%
W11	0.000	5.474	5.474	0.000	5.200	0.000	0.274	5.474	0.0%
W12	0.011	4.122	4.133	0.011	3.916	0.000	0.206	4.133	0.0%
W13	0.000	1.074	1.074	0.000	1.020	0.000	0.054	1.074	0.0%
W14	0.000	0.637	0.637	0.000	0.605	0.000	0.032	0.637	0.0%
W15	0.000	0.494	0.494	0.000	0.469	0.000	0.025	0.494	0.0%
W16	0.000	0.831	0.831	0.000	0.789	0.000	0.042	0.831	0.0%
W17	0.000	2.152	2.152	0.000	2.044	0.000	0.108	2.152	0.0%

WLA summary for White Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	0.981	0.214	0.981	0.214	0.0%	0.0%
W02	PA0024066	0.2500	15.503	2.676	15.503	2.676	0.0%	0.0%
W06	PA0025488	0.3000	59.038	6.425	59.038	6.425	0.0%	0.0%
W06	PA0040436	0.0090	0.680	0.068	0.680	0.068	0.0%	0.0%
W07	PA0056898	0.0650	8.868	0.105	8.868	0.105	0.0%	0.0%
W08	PA0057029	0.1440	1.164	0.084	1.164	0.084	0.0%	0.0%
W09	PA0052451	0.0012	0.113	0.046	0.113	0.046	0.0%	0.0%
W12	DE0000191	0.0300	0.027	0.011	0.027	0.011	0.0%	0.0%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
C01	28.965	53.686	82.651	28.965	2.634	7.566	0.537	39.702	52.0%
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%
Total Phosphorus									
C01	2.839	1.334	4.173	2.839	0.065	0.188	0.013	3.106	25.6%
C02	0.000	1.584	1.584	0.000	0.985	0.520	0.079	1.584	0.0%
C03	0.000	2.610	2.610	0.000	2.480	0.000	0.131	2.610	0.0%
C04	0.000	0.438	0.438	0.000	0.416	0.000	0.022	0.438	0.0%
C05	0.441	0.826	1.267	0.104	0.785	0.000	0.041	0.930	26.6%
C06	0.000	1.211	1.211	0.000	1.085	0.065	0.061	1.211	0.0%
C07	0.000	1.000	1.000	0.000	0.950	0.000	0.050	1.000	0.0%
C08	0.000	4.202	4.202	0.000	3.992	0.000	0.210	4.202	0.0%
C09	1.003	6.688	7.691	0.276	6.354	0.000	0.334	6.964	9.5%
Becks Pond	0.000	1.090	1.090	0.000	0.985	0.051	0.055	1.090	0.0%
Sunset Pond	0.000	0.904	0.904	0.000	0.859	0.000	0.045	0.904	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	26.503	2.650	26.503	2.650	0.0%	0.0%
C01	MD0065145	0.0500	2.462	0.189	2.462	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

Neither the Pennsylvania nor the Delaware MS4 permits actually identify the extent of the systems. Since these systems have not yet been delineated, the TMDL includes nonpoint source loadings into the WLA portion of the TMDL. Once these delineations are available, the nonpoint source loadings can then be separated out of the WLAs and moved under the LA. It is anticipated that the State's storm water program will revise the WLA into the appropriate WLA and LA as part of the storm water permit reissuance. Note that the overall reductions in the TMDL will not change.

The non-MS4 point source permittee's allocations for five-day carbon biological oxygen demand, ammonia, and total phosphorus are not reduced from their permitted levels and are shown in Table 2-2.

Wilmington has combined sewers with combined sewer overflows (CSOs) discharging to Brandywine Creek, Christina River, and Little Mill Creek. The CSO allocations are shown in the following table.

Baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	CSO ID numbers	Baseline (kg/day)	WLA (kg/day)	Reduction
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	2.606	0.618	76.3%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	5.931	1.631	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	11.443	4.107	64.1%
Total CSO load	-	19.980	6.356	68.2%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	0.441	0.104	76.4%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	1.003	0.276	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	1.966	0.730	62.9%
Total CSO load	-	3.410	1.110	67.4%

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of the state's water resources (USEPA, 1991).

As a result of water quality and biological investigations conducted by the Pennsylvania Department of Environmental Protection (PADEP) and Delaware Department of Natural Resources and Environmental Control (DNREC) that identified observed impacts on aquatic life, many streams in the Christina River Basin have been listed on the States' Section 303(d) lists of impaired waters. Parts of the watershed are heavily impacted by urbanization and are listed as impaired resulting from problems associated with elevated nutrient levels, including low dissolved oxygen (DO). These TMDLs, in conjunction with the low-flow Christina TMDL (USEPA, 2002), fulfill the requirements for nutrient and low dissolved oxygen TMDL development for waters in the Christina River basin included in the Section 303(d) lists for Pennsylvania and Delaware. A related study is underway to address impairments resulting from elevated bacteria and sediment loads.

1.1 Historical Perspective

In 1991, at the request of DNREC and PADEP, the Delaware River Basin Commission (DRBC) agreed to mediate water management issues in the "interstate" Christina River Basin. The issues included interstate and intrastate coordination of monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum pass-by requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware's Exceptional Recreational or Ecological Significance (ERES) objectives. A comprehensive basin approach was needed to address these management issues.

The DRBC facilitated a series of meetings with DNREC, PADEP, EPA, Chester County Water Resources Authority (CCWA, and the United States Geological Survey (USGS). EPA funded a study by Scientific Applications International Corporation (SAIC) for completion of an initial data assessment and problem identification study for the non-tidal portion of Brandywine Creek. The findings of this study, *Preliminary Study of the Brandywine Creek Sub-basin, Final Report, September 30, 1993*, provided a framework for use in a multi-step TMDL study for the entire Christina River Basin. The two states, DRBC and EPA, reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to produce Christina River Basin TMDLs under low-flow conditions.

Even as the parties reached agreement on how best to address the impacts of pollutants during low-flow conditions, they recognized that additional efforts would be necessary to address the

distinct water quality problems resulting from primarily nonpoint sources of pollutants during high-flow conditions. In 1993, EPA recommended that DRBC expand the effort to consider high-flow conditions. As a result, the Christina Basin Water Quality Management Committee (CBWQMC) was created with the purpose of addressing the applicable water quality problems and management policies on a watershed scale. The CBWQMC represents a variety of stakeholders and interested parties including the Brandywine Valley Association/Red Clay Valley Association (BVA/RCVA), Chester County Conservation District (CCCD), Chester County Health Department (CCHD), Chester County Planning Commission (CCPC), CCWA, DNREC, Delaware Nature Society (DNS), DRBC, New Castle County Conservation District (NCCD), DEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County (WRANCC).

The CBWQMC developed a unified, multi-phased, 5-year Water Quality Management Strategy (WQMS) that first addresses the water quality problems through voluntary watershed/water quality planning and management activities and second, establishes appropriate TMDLs. The reason for separating the development of TMDLs to address water quality problems between low-flow and high-flow TMDLs is that each scenario has different and distinct pollutants and problems at different flow regimes.

Since 1995, the CBWQMC has been conducting activities set forth in the WQMS designed to implement programs aimed at protecting and improving water quality. These activities include Geographic Information System (GIS) watershed inventory, water quality assessment, watershed pollutant potential and prioritization, stormwater monitoring, Best Management Practices (BMP) Implementation projects, and public education/outreach. A summary of these activities can be found in *Phase I and II Report, Christina River Basin Water Quality Management Strategy, May 1998* and *Phase III Report, Christina Basin Water Quality Management Strategy, August 5, 1999.* These reports describe ongoing efforts to provide pollution control and restore water quality within the Christina River Basin.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters requiring the development of a TMDL. The Clean Water Act (CWA) requires that upstream waters must meet the applicable WQS of the downstream state at or before the state line. In other words, Pennsylvania and Maryland waters are required to meet Delaware's WQS at the state line.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the CWA, the Endangered Species Act (ESA) and the Administrative Procedures Act (APA). The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), was entered on April 9, 1997. The Pennsylvania TMDL settlement requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed.

The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA, Civil Action No. 96-591 (SLR) (D.De), was entered on August 9, 1997. The Delaware TMDL settlement sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina River Basin. Under the schedule set forth in the settlement, Delaware was to establish

low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek, and White Clay Creek, by December 31, 1999. The Delaware settlement also expected Delaware to establish high-flow TMDLs by December 31, 2004. Pursuant to the Delaware agreement, EPA was required to establish TMDLs within one year should Delaware fail to do so.

1.2 Background Information

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of about 565 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware, and Cecil County, Maryland (see Figure 1-1 and Table 1-2). Major streams include the Christina River (tidal and nontidal), Brandywine Creek (tidal and nontidal), Red Clay Creek, and White Clay Creek (tidal and nontidal). These streams are used as habitat for aquatic life, for municipal and industrial water supplies and for recreational purposes. The Christina River Basin drains to the tidal Delaware River at Wilmington, Delaware.

The Christina River Basin is composed of diverse land uses including urban, rural and agricultural areas. Urban areas in the watershed include greater Wilmington and Newark, Delaware, and the Pennsylvania towns of West Chester, Downingtown, Kennett Square, Coatesville, Parkesburg, Honey Brook, Avondale, and West Grove. The land use distribution within the basin is summarized in Table 1-1.

Table 1-1. Christina River Basin land use summary (square miles)

Land Use	DE/MD	Pennsylvania	Total	%
Urban/Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Lands	21	5	26	5
Wooded	37	123	160	28
Water/other	3	3	6	2
Total	166	399	565	100

Source: Phase I/II Report Christina River Basin Water Quality Management Strategy (CBWQMC - May 1998)

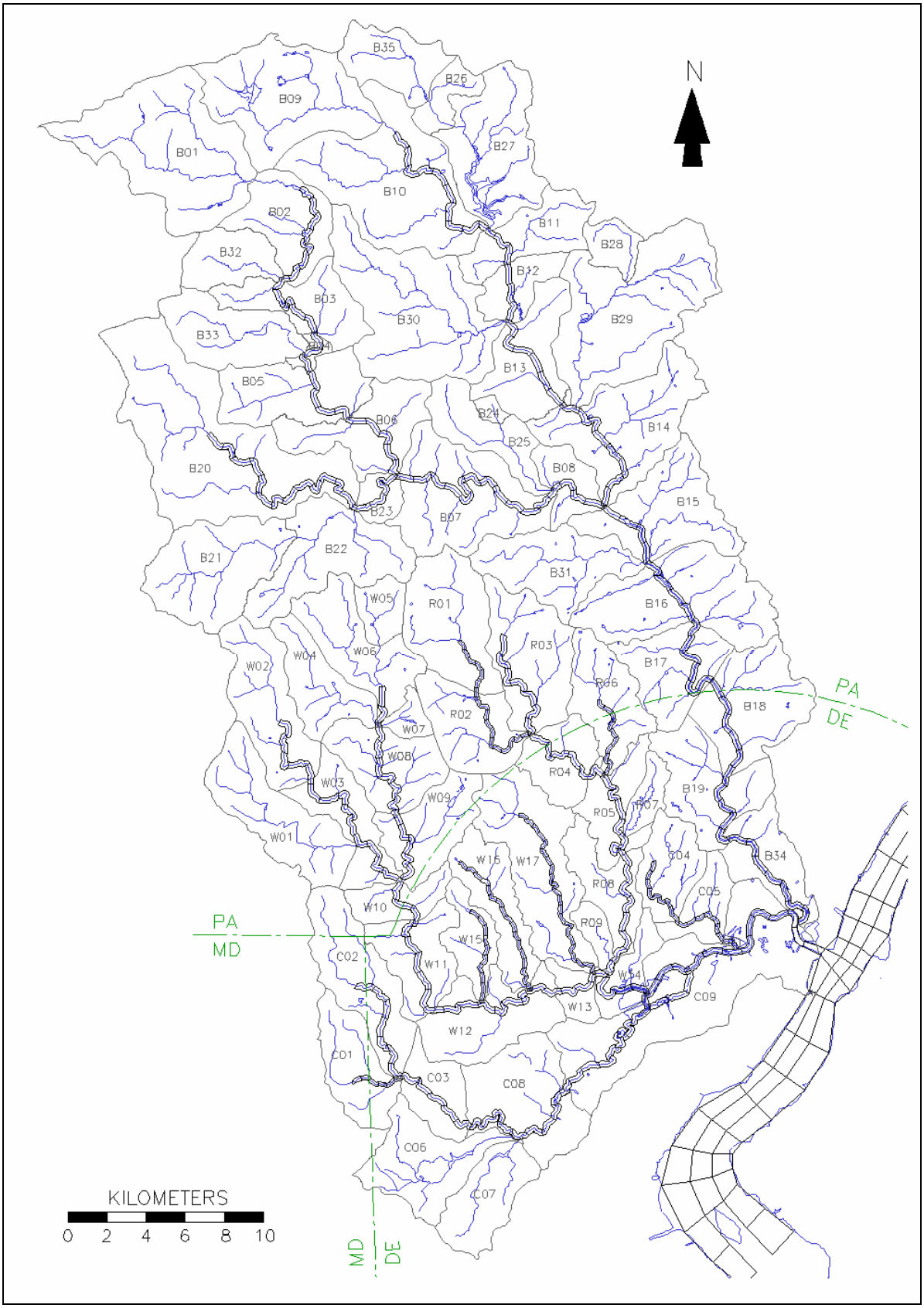

Figure 1-1. Christina River Basin delineation of HSPF model subbasins and EFDC model grid

Table 1-2. Subbasins in the HSPF models of Christina River Basin

Subbasin	Stream Name	Area (sq.mi)
Brandywine Creek Watershed		
B01	Upper Brandywine Creek West Br.	18.39
B02	Brandywine Creek West Branch	7.38
B03	Brandywine Creek West Branch	6.76
B04	Brandywine Creek West Branch	0.80
B05	Brandywine Creek West Branch	8.82
B06	Brandywine Creek West Branch	8.06
B07	Brandywine Creek West Branch	13.46
B08	Brandywine Creek West Branch	3.62
B09	Upper Brandywine Creek East Br.	14.68
B10	Brandywine Creek East Branch	18.31
B11	Brandywine Creek East Branch	6.31
B12	Brandywine Creek East Branch	3.70
B13	Brandywine Creek East Branch	7.94
B14	Brandywine Creek East Branch	12.92
B15	Brandywine Creek	10.36
B16	Brandywine Creek	14.06
B17	Brandywine Creek	7.51
B18	Brandywine Creek	10.37
B19	Brandywine Creek	8.64
B20	Upper Buck Run	25.54
B21	Upper Doe Run	11.05
B22	Lower Doe Run	10.96
B23	Lower Buck Run	1.95
B24	Tributary to Broad Run	0.60
B25	Broad Run	5.83
B26	Marsh Creek	2.61
B27	Marsh Creek	11.54
B28	Tributary to Valley Creek	2.40
B29	Valley Creek	18.21
B30	Beaver Creek	18.08
B31	Pocopson Creek	9.19
B32	Birch Run	4.66
B33	Rock Run	8.03
B34	Lower Brandywine Creek	6.05
B35	Upper Marsh Creek	5.80

Subbasin	Stream Name	Area (sq.mi)
White Clay Creek Watershed		
W01	White Clay Creek West Br.	10.23
W02	Upper White Clay Creek Middle Br.	9.51
W03	White Clay Creek Middle Br.	6.35
W04	Trib. to White Clay Creek East Br.	6.20
W05	Trib. to White Clay Creek East Br.	2.65
W06	Upper White Clay Creek East Br.	8.57
W07	Trout Run	1.37
W08	White Clay Creek East Branch	7.47
W09	White Clay Creek East Branch	6.85
W10	White Clay Creek	3.58
W11	White Clay Creek	6.53
W12	White Clay Creek	8.76
W13	White Clay Creek	2.08
W14	White Clay Creek	3.41
W15	Muddy Run	3.89
W16	Pike Creek	6.65
W17	Mill Creek	13.00
Red Clay Creek Watershed		
R01	Upper Red Clay Creek West Branch	10.08
R02	Red Clay Creek West Branch	7.39
R03	Red Clay Creek East Branch	9.90
R04	Red Clay Creek	5.11
R05	Red Clay Creek	5.24
R06	Burroughs Run	7.10
R07	Hoopes Reservoir	2.10
R08	Red Clay Creek	5.38
R09	Red Clay Creek	1.72
Christina River Watershed		
C01	Christina River West Branch	6.70
C02	Upper Christina River	9.73
C03	Christina River	4.47
C04	Upper Little Mill Creek	5.37
C05	Lower Little Mill Creek	3.84
C06	Muddy Run	8.64
C07	Belltown Run	6.37
C08	Christina River	10.70
C09	Lower Christina River (tidal)	21.90

1.3 Impairment Listing

In response to the requirements of Section 303(d) of the CWA, PADEP and DNREC listed multiple Christina River Basin waterbodies on the 1996 and 1998 Section 303(d) lists of impaired waterbodies based on available information. Pennsylvania identified a total of 60 stream segments as impaired by nutrients, organic enrichment, or low dissolved oxygen. Of that total, 14 stream segments were first listed in 1996 and 46 stream segments were listed in 1998 (Table 1-3). Delaware identified 15 stream segments on the 1998 Section 303(d) list (Table 1-4) as not meeting WQS for nutrients and low DO within the Christina River Basin. Pursuant to the TMDL Consent Decree in Delaware, those 15 stream segments were given high priority. Likewise, Pennsylvania identified 23 of the listed segments as high priority. A number of monitoring stations are located throughout the Christina River Basin within the listed waters. Data from these stations as well as biological assessments were used to determine the impairment and inclusion on the Section 303(d) lists. Excessive nutrients, organic enrichment and low DO are specified as the causes of impairment in the various listed stream segments. The pollutant sources are varied and include industrial and municipal point sources, agriculture, and Superfund sites.

Table 1-3. Christina River Basin stream segments on the PA 1998 Section 303(d) List

Watershed	Stream ID	Segment ID	Miles	Year Listed	Source of Impairment	Cause of Impairment	HSPF Subbasin
Trib to Brandywine Cr.	00026	27	1.3	1996	Other	Nutrients	B17
East Br. Brandywine Cr.	64954	970707-120-HLW	1.1	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00229	970703-1500-ACE	0.6	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00229	970707-1120-GLW	2.9	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00371	970707-1120-GLW	1.5	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00372	970707-1120-GLW	0.7	1996	Agriculture	Nutrients	B09
Indian Run	00360	360	3.3	1996	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	B10
Sucker Run	00202	970930-1437-GLW	3.6	1998	Agriculture	Nutrients	B05
Sucker Run	00203	970930-1437-GLW	1.6	1998	Agriculture	Nutrients	B05
Sucker Run	00204	970930-1437-GLW	0.9	1998	Agriculture	Nutrients	B05
Sucker Run	00205	970930-1437-GLW	0.7	1998	Agriculture	Nutrients	B05
West Br. Brandywine Cr.	00085	9700925-1348-GLW	4.7	1996	Agriculture	Nutrients	B04, B05, B06
West Br. Brandywine Cr.	00085	970618-1118-GLW	3.0	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00085	970618-1340-GLW	1.5	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00224	970619-1222-GLW	4.6	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00224	970619-1345-GLW	2.6	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00225	970619-1322-GLW	0.9	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00226	970619-1345-GLW	1.4	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00227	970618-1340-GLW	1.3	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00228	970618-1340-GLW	0.8	1998	Agriculture	Nutrients	B01
Broad Run	00434	971209-1445-ACW	3.2	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
Broad Run	00436	971209-1445-ACW	0.8	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
East Br. Red Clay Cr.	00413	971023-1050-MRB	5.3	1996	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00414	971204-1400-ACW	3.2	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00417	971204-1403-ACW	1.0	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00418	971204-1400-ACW	0.8	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00419	971023-1050-MRB	1.2	1996	Agriculture	Organic enrichment, low DO	R03
East Br. White Clay Cr.	00432	971113-1335-GLW	3.1	1998	Agriculture	Organic enrichment, low DO	W09
East Br. White Clay Cr.	00432	970506-1320-MRB	2.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00432	9417	2.0	1996	Municipal PS	Nutrients, low DO, organic enrichment	W08
East Br. White Clay Cr.	00432	971119-1116-GLW	1.2	1998	Agriculture	Organic enrichment, low DO	W06
East Br. White Clay Cr.	00438	970506-1320-MRB	0.6	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00439	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00443	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00444	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00445	970508-1430-ACE	2.4	1998	Agriculture	Organic enrichment, low DO	W08
East Br. White Clay Cr.	00446	970506-1320-MRB	0.5	1998	Agriculture	Nutrients	W08

Watershed	Stream ID	Segment ID	Miles	Year Listed	Source of Impairment	Cause of Impairment	HSPF Subbasin
East Br. White Clay Cr.	00447	970506-1320-MRB	0.8	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00448	970409-1130-MRB	0.8	1998	Agriculture	Nutrients	W04
East Br. White Clay Cr.	00450	970409-1130-MRB	0.2	1998	Agriculture	Nutrients	W04
East Br. White Clay Cr.	00454	971120-1331-GLW	5.4	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00455	971120-1331-GLW	2.5	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00456	971120-1331-GLW	0.2	1998	Agriculture	Nutrients	W06
Egypt Run	00440	970508-1245-ACE	1.5	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Egypt Run	00441	970508-1245-ACE	1.4	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Egypt Run	00442	970508-1245-ACE	0.8	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Indian Run	00475	115	1.1	1998	Agriculture	Nutrients	W03
Middle Br. White Clay Cr.	00462	115	9.3	1998	Agriculture	Nutrients	W02, W03
Middle Br. White Clay Cr.	00462	115B	2.2	1996	Agriculture, Municipal PS	Nutrients	W02
Middle Br. White Clay Cr.	00476	115	1.6	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00477	115	1.8	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00478	115	1.3	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00479	115	0.6	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00480	115	0.6	1998	Agriculture	Nutrients	W02
Red Clay Creek	00374	971203-1400-ACW	0.1	1998	Agriculture	Organic enrichment, low DO	R04
Trout Run	63874	970506-1425-MRB	1.7	1998	Agriculture	Nutrients	W07
Trout Run	63875	970506-1425-MRB	0.8	1998	Agriculture	Nutrients	W07
Trout Run	63876	970506-1425-MRB	0.2	1998	Agriculture	Nutrients	W07
Walnut Run	00435	971209-1445-ACW	1.4	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
West Br. Red Clay Cr.	00391	971023-1145-MRB	4.6	1998	Agriculture	Organic enrichment, low DO	R02
West Br. Red Clay Cr.	00396	971023-1315-MRB	1.8	1996	Agriculture	Nutrients	R02
West Br. White Clay Cr.	00465	9408	7.8	1996	Agriculture	Nutrients	W01
White Clay Creek	00373	971216-1230-GLW	1.4	1998	Agriculture	Nutrients	W10

Table 1-4. Christina River Basin stream segments on the DE 1998 Section 303(d) List

Waterbody ID	Watershed Name	Segment	Miles	Year Listed	Pollutants/Stressor	Probable Sources	HSPF Subbasin
DE040-001	Brandywine Creek	Lower Brandywine	3.8	1996	nutrients	PS, NPS, SF	B34
DE040-002	Brandywine Creek	Upper Brandywine	9.3	1996	nutrients	PS, NPS, SF	B18, B19
DE260-001	Red Clay Creek	Main Stem	12.8	1996	nutrients	PS, NPS, SF	R04, R05, R08, R09
DE260-002	Red Clay Creek	Burroughs Run	2.6	1996	nutrients	NPS	R06
DE320-001	White Clay Creek	Main Stem	15.6	1996	nutrients	PS, NPS	W10, W11, W12, W13, W14
DE320-002	White Clay Creek	Mill Creek	8.3	1996	nutrients	NPS	W17
DE320-003	White Clay Creek	Pike Creek	9.4	1996	nutrients	NPS	W16
DE320-004	White Clay Creek	Muddy Run	5.8	1996	nutrients	NPS	W15
DE120-001	Christina River	Lower Christina	1.5	1996	nutrients, DO	NPS, SF	C09
DE120-002	Christina River	Middle Christina River	7.5	1996	nutrients	NPS, SF	C09
DE120-003	Christina River	Upper Christina River	6.3	1996	nutrients	NPS, SF	C09
DE120-003-02	Christina River	Lower Christina Creek	8.4	1996	nutrients	NPS	C03, C08
DE120-005-01	Christina River	West Branch	5.3	1996	nutrients	NPS	C01
DE120-006	Christina River	Upper Christina Creek	8.3	1996	nutrients	NPS	C02
DE120-007-01	Christina River	Little Mill Creek	5.1	1996	nutrients, DO	NPS, SF	C04, C05
DE120-L01	Christina River	Smalleys Pond	30 Ac.	1996	Nutrients	NPS	C08
DE120-L02	Christina River	Becks Pond	25.6 ac	1996	Nutrients*	NPS	C07

PS= point source; NPS = nonpoint source; SF=superfund site, *delisted for nutrients in 2002

1.4 Water Quality Standards

The CWA requires states to adopt WQS to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These standards serve dual purposes: they establish water quality goals for a specific waterbody, and they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA. Within the Christina River Basin, there are four regulatory agencies that have applicable WQS. The PADEP, DNREC, and MDE have WQS that apply to those stream segments of the Christina River Basin located in the respective state. The DRBC is an interstate agency that has the authority to establish WQS and regulate pollution activities within the tidal Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins. Tables 1-5 and 1-6 below summarize the applicable WQS relating to DO and nutrients.

1.4.1 Pennsylvania WQS

Pennsylvania Code, Title 25, Chapter 93 sets forth water quality standards for surface waters of the state. These standards are based upon water uses which are to be protected and will be considered by PADEP in its regulation of discharges. Implementation of the numeric water quality criteria in Pennsylvania are summarized in Table 1-5 and 1-6, and defined in PA Code, Title 25, Chapter 96.3 as follows:

Chapter 96.3(c): "To protect existing and designated surface water uses, the water quality criteria described in Chapter 93 (relating to water quality standards), including the criteria in Chapters 93.7 and 93.8a(b) (relating to specific water quality criteria; and toxic substances) shall be achieved in all surface waters at least 99% of the time, unless otherwise specified in this title. The general water quality criteria in Chapter 93.6 (relating to general water quality criteria) shall be achieved in surface waters at all times at design conditions."

Chapter 96.3(d): "As an exception to subsection (c), the water quality criteria for total dissolved solids, nitrite-nitrate nitrogen, phenolics and fluoride established for the protection of potable water supply shall be met at least 99% of the time at the point of all existing or planned surface potable water supply withdrawals unless otherwise specified in this title."

In addition to numeric water quality criteria, waters in the Christina River Basin are also subject to narrative criteria stated in PA Code, Title 25, Chapter 93.6, as follows:

Chapter 93.6(a): "Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life."

Chapter 93.6(b): "In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits."

Chapter 93.9(g): Drainage List G contains the designated uses for the waters within the Brandywine Creek, Red Clay Creek, and White Clay Creek watersheds. Protected uses include cold water fishes, warm water fishes, migratory fishes, trout stocking fishes, high quality, and exceptional quality waters.

1.4.2 Delaware WQS

Delaware's water quality criteria for DO and nutrients are listed in Table 1-5 and Table 1-6. Marine waters are defined as waters of the state that contain natural levels of salinity greater than 5 parts per thousand (ppt). All waters within the Christina River Basin have natural salinity levels less than 5 ppt. Therefore, the fresh water designated use shall apply for this TMDL.

Table 1-5. Summary of applicable use designations and DO criteria

Agency	Designated Use	D.O. Criteria (mg/L)		Comments
		Daily avg.	Minimum	
PADEP	Warm water fish (WWF)	5.0	4.0	
	Cold water fish (CWF)	6.0	5.0	
	Trout stocking fishery (TSF)	6.0 5.0	5.0 4.0	Feb 15 - Jul 31 Aug 01 - Feb 14
	High Quality CWF		7.0	Special Protection Waters
	High Quality TSF	6.0	5.0	Special Protection Waters
	Exceptional value			Special Protection Waters
DNREC	Fresh waters	5.5	4.0	Year round
	Cold water fish	6.5	5.0	Seasonal
	Marine waters	5.0	4.0	Salinity greater than 5.0 ppt
	Exceptional recreation or ecological significance			Existing or natural water quality
MDE	Fresh waters	5.0	5.0	Use I waters, DO must not be less than 5.0 mg/L at any time
DRBC	Resident game fish	5.0	4.0	
	Trout	6.0	5.0 7.0	During spawning season
	Tidal: resident or anadromous fish	4.5		6.5 mg/L seasonal average during Apr 01 - Jun 15 and Sep 16 - Dec 31

Table 1-6. Summary of nutrient criteria

Parameter	Agency	Comments
Ammonia-Nitrogen*		
	PADEP	1-day and 30-day average ambient criteria are a function of pH and temperature for toxicity; Implementation Guidance document for Ammonia allocations for NBOD and Toxicity.
	DNREC	No specific numeric criteria; Narrative statement for prevention of toxicity.
	DRBC	NPDES effluents limited to a 30-day average of 20 mg/L as N.
Nitrate-Nitrogen		
	PADEP	Ambient criteria is maximum of 10 mg/L as N applied at the point of water supply intake, not at the point of an effluent discharge. For the case of an interstate stream, the state line shall be considered a point of water supply intake.
	DNREC	Ambient nitrate criteria is maximum of 10 mg/L as N; provision for site-specific nutrient controls. The DNREC Section 303(d) rationale document cites 3.0 mg/L total nitrogen as guidance for determining impairment.
	DRBC	No specific numeric criteria.
Phosphorus		
	PADEP	No specific numeric criteria are specified in the Pennsylvania Code, Title 25, Chapter 93 (Water Quality Standards). According to Chapter 95 (Wastewater Treatment Requirements), phosphorus effluent limits are set to a maximum of 2 mg/L whenever the Department determines that instream phosphorus alone or in combination with other pollutants contributes to impairment of designated stream uses.
	DNREC	No specific numeric criteria; provision for site-specific controls. The Section 303(d) rationale document cites 0.2 mg/L of total phosphorus as guidance for use impairment.
	DRBC	No specific numerical criteria.

* Maryland adopted the EPA water quality criteria for ammonia nitrogen in January 2001 (effective April 2001 - Title 26 Maryland Department of the Environment Subtitle 08 Water Pollution Chapter 02 Water Quality). This was approved by EPA in June 2001.

2.0 SOURCE ASSESSMENT

Waters of the Christina River Basin are used for recreation, public water supply, and to support aquatic life. Some of these uses are threatened by impairments caused by point and nonpoint sources of nutrients and oxygen demanding material. PADEP and DNREC identified the impaired stream segments based on historical water quality monitoring data and biological integrity field surveys. EPA characterizes the past and current condition of water quality in the Christina River Basin, and assesses available data, as part of the basis for these TMDLs. A data report prepared by Davis (1999) for the low-flow study describes the existing water quality in the basin. This data was used, in part, for developing these TMDLs.

A customized modeling framework was developed to support determination of nutrient and low DO TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a CSO flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of nutrients and oxygen demanding substances.

2.1 Point Sources

The term “point source” refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container. It also includes vessels or other floating craft from which pollutants are or may be discharged. The term “point source” also includes concentrated animal feeding operations, which are places where animals are confined and fed. Storm water runoff from certain areas is also considered a point source because the water is transported through a pipe or ditch.

Estimating the transport of nutrients into a surface water body from most point sources is a fairly straightforward matter. Both wastewater treatment plants (WWTP) and combined sewer overflows (CSOs) discharge though a constructed conveyance to a waterbody. Many of the nutrients transported in this way are removed through treatment process, and permit limits are established to ensure that WWTPs meet water quality standards. However, in some instances failures or leaks may occur, or a wet weather event may create flows that exceed the capacity of the WWTP or combined sewer systems. This can lead to a discharge of contaminated water into the river system.

2.1.1 Wastewater Treatment Plants

Treated industrial and municipal sewage can be a point source of nutrients. As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The locations of NPDES facilities in the Christina River Basin are shown in Figure 2-1 and listed in Table 2-1. The summer season nutrient and CBOD5 loads for each of the NPDES facilities, based on permit flow rate, are provided in Table 2-2 (see table footnote).

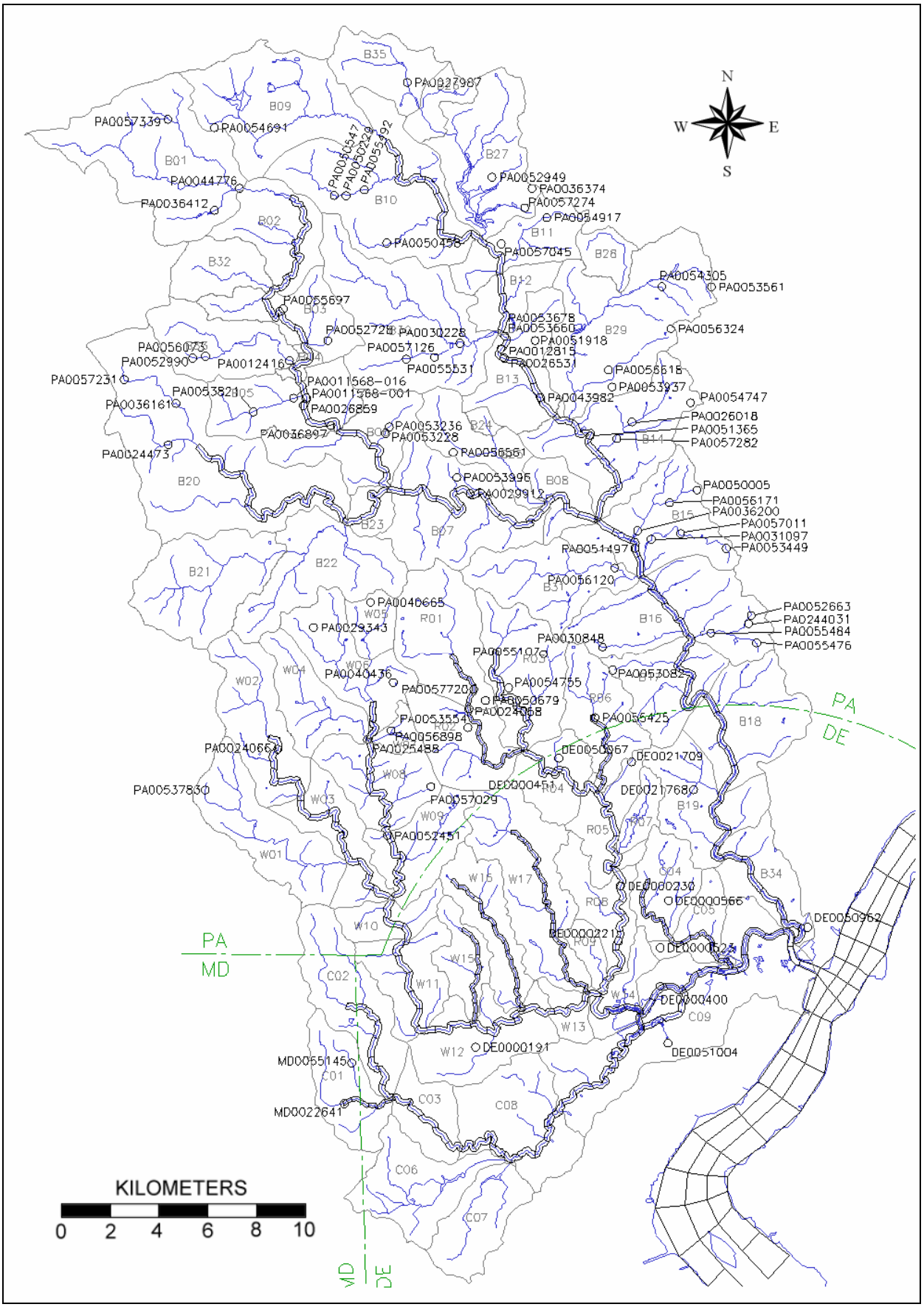

Figure 2-1. NPDES discharges in Christina River Basin

Table 2-1. NPDES point source discharges in Christina River Basin.

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek (main stem)								
76.610	54,15	DE0050962	0.0000	SWR	AMTRAK	TB-Brandywine Creek	Industrial	Stormwater
83.554	54,27	DE0021768	0.0250	STP	Winterthur Museum	Clenney Run	Municipal	Small STP
88.644	54,37	PA0053082	0.0206	STP	Mendenhall Inn	TB Brandywine Creek	Commercial	Small STP
89.917	54,38	PA0052663	0.0900	STP	Knight's Bridge Co/Villages at Painters	Harvey Run	Commercial	Small STP
89.917	54,38	PA0055476	0.0400	STP	Birmingham TSA/Ridings at Chadds Ford	TB Harvey Creek	Municipal	Small STP
89.917	54,38	PA0055484	0.0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0244031	0.1500	STP	Chadds Ford Township	Harvey Run		
90.553	54,39	PA0030848	0.0063	STP	Unionville - Chadds Ford Elem. School	Ring Run	Municipal	Small STP
93.098	54,42	PA0056120	0.0005	SRD	Schindler	Pocopson Creek	Municipal	Single Residence STP
92.462	54,43	PA0031097	0.0170	STP	Radley Run C.C.	Radley Run	Municipal	Small STP
92.462	54,43	PA0053449	0.1500	STP	Birmingham Twp. STP	Radley Run	Municipal	Small STP
93.735	54,43	PA0057011	0.0773	STP	Thornbury Twp./Bridlewood Farms STP	Radley Run		
92.462	54,44	PA0036200	0.0320	STP	Radley Run Mews	Plum Run	Municipal	Small STP
94.371	54,44	PA0056171	0.0005	SRD	McGlaughlin Jeffrey	Plum Run	Municipal	Single Residence STP
94.371	54,44	PAG050005	0.1400	GWC	Sun Company	TB Brandywine Creek	GWCleanup	New permit 03/27/98
94.371	54,44	PA0051497	0.0300	NCW	Lenape Forge	Brandywine Creek	Industrial	Cooling Water
Brandywine Creek East Branch								
98.647	54,52	PA0026018	1.8000	MUN	West Chester Borough MUA/Taylor Run	Taylor Run	Municipal	Large STP
98.647	54,52	PA0057282	0.0005	SRD	Jonathan & Susan Pope	TB Valley Creek	Municipal	Single Residence STP
99.276	54,53	PA0051365	0.3690	WFP	PA American Water	EB Brandywine Creek	Municipal	Ingram's Mill-Filter Backwash
100.535	54,55	PA0053937	0.0005	SRD	William and Patricia Kratz	Broad Run Creek	Municipal	Single Residence STP
100.535	54,55	PA0056324	0.0440	GWC	Mobil SS#16-GPB	TB-WB Valley Run	Commercial	DP
100.535	54,55	PA0056618	0.0005	SRD	O'Cornwell David & Jeanette	Broad Run	Municipal	Single Residence STP
100.535	54,55	PA0054305	0.0000	IND	Sun Co, Inc. (R&M)	TB Valley Creek	Industrial	
100.535	54,55	PA0053561	0.0360	GWC	Johnson Matthey	Valley Creek	GWCleanup	Permitted 03/12/96
101.794	54,57	PA0043982	0.4000	ATP2	Broad Run Sew Co.	EB Brandywine Creek	Municipal	Large STP
103.682	54,61	PA0012815	1.0280	IND	Sonoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103.682	54,60	PA0026531	7.5000	ATP2	Downingtown Area Regional Authority	EB Brandywine Creek	Municipal	Large STP
104.312	54,61	PA0051918	0.1440	NCW	Pepperidge Farms	Parke Run Creek	Industrial	Cooling Water
103.682	54,61	PA0055531	0.0007	STP	Khalife Paul	TB Valley Run	Commercial	Small STP
104.312	54,61	PA0057126	0.0000	IND	Hess Oil - SS #38291	Valley Run	Commercial	DP
104.312	54,61	PA0030228	0.0225	STP	Downingtown I&A School	Beaver Creek	Municipal	No flow since Feb 1994
104.312	54,61	PA0053678	0.0000	IND	Lambert Earl R.	EB Brandywine Creek	Industrial	DP
104.312	54,61	PA0053660	0.0000	IND	Mobil Oil Company #016	EB Brandywine Creek	Commercial	Air stripper at Service Sta
106.830	54,65	PA0054917	0.4750	STP	Uwchlan Twp. Municipal Authority	Shamona Creek	Municipal	Eagleview CC STP
107.459	54,66	PA0057045	0.0000	SWR	Shyrock Brothers, Inc.	EB Brandywine Creek	Commercial	Stormwater
108.088	54,67	PA0027987	0.0500	STP	Pennsylvania Tpk./Caruiel Service Plaza	Marsh Creek	Commercial	Small STP
108.088	54,67	PA0036374	0.0150	STP	Eaglepoint Dev. Assoc.	TB Marsh Creek	Municipal	Small STP
108.088	54,67	PA0052949	0.0300	IND	Phila. Suburban Water Co.	Marsh Creek	Industrial	Uwchlan DP
108.088	54,67	PA0057274	0.0005	SRD	Michael & Antionette Hughes	TB Marsh Creek	Municipal	Single Residence STP
109.977	54,70	PA0050458	0.0531	STP	Little Washington Drainage Co.	Culbertson Run	Municipal	Small STP
112.495	54,74	PA0057827	0.0005	SRD	McKenna	Indian Run	Municipal	Single Residence STP
112.495	54,74	PA0050547	0.0375	STP	Indian Run Village MHP	Indian Run	Municipal	Small STP
112.495	54,74	PA0055492	0.0005	SRD	Andrew and Gail Woods	Indian Run	Municipal	Single Residence STP
113.753	54,76	PA0054691	0.0005	SRD	Stoltzfus Ben Z.	TB Brandywine Creek	Municipal	Single Residence STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek West Branch								
97.976	46,79	PA0056561	0.0000	SWR	Richard M. Armstrong Co.	Broad Run	Commercial	Stormwater
101.708	40,79	PA0029912	0.1000	STP	Embreeville Hospital	WB Brandywine Creek	Municipal	Large STP
102.330	39,79	PA0053996	0.0005	SRD	Redmond Michael	TB-WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053228	0.0005	SRD	Gramm Jeffery	WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053236	0.0005	SRD	Woodward Raymond Sr. STP	WB Brandywine Creek	Municipal	Single Residence STP
110.416	24,79	PA0036897	0.3900	ATP1	South Coatesville Borough	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0026859	3.8500	ATP1	Coatesville City Authority	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0011568-001	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0011568-016	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0053821	0.0000	SWR	Chester County Aviation Inc.	Sucker Run	Commercial	Stormwater
112.282	20,79	PA0012416	0.1400	WFP	PA American Water	Rock Run	Industrial	Water Filtration Plant-Backwash
112.282	20,79	PA0052990	0.0005	SRD	Mitchell Rodney	Rock Run	Municipal	Single Residence STP
112.282	20,79	PA0056073	0.0005	SRD	Vreeland Russell Dr.	TB Rock Run	Municipal	Single Residence STP
113.526	18,79	PA0052728	0.0004	STP	Farmland Industries Inc./Turkey Hill	WB Brandywine Creek	Industrial	Small STP
114.770	16,79	PA0055697	0.0490	STP	Spring Run Estates	WB Brandywine Creek	Commercial	Small STP
120.368	06,79	PA0036412	0.0550	STP	Tel Hai Retirement Community	TB-WB Brandywine Creek	Municipal	Small STP
120.368	06,79	PA0044776	0.6000	STP	NW Chester Co. Municipal Authority	WB Brandywine Creek	Municipal	Large STP
120.368	06,79	PA0057339	0.0005	SRD	Brian & Cheryl Davidson	TB-WB Brandywine Creek	Municipal	Single Residence STP
Buck Run								
117.041	33,61	PA0024473	0.7000	STP	Parkersburg Borough Authority WWTP	TB-Buck Run	Municipal	Small STP-discontinued 06/10/97
117.041	33,61	PA0057231	0.0005	SRD	Archie & Cloria Shearer	TB-Buck Run	Municipal	Single Residence STP
Christina River (tidal)								
82.274	45,13	DE0000400-001	0.0000	NCW	Ciba-Geigy Corp.	Christina River	Industrial	Cooling Water
83.561	43,09	DE0051004	0.0000	SWR	Boeing	Nonesuch Creek	Industrial	Stormwater
Christina River West Branch								
99.587	16,09	MD0065145	0.0500	STP	Highlands WWTP	WB Christina River	Municipal	Small STP
100.209	14,09	MD0022641	0.4500	STP	Meadowview Utilities, Inc.	WB Christina River	Municipal	Small STP
Red Clay Creek								
89.828	43,26	DE0000221-001	0.0060	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
89.828	43,26	DE0000221-003	0.0040	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
91.746	43,29	DE0000230-001	0.3500	NCW	Hercules Inc.	Red Clay Creek	Industrial	Cooling Water
95.583	43,35	DE0021709-001	0.0150	STP	Greenville Country Club	TB-Red Clay Creek	Municipal	Small STP
96.861	43,37	PA0055425	0.0005	SRD	D'Ambro Anthony Jr.-Lot #22	TB-EB Red Clay Creek	Municipal	Single Residence STP
98.780	43,40	DE0050067	0.0015	STP	Center for Creative Arts	TB-Red Clay Creek	Municipal	Small STP
98.780	43,40	DE0000451-002	2.1700	NCW	NVF Yorklyn	Red Clay Creek	Industrial	Stormwater/Cooling Water
101.337	43,44	PA0055107	0.1500	STP	East Marlborough Township STP	TB-EB Red Clay Creek	Municipal	Large STP
Red Clay Creek West Branch								
103.313	32,43	PA0053554	0.0000	SWR	Earthgro Inc.	WB Red Clay Creek	Industrial	Stormwater
103.950	30,43	PA0024058	1.1000	STP	Kennett Square Boro. WWTP	WB Red Clay Creek	Municipal	Large STP
104.268	29,43	PA0050679	0.2500	NCW	National Vulcanized Fiber (NVF)	TB-WB Red Clay Creek	Industrial	Cooling Water
104.579	28,43	PA0057720-001	0.0720	STP	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Process Water
104.579	28,43	PA0057720-002	0.0900	NCW	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Cooling Water
White Clay Creek								
93.090	32,18	DE0000191-001	0.0300	NCW	FMC Corp.	Cool Run	Industrial	Stormwater/Cooling Water
102.824	15,18	PA0053783	0.0200	STP	Avon Grove School Dist	TB-WB White Clay Creek	Commercial	Small STP
108.696	06,18	PA0024066	0.2500	STP	West Grove Borough Authority STP	MB White Clay Creek	Municipal	Large STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
White Clay Creek East Branch								
102.750	19,24	PA0052451	0.0012	STP	Frances L. Hamilton Oates STP	EB White Clay Creek	Municipal	Small STP
104.020	19,26	PA0057029	0.1440	GWC	Hewlett Packard Co.	Egypt Run	GWCleanup	Groundwater Cleanup
106.560	19,30	PA0025488	0.3000	ATP2	Avondale Borough Sewer Authority	Indian Run	Municipal	Large STP
106.560	19,30	PA0056898	0.0650	IND	To-Jo Mushrooms Inc.	Trout Run	Industrial	Small STP-online Jan 98
107.830	19,32	PA0040436	0.0090	STP	Chadds Ford Investment Co./Red Fox GC	TB-EB White Clay Creek	Municipal	Small STP
107.830	19,32	PA0040665	0.0100	STP	Stone Barn Restuarantand Apt. Cplx	EB White Clay Creek	Commercial	Small STP
Little Mill Creek								
82.441	41,55	DE0000523-001	0.0000	SWR	General Motors Assembly	Little Mill Creek	Industrial	Stormwater
83.373	38,55	DE0000566	0.0000	SWR	DuPont Chestnut Run	Little Mill Creek	Industrial	Stormwater/Cooling Water
Delaware River								
63.839	57,04	DE0021555-001	0.5500	MUN	Delaware City STP	Delaware River	Municipal	
65.272	57,05	DE0000256-601	13.0000	IND	Star Enterprises	Delaware River	Industrial	
65.272	57,05	DE0000612-001	0.8000	IND	Formosa Plastics Corp.	Delaware River	Industrial	
65.272	57,05	DE0020001-001	0.6800	MUN	Standard Chlorine	Delaware River	Municipal	
65.272	57,05	DE0050911-001	0.3000	MUN	Occidental Chemical Corp.	Delaware River	Municipal	
75.237	57,15	DE0020320-001	90.0000	MUN	City of Wilmington	Delaware River	Municipal	
77.162	57,17	DE0000051-001	5.2000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-002	3.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-003	6.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
81.307	57,20	DE0000655-001	33.3000	IND	General Chemical Corporation	Delaware River	Industrial	
83.907	57,22	PA0012637-002	52.3500	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-101	69.8000	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-201	3.3400	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
85.199	57,23	PA0027103-001	44.0000	MUN	Delcora	Delaware River	Municipal	
82.639	58,21	NJ0005045-001	0.5000	IND	Monsanto	Delaware River	Industrial	SEE NOTE 2
63.839	59,04	NJ0024856-001	1.4450	MUN	City of Salem	Delaware River	Municipal	SEE NOTE 1
69.534	59,09	NJ0021598-001	2.4650	MUN	Pennsville Sewage Authority	Delaware River	Municipal	SEE NOTE 1
73.339	59,12	NJ0005100-661	22.9000	IND	Dupont-Chambers Works	Delaware River	Industrial	SEE NOTE 1
75.237	59,15	NJ0021601-001	1.7290	MUN	Carneys Pt. Sewage Authority	Delaware River	Municipal	SEE NOTE 1
76.045	59,16	NJ0024023-001	0.9500	MUN	Penns Grove Sewage Authority	Delaware River	Municipal	SEE NOTE 1
77.162	59,17	NJ0024635-001	0.0366	MUN	Fort Dix/Pedricktown Facility	Delaware River	Municipal	SEE NOTE 1
79.919	59,19	NJ0004286-001	2.1000	IND	Geon	Delaware River	Industrial	
82.639	59,21	NJ0027545-001	0.9860	MUN	Logan Township MUA	Delaware River	Municipal	SEE NOTE 1

NOTES:

[1] No flow limit available in PCS data base; flow limit shown is maximum reported flow during 01/01/95 to 12/31/98

[2] No flow limit or reported flow available in PCS data base; flow limit shown is an estimate

Table 2-2. NPDES permit flows and loads for nutrients and CBOD5

NPDES Number	HSPF Subbasin	Flow (mgd)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (kg/day)	NH3-N (kg/day)	TP (kg/day)
Brandywine Creek main stem								
DE0021768	B19	0.0250	15.00	1.50	2.00	1.42	0.14	0.19
PA0053082	B17	0.0206	10.00	3.00	2.00	0.78	0.23	0.16
PA0052663	B16	0.0900	10.00	1.00	2.00	3.41	0.34	0.68
PA0055476	B16	0.0400	10.00	3.00	2.00	1.51	0.45	0.30
PA0244031	B16	0.1500	10.00	1.50	0.50	5.68	0.85	0.28
PA0055484	B16	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0030848	B16	0.0063	25.00	80.00	20.00	0.60	1.91	0.48
PA0056120	B31	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0031097	B15	0.0170	25.00	20.00	2.00	1.61	1.29	0.13
PA0053449	B15	0.1500	15.00	1.50	2.00	8.52	0.85	1.14
PA0057011	B15	0.0773	25.00	3.50	2.00	7.32	1.02	0.59
PA0036200	B15	0.0320	25.00	20.00	2.00	3.03	2.42	0.24
PA0050005	B15	0.1400	2.00	0.04	0.11	1.06	0.02	0.06
PA0051497	B15	0.0300	2.00	0.10	0.10	0.23	0.01	0.01
PA0056171	B15	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Brandywine Creek East Branch								
PA0026018	B14	1.5000	25.00	2.50	2.00	141.95	14.20	11.36
PA0057282	B14	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0051365	B14	0.3690	2.00	0.10	0.10	2.79	0.14	0.14
PA0053937	B29	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0056324	B29	0.0440	2.00	0.04	0.11	0.33	0.01	0.02
PA0056618	B29	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053561	B29	0.0360	2.00	0.04	0.11	0.27	0.01	0.01
PA0043982	B13	0.4000	22.95	2.00	1.88	34.75	3.03	2.85
PA0012815	B13	1.0280	25.14	4.44	0.74	97.83	17.28	2.88
PA0026531	B13	7.5000	7.00	1.50	2.00	198.73	42.59	56.78
PA0030228	B30	0.0225	7.00	1.00	3.00	0.60	0.09	0.26
PA0051918	B13	0.1440	2.00	0.10	0.10	1.09	0.05	0.05
PA0055531	B30	0.0007	25.00	10.00	10.00	0.07	0.03	0.03
PA0054917	B11	0.4750	5.89	0.78	0.78	10.59	1.40	1.40
PA0036374	B27	0.0150	10.00	0.50	0.50	0.57	0.03	0.03
PA0057274	B27	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0050458	B10	0.0351	10.00	3.00	1.00	1.33	0.40	0.13
PA0057827	B10	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0050547	B10	0.0375	10.00	3.00	1.00	1.42	0.43	0.14
PA0055492	B10	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0052949	B10	0.0030	10.00	0.10	0.10	0.11	0.001	0.001
PA0027987	B10	0.0050	10.00	3.90	2.00	0.19	0.07	0.04
PA0054691	B09	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Brandywine Creek West Branch								
PA0029912	B07	0.1000	25.00	20.00	2.00	9.46	7.57	0.76
PA0053996	B07	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053228	B06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053236	B06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0036897	B05	0.3900	25.00	7.00	2.00	36.91	10.33	2.95
PA0026859	B05	3.8500	11.07	2.00	1.48	161.33	29.15	21.57
PA0011568-001	B05	0.6400	5.00	0.50	0.30	12.11	1.21	0.73
PA0011568-016	B05	0.5045	5.00	0.50	0.30	9.55	0.95	0.57
PA0056073	B33	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0012416	B33	0.1400	10.00	0.10	0.10	5.30	0.05	0.05

NPDES Number	HSPF Subbasin	Flow (mgd)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (kg/day)	NH3-N (kg/day)	TP (kg/day)
PA0052990	B33	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0052728	B03	0.0004	25.00	10.00	10.00	0.04	0.02	0.02
PA0055697	B03	0.0490	25.00	1.50	2.00	4.64	0.28	0.37
PA0036412	B01	0.0550	10.00	2.90	1.90	2.08	0.60	0.40
PA0044776	B01	0.6000	13.50	2.70	1.80	30.66	6.13	4.09
PA0057339	B01	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0057231	B20	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Christina River								
MD0022641	C01	0.7000	12.22	2.00	1.00	32.38	5.30	2.65
MD0065145	C01	0.0500	10.00	4.52	1.00	1.89	0.86	0.19
Red Clay Creek								
DE0000230	R08	0.3500	7.00	0.10	0.10	9.27	0.13	0.13
DE0021709	R05	0.0150	20.00	1.50	2.00	1.14	0.09	0.11
PA0055425	R06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
DE0050067	R04	0.0015	30.00	10.00	10.00	0.17	0.06	0.06
DE0000451	R04	2.1700	3.00	0.10	4.00	24.64	0.82	32.86
PA0055107	R03	0.1500	25.00	2.00	2.00	14.20	1.14	1.14
PA0024058	R02	1.1000	16.63	2.00	1.28	69.25	8.33	5.33
PA0050679	R01	0.2500	2.00	0.10	0.10	1.89	0.09	0.09
PA0057720-001	R01	0.0720	9.50	1.90	1.90	2.59	0.52	0.52
PA0057720-002	R01	0.0900	2.00	0.10	0.10	0.68	0.03	0.03
White Clay Creek								
DE0000191	W12	0.0300	3.00	0.10	0.10	0.34	0.01	0.01
PA0053783	W01	0.0200	10.00	3.00	2.00	0.76	0.23	0.15
PA0024066	W02	0.2500	25.00	4.80	2.00	23.66	4.54	1.89
PA0052451	W09	0.0012	25.00	10.00	10.00	0.11	0.05	0.05
PA0057029	W08	0.1440	2.00	0.04	0.11	1.09	0.02	0.06
PA0025488	W06	0.3000	25.00	2.00	4.00	28.39	2.27	4.54
PA0056898	W07	0.0650	25.00	3.50	0.30	6.15	0.86	0.07
PA0040436	W06	0.0090	25.00	10.00	2.00	0.85	0.34	0.07
PA0040665	W05	0.0100	25.00	10.00	2.00	0.95	0.38	0.08

For facilities with flow greater than 10,000 gpd, the CBOD5 and NH3-N limits above are summer limits and apply from May 1 to Oct 31 and the summer TP limits apply from Apr 1 to Oct 31. During the winter season from Nov 1 to Apr 30, the CBOD5 limit is 2 times the summer limit and the NH3-N limit is 3 times the summer limit. The winter TP limit is 2 times the summer limit and applies from Nov 1 to Mar 31. For small facilities with flow less than 10,000 gpd, the above limits apply year round.

2.1.2 Combined Sewer Overflows

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the combined stormwater and wastewater volume can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain storm water and untreated human and industrial waste, toxic materials, and debris. Because they are associated with wet weather events, CSOs typically discharge for short periods of time at random intervals.

There are 38 CSO outfalls[1] in the vicinity of the city of Wilmington. Nutrient loads from these CSOs were determined using the flow rates calculated by the XP-SWMM model and event mean concentrations calculated from storm events monitored in 2003 and 2004 (see Appendix E for storm monitoring data).

2.1.3 Stormwater Phase II Communities

Storm water runoff can contribute nutrients and other pollutants to a waterbody. Material can collect on streets, rooftops, parking lots, sidewalks, yards and parks and then during a precipitation event this material can be flushed into gutters, drains, and culverts and be discharged into a waterbody.

As part of the 1987 amendments to the Clean Water Act (CWA), Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the CWA requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4s). Large MS4s serve populations over 250,000 and medium MS4s serve populations between 100,000 and 250,000. These discharges are referred to as Phase I MS4 discharges. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s, including all systems within urbanized areas and other systems serving populations less than 100,000 as well as storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This expansion is referred to as Phase II of the MS4 program.

Storm water discharges that are regulated under Phase I and Phase II of the NPDES MS4 program are point sources that must be included in the WLA portion of a TMDL. Storm water discharges not currently subject to Phase I or Phase II of the MS4 program are not required to obtain NPDES permits and, therefore, for regulatory purposes, are analogous to nonpoint sources and are included in the LA portion of a TMDL.

An EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors, dated November 22, 2002, (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the wasteload allocation component of the TMDL and may not be addressed by the load allocation component of TMDL

- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls

- Industrial storm water permits need to reflect technology-based and water quality-based requirements.

Most of the townships and boroughs within the Christina River Basin in Chester County and all of New Castle County are covered by the Phase II MS4 program regulations. The delineation of the storm water collection system contributing areas within each municipality has not been

[1] Though currently there are 40 CSO locations in the City of Wilmington, the XP-SWMM model results provided by the City indicated only 38 CSO outfall locations with 37 of these discharging within the Christina River Basin.

completed at the present time. Therefore, it is not possible to assign a WLA specific to the storm sewer collection areas within each MS4 municipality. Instead, the TMDL will be presented as a WLA for the entire land area of the township, borough, or county. In the future, when the storm sewer collection systems have been delineated, it is anticipated that the State's storm water program will revise the WLA into the appropriate WLA and LA as part of the storm water permit reissuance. Note that the overall reductions in the TMDL will not change.

Runoff from urban areas may carry significant loads of nutrients that reach surface waters. To assess the relative loads of nutrients from different land uses within municipal boundaries, it was important to have an inventory of municipal land use data as a proportion of the HSPF subbasins in which the municipality resides. Since the 1995 land use data available for assessing the municipalities is different than the land use in the HSPF model, an aggregated land use was developed for this purpose as shown in Table 2-3. A list of MS4 municipalities in the study area is provided in Table 2-4 and their locations are shown in Figure 2-2.

Table 2-3. Aggregated land use categories used for MS4 assessments.

Aggregated Land Use for MS4 Assessments	HSPF Land Use	1995 Land Use
Residential	Residential-septic Residential-sewer	Single family Multi-family
Agricultural	Agricultural-cows Agricultural-crops Agricultural-mushroom	Agriculture
Open Land	Open land	Public/private open space
Forest	Forest	Wooded
Water	Wetlands, water	Water
Urban	Commercial/industry Undesignated use Roads, building-resid Roads, building-urban	Vacant Transportation/utility Unknown Institutional Industrial Commercial Mining

Table 2-4. Municipalities with MS4 permits in the Christina River Basin

Permit Number	Municipality Name	HSPF Model Subbasins
PAG130079	Avondale Borough	W04, W06, W07, W08
PAG130047	Birmingham Township	B15, B16
PAG130053	Caln Township	B03, B30, B12
PAG130142	Chadds Ford Township	B16, B17, B18
PAG130066	City of Coatesville	B05
PAG130140	Downingtown Borough	B12, B13, B30
PAI130523	East Bradford Township	B08, B14, B15, B29
PAI130524	East Brandywine Township	B10, B11, B12, B30
PAI130536	East Caln Township	B13, B29
PAI130512	East Fallowfield Township	B05, B06, B20, B23
PAG130123	East Marlborough Township	B07, B22, B31, R01, R03
PAG130058	Franklin Township Chester County	W01, W03, W08, C02

Permit Number	Municipality Name	HSPF Model Subbasins
PAI130535	Honey Brook Township	B01, B02, B09
PAG130037	Kennett Square Borough	R01, R03
PAG130146	Kennett Township	B16, B17, R01, R02, R03,R04, R06, W17
PAG130062	London Britain Township	W03, W09, W10, W11, C02
PAI130503	London Grove Township	W02, W03, W04, W05, W06,W08
PAI130516	New Garden Township	W06, W07, W08, W09, R01, R02
PAI130526	New London Township	W01, W02
PAI130539	Penn Township	W01, W02
PAG130134	Pennsbury Township	B16, B17, B31, R06
PAG130113	Pocopson Township	B07, B08, B15, B31
PAG130101	Sadsbury Township	B20
PAG130163	South Coatesville Borough	B05, B06
PAG130067	Thornbury Township	B15, B16
PAI130527	Upper Uwchlan Township	B10, B11, B27
PAI130505	Uwchlan Township	B11, B12, B27, B29
PAG130150	Valley Township	B03, B04, B05, B33
PAI130529	Wallace Township	B09, B10, B26, B27, B35
PAI130511	West Bradford Township	B06, B07, B08, B13, B14, B24, B25, B30
PAG130100, PAI130544	West Brandywine Township	B02, B03, B10, B30
PAG130145	West Caln Township	B01, B02, B03, B20, B32, B33
PAG130002	West Chester Borough	B14, B15
PAG130144	West Grove Borough	W02, W04
PAI130530	West Whiteland Township	B28, B29
DE0051071	City of Wilmington, DE	B34, C05
DE0051071	Elsmere, DE	C04, C05
DE0051071	Newport, DE	C09
DE0051071	City of Newark, DE	W11, W12, C01, C02, C03
DE0051071	New Castle County, DE	B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, C09

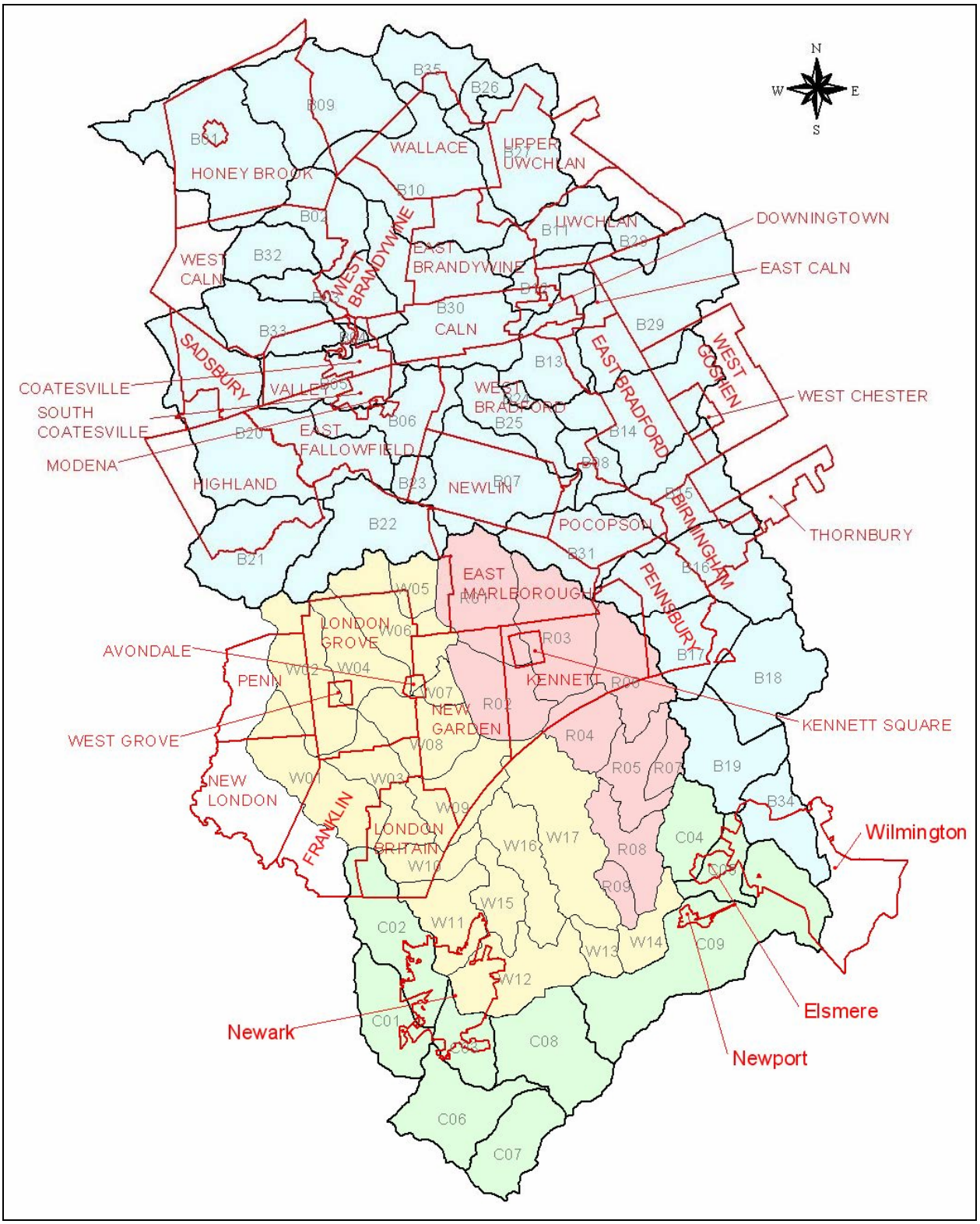

Figure 2-2. Municipalities with MS4 permits in Christina River Basin

2.2 Nonpoint Sources

Nonpoint sources of nutrients are generally much more difficult to identify and quantify than are point sources. In residential and urban areas, nonpoint sources can include leaking or faulty septic systems, landfill seepage, pet waste, storm water runoff (outside of Phase II communities), and other sources. In more rural areas, major contributors can be pasture runoff, manure storage and spreading, concentrated animal feedlots, and wildlife.

2.2.1 Septic Systems

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations that contribute to septic system failure include seasonal water table levels, compact glacial till, bedrock, and coarse sand and gravel outwash. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters down gradient (Horsely and Witten, 1996).

Site-specific information on the locations or numbers of septic systems in the Christina River Basin was not available. Therefore, estimates of the nutrient loads from septic systems were based on the assumptions outlined below:

- Number of septic systems (based on US Census 1990 and 2000)
- Estimated population served by the septic systems (an average of 2.8 people per septic system, US Census 1990)
- An average daily discharge of 70 gallons/person/day (Horsley and Witten, 1996)
- Septic effluent total nitrogen load of 26 g/person/day (Thomann and Mueller, 1987)
- Septic effluent total phosphorus load of 1.3 g/person/day
- Septic effluent CBODu load of 180 g/person/day (Thomann and Mueller, 1987)
- Average annual septic malfunction rate (1% of all septic systems)

The number of septic tanks in Chester County and New Castle County were estimated from US Census data (obtained online from http://factfinder.census.gov/). Examination of the number of housing units in rural areas in the two counties reported in the 1990 U.S. Census revealed that approximately each rural housing unit has a septic system (see Table 2-5). Since no septic system information was available from the 2000 US Census data, estimates were made based on information from the Chester County Health Department (CCHD, 2005). In Chester County, approximately 1,500 permits for septic systems are issued every year of which about 600 of are for repair work and 1,100 are for new permits. The total number of septic systems in Chester County in 2005 was estimated as about 69,000 based on the number in 1990 plus 1,100 new systems per year. Since about 80 percent of the septic systems in Chester County are within the Christina River Basin, there were about 55,200 septic systems in the Chester County portion of the basin in 2005.

Table 2-5. Census data related to septic system estimation

Category	New Castle County	Chester County
1990 Census: Number of rural housing units in County	10,335	50,396
1990 Census: Number septic systems in County	12,142	52,493
1990 Census: Rural population in County	29,468	146,612
1990 Estimated number septic systems in Christina River Basin	10,500	42,000
1995 Estimated number septic systems in Christina River Basin	7,041	46,400
1997 DNREC Inventory of septic systems in Christina River Basin	5,455	-
2004 DNREC Inventory of septic systems in Christina River Basin	1,713	-
2005 Estimated number septic systems in Christina River Basin	1,650	55,200
2005 Estimated number of malfunctioning septic systems	17	552
2005 Estimated potential nitrogen load (kg/day)	3.6	119.8
2005 Estimated potential phosphorus load (kg/day)	0.2	6.0
2005 Estimated potential CBODu load (kg/day)	24.8	829.1

The potential annual nutrient and CBODu load from malfunctioning as well as properly functioning septic systems was estimated using the data in Table 2-5. According to CCHD (2005), 600 permits are issued for repair work, which is approximately one percent of the total number of septic systems in Chester County. Therefore, it was assumed that at any given time one percent of the septic systems were malfunctioning. The same failure rate was applied to New Castle County. It was assumed that the delivery ratio for malfunctioning systems was 1.0 and for properly functioning systems was 0.02.

2.2.2 Agriculture Activities

Land used for agricultural purposes can be a source of nutrients. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all potential agricultural sources. Animals grazing in pasturelands deposit manure directly upon the land surface. Even though a pasture may be relatively large, and animal densities low, manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of contaminated runoff during a storm event. The occurrence and degree of nutrient loads from livestock are linked to temporally and spatially variable hydrologic factors, such as precipitation and runoff, except when manure is directly deposited into a waterbody (USEPA, 2001).

The application of manure that has been improperly composted can contribute nutrients that are conveyed into surface waters during runoff events. Animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to avoid this problem. Grazing animals, confined animal operations and manure application are all potential sources of nutrients in the Christina River Basin. The inventories of livestock in Chester County and New Castle County from the last three agricultural census periods are shown in Table 2-6.

Table 2-6. Livestock inventories from 1992, 1997, and 2002 USDA Agriculture Census.

Category	Chester County, PA			New Castle County, DE		
	1992	1997	2002	1992	1997	2002
Cattle and calves	50,795	48,897	41,878	3,446	2,628	2,665
Hogs and pigs	11,855	2,357	12,860	630	51	86

Category	Chester County, PA			New Castle County, DE		
	1992	1997	2002	1992	1997	2002
Poultry (layers, broilers, turkeys)	734,087	599,360	696,361	209,195	220,308	NA
Horses and ponies	4,330	5,293	8,597	770	737	833
Sheep and lambs	3,421	2,154	2,856	238	222	366

NA = not available

2.2.3 Wildlife

Wildlife also contribute nutrients to land surface and in streams. A precise estimate of the number of wild animals in the Christina River Basin is not available. Literature and empirical values were used to estimate wild animal population densities for different land use categories as shown in Table 2-7.

Table 2-7. Estimated wildlife density for associated land uses in Christina River Basin

Wild Animals	Agricutlure-Rowcrop (Animals/sq mile)	Agricutlure-Livestock (Animals/sq mile)	Forest Animals/sq mile)
Ducks	30	30	10
Geese	50	50	0
Deer	0	35	35
Beaver	5	5	10
Raccoons	2.5	2.5	5
Other	320	160	160

2.2.4 Representation of Nonpoint Sources in the HSPF Model

Nonpoint source flows and loads for the Christina River Basin nutrient and dissolved oxygen TMDLs were simulated using four HSPF watershed models, one for each of the four main watersheds in the basin (Brandywine Creek watershed, White Clay Creek watershed, Red Clay Creek watershed, and Christina River watershed). Under the HSPF model framework, each watershed was numerous subbasins with each subbasin having 12 land use categories. Loads for septic systems, livestock, and wildlife were not explicitly incorporated into the HSPF models. Instead they were implicitly lumped into the HSPF land use categories, and the overall load from a subbasin was approximated through comparison of model output to instream monitoring data during the calibration process (Senior and Koerkle, 2003a, 2003b, 2003d, 2003d). The data shown in Section 2.2 for septic systems, livestock, and wildlife are for information purposes and can be used during the implementation phase of the TMDL to target likely sources requiring load reduction.

3.0 TMDL ENDPOINT DETERMINATION

To meet the designated uses in the Christina River Basin, water quality targets, or endpoints, must be achieved under the variable flow conditions. The selection of these endpoints considers the water quality standards prescribed by those designated uses (Section 1-3).

Once the applicable use designation and water quality criteria is identified, the numeric water quality target or goal for the TMDL is determined. These targets represent a number where applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at all flow conditions. Figure 3-1 below shows the applicable use designations for stream segments included in the Christina River Basin TMDL. Using Tables 1-4 and 1-5 and Figure 3-1, the numeric water quality targets for DO can be identified for each segment. Table 3-1 below identifies the general water quality targets or endpoints for the Christina River Basin TMDLs.

Table 3-1. Summary of TMDL Endpoints

Parameter	Target Limit	Reference
Daily Average DO, warm water fish (PA)	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, cold water fish (PA)	6.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, fresh waters (DE)	5.5 mg/L	Delaware Water Quality Standards
Daily Average DO, cold water fish (DE)	6.5 mg/L	Delaware Water Quality Standards
Daily Average DO, tidal fresh waters (DE)	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater (MD)	5.0 mg/L	Maryland Water Quality Standards
Minimum DO, warm water fish (PA)	4.0 mg/L	Pennsylvania Water Quality Standards
Minimum DO, cold water fish (PA)	5.0 mg/L	Pennsylvania Water Quality Standards
Minimum DO, fresh waters (DE)	4.0 mg/L	Delaware Water Quality Standards
Minimum DO, cold water fish (DE)	5.0 mg/L	Delaware Water Quality Standards
Nitrate-Nitrogen	10 mg/L	PA and DE Water Quality Standards
Ammonia-Nitrogen	function(Temp, pH)	PA and EPA Water Quality Criteria
Total Nitrogen guideline (DE)	3.0 mg/L	DE 303(d) rationale document
Total Phosphorus guideline (DE)	0.2 mg/L	DE 303(d) rationale document

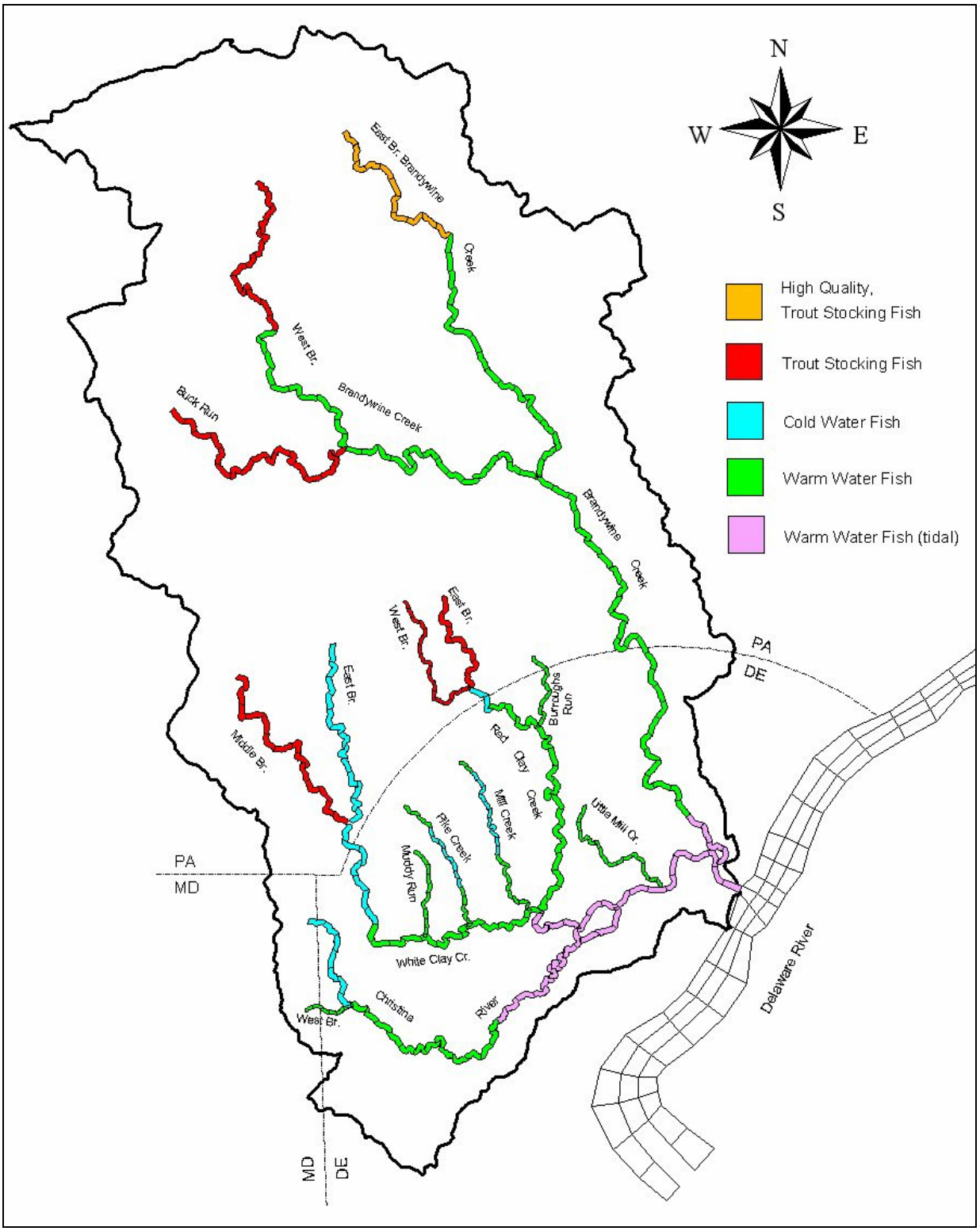

Figure 3-1. Use designations of streams included in the Christina River Basin water quality model

These TMDLs have also identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given our scientific knowledge regarding the interrelationship of nutrients, BOD, SOD and their impact on DO, EPA determined it necessary and appropriate to establish numeric targets for total nitrogen and total phosphorus based on applicable state narrative criteria to support the attainment of the numeric DO criterion and protection of aquatic habitat. Establishing numeric water quality endpoints or goals also provides the ability to measure the progress toward attainment of the WQS and to identify the amount or degree of deviation from the allowable pollutant load.

While the ultimate endpoint for the previous low-flow TMDL analysis was to ensure that the WQS for DO were maintained throughout the Christina River Basin, it is necessary to determine if other applicable water quality criteria are met and maintained. Specifically, this applies to the Pennsylvania WQS for nitrate-nitrogen of 10 mg/L and ammonia-nitrogen, which is based on temperature and pH. The Maryland WQS for ammonia-nitrogen adopted the EPA water quality criteria in January 2001 (see Table 1-6). As a result of the pollutant load reductions necessary to maintain the water quality criteria for DO, the WQS for nitrate-nitrogen and ammonia-nitrogen of Pennsylvania and Maryland were also evaluated. The ammonia-nitrogen standard is met throughout the Pennsylvania portion of the Christina River Basin. The only instances where the nitrate nitrogen value of 10 mg/L is exceeded are small distances on the East Branch Brandywine Creek and West Branch Brandywine Creek. As there are no drinking water withdrawals at these locations, the standard is not applicable and additional reduction is not necessary.

The Delaware WQS also set a numeric water quality criterion of 10 mg/L for nitrate-nitrogen. The WQS for nitrate-nitrogen of Delaware are met throughout the Delaware portion of the Christina River Basin. Delaware does not have numeric water quality criteria for ammonia nitrogen; however, the analysis indicates that ammonia-nitrogen levels throughout the Delaware portion of the Christina River Basin are consistent with the recommended EPA water quality criterion from Section 304(a) of the CWA.

Achieving these in-stream numeric water quality targets will ensure that the designated uses (aquatic life and human health uses) of waters in Pennsylvania, Delaware, and Maryland are supported during critical conditions.

Errata

4/30/2007

The2005 and 2006 Total Maximum Daily Load of Nutrients and Low Dissolved Oxygen Under High-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, *established April 8, 2005, and revised September 26, 2006, by EPA was not intended to modify wasteload allocations (WLAs)established in the* Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland*, to the two WWTPs discharging to the West Branch Christina River in Maryland. The two WWTPs are:*

Highlands WWTP MD0065145
Meadowview WWTP MD0022641

The corrected portions of Section 4 are shown in italics below.

4.5.2 Maryland Allocations at MD-DE State Line

Water flowing into Delaware from Maryland must meet Delaware WQS at the Delaware state line. There are two streams that enter Delaware from Maryland: the upper Christina River and Christina River West Branch. The results from the linked HSPF-EFDC models for these two streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The TMDL endpoints at the MD-DE state line for the upper Christina River were achieved under baseline conditions. Therefore, no load reductions were necessary to the portion of the watershed feeding the upper Christina River. The Maryland allocations for nutrients at the Delaware state line for the Christina River West Branch are shown in Table 4-2. The baseline and allocation loads in Table 4-2 represent the average daily nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve the endpoint concentration over that same period. The model simulations indicate the load reductions from baseline conditions were *72.8%* for total nitrogen, and 47.5% for total phosphorus.

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	*95.5*	26.2	*72.8%*
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)	Allocations (kg/day)	Percent

	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
C01	*57.781*	53.686	*110.467*	*57.781*	2.634	7.566	0.537	*67.718*	*38.9%*
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	*52.996*	2.650	*52.996*	2.650	0.0%	0.0%
C01	MD0065145	0.0500	*3.785*	0.189	*3.785*	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

TMDL METHODOLOGY AND CALCULATION

4.1 Methodology

This section discusses the methodology used for TMDL development and results in terms of TMDLs and required load reductions for the stream segments listed on Pennsylvania's and Delaware's Section 303(d) lists as impaired due to nutrients and low DO (see Figures 4-1 and 4-2).

To determine nutrient TMDLs for the Christina River Basin listed waters, three models were used: the HSPF watershed loading model, the XP-SWMM CSO discharge model, and the EFDC receiving water model. The HSPF and EFDC models were calibrated using the four-year period October 1, 1994 to October 1, 1998. All three models were run using this same four-year simulation period to calculate the baseline and allocation loads. The HSPF model was used to estimate nonpoint source loads from 70 subbasins in the Christina River Basin. The nonpoint source loads were then input to the EFDC receiving water model for more detailed analysis of instream water quality conditions. The HSPF model was also used to calculate nutrient loads at the Pennsylvania-Delaware state line since the Delaware WQS applies to Pennsylvania at their common border. The calculation at the state line affected four streams: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run in the Red Clay Creek watershed. In addition, the HSPF model was used to calculate nutrient loads for several smaller listed stream segments that were not included in the EFDC model. The XP-SWMM model was used to calculate nutrient loads from the CSO discharge points in the City of Wilmington. The daily time-series loads from the HSPF model and from the XP-SWMM model were then input to the EFDC receiving water model to simulate nutrient concentrations in the tidal waters of the Christina River and Brandywine Creek.

Baseline conditions for the TMDL included meteorology and hydrology for the October 1, 1994, to October 1, 1998, calibration period. NPDES flows were set to their permit limits for the entire four-year simulation period. The Pennsylvania NPDES facilities operated with seasonal permit concentrations for CBOD, ammonia nitrogen, and total phosphorus. During the winter periods from November 1 to April 30, the concentration of 5-day CBOD (CBOD5) was set to two times the summer concentration and ammonia-nitrogen concentration was set to three times the summer value. During the period November 1 to March 31, the total phosphorus concentrations were set to twice of the summer permit concentration. CSO loads from the City of Wilmington were estimated using simulated flow rates from the XP-SWMM model and event mean concentrations from a storm-water monitoring program. Septic loads and land use coverage from 1995 were used for the baseline conditions in the HSPF watershed model.

4.2 TMDL Calculation

TMDLs were established for each individual stream segment listed for nutrients on the Pennsylvania and Delaware Section 303(d) lists. Each TMDL consists of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). These TMDLs identify the sources of pollutants that cause or contribute to the impairment and allocate appropriate loadings to the various sources. The basic equation used for TMDLs and allocations to sources is:

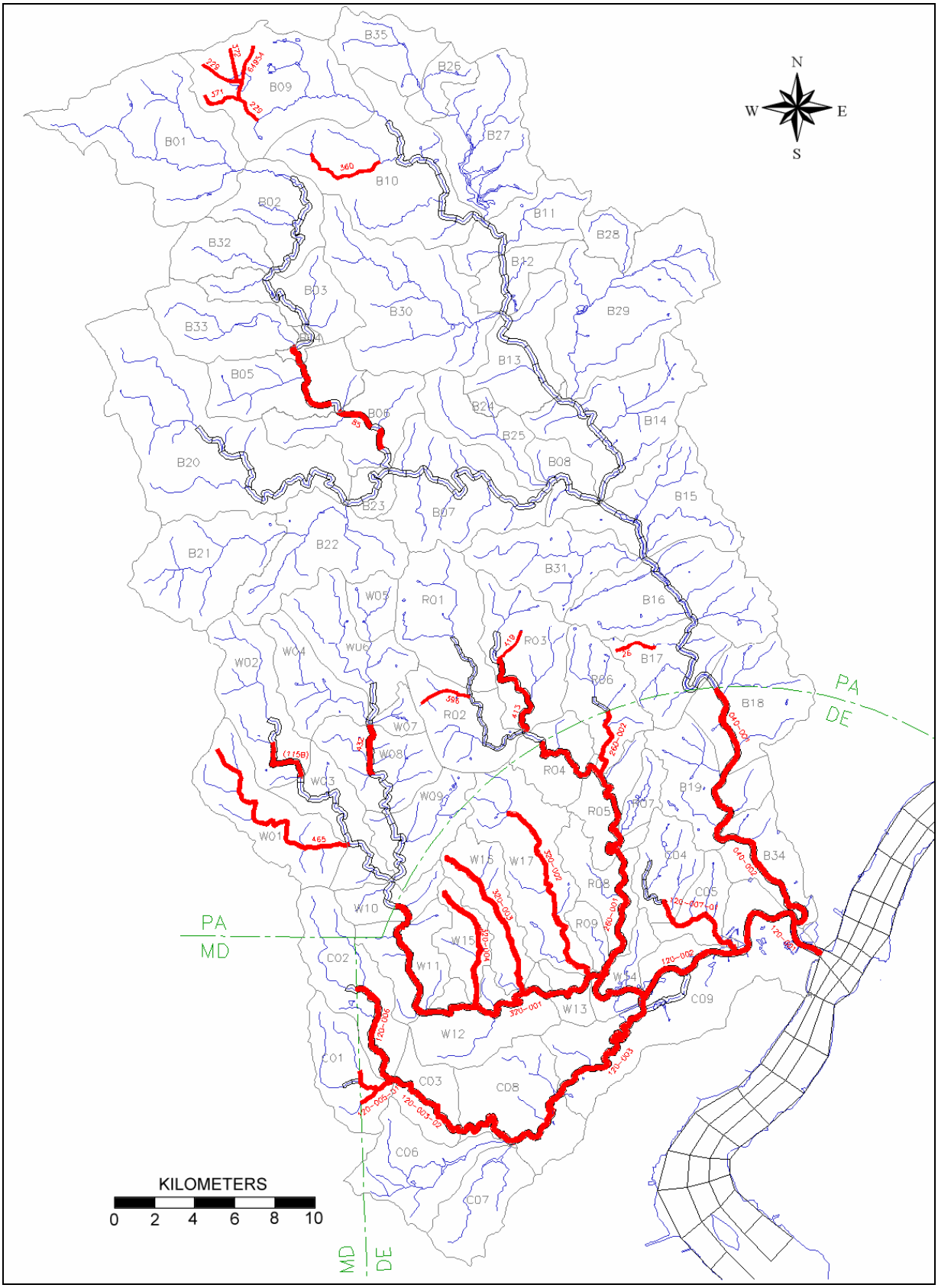

Figure 0-1. Stream segments impaired by nutrients and low DO on 1996 Section 303(d) lists

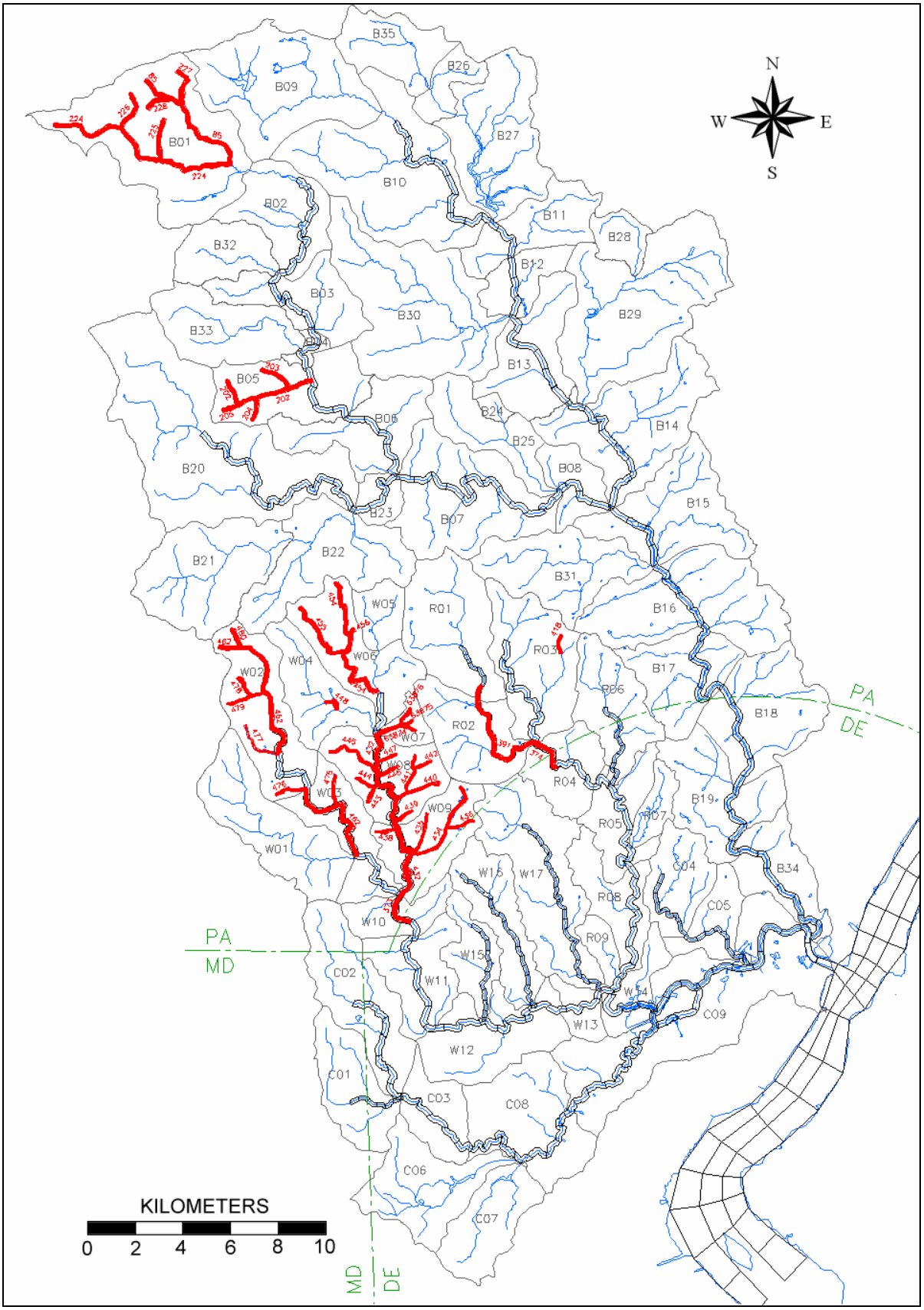

Figure 0-2. Stream segments impaired by nutrients and low DO on 1998 Section 303(d) lists

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The WLA portion of this equation is the total loading assigned to point sources. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent of MOS was used for this TMDL.

4.3 Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. Based on the water quality model simulations, none of the non-MS4 NPDES permitted dischargers in the impaired subbasins were required to reduce their present NPDES permit limits for CBOD, nitrogen, or phosphorus.

The wasteload allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. EPA's stormwater permitting regulations require municipalities to obtain permit coverage for all stormwater discharges from municipal separate storm sewer systems (MS4). On November 22, 2002, an EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the wasteload allocation component of the TMDL and may not be addressed by the load allocation component of TMDL
- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls
- Industrial storm water permits need to reflect technology-based and water quality-based requirements

Based on this memorandum, MS4s within the Christina River watershed are treated as point sources for TMDL and NPDES permitting purposes, and the nutrient loading generated within the boundary of an MS4 area was assigned a WLA. Each of the townships/municipalities within the watershed has been designated by PADEP as needing coverage under NPDES Phase II Stormwater Regulations, and comprises almost the entire watershed area. To determine the nutrient loading associated with each MS4, the township boundary GIS layer was overlaid with the land-use coverage. Nutrient loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C).

At this time, EPA cannot determine what portion of the municipalities are designated/used for collection or conveying stormwater, as opposed to portions that are truly nonpoint sources. As part of the Phase II process, MS4s will be responsible for evaluating and mapping out areas that are contributing to or collected in storm sewers. Since these systems have not yet been delineated, the TMDL includes nonpoint source loadings into the WLA portion of the TMDL. Once these delineations are available, the nonpoint source loadings can then be separated out of the WLAs and moved under the LA. Until that time, the WLAs have been broken down by land

uses. These areas should not be precluded from nonpoint source funding, such as Growing Greener and Section 319 grants.

The TMDL loads are one scenario of load reductions which, together with other sources' reductions, result in achieving instream water quality criteria throughout the length of the impaired waterbody. In the future, the States may allow an alternate reduction scenario, which also demonstrates that water quality standards are met throughout the length of impaired waterbody, or may redistribute the wateload allocations within an impaired waterbody segment. It is anticipated that any re-allocation of the wasteload allocation would be done as part of the NPDES permitting to allow for public participation.

4.4 Load Allocations

According to federal regulations (40 CFR 130.2(g)), load allocations are best estimates of the nonpoint source or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading.

As explained in Section 4.2, once a municipality delineates its MS4 area, the nutrient loads associated with nonpoint sources may be parsed out of the WLA and moved under the LA portion of the TMDL. Note that the total allocation will be unchanged.

4.5 TMDL Results and Allocations

The impaired stream segments on the Section 303(d) list for nutrients and low DO in the Pennsylvania portion of the Christina River Basin are located in the Brandywine Creek, White Clay Creek, and Red Clay Creek watersheds. The HSPF and EFDC models for were run for the period October 1, 1994, to October 1, 1998, for both the baseline (current) conditions and for the TMDL allocation conditions. The WLA from the low-flow TMDL (USEPA, 2002) was used as the baseline conditions for the NPDES facilities in this high-flow TMDL. Watershed nutrient loads were adjusted in the TMDL allocation scenarios until the target endpoints described in Section 3.0 were achieved. The allocation process included the following steps.

(1) For the impaired Pennsylvania subbasins, the nutrient loads were reduced as necessary to protect the DO water quality standards.
(2) At the Delaware-Pennsylvania state line, the simulated TN and TP concentrations were used to determine the Pennsylvania allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.
(3) At the Maryland-Delaware state line, the simulated TN and TP concentrations were used to calculate the Maryland allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.
(4) For Delaware's upper subbasins, the TN and TP guidance concentrations were used to adjust nutrient loads, as necessary, in each subbasin. Also, protection of the WQS for DO, nitrate-nitrogen, and ammonia-nitrogen was determined and additional load reductions were made, as necessary, to achieve the WQS.
(5) For the tidal Christina River near the mouth of the basin, the model was run with reductions stipulated in steps (1) to (3) above and the TMDL endpoints pertaining to Delaware (see Table 3-1) were evaluated to determine if reductions were necessary to CSO loads from the City of Wilmington.

4.5.1 Pennsylvania Allocations at PA-DE State Line

Water flowing into Delaware from Pennsylvania must meet Delaware WQS at the Delaware state line. There are four streams that enter Delaware from Pennsylvania: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run. The results from the linked HSPF-EFDC models for these four streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The Pennsylvania allocations for nutrients at the state line are shown in Table 4-1. The baseline and allocation loads in Table 4-1 represent the average nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve an average endpoint concentration over that same period. Model results indicate the load reductions from baseline conditions range from about 0% to 46% for total nitrogen, and from 0% to 73% for total phosphorus.

Table 4-1. Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

4.5.2 Maryland Allocations at MD-DE State Line

Water flowing into Delaware from Maryland must meet Delaware WQS at the Delaware state line. There are two streams that enter Delaware from Maryland: the upper Christina River and Christina River West Branch. The results from the linked HSPF-EFDC models for these two streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The TMDL endpoints at the MD-DE state line for the upper Christina River were achieved under baseline conditions. Therefore, no load reductions were necessary to the portion of the watershed feeding the upper Christina River. The Maryland allocations for nutrients at the Delaware state line for the Christina River West Branch are shown in Table 4-2. The baseline and allocation loads in Table 4-2 represent the average daily nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve the endpoint concentration over that same period. The model simulations indicate the load reductions from baseline conditions were 61.9% for total nitrogen, and 47.5% for total phosphorus.

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	68.7	26.2	61.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

4.5.3 Nitrate-Nitrogen and Ammonia-Nitrogen Allocations

Under baseline conditions, the model indicated that the daily average nitrate concentrations were less than 10 mg/L at all grid cell locations within the listed impaired water segments. Therefore, no reductions in nitrogen loads were necessary to achieve compliance with the nitrate-nitrogen WQS of 10 mg/L. Ammonia-nitrogen, which is based on pH and temperature, was investigated during the low-flow study (USEPA, 2002) and it was determined that the ammonia-nitrogen standard was protected throughout the Christina River Basin. Since the critical period for potential violations of the ammonia-nitrogen standard occur during low-flow summer months, no additional investigation was deemed necessary for this high-flow study.

4.5.4 Nitrogen and Phosphorus Allocations

In Pennsylvania, it was necessary to reduce nitrogen and phosphorus loads from both point and nonpoint sources in a number of subbasins in order to protect the minimum and daily average DO water quality standards. The models were run in an iterative fashion to determine the load reductions required from point and nonpoint sources to protect the DO criteria. The load allocations and WLAs are summarized by impaired subbasin in Tables 4-3 to 4-10 below. An explicit 5% margin of safety (MOS) is included in the TMDL allocation. The baseline and preliminary TMDL allocation loads shown in Table 4-3 to 4-10 represent the average daily loads calculated from the HSPF and EFDC model simulations covering the period October 1, 1994, to October 1, 1998. The model results for the baseline condition and TMDL allocations are presented in the graphs in Appendix D. These graphs represent transects along the impaired stream segments included in the water quality model and show the model results in relation to the TMDL target endpoints.

4.5.5 Dissolved Oxygen Allocations

Under the low-flow study (USEPA, 2002), an analysis was performed to investigate potential dissolved oxygen WQS violations during critical conditions. The NPDES point source discharges were set to their maximum permitted flows and concentrations and the model was run under 7Q10 (minimum 7-day flow expected to occur every 10 years) stream flow conditions. As a result of the low-flow study, WLAs were established for several NPDES discharges on East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and West Branch Christina River to protect the dissolved oxygen WQS. For the baseline conditions of this high-flow TMDL, the NPDES discharges in the Christina River Basin were set to the recommended WLA values from the low-flow study during the summer season. During the

winter season, the permitted concentrations of ammonia nitrogen, total phosphorus, and CBOD were increased as described in Section 4.1. The model results for the high-flow TMDL allocations presented in Tables 4-1 to 4-10, indicate that no additional reductions to the non-MS4 NPDES discharges over and above those recommended in the low-flow TMDL are necessary to protect the dissolved oxygen WQS. However, nonpoint sources, including MS4s, and CSO load reductions were necessary to achieve the TMDL targets related to dissolved oxygen, total nitrogen, and total phosphorus.

Table 4-3. TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
B01	31.559	362.174	393.733	31.559	170.416	36.023	10.865	248.863	36.8%
B02	0.000	114.369	114.369	0.000	65.191	0.000	3.431	68.622	40.0%
B03	2.167	89.226	91.393	2.167	67.779	8.510	4.015	82.471	9.8%
B04	0.000	5.369	5.369	0.000	5.101	0.000	0.268	5.369	0.0%
B05	558.690	77.512	636.202	558.690	34.049	10.133	2.325	605.197	4.9%
B06	0.156	123.362	123.518	0.156	80.940	1.095	4.318	86.509	30.0%
B09	0.078	252.455	252.533	0.078	97.148	99.515	10.351	207.092	18.0%
B10	3.721	252.455	256.176	3.721	179.343	17.320	10.351	210.735	17.7%
B17	1.013	83.890	84.903	1.013	43.626	30.491	3.901	79.031	6.9%
B18	0.000	103.795	103.795	0.000	98.605	0.000	5.190	103.795	0.0%
B19	0.946	64.711	65.657	0.946	61.475	0.000	3.236	65.657	0.0%
B32	0.000	29.001	29.001	0.000	24.796	0.000	1.305	26.101	10.0%
B33	1.799	95.092	96.891	1.799	80.541	0.763	4.279	87.382	9.8%
B34	11.443	33.958	45.401	4.107	32.260	0.000	1.698	38.065	16.2%
Total Phosphorus									
B01	6.360	6.920	13.280	6.360	3.256	0.688	0.208	10.512	20.8%
B02	0.000	2.185	2.185	0.000	1.245	0.000	0.066	1.311	40.0%
B03	0.540	16.229	16.769	0.540	12.328	1.548	0.730	15.146	9.7%
B04	0.000	0.988	0.988	0.000	0.939	0.000	0.049	0.988	0.0%
B05	35.524	14.615	50.139	35.524	6.420	1.911	0.438	44.293	11.7%
B06	0.040	25.254	25.294	0.040	16.570	0.224	0.884	17.718	30.0%
B09	0.020	3.849	3.869	0.020	1.481	1.517	0.158	3.176	17.9%
B10	0.429	3.848	4.277	0.429	2.734	0.264	0.158	3.585	16.2%
B17	0.221	7.508	7.729	0.221	3.904	2.729	0.349	7.203	6.8%
B18	0.000	8.586	8.586	0.000	8.157	0.000	0.429	8.586	0.0%
B19	0.189	2.376	2.565	0.189	2.257	0.000	0.119	2.565	0.0%
B32	0.000	2.147	2.147	0.000	1.836	0.000	0.097	1.933	10.0%
B33	0.115	1.729	1.844	0.115	1.465	0.014	0.078	1.672	9.3%
B34	1.966	2.843	4.809	0.730	2.701	0.000	0.142	3.573	25.7%

Table 4-4. WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B01	PA0036412	0.0550	2.682	0.559	2.682	0.559	0.0%	0.0%
B01	PA0044776	0.6000	28.799	5.781	28.799	5.781	0.0%	0.0%
B01	PA0057339	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B03	PA0052728	0.0004	0.036	0.015	0.036	0.015	0.0%	0.0%
B03	PA0055697	0.0490	2.131	0.525	2.131	0.525	0.0%	0.0%
B05	PA0011568-001	0.6400	14.045	1.029	14.045	1.029	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B05	PA0011568-016	0.5045	23.868	0.811	23.868	0.811	0.0%	0.0%
B05	PA0026859	3.8500	466.237	29.508	466.237	29.508	0.0%	0.0%
B05	PA0036897	0.3900	54.54	4.176	54.54	4.176	0.0%	0.0%
B06	PA0053228	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B06	PA0053236	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B09	PA0054691	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0050458	0.0351	1.724	0.188	1.724	0.188	0.0%	0.0%
B10	PA0050547	0.0375	1.841	0.201	1.841	0.201	0.0%	0.0%
B10	PA0055492	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0057827	0.0050	0.078	0.02	0.078	0.02	0.0%	0.0%
B17	PA0053082	0.0206	1.013	0.221	1.013	0.221	0.0%	0.0%
B19	DE0021768	0.0250	0.947	0.189	0.947	0.189	0.0%	0.0%
B33	PA0012416	0.1400	1.643	0.075	1.643	0.075	0.0%	0.0%
B33	PA0052990	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B33	PA0056073	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B34	(DE CSO)	See Table 4-11						

Table 4-5. TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
R01	3.677	126.926	130.603	3.677	54.709	5.581	3.173	67.140	48.6%
R02	49.825	104.678	154.503	49.825	49.722	0.000	2.617	102.164	33.9%
R03	6.807	120.151	126.958	6.807	57.071	0.000	3.004	66.882	47.3%
R04	2.197	39.984	42.181	2.197	18.992	0.000	1.000	22.189	47.4%
R05	0.568	34.713	35.281	0.568	16.489	0.000	0.868	17.925	49.2%
R06	0.078	67.015	67.093	0.078	63.664	0.000	3.351	67.093	0.0%
R07	0.000	3.012	3.012	0.000	2.861	0.000	0.151	3.012	0.0%
R08	0.318	23.882	24.200	0.318	22.688	0.000	1.194	24.200	0.0%
R09	0.000	7.346	7.346	0.000	6.979	0.000	0.367	7.346	0.0%
Total Phosphorus									
R01	0.914	2.277	3.191	0.914	0.982	0.100	0.057	2.053	35.7%
R02	7.506	45.473	52.979	7.506	4.320	0.000	0.227	12.053	77.2%
R03	1.606	2.845	4.451	1.606	1.352	0.000	0.071	3.029	31.9%
R04	1.699	6.407	8.106	1.699	1.887	0.000	0.099	3.685	54.5%
R05	0.114	4.249	4.363	0.114	4.037	0.000	0.212	4.363	0.0%
R06	0.020	1.269	1.289	0.020	1.206	0.000	0.063	1.289	0.0%
R07	0.000	0.424	0.424	0.000	0.403	0.000	0.021	0.424	0.0%
R08	0.133	1.383	1.516	0.133	1.314	0.000	0.069	1.516	0.0%
R09	0.000	0.360	0.360	0.000	0.342	0.000	0.018	0.360	0.0%

Table 4-6. WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R01	PA0050679	0.2500	0.321	0.134	0.321	0.134	0.0%	0.0%
R01	PA0057720-001	0.0720	3.240	0.732	3.240	0.732	0.0%	0.0%
R01	PA0057720-002	0.0900	0.116	0.048	0.116	0.048	0.0%	0.0%
R02	PA0024058	1.1000	49.825	7.506	49.825	7.506	0.0%	0.0%
R03	PA0055107	0.1500	6.807	1.606	6.807	1.606	0.0%	0.0%
R04	DE0000451	2.1700	1.972	1.643	1.972	1.643	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R04	DE0050067	0.0015	0.225	0.056	0.225	0.056	0.0%	0.0%
R05	DE0021709	0.0150	0.568	0.114	0.568	0.114	0.0%	0.0%
R06	PA0055425	0.0005	0.078	0.020	0.078	0.020	0.0%	0.0%
R08	DE0000230	0.3500	0.318	0.133	0.318	0.133	0.0%	0.0%

Table 4-7. TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
W01	0.981	157.038	158.019	0.981	74.593	0.000	3.926	79.500	49.7%
W02	15.503	133.766	149.269	15.503	47.807	9.378	3.010	75.697	49.3%
W03	0.000	87.269	87.269	0.000	41.453	0.000	2.182	43.635	50.0%
W04	0.000	83.361	83.361	0.000	38.121	1.476	2.084	41.681	50.0%
W06	59.718	168.665	228.383	59.718	50.433	29.683	4.217	144.051	36.9%
W07	8.868	29.463	38.331	8.868	13.994	0.000	0.737	23.599	38.4%
W08	1.164	129.466	130.630	1.164	61.496	0.000	3.237	65.897	49.6%
W09	0.113	79.504	79.617	0.113	37.764	0.000	1.988	39.865	49.9%
W10	0.000	32.949	32.949	0.000	15.651	0.000	0.824	16.475	50.0%
W11	0.000	39.714	39.714	0.000	37.728	0.000	1.986	39.714	0.0%
W12	0.027	52.612	52.639	0.027	49.981	0.000	2.631	52.639	0.0%
W13	0.000	12.866	12.866	0.000	12.223	0.000	0.643	12.866	0.0%
W14	0.000	13.572	13.572	0.000	12.893	0.000	0.679	13.572	0.0%
W15	0.000	34.796	34.796	0.000	33.056	0.000	1.740	34.796	0.0%
W16	0.000	39.019	39.019	0.000	37.068	0.000	1.951	39.019	0.0%
W17	0.000	84.250	84.250	0.000	80.038	0.000	4.213	84.250	0.0%
Total Phosphorus									
W01	0.214	1.921	2.135	0.214	0.821	0.000	0.043	1.078	49.5%
W02	2.676	1.418	4.094	2.676	0.507	0.100	0.032	3.315	19.0%
W03	0.000	16.736	16.736	0.000	7.155	0.000	0.377	7.532	55.0%
W04	0.000	1.170	1.170	0.000	0.482	0.019	0.026	0.527	55.0%
W06	6.493	2.203	8.696	6.493	0.330	0.194	0.028	7.044	19.0%
W07	0.105	1.890	1.995	0.105	0.808	0.000	0.043	0.955	52.1%
W08	0.084	59.994	60.078	0.084	15.958	0.000	0.840	16.882	71.9%
W09	0.046	15.519	15.565	0.046	6.635	0.000	0.349	7.030	54.8%
W10	0.000	4.907	4.907	0.000	2.098	0.000	0.110	2.208	55.0%
W11	0.000	5.474	5.474	0.000	5.200	0.000	0.274	5.474	0.0%
W12	0.011	4.122	4.133	0.011	3.916	0.000	0.206	4.133	0.0%
W13	0.000	1.074	1.074	0.000	1.020	0.000	0.054	1.074	0.0%
W14	0.000	0.637	0.637	0.000	0.605	0.000	0.032	0.637	0.0%
W15	0.000	0.494	0.494	0.000	0.469	0.000	0.025	0.494	0.0%
W16	0.000	0.831	0.831	0.000	0.789	0.000	0.042	0.831	0.0%
W17	0.000	2.152	2.152	0.000	2.044	0.000	0.108	2.152	0.0%

Table 4-8. WLA summary for White Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	0.981	0.214	0.981	0.214	0.0%	0.0%
W02	PA0024066	0.2500	15.503	2.676	15.503	2.676	0.0%	0.0%
W06	PA0025488	0.3000	59.038	6.425	59.038	6.425	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W06	PA0040436	0.0090	0.680	0.068	0.680	0.068	0.0%	0.0%
W07	PA0056898	0.0650	8.868	0.105	8.868	0.105	0.0%	0.0%
W08	PA0057029	0.1440	1.164	0.084	1.164	0.084	0.0%	0.0%
W09	PA0052451	0.0012	0.113	0.046	0.113	0.046	0.0%	0.0%
W12	DE0000191	0.0300	0.027	0.011	0.027	0.011	0.0%	0.0%

Table 4-9. TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
C01	28.965	53.686	82.651	28.965	2.634	7.566	0.537	39.702	52.0%
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%
Total Phosphorus									
C01	2.839	1.334	4.173	2.839	0.065	0.188	0.013	3.106	25.6%
C02	0.000	1.584	1.584	0.000	0.985	0.520	0.079	1.584	0.0%
C03	0.000	2.610	2.610	0.000	2.480	0.000	0.131	2.610	0.0%
C04	0.000	0.438	0.438	0.000	0.416	0.000	0.022	0.438	0.0%
C05	0.441	0.826	1.267	0.104	0.785	0.000	0.041	0.930	26.6%
C06	0.000	1.211	1.211	0.000	1.085	0.065	0.061	1.211	0.0%
C07	0.000	1.000	1.000	0.000	0.950	0.000	0.050	1.000	0.0%
C08	0.000	4.202	4.202	0.000	3.992	0.000	0.210	4.202	0.0%
C09	1.003	6.688	7.691	0.276	6.354	0.000	0.334	6.964	9.5%
Becks Pond	0.000	1.090	1.090	0.000	0.985	0.051	0.055	1.090	0.0%
Sunset Pond	0.000	0.904	0.904	0.000	0.859	0.000	0.045	0.904	0.0%

Table 4-10. WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	26.503	2.650	26.503	2.650	0.0%	0.0%
C01	MD0065145	0.0500	2.462	0.189	2.462	0.189	0.0%	0.0%
C05	(DE CSO)	See Table 4-11						
C09	(DE CSO)	See Table 4-11						

4.5.6 CSO Allocations

The City of Wilmington has 38 combined sewer overflows (CSOs) that discharge within the Christina River Basin study area. A summary of the baseline and allocated annual average nitrogen and phosphorus for CSOs grouped by EFDC model grid cell is provided in Appendix E,

Table E-5. After applying the TMDL allocations listed in Tables 4-1 to 4-10, the water quality model indicated that the TP target of 0.2 mg/L was protected in lower Brandywine Creek and lower Christina River where the CSOs discharge. However, the model indicated that the TN target of 3.0 mg/L and the water quality standards for DO were not protected; therefore, the CSO loads were reduced to meet these endpoints. The combined reduction of nutrients from the watershed loads and the CSO loads resulted in achievement of the TN target and protection of the DO water quality standards in lower Brandywine Creek and lower Christina River. The baseline and allocated annual average loads for CSO discharges from the City of Wilmington are shown in Table 4-11.

Please note that the TMDL CSO load reductions shown in Appendix E, Table E-5, are one scenario of load reductions, which, together with other sources' reductions, result in achieving instream water quality criteria throughout the length of the impaired waterbody. It should be noted that other scenarios are possible. In the future DNREC may allow an alternate CSO load reduction scenario, which also demonstrates that water quality standards are met throughout the length of the impaired waterbody.

Table 4-11. Baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	CSO ID numbers	Baseline (kg/day)	WLA (kg/day)	Reduction
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	2.606	0.618	76.3%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	5.931	1.631	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	11.443	4.107	64.1%
Total CSO load	-	19.980	6.356	68.2%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	0.441	0.104	76.4%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	1.003	0.276	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	1.966	0.730	62.9%
Total CSO load	-	3.410	1.110	67.4%

4.6 Consideration of Critical Conditions

Federal Regulations (40 CFR 130.7(c)(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. Critical conditions include combinations of environmental factors that result in attaining and maintaining the water quality criteria and have an acceptably low frequency of occurrence

(USEPA, 2001). The nutrient and low DO TMDLs for Christina River Basin adequately address critical conditions for flow and loading through analysis of a four-year hydrologic simulation that includes typical low and high flow extremes in the basin.

4.7 Consideration of Seasonal Variation

The critical conditions for nutrient impairments of aquatic life habitat cannot be defined with a fixed flow rate. A long-term continuous simulation is the one way to determine when the nutrient concentrations are above the target endpoints. Therefore, the models were run for a four-year period (October 1, 1994 to October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997 as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin.

5.0 REASONABLE ASSURANCE AND IMPLEMENTATION

EPA's regulations require that there is reasonable assurance that TMDLs can be implemented. Reasonable assurance indicates a high degree of confidence that the goals outlined in the TMDL, whether in the form of WLAs or LAs, can be achieved. In terms of the Christina River High-flow TMDL, various programs exist that can be utilized to help implement TMDLs.

Reasonable assurance indicates a high degree of confidence that each waste load allocation (WLA) and load allocation in a TMDL can be implemented. For point sources, federal regulations at 40 CFR 122.44(d)(1)(vii)(B), require effluent limitations for an NPDES permit to be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of a NPDES permit that is inconsistent with the WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the states' current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint source water quality problems, consider alternative solutions, and recommend control measures.

With regard to load allocations for nonpoint sources, programs including Section 319 programs are available. Pennsylvania's Growing Greener funding has provided more than $65 million dollars to environmental initiatives throughout the Commonwealth of Pennsylvania. Section 319 grant funding, supported by the Unified Watershed Assessment and the Watershed Restoration Action Strategies, is designed to focus resources towards the implementation of Best Management Practices for nonpoint source pollutants.

Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of nutrients reaching the streams can be made through the planning of riparian buffer zones, contour strips, cover crops, or stormwater retention techniques. These BMPs range in efficiency from 20% to 70% for nutrient reduction. Further investigations should be performed in order to assess both the extent of existing BMPs, and to determine the most cost-effective and environmentally protective combination of BMPs required for meeting the nutrient reductions outlined in this report.

There are state and local policies and regulations in place to help ensure implementation of BMPs. At the state level, PADEP has developed a Proposed Comprehensive Stormwater Management Policy (Appendix A) that encourages implementation of BMPs for stormwater control to reduce pollutant loadings, recharge groundwater tables, enhance stream baseflow during drought periods, and reduce the threat of stream bank erosion and flooding. This policy seeks to integrate watershed management plans with permitting programs; therefore incorporation of TMDL targets at this stage is essential for setting goals for future watershed management plans. Such watershed management plans should be consistent with Stormwater Management Plans developed by counties and implemented by municipalities on a watershed basis, as required by the Pennsylvania Stormwater Management Act (Act 167).

At the Federal level, EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from separate storm sewer systems (MS4s). Due

to the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs, and only using numeric limits in unique instances. Such BMP plans should accompany monitoring plans that test the performance of BMPs and provide a basis for adaptive management techniques. This iterative strategy is consistent with the watershed management approach discussed above, and allows an implementation plan where realistic goals can be set to improve the water quality of the streams through the use of BMPs throughout the watershed. The intention is to implement BMPs as required through the Federal and state policies and regulations described above with the ultimate goal of achieving the WLA to meet interstate instream water quality standards. For more information, see the EPA memorandum titled *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs* (Nov 22, 2002) in Appendix B.

For purposes of this TMDL, WLAs were developed for each municipality holding MS4 permits. Distribution of loads was estimated using land use data within municipal boundaries and application of unit area loadings (lbs/acre/year) determined for subbasins defined in the HSPF model and used for TMDL development. As additional data are collected by PADEP regarding drainage areas of each storm sewer system in the basin, these WLAs can be refined to more detailed representation of WLAs for each stormwater permit and LAs for areas not bound by such permits. To do this, the drainage area of each storm sewer should be delineated so that the area and distributions of land use can be determined. The remaining load in each respective township can then be assigned to LAs. Until such storm water drainage area data are available, the WLAs and required load reductions reported herein are applicable.

6.0 PUBLIC PARTICIPATION

Public participation is not only a requirement of the TMDL process, but is essential to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. Also, EPA must provide a summary of all public comments and responses to those comments to indicate how the comments were considered in the final decision.

Multiple publicly held meetings have been provided throughout all stages of the project to inform and update the public on all aspects of the project as it evolved. The public was encouraged to participate in data collection efforts and provide comments on a report of the data review and proposed TMDL methodology prior to TMDL development.

A first draft of the 2005 *Nutrient and Low Dissolved Oxygen TMDL Under High-Flow Conditions for Christina River Basin, Pennsylvania-Delaware-Maryland* was open for public comment on January 20, 2005, with a notice in the *Philadelphia Inquirer* and the *Wilmington New Journal*. On January 6, 2005, a public meeting was held at the Red Clay Room in Kennett Square. Two additional public meetings were held on February 10, 2005, in Newark, DE, and February 17, 2005, in West Chester, PA.

Following the public comment period, the Christina River Basin watershed and receiving water models used for development of nutrient and low dissolved oxygen TMDLs were revised to address the concerns of stakeholders.

For these revised TMDLs EPA held one informational meeting to present details and answer questions regarding the Christina River TMDLs on February 3, 2006, from 9 to 11 am in the Red Clay Room, 423 Dalmatian Street, Kennett Square, Pa. 19348. Public notice announcements were published in the *Philadelphia Inquirer* and the *Wilmington News Journal* on January 20, 2006.

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Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Basin, Pennsylvania, Delaware, and Maryland

September 2006

U.S. Environmental Protection Agency
Region III
1650 Arch Street
Philadelphia, Pennsylvania

Signed
Jon M. Capacasa, Director
Water Protection Division

9/7/2006
Date

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Executive Summary

Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Watershed Pennsylvania, Delaware, and Maryland

The Clean Water Act requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the state where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint and natural background sources, including a margin of safety (MOS), which may be discharged to a water quality-limited waterbody without violating water quality standards.

This document revises the bacteria TMDLs established by the U.S. Environmental Protection Agency (EPA) on April 8, 2005. Although the sediment TMDLs is not being revised[a], this document supersedes the 2005 document in its entirety.

TMDLs are defined as the summation of the point source wasteload allocations (WLAs) plus the summation of the nonpoint source load allocations (LAs) plus a MOS and are often shown as:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The TMDL is a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards. The TMDL is a scientifically-based strategy that considers current and foreseeable conditions, the best available data, and accounts for uncertainty with the inclusion of a MOS value.

The TMDLs are to achieve and maintain the States' existing water quality standards and must meet the following eight regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDLs are designed to implement the applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual WLAs and (LAs).
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a MOS.
7. There is reasonable assurance that the proposed TMDLs can be met.
8. The TMDLs have been subject to public participation.

As interstate TMDLs, both Pennsylvania and Maryland have the responsibility of meeting downstream Delaware's water quality standards.

[a] Although the sediment TMDLs are not revised, Table 4-7 was corrected.

The Pennsylvania Department of Environment Protection (PADEP) identified waterbodies within Pennsylvania's portion of the Christina River Watershed as impaired by bacteria and sediment, which are addressed in this TMDL Report. The Delaware Department of Natural Resources and Environmental Control (DNREC) identified waterbodies within Delaware's portion of the Christina River Basin as impaired by bacteria. Maryland's Department of the Environment has not identified waterbodies within the Christina River Watershed as impaired.

Both PADEP and DNREC have designated the primary contact recreation (swimming) and protection of aquatic life (fishing) uses for waterbodies in the Christina River Basin. The state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas Delaware uses *enterococcus* bacteria. Maryland uses either *E. coli* or *enterococcus* bacteria. While the states list waterbodies for bacteria impairments, only Pennsylvania and Maryland list waterbodies for sediment, suspended solids, or siltation impairments.

The bacteria TMDL endpoints are identified in Table 1-6 and 1-7. The sediment TMDL endpoint is based on the reference watershed method described in Section 3.2.1.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model Hydrologic Simulation Program Fortran (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the U.S. Geological Survey (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of bacteria and sediment.

The pathogen TMDLs are as follows:

Fecal coliform bacteria average annual TMDL allocations for the Christina River Basin

Subbasin	Baseline Load (cfu*/season)			TMDL Allocation (cfu/season)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Swimming Season (May 1 - Sep 30)									
Red Clay (R01)	1.872E+12	2.914E+15	2.916E+15	8.734E+10	2.139E+14		1.126E+13	2.252E+14	92.28%
Red Clay (R02)	6.037E+12	1.319E+15	1.325E+15	1.274E+12	1.133E+14		6.031E+12	1.206E+14	90.90%
Red Clay (R03)	1.304E+12	1.435E+15	1.437E+15	1.738E+11	1.206E+14		6.359E+12	1.272E+14	91.15%
White Clay (W04)		1.726E+15	1.726E+15		1.040E+14		5.478E+12	1.095E+14	93.66%
White Clay (W07)	7.529E+10	3.140E+13	3.148E+13	7.529E+10	2.885E+12		1.557E+11	3.115E+12	90.10%
Non-swimming Season (Oct 1 - Apr 30)									
Red Clay (R01)	1.872E+12	6.404E+15	6.406E+15	8.734E+11	2.895E+15		1.524E+14	3.049E+15	52.40%
Red Clay (R02)	6.037E+12	3.406E+15	3.412E+15	1.274E+13	1.571E+15		8.338E+13	1.668E+15	51.12%
Red Clay (R03)	1.304E+12	3.704E+15	3.705E+15	1.738E+12	1.720E+15		9.062E+13	1.812E+15	51.08%

Subbasin	Baseline Load (cfu*/season)			TMDL Allocation (cfu/season)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
White Clay (W04)		2.499E+15	2.499E+15		2.370E+15		1.249E+14	2.495E+15	0.16%
White Clay (W07)	1.043E+11	6.899E+13	6.910E+13	7.529E+11	6.475E+13		3.450E+12	6.899E+13	0.15%

*****Colony forming units

Fecal coliform average annual TMDL allocations for MS4 municipalities

Town	Sub-Watershed	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	2.61E+15	2.06E+14	92.09%
Kennett Square Boro	Red Clay	2.35E+14	1.88E+13	91.98%
Kennett TWP	Red Clay	1.44E+15	1.24E+14	91.38%
New Garden TWP	Red Clay	1.12E+15	9.38E+13	91.60%
Avondale Boro	White Clay	3.81E+13	2.42E+12	93.64%
London Grove TWP	White Clay	1.54E+15	9.27E+13	93.99%
New Garden TWP	White Clay	3.00E+13	2.76E+12	90.82%
West Grove Boro	White Clay	8.48E+13	5.09E+12	93.99%
Town	**Sub-Watershed**	**Non-Swimming Season Baseline (cfu /season)**	**Non-Swimming Season TMDL (cfu/season)**	**Percent Reduction**
East Marlborough TWP	Red Clay	5.95E+15	2.85E+15	52.08%
Kennett Square Boro	Red Clay	5.45E+14	2.62E+14	51.95%
Kennett TWP	Red Clay	3.65E+15	1.78E+15	51.26%
New Garden TWP	Red Clay	2.76E+15	1.34E+15	51.52%
Avondale Boro	White Clay	5.83E+13	5.53E+13	5.06%
London Grove TWP	White Clay	2.23E+15	2.12E+15	5.04%
New Garden TWP	White Clay	6.59E+13	6.25E+13	5.15%
West Grove Boro	White Clay	1.23E+14	1.17E+14	5.04%

Average annual state line allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	Allocation (cfu/yr)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Cr. (at PA-DE Line)	3.12E+15	2.01E+14	93.56%
White Clay Cr. (at PA-DE Line)	6.86E+14	2.06E+14	70.03%
Red Clay Cr. (at PA-DE Line)	2.58E+14	1.08E+14	58.05%
Burroughs Run (at PA-DE Line)	1.85E+13	1.30E+13	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	1.86E+13	7.73E+12	58.40%

Neither the Pennsylvania nor the Delaware MS4 permits actually identify the extent of the systems. Therefore, the WLAs are for the whole municipal area and by subbasin. Appendix E contains sample calculations for determining WLAs for storm water permits within an MS4 permitted area. The same procedure should be used when converting the TMDL WLA into WLA and LA values when the actual extent of the MS4 system is known.

The non-MS4 point source permittee's allocations for fecal coliform, *enterococci*, and total suspended solids are not reduced from their permitted levels and are shown in Table 2-2.

Permit DE0020320-001, the City of Wilmington, is not shown in Table 2-2 because it discharges to the Delaware River. However, Wilmington has combined sewers with combined sewer overflows (CSOs) discharging to Brandywine Creek, Christina River, and Little Mill Creek. The CSO allocations are shown in the following table.

Table 4-5. Summary of average annual CSO enterococci baseline loads and WLA TMDL

Location	CSO ID Numbers	Baseline (cfu/yr)	WLA (cfu/yr)	Reduction
Little Mill Creek (C05)	27, 28, 29	1.56E+14	3.69E+13	76.32%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	3.54E+14	9.75E+13	72.47%
Brandywine Creek (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	6.89E+14	2.55E+14	63.07%
Total CSO Loads	-	1.20E+15	3.89E+14	67.57%

All of New Castle County is covered by a MS4 permit and the allocations by subbasin are shown in the following table.

Average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Brandywine Creek in Delaware						
Brandywine Cr. (B18)	1.11E+14	0.00E+00	5.55E+12	2.92E+11	5.85E+12	94.75%
Brandywine Cr. (B19)	5.57E+13	3.45E+10	6.31E+12	3.32E+11	6.68E+12	88.00%
White Clay Creek in Delaware						
White Clay Cr. (W11)	4.07E+13	0.00E+00	9.96E+12	5.24E+11	1.05E+13	74.23%
White Clay Cr. (W12)	1.49E+14	4.15E+10	1.79E+13	9.44E+11	1.89E+13	87.31%
White Clay Cr. (W13)	3.01E+13	0.00E+00	3.91E+12	2.06E+11	4.11E+12	86.34%
White Clay Cr. (W14)	3.82E+13	0.00E+00	3.99E+12	2.10E+11	4.20E+12	89.00%
White Clay Cr. (W15)	2.85E+13	0.00E+00	8.95E+12	4.71E+11	9.42E+12	66.90%
White Clay Cr. (W16)	1.02E+14	0.00E+00	1.32E+13	6.95E+11	1.39E+13	86.41%
White Clay Cr. (W17)	2.41E+14	0.00E+00	3.34E+13	1.76E+12	3.52E+13	85.43%
Red Clay Creek in Delaware						
Red Clay Cr. (R04)	5.89E+13	3.00E+12	8.52E+12	4.48E+11	1.20E+13	79.67%
Red Clay Cr. (R05)	2.25E+13	2.07E+10	7.90E+12	4.16E+11	8.34E+12	63.01%
Red Clay Cr. (R06)	1.51E+13	6.22E+08	1.01E+13	5.34E+11	1.07E+13	29.32%
Red Clay Cr. (R07)	6.05E+12	0.00E+00	1.74E+12	9.16E+10	1.83E+12	69.75%
Red Clay Cr. (R08)	7.61E+13	4.84E+11	7.83E+12	4.12E+11	8.73E+12	88.54%
Red Clay Cr. (R09)	2.88E+13	0.00E+00	2.89E+12	1.52E+11	3.04E+12	89.44%
Christina River and Tidal Brandywine Creek						
Christina River (C01)	3.51E+13	0.00E+00	1.27E+13	6.69E+11	1.34E+13	61. 90%
Christina River (C02)	8.16E+13	0.00E+00	2.47E+13	1.30E+12	2.60E+13	68.15%
Christina River (C03)	6.64E+13	0.00E+00	9.35E+12	4.92E+11	9.84E+12	85.18%
Christina River (C04)	8.69E+13	0.00E+00	6.73E+12	3.54E+11	7.09E+12	91.84%
Christina River (C05) *	2.21E+14	3.69E+13	4.84E+12	2.55E+11	4.20E+13	81.01%

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Christina River (C06)	7.45E+13	0.00E+00	1.65E+13	8.70E+11	1.74E+13	76.66%
Christina River (C07)	7.16E+13	0.00E+00	1.08E+13	5.70E+11	1.14E+13	84.08%
Christina River (C08)	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
Christina River (C09) *	6.84E+14	9.75E+13	3.54E+13	1.87E+12	1.35E+14	80.30%
Tidal Brandywine Cr. (B34) *	8.23E+14	2.55E+14	1.33E+13	6.98E+11	2.68E+14	67.38%
Sunset Lake	6.39E+13	0.00E+00	1.41E+13	7.46E+11	1.49E+13	76.66%
Beck's Pond	6.27E+13	0.00E+00	9.45E+12	4.99E+11	9.98E+12	84.08%
Smalley's Pond	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
* CSO loads are included in the Baseline and WLA in these subbasins.						

For more detailed information, see the appendices.

Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Watershed Pennsylvania, Delaware, and Maryland

I. Introduction

The Clean Water Act (CWA) requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the state where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint and natural background sources, including a margin of safety (MOS), which may be discharged to a water quality-limited waterbody without violating water quality standards.

TMDLs are defined as the summation of the point source wasteload allocations (WLAs) plus the summation of the nonpoint source load allocations (LAs) plus a MOS and are often shown as:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards. The TMDL is a scientifically-based strategy that considers current and foreseeable conditions, the best available data, and accounts for uncertainty with the inclusion of a MOS value.

The TMDLs are to achieve and maintain the states' existing water quality standards and must meet the following eight regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDLs are designed to implement the applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual WLAs and LAs.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a MOS.
7. There is reasonable assurance that the proposed TMDLs can be met.
8. The TMDLs have been subject to public participation.

As interstate TMDLs, both Pennsylvania and Maryland have the responsibility of meeting downstream Delaware's water quality standards.

As a result of water quality and biological investigations conducted by the Pennsylvania Department of Environmental Protection (PADEP), Delaware Department of Natural Resources and Environmental Control (DNREC), and Maryland Department of Environment that identified

observed impacts on aquatic life, many streams in the Christina River Basin have been listed on the states' Section 303(d) lists of impaired waters. Parts of the watershed are heavily impacted by urbanization and are listed as impaired due to problems associated with elevated bacteria levels and sediment (also referred to as siltation). This study will fulfill the requirements for bacteria and sediment TMDL development for waters in the Christina River Basin included in the Section 303(d) lists for Pennsylvania and Delaware. A related study addresses those impairments resulting from nutrients and low dissolved oxygen concentrations.

1.1 Historical Perspective

In 1991, at the request of DNREC and PADEP, the Delaware River Basin Commission (DRBC) agreed to mediate water management issues in the "interstate" Christina River Basin. The issues included interstate and intrastate coordination of monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum pass-by requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware's Exceptional Recreational or Ecological Significance (ERES) objectives. A comprehensive basin approach was needed to address these management issues.

The DRBC facilitated a series of meetings with DNREC, PADEP, EPA, Chester County Water Resources Authority (CCWA), and the United States Geological Survey (USGS). EPA funded a study by Scientific Applications International Corporation for completion of an initial data assessment and problem identification study for the non-tidal portion of Brandywine Creek. The findings of this study, *Preliminary Study of the Brandywine Creek Sub-basin, Final Report, September 30, 1993*, provided a framework for use in a multi-step TMDL study for the entire Christina River Basin. The two States, DRBC and EPA, reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to produce Christina River Basin TMDLs under low-flow conditions. EPA established the Christina River Basin Low-Flow TMDL on January 19, 2001 (later revised on October 8, 2002). See Region III web site at http://www.epa.gov/reg3wapd/tmdl/.

Even as the parties reached agreement on how best to address the impacts of pollutants during low-flow conditions, they recognized that additional efforts would be necessary to address the distinct water quality problems resulting from nonpoint sources of pollutants during high-flow or variable flow conditions. In 1993, EPA recommended that DRBC expand the effort to consider high-flow conditions. As a result, the Christina Basin Water Quality Management Committee (CBWQMC) was created with the purpose of addressing the applicable water quality problems and management policies on a watershed scale. The CBWQMC represents a variety of stakeholders and interested parties including the Brandywine Valley Association/Red Clay Valley Association, Chester County Conservation District, Chester County Health Department (CCHD), Chester County Planning Commission, CCWA, DNREC, Delaware Nature Society, DRBC, New Castle County Conservation District (NCCD), PADEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County.

The CBWQMC developed a unified, multi-phased, five-year Water Quality Management Strategy (WQMS) that (1) addresses the water quality problems through voluntary watershed/water quality planning and management activities and (2), establishes appropriate TMDLs. The reason for separating the development of TMDLs to address water quality

problems between low-flow and high-flow TMDLs is that each scenario has different and distinct pollutants and problems at different flow regimes.

Since 1995, the CBWQMC has been conducting activities set forth in the WQMS designed to implement programs aimed at protecting and improving water quality. These activities include Geographic Information System (GIS) watershed inventory, water quality assessment, watershed pollutant potential and prioritization, stormwater monitoring, best management practices (BMP) Implementation projects and public education/outreach. A summary of these activities can be found in *Phase I and II Report, Christina River Basin Water Quality Management Strategy, May 1998,* and *Phase III Report, Christina Basin Water Quality Management Strategy, August 5, 1999.* These reports describe ongoing efforts to provide pollution control and restore water quality within the Christina River Basin.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters still requiring the development of a TMDL. Maryland has identified biological impairments in the West Branch Christina River. The CWA requires that upstream waters must meet the applicable water quality standard of the downstream state at or before the state line. In other words, both Maryland and Pennsylvania are required to meet Delaware's water quality standard at the Delaware State line.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the CWA, the Endangered Species Act, and the Administrative Procedures Act. The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), effective date April 9, 1997, requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed.

The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA, Civil Action No. 96-591 (SLR) (D.De), effective date August 9, 1997, sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina River Basin. Under the schedule set forth the settlement, Delaware was to establish low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek and White Clay Creek, by December 31, 1999. The Delaware settlement also expected Delaware to establish high-flow TMDLs by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

1.2 Background Information

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of about 564 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware, and Cecil County, Maryland (Figure 1-1). Major streams include the Christina River (tidal and nontidal), Brandywine Creek (tidal and nontidal), Red Clay Creek and White Clay Creek (tidal and nontidal). These streams are designated as habitat for aquatic life, for municipal and industrial water supplies, and for recreational purposes. The Christina River Basin drains to the tidal Delaware River at Wilmington, Delaware.

The Christina River Basin is composed of diverse land uses including urban, rural and agricultural areas. Urban areas in the watershed include greater Wilmington and Newark, Delaware, and the Pennsylvania towns of West Chester, Downingtown, Kennett Square, Coatesville, Parkesburg, Honey Brook, Avondale and West Grove. The land use distribution within the basin is summarized in Table 1-1 and the Brandywine Creek Watershed subbasins are shown in Fingure 1-1 and identified in Table 1-2.

Table 1-1. Christina River Basin land use summary (square miles)

Land Use	DE/MD	Pennsylvania	Total	%
Urban/Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Lands	21	5	26	5
Wooded	37	123	160	28
Water/other	3	3	6	2
Total	166	399	565	100

Source: Phase I/II Report Christina River Basin Water Quality Management Strategy (CBWQMC - May 1998)

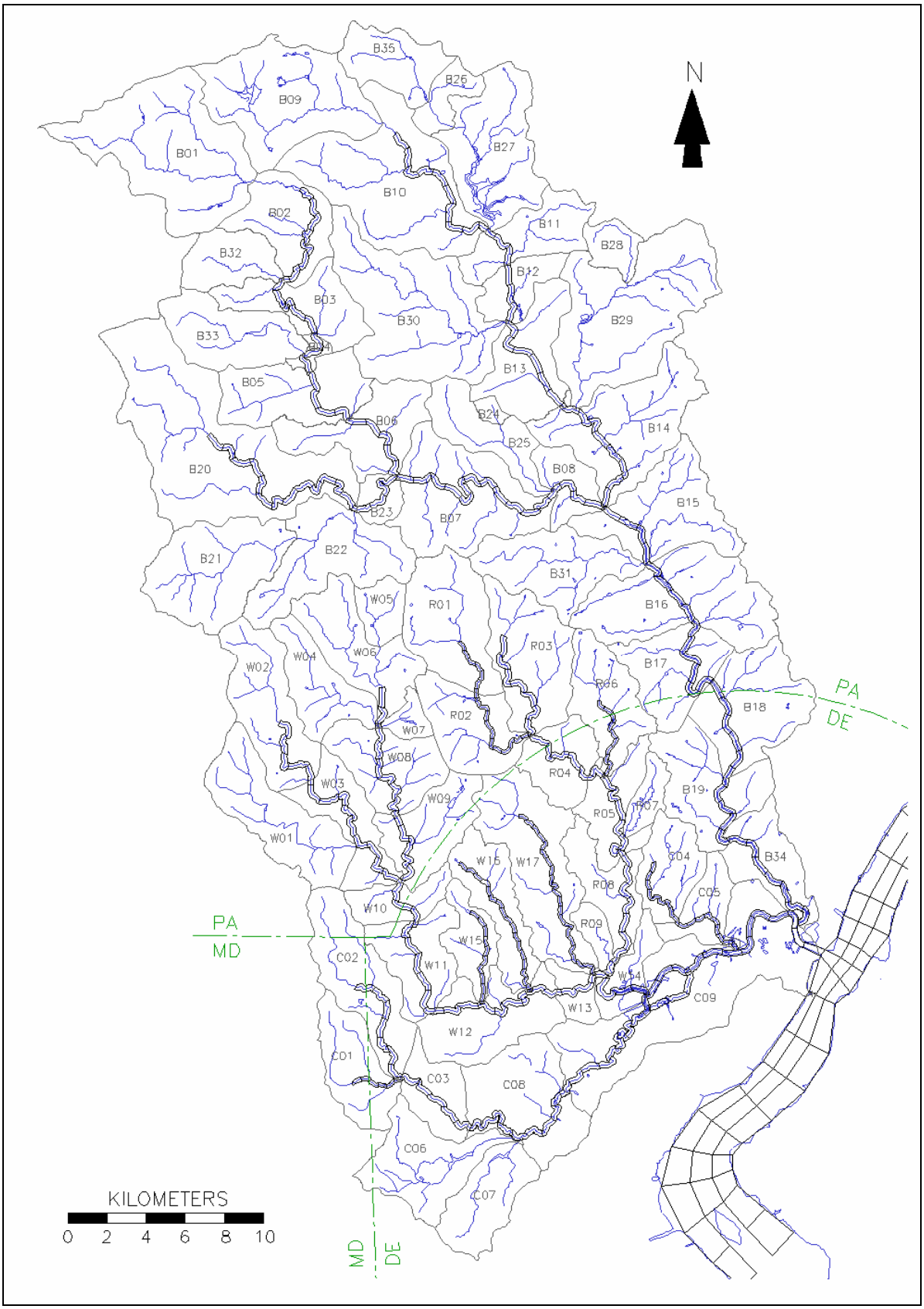

Figure 1-1. Christina River Basin delineation of HSPF model subbasins and EFDC model grid.

Table 1-2. Subbasins in the HSPF models of the Christina River Basin

Subbasin	Stream Name	Area (mi2)
Brandywine Creek Watershed		
B01	Upper Brandywine Creek West Br.	18.39
B02	Brandywine Creek West Branch	7.38
B03	Brandywine Creek West Branch	6.76
B04	Brandywine Creek West Branch	0.80
B05	Brandywine Creek West Branch	8.82
B06	Brandywine Creek West Branch	8.06
B07	Brandywine Creek West Branch	13.46
B08	Brandywine Creek West Branch	3.62
B09	Upper Brandywine Creek East Br.	14.68
B10	Brandywine Creek East Branch	18.31
B11	Brandywine Creek East Branch	6.31
B12	Brandywine Creek East Branch	3.70
B13	Brandywine Creek East Branch	7.94
B14	Brandywine Creek East Branch	12.92
B15	Brandywine Creek	10.36
B16	Brandywine Creek	14.06
B17	Brandywine Creek	7.51
B18	Brandywine Creek	10.37
B19	Brandywine Creek	8.64
B20	Upper Buck Run	25.54
B21	Upper Doe Run	11.05
B22	Lower Doe Run	10.96
B23	Lower Buck Run	1.95
B24	Tributary to Broad Run	0.60
B25	Broad Run	5.83
B26	Marsh Creek	2.61
B27	Marsh Creek	11.54
B28	Tributary to Valley Creek	2.40
B29	Valley Creek	18.21
B30	Beaver Creek	18.08
B31	Pocopson Creek	9.19
B32	Birch Run	4.66
B33	Rock Run	8.03
B34	Brandywine Creek	6.05
B35	Upper Marsh Creek	5.80

Subbasin	Stream Name	Area (mi2)
White Clay Creek Watershed		
W01	White Clay Creek West Br.	10.23
W02	Upper White Clay Creek Middle Br.	9.51
W03	White Clay Creek Middle Br.	6.35
W04	Trib. to White Clay Creek East Br.	6.20
W05	Trib. to White Clay Creek East Br.	2.65
W06	Upper White Clay Creek East Br.	8.57
W07	Trout Run	1.37
W08	White Clay Creek East Branch	7.47
W09	White Clay Creek East Branch	6.85
W10	White Clay Creek	3.58
W11	White Clay Creek	6.53
W12	White Clay Creek	8.76
W13	White Clay Creek	2.08
W14	White Clay Creek	3.41
W15	Muddy Run	3.89
W16	Pike Creek	6.65
W17	Mill Creek	13.00
Red Clay Creek Watershed		
R01	Upper Red Clay Creek West Branch	10.08
R02	Red Clay Creek West Branch	7.39
R03	Red Clay Creek East Branch	9.90
R04	Red Clay Creek	5.11
R05	Red Clay Creek	5.24
R06	Burroughs Run	7.10
R07	Hoopes Reservoir	2.10
R08	Red Clay Creek	5.38
R09	Red Clay Creek	1.72
Christina River Watershed		
C01	Christina River West Branch	6.70
C02	Upper Christina River	9.73
C03	Christine River	4.47
C04	Upper Little Mill Creek	5.37
C05	Little Mill Creek	3.84
C06	Muddy Run	8.64
C07	Belltown Run	6.37
C08	Christina River	10.70
C09	Lower Christina River	21.90

Both PADEP and DNREC identified the impaired stream segments based on historical monitoring data. The two state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator

of bacteria contamination whereas Delaware uses *enterococcus* bacteria. Fecal coliforms are a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are usually released into the environment through human and animal feces. The presence of fecal coliform bacteria pollution may come from storm water runoff, pets, wildlife, and human sewage. If they are present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, they may cause disease, infections, or rashes. *Enterococcus* is a common bacterium normally found in the intestinal tract of warm-blooded animals including humans. The presence of *enterococci* in surface water samples is used as an indicator of the presence of human sewage. *Enterococci* have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to die off in saltwater.

1.3 Impairment Listing

TMDL development for this study is limited to bacteria and sediment impairments. Listings of the water segments in the Christina River Basin impaired by bacteria and sediment are provided in this section.

1.3.1 Bacteria Impairments

There are six subbasins containing stream segments on Pennsylvania's Section 303(d) list for bacteria impairment, and 19 waterbodies listed for bacteria impairment on Delaware's Section 303(d) list (see Table 1-3). There are no streams in the Maryland portion of the basin listed for bacteria impairment.

Table 1-3. Segments impaired by bacteria in Christina River Basin.

Assessment ID	Waterbody Name	Size	Potential Source
Pennsylvania			
Subbasin R01	Mainstem and tributaries W. Br. Red Clay Creek	13.2 mi	NPS
Subbasin R02	Mainstem and tributaries W. Br. Red Clay Creek	18.9 mi	NPS
Subbasin R03	Mainstem and tributaries E. Br. Red Clay Creek	15.9 mi	NPS
Subbasin R04	Mainstem and tributaries Red Clay Creek	2.4 mi	NPS
Subbasin R06	Tributaries Red Clay Creek	8.6 mi	NPS
Subbasin W04	Tributaries E. Br. White Clay Creek	6.0 mi	PS
Delaware			
DE040-001	Lower Brandywine Creek	3.8 mi	PS, NPS
DE040-002	Upper Brandywine Creek	9.3 mi	PS, NPS
DE260-001	Red Clay Creek	12.8 mi	PS, NPS
DE260-002	Burroughs Run	2.6 mi	NPS
DE320-001	White Clay Creek (mainstem)	15.6 mi	PS, NPS
DE320-002	Mill Creek	8.3 mi	NPS
DE320-003	Pike Creek	5.4 mi	NPS
DE320-004	Middle Run	4.5 mi	NPS

Assessment ID	Waterbody Name	Size	Potential Source
DE120-003	Upper Christina River	6.3 mi	NPS
DE120-004-01	Lower Christina Creek	8.4 mi	NPS
DE120-004-02	Belltown Run	3.8 mi	NPS
DE120-004-03	Muddy Run	8.0 mi	NPS
DE120-005-01	West Branch Christina River	5.3 mi	NPS
DE120-006	Upper Christina Creek (mainstem)	8.3 mi	NPS
DE120-007-01	Little Mill Creek and Willow Run	5.1 mi	NPS
DE120-007-02	Chestnut Run	2.8 mi	NPS
DE120-L01	Smalleys Pond	30.0 ac	NPS
DE120-L02	Becks Pond	25.6 ac	NPS
DE120-L03	Sunset Pond	40.0 ac	NPS

1.3.2 Sediment Impairments

There are 14 stream segments on Pennsylvania's 1996 Section 303(d) list for sediment or siltation impairment (see Table 1-3). On Pennsylvania's 1998 Section 303(d) list 61 stream segments are listed for sediment or siltation impairments (see Table 1-4). There are no streams listed for sediment impairment in the Delaware or Maryland portions of the Christina River Basin.

Table 1-4. Pennsylvania streams requiring TMDLs for sediment on 1996 Section 303(d) list

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
5	64954_0.0_1.06	Unt E. Br. Brandywine Cr.	64954	0.0	1.06	970707-1120-GLW	1996
6	00229_24.5_27.3	E. Br. Brandywine Cr.	00229	24.46	27.3	970707-1120-GLW	1996
7	00371_0.0_1.46	Unt E. Br. Brandywine Cr.	00371	0.0	1.46	970707-1120-GLW	1996
8	00372_0.0_0.72	Unt E. Br. Brandywine Cr.	00372	0.0	0.72	970707-1120-GLW	1996
20	00085_10.52_16.4	W. Br. Brandywine Cr.	00085	10.52	16.4	19970925-1348-GLW	1996
Watershed=03I (White Clay Creek and Red Clay Creek)							
65	00465_0.0_7.78	W. Br. White Clay Cr.	00465	0.0	7.78	9408	1996*
SS1	00475_0.0_1.09	Indian Run	00475	0.0	1.09	115	1996
SS2	00462_2.56_14.08	Mid. Br. White Clay Cr.	00462	2.56	14.08	115	1996*
SS3	00462_6.53_8.76	Unt Mid. Br. White Clay Cr.	00462	6.53	8.76	115B	1996*
SS4	00476_0.0_1.56	Unt Mid. Br. White Clay Cr.	00476	0.0	1.56	115	1996
SS5	00477_0.0_1.80	Unt Mid. Br. White Clay Cr.	00477	0.0	1.80	115	1996
SS6	00478_0.0_1.26	Unt Mid. Br. White Clay Cr.	00478	0.0	1.26	115	1996
SS7	00479_0.0_0.63	Unt Mid. Br. White Clay Cr.	00479	0.0	0.63	115	1996
SS8	00480_0.0_0.56	Unt Mid. Br. White Clay Cr.	00480	0.0	0.56	115	1996

* Due to discrepancies between various Pennsylvania Section 303(d) lists, some listing dates may be in error. These marked listings were included on Pennsylvania's 1996 Section 303(d) list and are covered under the above-cited Consent Decree requirements for Pennsylvania.

Table 1-5. Pennsylvania streams requiring TMDLs for sediment (1998 Section 303(d) listings according to Pennsylvania's 2004 Section 303(d) list).

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
1	00185_0.0_3.31	Unt Buck Run	00185	0.0	3.31	19970710-1040-GLW	1998
2	00186_0.0_0.91	Unt Buck Run	00186	0.0	0.91	19970710-1040-GLW	1998
3	00187_0.0_1.04	Unt Buck Run	00187	0.0	1.04	970710-1340-GLW	1998
9	00076_0.0_3.42	Plum Run	00076	0.0	3.42	971023-1320-GLW	1998
10	00077_0.0_0.73	Unt Plum Run	00077	0.0	0.73	971023-1320-GLW	1998
67	00078_0.0_1.35	Unt Plum Run	00078	0.0	1.35	971023-1320-GLW	1998
11	00079_0.0_1.41	Unt Plum Run	00079	0.0	1.41	971023-1320-GLW	1998
12	00080_0.0_0.18	Unt Plum Run	00080	0.0	0.18	971023-1320-GLW	1998
13	00053_0.0_1.16	Pocopson Creek	00053	0.0	1.16	971021-1108-GLW	1998
14	00054_0.0_0.49	Unt Pocopson Creek	00054	0.0	0.49	971021-1108-GLW	1998
15	00071_0.0_2.22	Radley Run	00071	0.0	2.22	971024-1120-GLW	1998
16	00072_0.0_0.94	Unt Radley Run	00072	0.0	0.94	971024-1120-GLW	1998
17	00236_0.0_2.34	Taylor Run	00236	0.0	2.34	971006-1127-GLW	1998
18	00237_0.0_1.08	Unt Taylor Run	00237	0.0	1.08	971006-1127-GLW	1998
19	00238_0.0_0.34	Unt Taylor Run	00238	0.0	0.34	971006-1127-GLW	1998
	00239_0.0_0.97	Unt Taylor Run	00239	0.0	0.97	971006-1127-GLW	1998
21	00085_28.4_31.4	W. Br. Brandywine Cr.	00085	28.4	31.4	970618-1118-GLW	1998
22	00085_31.4_32.9	W. Br. Brandywine Cr.	00085	31.4	32.9	970618-1340-GLW	1998
23	00224_0.0_4.58	Unt W. Br. Brandywine Cr.	00224	0.0	4.58	970619-1222-GLW	1998
24	00224_4.58_7.16	Unt W. Br. Brandywine Cr.	00224	4.58	7.16	970619-1345-GLW	1998
25	00225_0.0_0.92	Unt W. Br. Brandywine Cr.	00225	0.0	0.92	970619-1222-GLW	1998
26	00226_0.0_1.41	Unt W. Br. Brandywine Cr.	00226	0.0	1.41	970619-1345-GLW	1998
27	00227_0.0_1.31	Unt W. Br. Brandywine Cr.	00227	0.0	1.31	970618-1340-GLW	1998
28	00228_0.0_0.78	Unt W. Br. Brandywine Cr.	00228	0.0	0.78	970618-1340-GLW	1998
Watershed=03I (White Clay Creek and Red Clay Creek)							
29	00434_0.24_3.49	Broad Run	00434	0.24	3.49	971029-1445-ACW	1998
30	00436_0.0_0.85	Unt Broad Run	00436	0.0	0.85	971029-1445-ACW	1998
31	00393_0.50_0.97	Bucktoe Creek	00393	0.50	0.97	971218-1300-ACW	1998
32	00394_0.0_1.12	Unt Bucktoe Creek	00394	0.0	1.12	971218-1300-ACW	1998
33	00395_0.0_1.09	Unt Bucktoe Creek	00395	0.0	1.09	971218-1300-ACW	1998
34	00413_0.0_5.29	E. Br. Red Clay Cr.	00413	0.0	5.29	971023-1050-MRB	1998
35	00414_0.03_3.28	Unt E. Br. Red Clay Cr.	00414	0.03	3.28	971204-1400-ACW	1998
36	00418_0.0_0.84	Unt E. Br. Red Clay Cr.	00418	0.0	0.84	971204-1400-ACW	1998
37	00419_0.0_1.24	Unt E. Br. Red Clay Cr.	00419	0.0	1.24	971203-1051-MRB	1998
38	00432_0.0_3.1	E. Br. White Clay Cr.	00432	0.0	3.1	971113-1335-GLW	1998
39	00432_3.1_5.77	E. Br. White Clay Cr.	00432	3.1	5.77	970506-1320-MRB	1998
40	00432_9.47_10.0	E. Br. White Clay Cr.	00432	9.47	10.0	971119-1116-GLW	1998

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
41	00438_0.0_0.62	Unt E. Br. White Clay Cr.	00438	0.0	0.62	970506-1320-MRB	1998
42	00439_0.0_0.67	Unt E. Br. White Clay Cr.	00439	0.0	0.67	970506-1320-MRB	1998
43	00443_0.0_0.71	Unt E. Br. White Clay Cr.	00443	0.0	0.71	970506-1320-MRB	1998
44	00444_0.0_0.71	Unt E. Br. White Clay Cr.	00444	0.0	0.71	970506-1320-MRB	1998
45	00445_0.0_2.44	Unt E. Br. White Clay Cr.	00445	0.0	2.44	970508-1430-ACE	1998
46	00446_0.0_0.5	Unt E. Br. White Clay Cr.	00446	0.0	0.5	970506-1320-MRB	1998
47	00447_0.0_0.77	Unt E. Br. White Clay Cr.	00447	0.0	0.77	970506-1320-MRB	1998
48	00448_2.49_2.85	Unt E. Br. White Clay Cr.	00448	2.49	2.85	970409-1130-MRB	1998
49	00450_0.0_0.25	Unt E. Br. White Clay Cr.	00450	0.0	0.25	970409-1130-MRB	1998
50	00454_0.0_5.4	Unt E. Br. White Clay Cr.	00454	0.0	5.4	971120-1331-GLW	1998
51	00455_0.0_2.52	Unt E. Br. White Clay Cr.	00455	0.0	2.52	971120-1331-GLW	1998
52	00456_0.0_0.22	Unt E. Br. White Clay Cr.	00456	0.0	0.22	971120-1331-GLW	1998
53	00440_0.0_1.52	Egypt Run	00440	0.0	1.52	970508-1245-ACE	1998
54	00441_0.0_1.38	Unt Egypt Run	00441	0.0	1.38	970508-1245-ACE	1998
55	00442_0.0_0.76	Unt Egypt Run	00442	0.0	0.76	970508-1245-ACE	1998
56	63874_0.0_1.7	Trout Run	63874	0.0	1.7	970506-1425-MRB	1998
57	63875_0.0_0.82	Unt Trout Run	63875	0.0	0.82	970506-1425-MRB	1998
58	63876_0.0_0.21	Unt Trout Run	63876	0.0	0.21	970506-1425-MRB	1998
59	00435_0.0_1.39	Walnut Run	00435	0.0	1.39	971209-1445-ACW	1998
60	00391_0.0_4.6	W. Br. Red Clay Cr.	00391	0.0	4.6	971023-1145-MRB	1998
61	00396_0.0_1.8	Unt W. Br. Red Clay Cr.	00396	0.0	1.8	971023-1315-MRB	1998
66	00373_1.85_3.26	White Clay Creek	00373	1.85	3.26	971216-1230-GLW	1998

1.4 Water Quality Standards

1.4.1 Pennsylvania Water Quality Standards

Pennsylvania Code, Title 25, Chapter 93 sets forth water quality standards for surface waters of the Commonwealth. These standards are based upon water uses which are to be protected and will be considered by PADEP in implementing its authority under the Clean Streams Law and other Commonwealth statutes that authorize protection of surface water quality. With regard to bacteria, waters in the Christina River Basin are designated for contact recreation and potable water supply uses. Contact recreation is classified as swimming season (May 1 through September 30) and non-swimming season (October 1 through April 30). The water quality criteria for bacteria are more stringent during the swimming season. Statewide water uses in Pennsylvania include aquatic life, water supply, and recreation. Waters within the Christina River Basin include exceptional value and high quality waters. The applicable numeric water quality criteria for bacteria in the Pennsylvania portion of the Christina River Basin are shown in Table 1-6.

Implementation of the numeric water quality criteria in Pennsylvania are summarized in Table 1-6 and defined in PA Code, Title 25, Chapter 96.3 as follows:

Chapter 96.3(c): "To protect existing and designated surface water uses, the water quality criteria described in Chapter 93 (relating to water quality standards), including the criteria in Chapters 93.7 and 93.8a(b) (relating to specific water quality criteria; and toxic substances) shall be achieved in all surface waters at least 99 percent of the time, unless otherwise specified in this title. The general water quality criteria in Chapter 93.6 (relating to general water quality criteria) shall be achieved in surface waters at all times at design conditions."

Chapter 96.3(d): "As an exception to subsection (c), the water quality criteria for total dissolved solids, nitrite-nitrate nitrogen, phenolics and fluoride established for the protection of potable water supply shall be met at least 99 percnt of the time at the point of all existing or planned surface potable water supply withdrawals unless otherwise specified in this title."

In addition to numeric water quality criteria, waters in the Christina River Basin are also subject to narrative criteria stated in PA Code, Title 25, Chapter 93.6 as follows:

Chapter 93.6(a): "Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life."

Chapter 93.6(b): "In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits."

The TMDL developed for sediment rely on above narrative criteria for their endpoint. Because neither Pennsylvania nor EPA has numeric water quality criteria for sediment, a method was developed to determine water quality objectives that would result in the impaired stream segments attaining their designated uses. The method employed for these TMDLs is termed the "Reference Watershed Approach." The Reference Watershed Approach compares two watersheds, one attaining its uses and one that is impaired based on biological assessments. Both watersheds must have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible. However, most of the variations can be adjusted in the model. The objective of the process is to reduce the loading rate of pollutants in the impaired stream segment to a level equivalent to the loading rate in the non-impaired, reference stream segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

Table 1-6. Pennsylvania water quality standards (PA Code, Title 25, Chapter 93.7)

Pollutant	Designated Use	Criteria		Period
Fecal Coliform Bacteria (cfu/100 mL)	Water Contact Recreation (statewide)	Maximum geometric mean of 200 cfu per 100 mL, based on a minimum of 5 consecutive samples each sample collected on different days during a 30-day period.	No more than 10% of the total samples taken during a 30-day period may exceed 400 cfu per 100 mL	May 1 to Sep 30
		Maximum geometric mean of 2,000 cfu per 100 mL, based on a minimum of 5 consecutive samples each sample collected on different days during a 30-day period		Oct 1 to Apr 30
	Potable Water Supply (statewide)	Maximum of 5,000 cfu per 100 mL as a monthly average value, no more than this number in more than 20 samples collected during a month, nor more than 20,000 cfu per 100 mL in more than 5% of the samples		year round
Total Dissolved Solids TDS (mg/L)	Potable Water Supply (statewide)	maximum = 750	monthly avg. = 500	year round

cfu – colony forming units

1.4.2 Delaware Water Quality Standards

Delaware amended its water quality standards on July 11, 2004. EPA approved the revised standards for *enterococci* bacteria in November 2004. The Christina River and Brandywine Creek are designated as public and industrial water supply, primary and secondary contact recreation, and for fish, aquatic and wildlife. Portions of the Brandywine Creek are also designated as ERES waters.

The Delaware water quality standards contain criteria for bacteria for primary and secondary contact waters as well as shellfish harvesting waters. There are no shellfish harvesting waters in the Christina River Basin. Waters in the Christina River Basin within Delaware are designated for both primary and secondary contact recreation uses as shown in Table 1-6.

Table 1-7. Delaware bacteria water quality standards, *enterococcus* bacteria (cfu/100 mL).

Waterbody Use Designation	Criteria	
	Single-Sample Value	Geometric Mean
Primary contact recreation fresh waters	185	100
Primary contact recreation marine waters	104	35
Secondary contact recreation fresh waters	925	500
Secondary contact recreation marine waters	520	175

Delaware is committed to bacteria source tracking to be able to determine the source of bacteria causing impairments under the supposed assumption that bacteria from wildlife sources does not pay as great a threat to human health as bacteria from human sources does. However, DNREC does not have information from the Christina River and Brandywine Creek Watersheds on which to estimate the wildlife contribution to the bacteria impairment. Therefore, no reductions to monitoring data will be taken.

"Marine waters" are defined as waters of the state that contain natural levels of salinity greater than five parts per thousand (ppt). All waters within the Christina River Basin have natural salinity levels less than five ppt. Therefore, the primary contact fresh-water criteria for *enterococcus* bacteria were used as the target end points for this TMDL.

1.4.3 Maryland Water Quality Standards

All surface waters shall be protected for water contact recreation, fishing, and protection of aquatic life and wildlife. For fresh waters, Maryland uses either *enterococci* or *E. coli* as the bacteria indicator. For waters not designated as beaches, only the steady state geometric mean indicator density for *enterococci* is 33 counts/100 mL and for *E. coli* 126 counts/100 mL is the applicable criterion.

2.0 SOURCE ASSESSMENT

Waters of the Christina River Basin are used for recreation, public water supply, and to support aquatic life. Some of these uses are threatened due to impairment caused by point and nonpoint sources of bacteria and sediment. PADEP and DNREC identified the impaired stream segments based on historical monitoring data and biological integrity field surveys. The two state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas, Delaware uses enterococcus bacteria. While both states list waterbodies for bacteria impairments, only Pennsylvania lists waterbodies for sediment, suspended solids, or siltation impairments.

Fecal coliform is a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are usually released into the environment through human and animal feces. The presence of fecal coliform bacteria pollution may come from storm water runoff, pets, wildlife, and human sewage. If present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, fecal coliform may cause disease, infections, or rashes.

Enterococcus is a common bacterium normally found in the intestinal tract of warm-blooded animals including humans. The presence of enterococci in surface water samples is used as an indicator of the presence of human sewage. Enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to die off in saltwater.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (Hydrolic Systems Program Fortran (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the USGS (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow (CSO) flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of bacteria and sediment.

2.1 Point Sources

The term “point source” refers to any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container including vessels or other floating craft from which pollutants are or may be discharged. The point source also includes concentrated animal feeding operations, places where animals are confined and fed. Storm water runoff from certain areas may also be considered a point source because the water is transported through a pipe or ditch.

Estimating the transport of sediments and pathogens into a surface waterbody from most point sources is a fairly straightforward matter. Wastewater treatment plants (WWTPs), CSOs, and municipal separate storm sewer systems (MS4s) discharge though a constructed conveyance to a waterbody. Many of the pathogen organisms transported to WWTPs are removed during the treatment process, and permit limits are established to ensure that WWTPs meet water quality standards. However, in some instances failures or leaks may occur, or a wet weather event may create flows that exceed the capacity of the WWTP or CSO. This can lead to a discharge of contaminated water exceeding the permitted limits into the river system. MS4s discharge to waterbodies without being treated by a WWTP.

2.1.1 Wastewater Treatment Plants

Treated industrial and municipal sewage can be a point source of sediment and bacterial contamination. Not all human pathogens or sediment are removed or rendered harmless by treatment processes. Periodic effluent overflows and high-flow bypass in WWTPs can cause occasional high loading of pathogens. Raw sewage entering the WWTP typically has a total coliform count ranging from 10^7 to 10^9 cfu/100 mL (Novotny et al., 1989). Associated with raw sewage are proportionally high concentrations of pathogenic bacteria, viruses and protozoans. A typical wastewater treatment plant reduces the total coliform count by about three orders of magnitude. The magnitude of reduction, however, varies with the treatment process.

Treatment of municipal waste is generally identified as primary, secondary or advanced (also called tertiary) treatment, although the distinctions are somewhat arbitrary. Primary treatment involves removing suspended solids with screens and the use of gravity settling ponds followed by disinfection. Most protozoan cysts settle out in ponds after 11 days due to their size (EPA, 2001). Secondary treatment uses biological treatment to decompose organic matter to cell material and by-products, and the subsequent removal of cell matter, usually by gravity settling. Activated sludge processes involve the production of an activated mass of microorganisms capable of stabilizing waste aerobically. Secondary treatment by activated sludge typically reduces bacteria concentrations by 90 to 99 percent.

Tertiary treatment is any practice beyond secondary treatment and is very effective in destroying most pathogens. Tertiary treatment can include disinfection, filtration, and coagulation. Disinfection is the most common treatment technique to combat waterborne diseases, and the most frequently used disinfectant is chlorine (EPA, 2001). Chlorine kills many microbes, including most pathogens, except protozoan cysts, which are resistant to chlorine. Other disinfectants used are ozone, ultraviolet light, and iodine.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The locations of NPDES facilities in the Christina River Basin are shown in Figure 2-1 and listed in Table 2-1. The fecal coliform bacteria, enterococci bacteria, and total suspended solids loads for each of the NPDES facilities, based on permit flow rate, are provided in Table 2-2. Note that fecal coliform bacteria were not simulated for the Delaware or Maryland NPDES facilities.

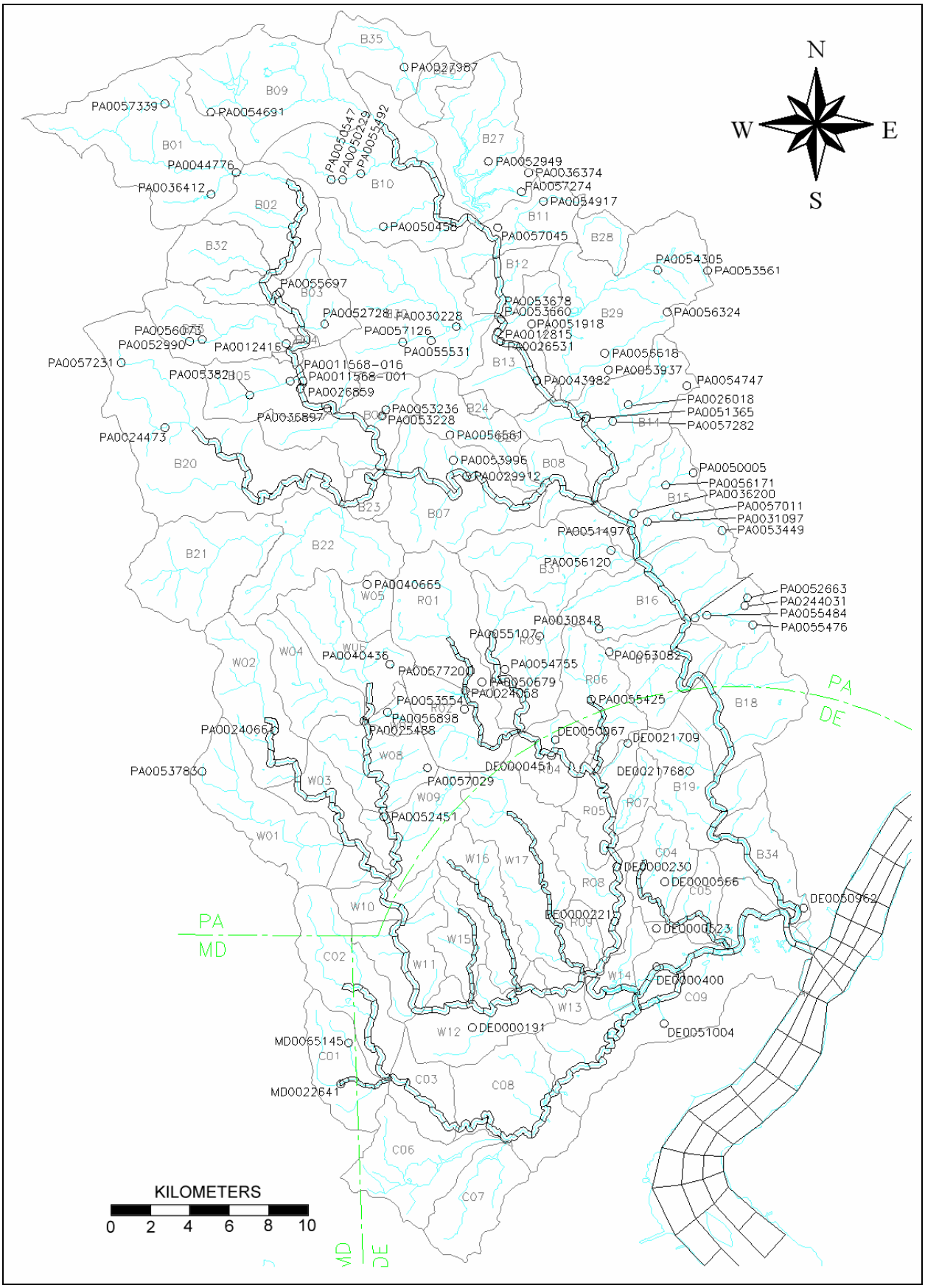

Figure 2-1. NPDES discharges in Christina River Basin

Table 2-1. NPDES point source discharges in Christina River Basin

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek (main stem)								
76.610	54,15	DE0050962	0.0000	SWR	AMTRAK	TB-Brandywine Creek	Industrial	Stormwater
83.554	54,27	DE0021768	0.0250	STP	Winterthur Museum	Clenney Run	Municipal	Small STP
88.644	54,37	PA0053082	0.0206	STP	Mendenhall Inn	TB Brandywine Creek	Commercial	Small STP
89.917	54,38	PA0052663	0.0900	STP	Knight's Bridge Co/Villages at Painters	Harvey Run	Commercial	Small STP
89.917	54,38	PA0055476	0.0400	STP	Birmingham TSA/Ridings at Chadds Ford	TB Harvey Creek	Municipal	Small STP
89.917	54,38	PA0055484	0.0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0244031	0.1500	STP	Chadds Ford Township	Harvey Run		
90.553	54,39	PA0030848	0.0063	STP	Unionville - Chadds Ford Elem. School	Ring Run	Municipal	Small STP
93.098	54,42	PA0056120	0.0005	SRD	Schindler	Pocopson Creek	Municipal	Single Residence STP
92.462	54,43	PA0031097	0.0170	STP	Radley Run C.C.	Radley Run	Municipal	Small STP
92.462	54,43	PA0053449	0.1500	STP	Birmingham Twp. STP	Radley Run	Municipal	Small STP
93.735	54,43	PA0057011	0.0773	STP	Thornbury Twp./Bridlewood Farms STP	Radley Run		
92.462	54,44	PA0036200	0.0320	STP	Radley Run Mews	Plum Run	Municipal	Small STP
94.371	54,44	PA0056171	0.0005	SRD	McGlaughlin Jeffrey	Plum Run	Municipal	Single Residence STP
94.371	54,44	PAG050005	0.1400	GWC	Sun Company	TB Brandywine Creek	GWCleanup	New permit 03/27/98
94.371	54,44	PA0051497	0.0300	NCW	Lenape Forge	Brandywine Creek	Industrial	Cooling Water
Brandywine Creek East Branch								
98.647	54,52	PA0026018	1.8000	MUN	West Chester Borough MUA/Taylor Run	Taylor Run	Municipal	Large STP
98.647	54,52	PA0057282	0.0005	SRD	Jonathan & Susan Pope	TB Valley Creek	Municipal	Single Residence STP
99.276	54,53	PA0051365	0.3690	WFP	PA American Water	EB Brandywine Creek	Municipal	Ingram's Mill-Filter Backwash
100.535	54,55	PA0053937	0.0005	SRD	William and Patricia Kratz	Broad Run Creek	Municipal	Single Residence STP
100.535	54,55	PA0056324	0.0440	GWC	Mobil SS#16-GPB	TB-WB Valley Run	Commercial	DP
100.535	54,55	PA0056618	0.0005	SRD	O'Cornwell David & Jeanette	Broad Run	Municipal	Single Residence STP
100.535	54,55	PA0054305	0.0000	IND	Sun Co, Inc. (R&M)	TB Valley Creek	Industrial	
100.535	54,55	PA0053561	0.0360	GWC	Johnson Matthey	Valley Creek	GWCleanup	Permitted 03/12/96
101.794	54,57	PA0043982	0.4000	ATP2	Broad Run Sew Co.	EB Brandywine Creek	Municipal	Large STP
103.682	54,61	PA0012815	1.0280	IND	Sonoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103.682	54,60	PA0026531	7.5000	ATP2	Downingtown Area Regional Authority	EB Brandywine Creek	Municipal	Large STP
104.312	54,61	PA0051918	0.1440	NCW	Pepperidge Farms	Parke Run Creek	Industrial	Cooling Water
103.682	54,61	PA0055531	0.0007	STP	Khalife Paul	TB Valley Run	Commercial	Small STP
104.312	54,61	PA0057126	0.0000	IND	Hess Oil - SS #38291	Valley Run	Commercial	DP
104.312	54,61	PA0030228	0.0225	STP	Downingtown I&A School	Beaver Creek	Municipal	No flow since Feb 1994
104.312	54,61	PA0053678	0.0000	IND	Lambert Earl R.	EB Brandywine Creek	Industrial	DP
104.312	54,61	PA0053660	0.0000	IND	Mobil Oil Company #016	EB Brandywine Creek	Commercial	Air stripper at Service Sta
106.830	54,65	PA0054917	0.4750	STP	Uwchlan Twp. Municipal Authority	Shamona Creek	Municipal	Eagleview CC STP
107.459	54,66	PA0057045	0.0000	SWR	Shyrock Brothers, Inc.	EB Brandywine Creek	Commercial	Stormwater
108.088	54,67	PA0027987	0.0500	STP	Pennsylvania Tpk./Caruiel Service Plaza	Marsh Creek	Commercial	Small STP
108.088	54,67	PA0036374	0.0150	STP	Eaglepoint Dev. Assoc.	TB Marsh Creek	Municipal	Small STP
108.088	54,67	PA0052949	0.0000	IND	Phila. Suburban Water Co.	Marsh Creek	Industrial	Uwchlan DP
108.088	54,67	PA0057274	0.0005	SRD	Michael & Antionette Hughes	TB Marsh Creek	Municipal	Single Residence STP
109.977	54,70	PA0050458	0.0531	STP	Little Washington Drainage Co.	Culbertson Run	Municipal	Small STP
112.495	54,74	PA0057827	0.0005	SRD	McKenna	Indian Run	Municipal	Single Residence STP
112.495	54,74	PA0050547	0.0375	STP	Indian Run Village MHP	Indian Run	Municipal	Small STP
112.495	54,74	PA0055492	0.0005	SRD	Andrew and Gail Woods	Indian Run	Municipal	Single Residence STP
113.753	54,76	PA0054691	0.0005	SRD	Stoltzfus Ben Z.	TB Brandywine Creek	Municipal	Single Residence STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek West Branch								
97.976	46,79	PA0056561	0.0000	SWR	Richard M. Armstrong Co.	Broad Run	Commercial Stormwater	
101.708	40,79	PA0029912	0.1000	STP	Embreeville Hospital	WB Brandywine Creek	Municipal	Large STP
102.330	39,79	PA0053996	0.0005	SRD	Redmond Michael	TB-WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053228	0.0005	SRD	Gramm Jeffery	WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053236	0.0005	SRD	Woodward Raymond Sr. STP	WB Brandywine Creek	Municipal	Single Residence STP
110.416	24,79	PA0036897	0.3900	ATP1	South Coatesville Borough	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0026859	3.8500	ATP1	Coatesville City Authority	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0011568-001	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0011568-016	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0053821	0.0000	SWR	Chester County Aviation Inc.	Sucker Run	Commercial Stormwater	
112.282	20,79	PA0012416	0.1400	WFP	PA American Water	Rock Run	Industrial Water Filtration Plant-Backwash	
112.282	20,79	PA0052990	0.0005	SRD	Mitchell Rodney	Rock Run	Municipal	Single Residence STP
112.282	20,79	PA0056073	0.0005	SRD	Vreeland Russell Dr.	TB Rock Run	Municipal	Single Residence STP
113.526	18,79	PA0052728	0.0004	STP	Farmland Industries Inc./Turkey Hill	WB Brandywine Creek	Industrial	Small STP
114.770	16,79	PA0055697	0.0490	STP	Spring Run Estates	WB Brandywine Creek	Commercial	Small STP
120.368	06,79	PA0036412	0.0550	STP	Tel Hai Retirement Community	TB-WB Brandywine Creek	Municipal	Small STP
120.368	06,79	PA0044776	0.6000	STP	NW Chester Co. Municipal Authority	WB Brandywine Creek	Municipal	Large STP
120.368	06,79	PA0057339	0.0005	SRD	Brian & Cheryl Davidson	TB-WB Brandywine Creek	Municipal	Single Residence STP
Buck Run								
117.041	33,61	PA0024473	0.7000	STP	Parkersburg Borough Authority WWTP	TB-Buck Run	Municipal	Small STP-discontinued 06/10/97
117.041	33,61	PA0057231	0.0005	SRD	Archie & Cloria Shearer	TB-Buck Run	Municipal	Single Residence STP
Christina River (tidal)								
82.274	45,13	DE0000400-001	0.0000	NCW	Ciba-Geigy Corp.	Christina River	Industrial	Cooling Water
83.561	43,09	DE0051004	0.0000	SWR	Boeing	Nonesuch Creek	Industrial	Stormwater
Christina River West Branch								
99.587	16,09	MD0065145	0.0500	STP	Highlands WWTP	WB Christina River	Municipal	Small STP
100.209	14,09	MD0022641	0.4500	STP	Meadowview Utilities, Inc.	WB Christina River	Municipal	Small STP
Red Clay Creek								
89.828	43,26	DE0000221-001	0.0060	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
89.828	43,26	DE0000221-003	0.0040	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
91.746	43,29	DE0000230-001	0.3500	NCW	Hercules Inc.	Red Clay Creek	Industrial	Cooling Water
95.583	43,35	DE0021709-001	0.0150	STP	Greenville Country Club	TB-Red Clay Creek	Municipal	Small STP
96.861	43,37	PA0055425	0.0005	SRD	D'Ambro Anthony Jr.-Lot #22	TB-EB Red Clay Creek	Municipal	Single Residence STP
98.780	43,40	DE0050067	0.0015	STP	Center for Creative Arts	TB-Red Clay Creek	Municipal	Small STP
98.780	43,40	DE0000451-002	2.1700	NCW	NVF Yorklyn	Red Clay Creek	Industrial	Stormwater/Cooling Water
101.337	43,44	PA0055107	0.1500	STP	East Marlborough Township STP	TB-EB Red Clay Creek	Municipal	Large STP
Red Clay Creek West Branch								
103.313	32,43	PA0053554	0.0000	SWR	Earthgro Inc.	WB Red Clay Creek	Industrial	Stormwater
103.950	30,43	PA0024058	1.1000	STP	Kennett Square Boro. WWTP	WB Red Clay Creek	Municipal	Large STP
104.268	29,43	PA0050679	0.2500	NCW	National Vulcanized Fiber (NVF)	TB-WB Red Clay Creek	Industrial	Cooling Water
104.579	28,43	PA0057720-001	0.0720	STP	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Process Water
104.579	28,43	PA0057720-002	0.0900	NCW	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Cooling Water
White Clay Creek								
93.090	32,18	DE0000191-001	0.0300	NCW	FMC Corp.	Cool Run	Industrial	Stormwater/Cooling Water
102.824	15,18	PA0053783	0.0200	STP	Avon Grove School Dist	TB-WB White Clay Creek	Commercial	Small STP
108.696	06,18	PA0024066	0.2500	STP	West Grove Borough Authority STP	MB White Clay Creek	Municipal	Large STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
White Clay Creek East Branch								
102.750	19,24	PA0052451	0.0012	STP	Frances L. Hamilton Oates STP	EB White Clay Creek	Municipal	Small STP
104.020	19,26	PA0057029	0.1440	GWC	Hewlett Packard Co.	Egypt Run	GWCleanup	Groundwater Cleanup
106.560	19,30	PA0025488	0.3000	ATP2	Avondale Borough Sewer Authority	Indian Run	Municipal	Large STP
106.560	19,30	PA0056898	0.0650	IND	To-Jo Mushrooms Inc.	Trout Run	Industrial	Small STP-online Jan 98
107.830	19,32	PA0040436	0.0090	STP	Chadds Ford Investment Co./Red Fox GC	TB-EB White Clay Creek	Municipal	Small STP
107.830	19,32	PA0040665	0.0100	STP	Stone Barn Restuarantand Apt. Cplx	EB White Clay Creek	Commercial	Small STP
Little Mill Creek								
82.441	41,55	DE0000523-001	0.0000	SWR	General Motors Assembly	Little Mill Creek	Industrial	Stormwater
83.373	38,55	DE0000566	0.0000	SWR	DuPont Chestnut Run	Little Mill Creek	Industrial	Stormwater/Cooling Water
Delaware River								
63.839	57,04	DE0021555-001	0.5500	MUN	Delaware City STP	Delaware River	Municipal	
65.272	57,05	DE0000256-601	13.0000	IND	Star Enterprises	Delaware River	Industrial	
65.272	57,05	DE0000612-001	0.8000	IND	Formosa Plastics Corp.	Delaware River	Industrial	
65.272	57,05	DE0020001-001	0.6800	MUN	Standard Chlorine	Delaware River	Municipal	
65.272	57,05	DE0050911-001	0.3000	MUN	Occidental Chemical Corp.	Delaware River	Municipal	
75.237	57,15	DE0020320-001	90.0000	MUN	City of Wilmington	Delaware River	Municipal	
77.162	57,17	DE0000051-001	5.2000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-002	3.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-003	6.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
81.307	57,20	DE0000655-001	33.3000	IND	General Chemical Corporation	Delaware River	Industrial	
83.907	57,22	PA0012637-002	52.3500	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-101	69.8000	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-201	3.3400	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
85.199	57,23	PA0027103-001	44.0000	MUN	Delcora	Delaware River	Municipal	
82.639	58,21	NJ0005045-001	0.5000	IND	Monsanto	Delaware River	Industrial	SEE NOTE 2
63.839	59,04	NJ0024856-001	1.4450	MUN	City of Salem	Delaware River	Municipal	SEE NOTE 1
69.534	59,09	NJ0021598-001	2.4650	MUN	Pennsville Sewage Authority	Delaware River	Municipal	SEE NOTE 1
73.339	59,12	NJ0005100-661	22.9000	IND	Dupont-Chambers Works	Delaware River	Industrial	SEE NOTE 1
75.237	59,15	NJ0021601-001	1.7290	MUN	Carneys Pt. Sewage Authority	Delaware River	Municipal	SEE NOTE 1
76.045	59,16	NJ0024023-001	0.9500	MUN	Penns Grove Sewage Authority	Delaware River	Municipal	SEE NOTE 1
77.162	59,17	NJ0024635-001	0.0366	MUN	Fort Dix/Pedricktown Facility	Delaware River	Municipal	SEE NOTE 1
79.919	59,19	NJ0004286-001	2.1000	IND	Geon	Delaware River	Industrial	
82.639	59,21	NJ0027545-001	0.9860	MUN	Logan Township MUA	Delaware River	Municipal	SEE NOTE 1

NOTES:

[1] No flow limit available in PCS data base; flow limit shown is maximum reported flow during 01/01/95 to 12/31/98

[2] No flow limit or reported flow available in PCS data base; flow limit shown is an estimate

Table 2-2. Fecal coliform, *enterococci*, and TSS loads for NPDES facilities

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
Brandywine Creek main stem								
DE0021768	B19	0.0250	15		100	1.42		9.464E+07
PA0053082	B17	0.0206	10	200	100	0.78	1.560E+08	7.798E+07
PA0052663	B16	0.0900	10	200	100	3.41	6.814E+08	3.407E+08
PA0055476	B16	0.0400	10	200	100	1.51	3.028E+08	1.514E+08
PA0244031	B16	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0055484	B16	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0030848	B16	0.0063	30	200	100	0.72	4.770E+07	2.385E+07
PA0056120	B31	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0031097	B15	0.0170	20	200	100	1.29	1.287E+08	6.435E+07
PA0053449	B15	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0057011	B15	0.0773	30	200	100	8.78	5.852E+08	2.926E+08
PA0036200	B15	0.0320	30	200	100	3.63	2.423E+08	1.211E+08
PAG0050005	B15	0.1400	10	2	2	5.30	1.060E+07	1.060E+07
PA0051497	B15	0.0300	10	2	2	1.14	2.271E+06	2.271E+06
PA0056171	B15	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek East Branch								
PA0026018	B14	1.5000	30	200	100	170.34	1.136E+10	5.678E+09
PA0057282	B14	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0051365	B14	0.3690	20	2	2	27.94	2.794E+07	2.794E+07
PA0053937	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0056324	B29	0.0440	10	2	2	1.67	3.331E+06	3.331E+06
PA0056618	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053561	B29	0.0360	10	2	2	1.36	2.725E+06	2.725E+06
PA0043982	B13	0.4000	30	200	100	45.42	3.028E+09	1.514E+09
PA0012815	B13	1.0280	50	200	100	194.57	7.783E+09	3.891E+09
PA0026531	B13	7.5000	30	200	100	810.15	5.687E+10	2.839E+10
PA0030228	B30	0.0225	20	200	100	1.70	1.703E+08	8.517E+07
PA0051918	B13	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0055531	B30	0.0007	30	200	100	0.08	5.300E+06	2.650E+06
PA0054917	B11	0.4750	20	200	100	35.96	3.596E+09	1.798E+09
PA0036374	B27	0.0150	30	200	100	1.70	1.136E+08	5.678E+07
PA0057274	B27	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050458	B10	0.0351	20	200	100	2.66	2.657E+08	1.329E+08
PA0057827	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050547	B10	0.0375	20	200	100	2.84	2.839E+08	1.420E+08
PA0055492	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052949	B10	0.0030	20	2	2	0.23	2.271E+05	2.271E+05
PA0027987	B10	0.0050	20	200	100	0.38	3.785E+07	1.893E+07
PA0054691	B09	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek West Branch								
PA0029912	B07	0.1000	30	200	100	11.36	7.571E+08	3.785E+08
PA0053996	B07	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053228	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053236	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0036897	B05	0.3900	30	200	100	44.29	2.953E+09	1.476E+09
PA0026859	B05	3.8500	30	200	100	437.22	2.915E+10	1.457E+10
PA0011568-001	B05	0.6400	30	200	100	72.68	4.845E+09	2.423E+09
PA0011568-016	B05	0.5045	30	200	100	57.29	3.819E+09	1.910E+09
PA0056073	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
PA0012416	B33	0.1400	20	2	2	10.60	1.060E+07	1.060E+07
PA0052990	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052728	B03	0.0004	30	200	100	0.05	3.028E+06	1.514E+06
PA0055697	B03	0.0490	30	200	100	5.56	3.710E+08	1.855E+08
PA0036412	B01	0.0550	28	200	100	5.83	4.164E+08	2.082E+08
PA0044776	B01	0.6000	30	200	100	68.14	4.542E+09	2.271E+09
PA0057339	B01	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0057231	B20	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Christina River								
MD0022641	C01	0.7000	30		100	79.49		2.650E+09
MD0065145	C01	0.0500	30		100	5.68		1.893E+08
DE0020230	C09	0.3500	7		2	9.27		2.650E+07
Red Clay Creek								
DE0021709	R05	0.0150	15		100	0.85		5.678E+07
PA0055425	R06	0.0005	20	200		0.04	3.785E+06	0.000E+00
DE0050067	R04	0.0015	30		100	0.17		5.678E+06
DE0000451	R04	2.1700	20		2	164.29		1.643E+08
PA0055107	R03	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0053554	R02	0.0000	100	200	100	0.00	0.000E+00	0.000E+00
PA0024058	R02	1.1000	30	200	100	124.92	8.328E+09	4.164E+09
PA0050679	R01	0.2500	10	2	2	9.46	1.893E+07	1.893E+07
PA0057720-001	R01	0.0720	30	200	100	8.18	5.451E+08	2.725E+08
PA0057720-002	R01	0.0900	10	2	2	3.41	6.814E+06	6.814E+06
White Clay Creek								
DE0000191	W12	0.0300	10		2	1.14		2.271E+06
PA0053783	W01	0.0200	10	200	100	0.76	1.514E+08	7.571E+07
PA0024066	W02	0.2500	30	200	100	28.39	1.893E+09	9.464E+08
PA0052451	W09	0.0012	30	200	100	0.14	9.085E+06	4.542E+06
PA0057029	W08	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0025488	W06	0.3000	30	200	100	34.07	2.271E+09	1.136E+09
PA0056898	W07	0.0650	30	200	100	7.38	4.921E+08	2.461E+08
PA0040436	W06	0.0090	20	200	100	0.68	6.814E+07	3.407E+07
PA0040665	W05	0.0100	20	200	100	0.76	7.571E+07	3.785E+07

2.1.2 Combined Sewer Overflows

Combined sewer systems (CSSs) are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, CSSs transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a waterbody. However, during periods of heavy rainfall or snowmelt (wet weather) the combined storm water and wastewater volume can exceed the capacity of the sewer system or treatment plant. For this reason, CSSs are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other waterbodies. These overflows, referred to as combined sewer overflows (CSOs), contains storm water and untreated human and industrial waste, toxic materials, and debris. CSOs typically discharge for short periods of time at random intervals due to their association with wet weather events.

There are 38 CSO outfalls in the vicinity of the city of Wilmington. Bacteria loads from these CSOs were determined using the flow rates calculated by the XP-SWMM model and event mean concentrations measured during two storm events in 2003.

2.1.3 Storm Water Phase II Communities

Storm water runoff can contribute bacteria and other pollutants to a waterbody. Material can collect on streets, rooftops, parking lots, sidewalks, yards and parks and then during a precipitation event this material can be flushed into gutters, drains and culverts and be discharged into a waterbody.

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the CWA requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4s). Large MS4s serve populations over 250,000 and medium MS4s serve populations between 100,000 and 250,000. These discharges are referred to as Phase I MS4 discharges. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s, including all systems within urbanized areas and other systems serving populations less than 100,000 as well as storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This expansion is referred to as Phase II of the MS4 program.

Storm water discharges that are regulated under Phase I and Phase II of the NPDES MS4 program are point sources that must be included in the WLA portion of a TMDL. Storm water discharges not currently subject to Phase I or Phase II of the MS4 program are not required to obtain NPDES permits. Therefore, for regulatory purposes, are analogous to nonpoint sources and are included in the LA portion of a TMDL.

An EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors, dated November 22, 2002, (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the WLA component of the TMDL and may not be addressed by the LA component of TMDL.

- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls.

- Industrial storm water permits need to reflect technology-based and water quality-based requirements.

Most of the townships and boroughs within the Christina River Basin in Chester County and all of New Castle County are covered by the Phase II MS4 program regulations. The delineation of the storm water collection system contributing areas within each municipality has not been completed at the present time. Therefore, it is not possible to assign a WLA specific to the storm sewer collection areas within each MS4 municipality. Instead, the TMDL will be presented as a WLA for the entire land area of the township, borough, or county. In the future, when the storm sewer collection systems have been delineated, it is anticipated that the State's storm water program will revise the WLA into the appropriate WLA and LA as part of the storm water permit reissuance. Note that the overall reductions in the TMDL will not change.

Runoff from urban areas may carry significant loads of bacteria and sediment and increased storm runoff flows may cause streambed and bank erosion. To assess the relative loads of bacteria and sediment from different land uses within municipal boundaries, it was important to have an inventory of municipal land use data as a proportion of the HSPF subbasins in which the municipality resides. Since the 1995 land use data available for assessing the municipalities is different than the land use categories used by the USGS to develop their HSPF models of Christina River Basin, an aggregated land use was developed for this purpose as shown in Table 2-3. A list of MS4 municipalities in the study area is provided in Table 2-4 and their locations are shown in Figure 2-2.

Table 2-3. Aggregated land use categories used for MS4 assessments

Aggregated Land Use for MS4 Assessments	HSPF Land Use	1995 Land Use
Residential	Residential-septic Residential-sewer	Single family Multi-family
Agricultural	Agricultural-cows Agricultural-crops Agricultural-mushroom	Agriculture
Open Land	Open land	Public/private open space
Forest	Forest	Wooded
Water	Wetlands, water	Water
Urban	Commercial/industry Undesignated use Roads, building-residential Roads, building-urban	Vacant Transportation/utility Unknown Institutional Industrial Commercial Mining

Table 2-4. Municipalities with MS4 permits in the Christina River Basin

Permit Number	**Municipality Name**	**HSPF Model Subbasins**
PAG130079	Avondale Borough	W04, W06, W07, W08
PAG130047	Birmingham Township	B15, B16
PAG130053	Caln Township	B03, B30, B12
PAG130142	Chadds Ford Township	B16, B17, B18
PAG130066	City of Coatesville	B05
PAG130140	Downingtown Borough	B12, B13, B30
PAI130523	East Bradford Township	B08, B14, B15, B29
PAI130524	East Brandywine Township	B10, B11, B12, B30
PAI130536	East Caln Township	B13, B29
PAI130512	East Fallowfield Township	B05, B06, B20, B23
PAG130123	East Marlborough Township	B07, B22, B31, R01, R03
PAG130058	Franklin Township Chester County	W01, W03, W08, C02
PAI130535	Honey Brook Township	B01, B02, B09
PAG130037	Kennett Square Borough	R01, R03
PAG130146	Kennett Township	B16, B17, R01, R02, R03,R04, R06, W17
PAG130062	London Britain Township	W03, W09, W10, W11, C02

Permit Number	Municipality Name	HSPF Model Subbasins
PAI130503	London Grove Township	W02, W03, W04, W05, W06,W08
PAI130516	New Garden Township	W06, W07, W08, W09, R01, R02
PAI130526	New London Township	W01, W02
PAI130539	Penn Township	W01, W02
PAG130134	Pennsbury Township	B16, B17, B31, R06
PAG130113	Pocopson Township	B07, B08, B15, B31
PAG130101	Sadsbury Township	B20
PAG130163	South Coatesville Borough	B05, B06
PAG130067	Thornbury Township	B15, B16
PAI130527	Upper Uwchlan Township	B10, B11, B27
PAI130505	Uwchlan Township	B11, B12, B27, B29
PAG130150	Valley Township	B03, B04, B05, B33
PAI130529	Wallace Township	B09, B10, B26, B27, B35
PAI130511	West Bradford Township	B06, B07, B08, B13, B14, B24, B25, B30
PAG130100, PAI130544	West Brandywine Township	B02, B03, B10, B30
PAG130145	West Caln Township	B01, B02, B03, B20, B32, B33
PAG130002	West Chester Borough	B14, B15
PAG130144	West Grove Borough	W02, W04
PAI130530	West Whiteland Township	B28, B29
DE0051071	City of Wilmington, DE	B34, C05
DE0051071	Elsmere, DE	C04, C05
DE0051071	Newport, DE	C09
DE0051071	City of Newark, DE	W11, W12, C01, C02, C03
DE0051071	New Castle County, DE	B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, C09

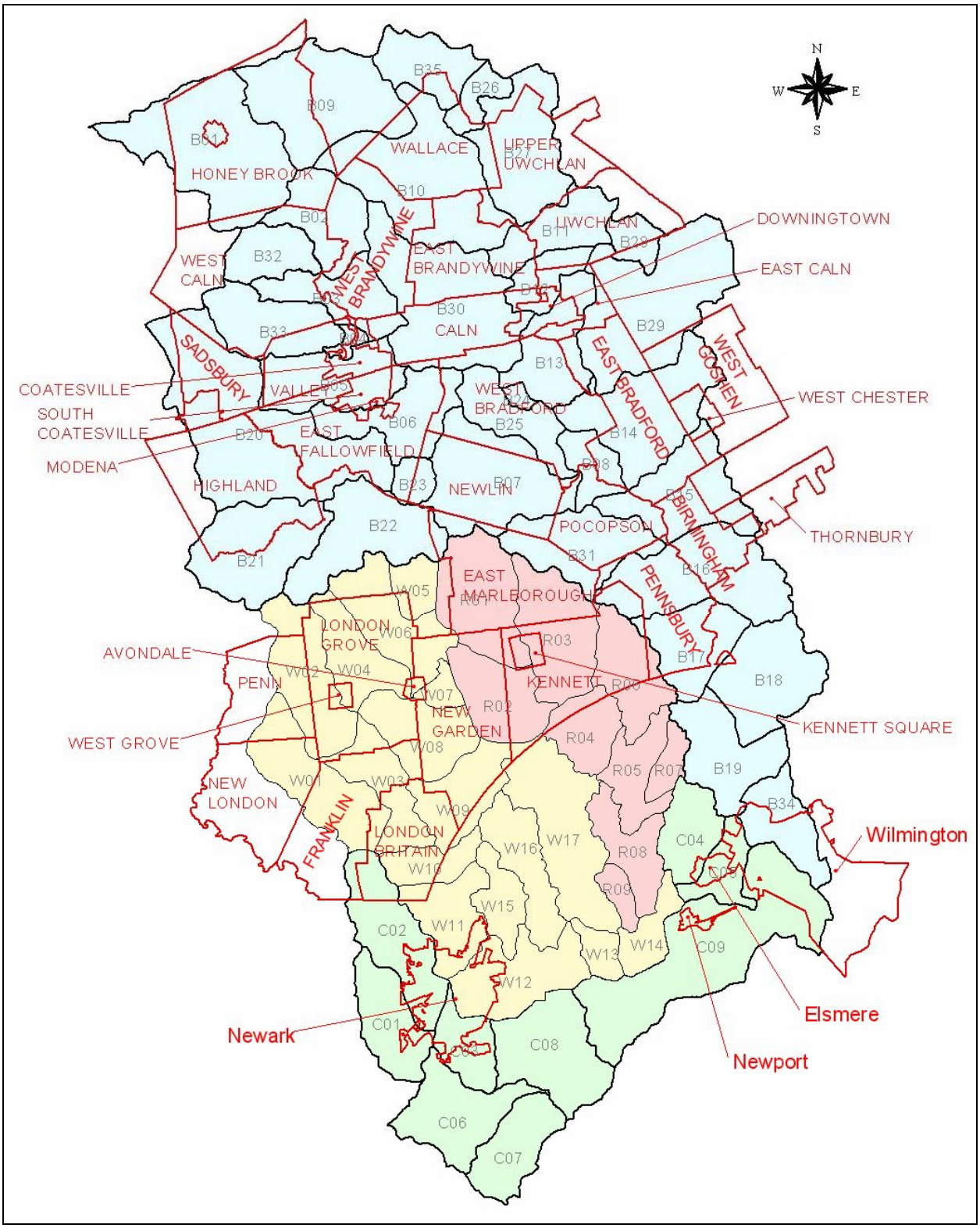

Figure 2-2. Municipalities with MS4 permits in Christina River Basin

2.2 Nonpoint Sources

Nonpoint sources of sediment and bacteria are generally much more difficult to identify and quantify than are point sources. In residential and urban areas, nonpoint sources can include leaking or faulty septic systems, landfill seepage, pet waste, storm water runoff (outside of Phase II communities) and other sources. In more rural areas, major contributors can be pasture runoff, manure storage and spreading, concentrated animal feedlots, and wildlife.

2.2.1 Septic Systems

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations that contribute to septic system failure include seasonal high water table levels, compact glacial till, bedrock, and coarse sand and gravel outwash. When septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters down gradient (Horsely and Witten, 1996).

Site-specific information on the locations or numbers of septic systems in Chester County was not available. A GIS database maintained by DNREC contained information on the number of septic systems in the New Castle County portion of the Christina River Basin for the years 1997 and 2004. This inventory was interpolated and extrapolated to estimate the number of septic systems in 1990, 1995, and 2005 (see Table 2-3). Estimates of the bacteria loads from septic systems will be based on the assumptions outlined below:

- Number of septic systems (based on US Census 1990 and 2000 and DNREC GIS database)
- Estimated population served by the septic systems (an average of 2.8 people per septic system, US Census 1990)
- An average daily discharge of 70 gallons/person/day (Horsley and Witten, 1996)
- Septic effluent fecal coliform concentration of 1.0E+07 cfu/100mL bacteria concentration (Powelson and Mills, 2001) from malfunctioning septic systems
- Septic effluent enterococcus concentration of 8.0E+05 cfu/100mL from malfunctioning septic systems
- Septic effluent concentrations of 200 cfu/100mL (fecal coliform) and 100 cfu/100mL (*enterococci*) from properly functioning septic systems

The number of septic tanks in Chester County was estimated from US Census data (obtained online from http://factfinder.census.gov/). Examination of the number of housing units in rural areas in the two counties reported in the 1990 U.S. Census revealed that approximately each rural housing unit has a septic system (see Table 2-5). Since no septic system information was available from the 2000 US Census data, estimates were made based on information from the Chester County Health Department (CCHD, 2005). In Chester County, approximately 1,500 permits for septic systems are issued every year of which about 600 of are for repair work and 1,100 are for new permits. The total number of septic systems in Chester County in 2005 was estimated as about 69,000 based on the number in 1990 plus 1,100 new systems per year. Since about 80 percent of the septic systems in Chester County are within the Christina River Basin, there were about 55,200 septic systems in the Chester County portion of the basin in 2005.

Table 2-5. Census data related to septic system estimation

Category	New Castle County	Chester County
1990 Census: Number of rural housing units in County	10,335	50,396
1990 Census: Number septic systems in County	12,142	52,493
1990 Census: Rural population in County	29,468	146,612
1990 Estimated number septic systems in Christina River Basin	10,500	42,000
1995 Estimated number septic systems in Christina River Basin	7,041	46,400
1997 DNREC Inventory of septic systems in Christina River Basin	5,455	-
2004 DNREC Inventory of septic systems in Christina River Basin	1,713	-
2005 Estimated number septic systems in Christina River Basin	1,650	55,200
2005 Estimated number of malfunctioning septic systems	17	552
2005 Estimated potential bacteria load (cfu/year)	3.6E+11	1.5E+14

The potential annual bacteria load from malfunctioning as well as properly functioning septic systems was estimated using the data in Table 2-5. According to CCHD (2005), 600 permits are issued for repair work, which is approximately one percent of the total number of septic systems in Chester County. Therefore, it was assumed that at any given time one percent of the septic systems were malfunctioning. The same failure rate was applied to New Castle County.

2.2.2 Agriculture Activities

Land used for agricultural purposes can be a significant source of sediment and bacteria. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all potential agricultural sources. Animals grazing in pasturelands deposit manure directly upon the land surface. Even though a pasture may be relatively large, and animal densities low, manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of contaminated runoff during a storm event. The occurrence and degree of bacteria loads from livestock are linked to temporally and spatially variable hydrologic factors, such as precipitation and runoff, except when manure is directly deposited into a waterbody (EPA, 2001).

The application of manure that has been improperly composted can contribute bacteria that are conveyed into surface waters during runoff events. The bacterial content of animal waste varies with collection, storage, and application method. Therefore, animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to minimize waterbody impacts. Grazing animals, confined animal operations and manure application are all potential sources of nutrients and bacteria in the Christina River Basin. The inventories of livestock in Chester County and New Castle County from the last three agricultural census periods are shown in Table 2-6.

The monthly-varying fecal coliform bacteria accumulation rates used in the watershed-loading model categorized by land use in Chester County are provided in Table 2-7. The enterococci bacteria accumulation rates broken down by land use for enterococci bacteria for Chester County and New Castle County are given in Tables 2-8 and 2-9, respectively.

Table 2-6. Livestock inventories from 1992, 1997, and 2002 USDA Agriculture Census

Category	**Chester County, PA**			**New Castle County, DE**		
	1992	1997	2002	1992	1997	2002
Cattle and calves	50,795	48,897	41,878	3,446	2,628	2,665
Hogs and pigs	11,855	2,357	12,860	630	51	86
Poultry (layers, broilers, turkeys)	734,087	599,360	696,361	209,195	220,308	NA
Horses and ponies	4,330	5,293	8,597	770	737	833
Sheep and lambs	3,421	2,154	2,856	238	222	366

NA = not available

Table 2-7. Fecal coliform bacteria accumulation rates (cfu/acre/day) for Chester County

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	5.1E+09	5.1E+09	2.0E+10	2.0E+10	2.0E+10	2.0E+10
AGRICULTURAL-CROPS	6.1E+09	6.1E+09	9.5E+09	1.0E+10	1.0E+10	1.0E+10
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	2.0E+10	2.0E+10	2.0E+10	2.0E+10	1.0E+10	5.1E+09
AGRICULTURAL-CROPS	1.0E+10	1.0E+10	1.0E+10	1.0E+10	9.3E+09	6.1E+09
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07

Table 2-8. *Enterococci* **accumulation rates (cfu/acre/day) for Chester County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	8.90E+07	8.90E+07	2.50E+08	3.30E+08	3.10E+08	2.90E+08
AGRICULTURAL-CROPS	3.00E+07	3.00E+07	9.00E+07	2.40E+08	2.20E+08	1.20E+08
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+06	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+07	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	2.80E+08	2.80E+08	3.30E+08	2.70E+08	1.90E+08	8.90E+07
AGRICULTURAL-CROPS	1.20E+08	1.20E+08	1.40E+08	4.90E+08	4.60E+08	3.00E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

Table 2-9. *Enterococci* **accumulation rates (cfu/acre/day) for New Castle County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	6.10E+08	6.10E+08	2.00E+09	2.00E+09	2.00E+09	2.00E+09
AGRICULTURAL-CROPS	1.20E+07	1.20E+07	2.50E+07	1.30E+08	1.30E+08	3.30E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05

Land Use	JUL	AUG	SEP	OCT	NOV	DEC
AGRICULTURAL-COWS	2.00E+09	2.00E+09	2.00E+09	2.00E+09	1.00E+09	6.10E+08
AGRICULTURAL-CROPS	3.20E+07	3.20E+07	3.60E+07	4.00E+08	4.00E+08	1.20E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

2.2.3 Wildlife

Wildlife also generates bacteria on the land surfaces and in streams. Wild animals are also assumed to be the only source of bacteria on forested land. A precise estimate of the number of wild animals in the Christina River Basin is not available. Literature and empirical values are used in this study, as shown in Table 2-10, to estimate wild animal population densities for different land use categories. Monthly adjustment factors were used to account for seasonal variations in wild animal populations.

Table 2-10. Estimated wildlife density for associated land uses in Christina River Basin

Wild Animals	Agricutlure-Rowcrop (Animals/sq mile)	Agricutlure-Livestock (Animals/sq mile)	Forest Animals/sq mile)
Ducks	30	30	10
Geese	50	50	0
Deer	0	35	35
Beaver	5	5	10
Raccoons	2.5	2.5	5
Other	320	160	160

2.2.4 Domestic Pets

Domestic pets are potential sources of bacteria in a similar way as wildlife. Cats and dogs can contribute fecal material within the watershed that may find its way into surface waters. This source is more likely in more populated areas where large numbers of pets tend to be found.

A 1999 national study American Pet Products Manufactures Association (APPMA, 1999) reported that 39.1 percent of households own at least one dog and 32.1 percent own at least one cat. The average number of dogs per dog-owning household is 1.41, and the average number for cats is 2.40 per cat-owning household. There are an estimated 149,812 households in the Christina River Basin (US Census Bureau, 2000). Based on the APPMA national study, approximately 58,576 households own dogs and 48,090 households own cats. Using these values results in an estimate of 82,593 dogs and 115,415 cats within the Christina River Basin. The bacteria load from these animals was estimated in the HSPF watershed model runoff from urban and residential areas.

3.0 TMDL ENDPOINT DETERMINATION

To meet the designated uses in the Christina River Basin, water quality targets, or endpoints, must be achieved under the variable flow conditions. The selection of these endpoints considers the water quality standards prescribed by those designated uses (Section 1.3), but where no numeric criteria were found in the standards, interpretations of the narrative standard or site-specific endpoints were applied.

3.1 Bacteria TMDL Endpoints

In Pennsylvania, the TMDL target endpoints for bacteria are the fecal coliform bacteria water quality standards presented in Table 1-6. These targets represent numbers where the applicable water quality is achieved and maintained to protect designated uses. In these TMDLs, the targets were selected to maintain recreational contact uses during both the swimming and non-swimming seasons. During the swimming season, from May 1 through September 30, the 30-day geometric mean fecal coliform bacteria levels must be less than the target value of 200 cfu/100mL and not more than 10 percent of fecal bacteria concentrations within a 30-day period can exceed 400 cfu/100mL. During the non-swimming season (October 1 through April 30), the 30-day geometric mean target level is 2,000 cfu/100mL.

In Delaware, the TMDL target endpoint for bacteria is the *enterococcus* bacteria geometric mean water quality standard presented in Table 1-7. The target were selected to protect the primary contact recreation designated use in freshwaters in Delaware. The TMDL target endpoint for *enterococcus* bacteria is the geometric mean concentration of 100 cfu/100mL. The proposed *enterococcus* bacteria TMDLs in Delaware used both the geometric mean and the single sample maximum. However, based on the Environmental Protection Agency's 2004 explanation[1] of the appropriate (see below) use of the single sample maximum criterion, these established *enterococcus* bacteria TMDLs in Delaware are based on the geometric mean criterion only. It should be noted that the TMDL, WLA, and LA values remain unchanged from the proposed values.

In promulgating the 2004 final rule, *Water quality Standards for Coastal and Great Lakes Recreational Waters* rule, the preamble to the final rule discusses comments received regarding the implementation of the single sample maximum criterion and the intent of EPA's *Ambient Water Quality Criteria for Bacteria –1986*[2]. The 1986 bacteria criteria document did not discuss using the single sample maximum as a never-to-be-surpassed value for all applications under the CWA. The geometric mean is the more relevant value for describing the risk of contact recreation uses and the single sample maximum criterion is best used for making beach notification and closure decisions based on limited data. In the future, DNREC intends to limit the use of the single sample maximum to beach closures or to where decisions must be made with limited data. Because the daily simulations from October 1, 1994, through

[1] 69 *FR* 67218-67243
[2] EPA 440/5-84-002, January 1986

October 1, 1998, provide adequate data for use of the geometric mean as the indicator of attainment of water quality standards, the single sample maximum criterion is not used for these TMDLs.

3.2 Sediment TMDL Endpoints

Pennsylvania's narrative standard, Chapter 93.6(a), must be interpreted with respect to sediment. PADEP uses a reference watershed approach to develop TMDL endpoints for the allowable sediment loading rates in the impaired watersheds.

3.2.1 Reference Watershed Approach

The reference watershed approach was used to estimate the necessary sediment load reduction required to restore a healthy aquatic community and allow the streams in the impaired watershed to achieve their designated uses. In the reference watershed approach, two watersheds are used, one attaining its uses and the other being impaired. Both watersheds must have similar land cover and land use characteristics. Other features such as base geologic formation, soils, percent slope, and geographic eco-region should be matched to the extent possible. The objective of this process is to reduce the loading rate of sediment in the impaired watershed to a level equivalent to or slightly lower than the loading rate in the unimpaired reference watershed. Achieving the sediment loadings recommended in the TMDLs will ensure protection of the designated aquatic life of the impaired watershed.

3.2.2 Considerations for Reference Watershed Selection

Two factors form the basis for selecting a suitable reference watershed. First, the watershed must have been assessed by PADEP and determined to be attaining water quality standards and meeting designated uses. Second, the watershed should closely resemble the impaired watershed in physical properties such as land cover, land use, physiographic province, size and geology. The 35 subbasins used in the modeling were screened for an unimpaired subbasin.

There are four steps in matching a reference watershed to an impaired watershed (see Figure 3-1). The first step is to locate watersheds that have been recently assessed and are not impaired. Step 2 is to identify a pool of unimpaired watersheds similar in size and geology to the impaired watersheds. Step 3 involves comparing the land cover data of the watersheds and selecting unimpaired watersheds that had land cover characteristics similar to those of the impaired watersheds. Land use distributions were compared on a percentage basis as calculated from HSPF land use input data. It is important to have a good match between the sizes of the reference and impaired watersheds so that reasonable comparisons could be made. As a result, the Step 4 is to resize the reference watersheds to produce a load that reasonably matches the impaired watersheds.

Once the reference watersheds were selected, their existing sediment loads were estimated based on the HSPF watershed model simulation. The estimated existing reference watershed sediment loads were then considered as the target endpoints the impaired watersheds.

3.2.3 Selected Reference Watershed and Endpoints

The TMDL endpoints established for this study were determined using the reference watersheds listed in Table 3-2 and shown in Figure 3-2. The methodology used for identification of candidate reference watersheds and final selection of reference watersheds for the TMDL target is outlined in Appendix K of the model report (USEPA, 2005). The listed segments in the Brandywine Creek watershed were grouped as either a predominately residential/urban watershed or a rural/agricultural watershed based on the land use characteristics of their associated HSPF model subbasin (see Table 3-1). The TMDL sediment endpoints (as unit area loads) for each of the reference watersheds are presented in Table 3-2. The TMDL process uses these loading rates in the non-impaired watersheds as targets for loading reductions in the impaired watersheds.

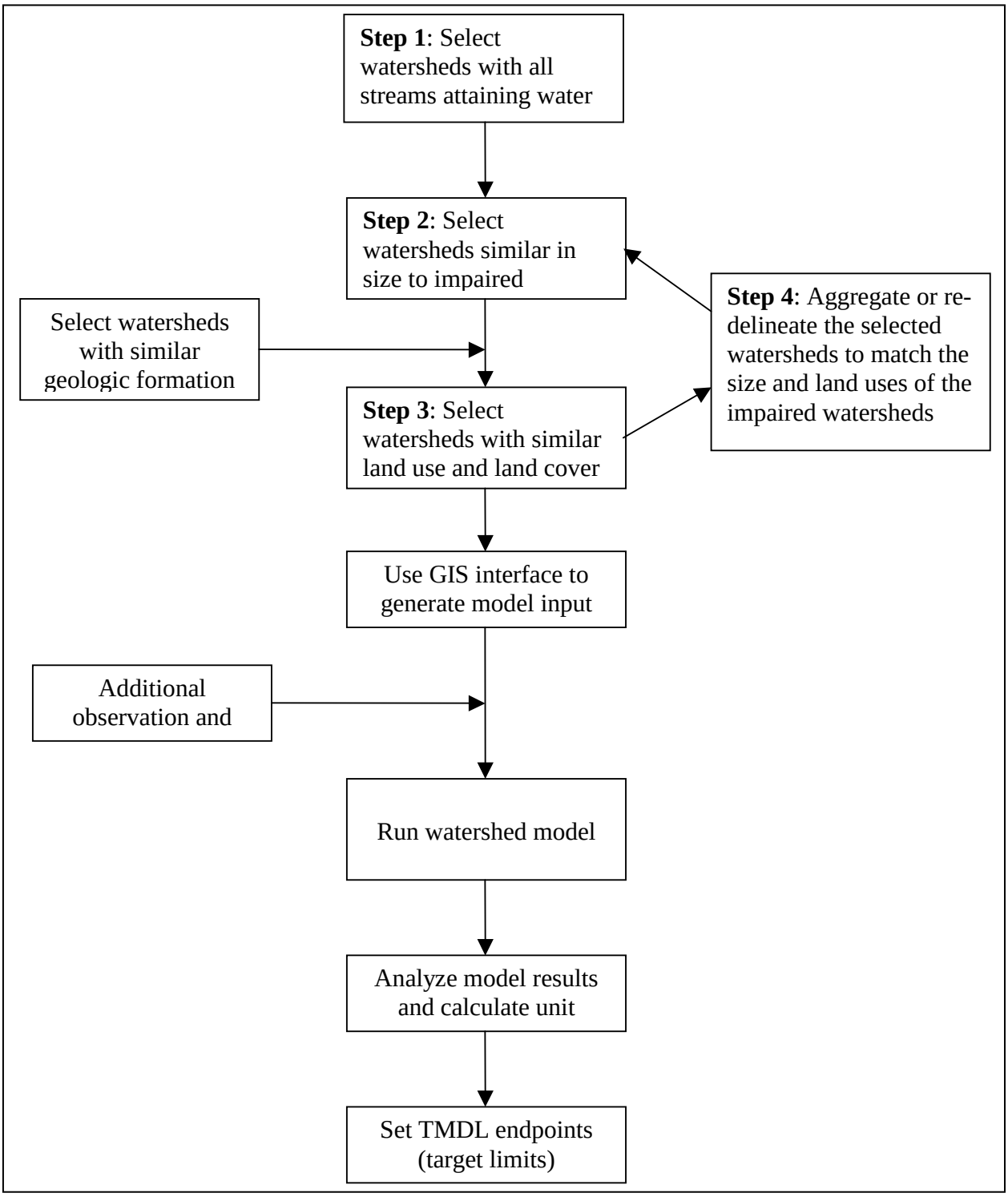

Figure 3-1. Reference watershed approach for derivation of TMDL target limits

Table 3-1. Land use characteristics of impaired subbasins and reference watersheds

HSPF Subbasin	Area (sq.mi.)	Land uses (percent)			Predominate Watershed Type
		Residential-Urban	Agriculture-Rural	Forested-Wetland	
Subbasins impaired by siltation in Brandywine Creek watershed:					
B01	18.39	7.9	68.1	20.6	Rural
B05	8.82	38.6	19.1	36.3	Residential-Urban
B06	8.06	22.7	39.6	35.9	Residential-Urban
B09	14.68	8.3	54.0	35.4	Rural
B14	12.92	32.3	31.9	31.2	Residential-Urban
B15	10.36	33.6	40.7	17.8	Residential-Urban
B20	25.54	13.3	58.8	25.9	Rural
B31	9.19	26.8	48.8	22.4	Residential-Urban
Subbasins impaired by siltation in White Clay Creek watershed:					
W01	10.23	19.4	51.8	26.2	Rural
W02	9.51	16.7	63.4	17.9	Rural
W03	6.35	18.3	44.7	36.4	Rural
W04	6.20	14.1	57.5	24.0	Rural
W06	8.57	5.4	67.5	22.0	Rural
W07	1.37	16.8	62.0	19.0	Rural
W08	7.47	14.6	50.4	32.9	Rural
W09	6.85	31.1	32.7	33.3	Residential-Urban
Subbasins impaired by siltation in Red Clay Creek watershed:					
R01	10.08	18.2	58.6	18.8	Rural
R02	7.39	15.2	58.4	25.4	Rural
R03	9.90	21.4	47.3	23.1	Residential-Urban
Reference Watersheds:					
B25	5.83	26.8	40.7	30.5	Brandywine Cr. – Urban
B32	4.66	14.2	31.6	53.0	Brandywine Cr. – Rural
R04	5.11	44.7	17.8	29.2	Red Clay Creek
W10	3.58	18.8	27.1	53.7	White Clay Creek

Table 3-2. Sediment endpoints for Christina River Basin TMDL

Reference Watershed ID	Watershed Name	Unit Area Sediment Load (tons/acre/year)
B25	Broad Run (Brandywine Creek)	0.089
B32	Birch Run (Brandywine Creek)	0.045
R04	Red Clay Creek	0.635
W10	White Clay Creek	1.043

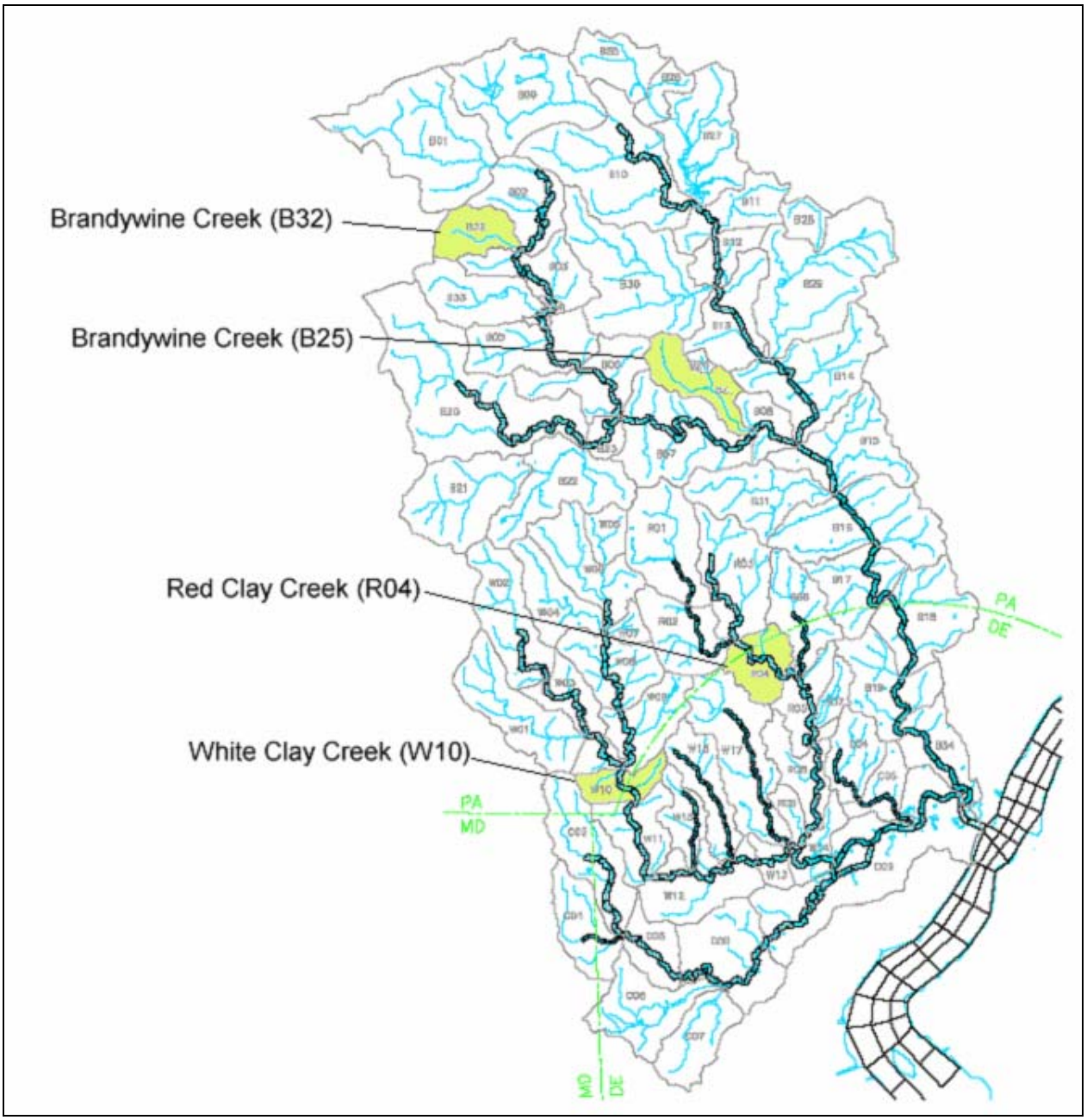

Figure 3-2. Locations of reference watersheds in Christina River Basin

4.0 TMDL METHODOLOGY AND CALCULATION

4.1 Bacteria TMDLs

The following sections discuss the methods used for developing the April 2005 TMDLs and the 2006 CSO allocations. TMDLs, allocated loads, and percent reductions were developed for the stream segments listed on Pennsylvania's and Delaware's Section 303(d) lists of impaired waters for bacteria shown in Figure 4-1.

4.1.1 Methodology

The HSPF watershed models were used to calculate the baseline and allocation loads for fecal coliform bacteria for the TMDLs for the Pennsylvania listed waters. The models were calibrated over a four-year period (October 1, 1994 through October 1, 1998) to include both low and high streamflow. Following calibration, the same four-year period was used for the baseline and TMDL allocation simulations. For the baseline condition, all NPDES point sources were set to their permitted flow and bacteria levels (see Table 2-2). Estimates of septic system loads and bacteria accumulation and storage on different land uses in the watersheds were also incorporated into the models. A series of model runs were made in which the bacteria loads from failed septic systems and land sources were reduced until insteam water quality standards were met. A detailed description of the background, configuration, and calibration of the modeling system is provided in the modeling report (EPA, 2005).

Three models were used to determine *enterococcus* bacteria TMDLs for the Delaware listed waters: the HSPF watershed loading model, the XP-SWMM[1] CSO discharge model, and the EFDC[2] receiving water model. All three models were run for the October 1, 1994, through October 1, 1998, period and the baseline and allocation loads were determined. Since Pennsylvania and Maryland have the responsibility to meet the Delaware water quality standards at the state line, the HSPF models were used to calculate *enterococcus* bacteria loads at the Pennsylvania-Delaware state line for Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run in the Red Clay Creek Watershed. A Maryland allocation was used to calculate *enterococcus* bacteria loads at the Maryland/Delaware state line for the Christina River.

The XP-SWMM model was used to calculate *enterococcus* loads from the CSO discharge points in the City of Wilmington. The daily time-series loads from the HSPF model and from the XP-SWMM model were then input to the EFDC[3] receiving water model to calculate *enterococcus* concentrations in the tidal waters of the Christina River, Brandywine Creek, and Little Mill Creek. More detailed descriptions of the calibration and application of these models are provided in the modeling report (EPA, 2005).

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[1] The City of Wilmington provided the CSO discharges based on their XP-SWMM model runs.
[2] In reviewing the April 2005 TMDLs, it was discovered that Little Mill watershed was inadvertently left out the EDFC model.
[3] EDFC was used because HSPF is not applicable to tidal waters.

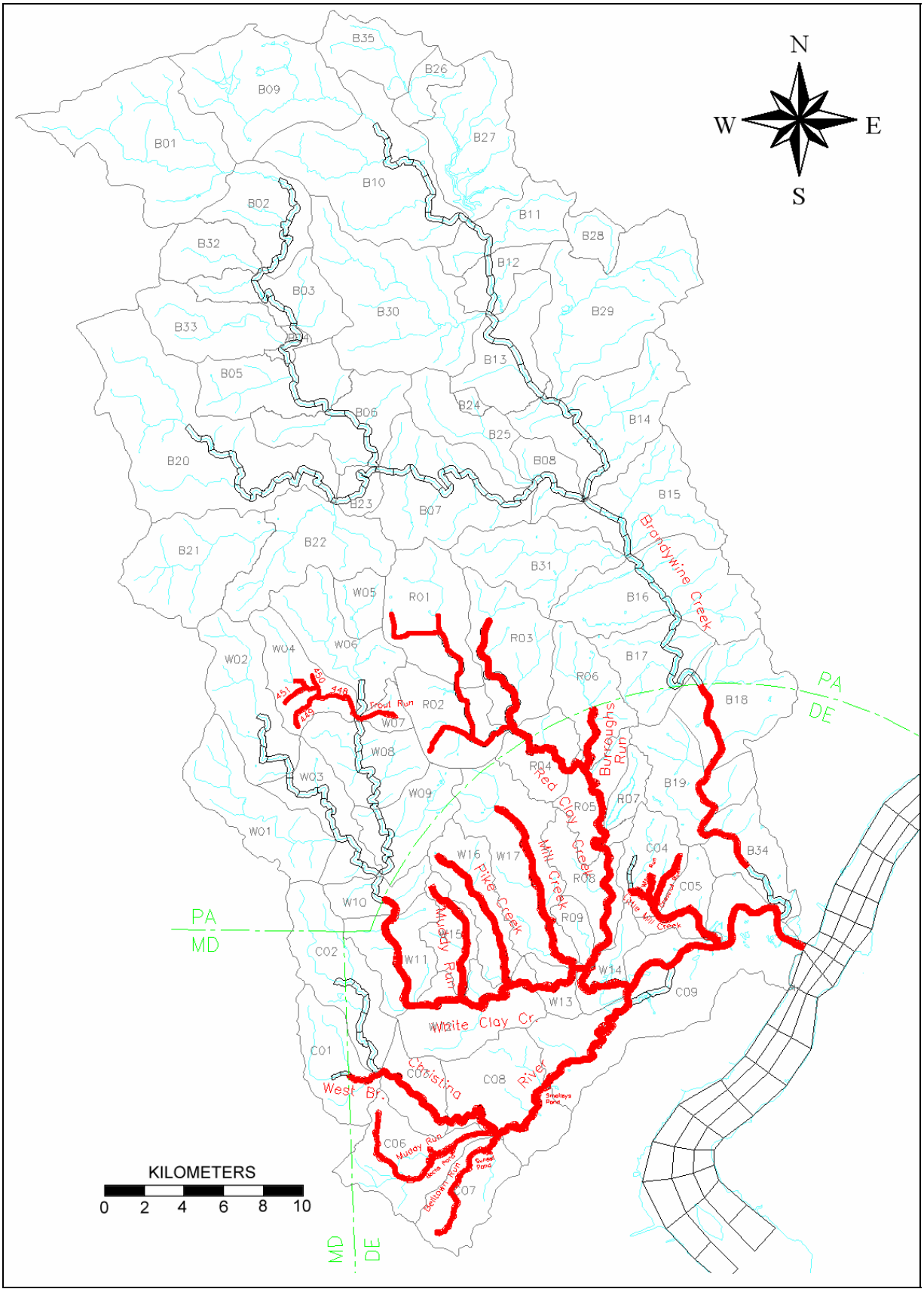

Figure 4-1. Locations of stream segments impaired by bacteria

4.1.2 TMDL Calculation

TMDLs were established for each fecal coliform bacteria-listed stream on Pennsylvania's Section 303(d) list. Each TMDL is the sum of the point source WLAs and the nonpoint source LAs, and a MOS. These TMDLs identify the sources of pollutants that cause or contribute to the impairment of the fecal coliform bacteria criteria and allocate appropriate loadings to the various sources. The basic equation used for TMDLs and allocations to sources is:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The WLA portion of this equation is the total loading assigned to point sources permitted under the NPDES program. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent MOS was used for this TMDL.

4.1.3 Wasteload Allocations

Federal regulations (40 CFR § 130.7) require TMDLs to include individual WLAs for each point source. None of the NPDES permitted dischargers, except as noted below, in the impaired subbasins were required to reduce their present NPDES permit limits of 200 cfu/100mL for fecal coliform bacteria or 100 cfu/100mL for *enterococcus* bacteria.

The City of Wilmington's CSOs are NPDES permitted discharges that currently have no permit limits. Future permits will contain permit limits and require reductions in loads discharged to the Christina River, Little Mill Creek, and Brandywine Creek.

EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from municipal separate storm sewer systems (MS4) as described in Section 2.1.3. MS4s within the Christina River watershed receive allocations expressed as WLAs, enforceable through the NPDES permitting process.

Most of the townships/municipalities within the watershed have been designated by PADEP as covered under the NPDES Phase II Storm Water Regulations, and comprise the almost the entire watershed area. DNREC has issued MS4 permits covering all of New Castle County. MS4 bacteria baseline and allocation loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C, Tables C-1, C-2, C-3, C-4, C-8, C-9, C-10, C-11, C-12, and C13). MS4 permits issued to date require gathering information regarding the systems.

4.1.4 Load Allocations

According to Federal regulations (40 CFR § 130.2(g)), LAs are best estimates of the nonpoint source or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading.

As explained in Section 2.1.3, once a municipality delineates its MS4 sewershed area, the loads associated with nonpoint sources may be parsed out of the WLA and moved to the LA portion of the TMDL. Note that the total allocation will be unchanged. Example calculations are shown in Appendix E.

4.1.5 CSO Overflows

One of the key principles of the 1994 CSO Control Policy[4] is to provide levels of control that are presumed to meet appropriate health and environmental criteria. After the nine minimum controls, technology-based measures, were implemented, permittees were to develop long-term control plans. The permittees could use one of two approaches: (1) demonstrate its plan was adequate to meet the water quality-based requirements of the CWA or (2) implement a minimum level of treatment presumed to meet the water quality-based requirements. Wilmington selected the presumptive approach which requires capture for treatment of 85 percent of the combined sewage flows and limiting CSO discharges to less than an average of four to six events per year. Guidance[5] defines the required capture as:

> The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis.

The CSO loads are equal to the volume multiplied by the event mean concentration. See Appendix D for a discussion of the event mean concentration.

TMDLs and WLAs are generally expressed as loads, mass per unit time. When the TMDLs and WLAs are storm water related, as these TMDLs are, they are often expressed as average annual loads. This means that the analysis (or computer modeling) indicates that instream water quality standards are met each and every day (or as required by the water quality standards) over the predictive time-frame used when all loads are reduced as specified, and the loads entering the waterbody from each source are added together and divided by the number of years in the predictive time-frame used. Because Pennsylvania's bacteria criteria are based on the swimming/non-swimming seasons, the TMDLs and WLAs are average annual seasonal loads. TMDLs, WLAs, and LAs shown in following Tables 4-3 to 4-10 in average annual units are also shown in Appendix F in terms of units per day.

4.1.6 TMDL Results and Allocations

4.1.6.1 Fecal Coliform Bacteria

The fecal coliform bacteria impaired stream segments on Pennsylvania's Section 303(d) list are located in the East Branch White Clay Creek in subbasins W04 and W07 and the Red Clay Watershed in subbasins R01, R02, and R03. The HSPF models for the White Clay Creek and Red Clay Creek were run for the four-year period October 1, 1994, through October 1, 1998, for both the baseline (current) conditions and for the TMDL allocation conditions. Bacteria watershed loads were adjusted in the TMDL allocation scenario until the fecal coliform bacteria 30-day geometric mean water quality standards were achieved for both the swimming season (200 cfu/100mL from May 1 through September 30) and non-swimming season (2,000 cfu/100mL from October 1 to April 30). Watershed loads include domestic and wild animals, and failed septic systems.

The TMDLs and allocations are presented in Tables 4-1 through 4-3. A five percent MOS was used, which means the model instream fecal coliform bacteria concentrations were

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[4] 59*FR*18688

[5] *Combined Sewer Overflows – Guidance For Long-Term Control Plan,* September 1995, EPA 832-B-95-005.

compared to 190 cfu/100mL and 1900 cfu/100mL instead of the water criteria of 200 cfu/100mL and 2000 cfu/100mL.

The non-MS4 point sources in both the Red Clay Creek and White Clay Creek where not reduced. See Table 2-2 for point source WLAs. The septic system loads were reduced by elimination of failed systems.

The baseline and TMDL allocation loads shown in Table 4-1 represent the average seasonal loads calculated from the HSPF model simulation during the period October 1, 1994, through October 1, 1998. In addition to the load allocations at the subbasin scale, the bacteria loads were allocated to the MS4 townships. Four municipalities including Avondale, London Grove, New Garden, and West Grove are located in subbasins W04 and W07. Four municipalities including East Marlborough Township, Kennett Square, Kennett Township and New Garden Townships are located in subbasins R01, R02, and R04. The TMDL allocations for the affected municipalities are shown in Table 4-2. Allocations for fecal coliform bacteria loads for septic systems in each of the impaired subbasins are provided in Table 4-3.

Table 4-1. Average annual seasonal fecal coliform bacteria TMDL allocations for the Christina River Basin

Subbasin	Baseline Load (cfu/season)			TMDL Allocation (cfu/season)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Swimming Season (May 1 - Sep 30)									
Red Clay (R01)	1.872E+12	2.914E+15	2.916E+15	8.734E+10	2.139E+14		1.126E+13	2.252E+14	92.28%
Red Clay (R02)	6.037E+12	1.319E+15	1.325E+15	1.274E+12	1.133E+14		6.031E+12	1.206E+14	90.90%
Red Clay (R03)	1.304E+12	1.435E+15	1.437E+15	1.738E+11	1.206E+14		6.359E+12	1.272E+14	91.15%
White Clay (W04)		1.726E+15	1.726E+15		1.040E+14		5.478E+12	1.095E+14	93.66%
White Clay (W07)	7.529E+10	3.140E+13	3.148E+13	7.529E+10	2.885E+12		1.557E+11	3.115E+12	90.10%
Non-swimming Season (Oct 1 - Apr 30)									
Red Clay (R01)	1.872E+12	6.404E+15	6.406E+15	8.734E+11	2.895E+15		1.524E+14	3.049E+15	52.40%
Red Clay (R02)	6.037E+12	3.406E+15	3.412E+15	1.274E+13	1.571E+15		8.338E+13	1.668E+15	51.12%
Red Clay (R03)	1.304E+12	3.704E+15	3.705E+15	1.738E+12	1.720E+15		9.062E+13	1.812E+15	51.08%
White Clay (W04)		2.499E+15	2.499E+15		2.370E+15		1.249E+14	2.495E+15	0.16%
White Clay (W07)	1.043E+11	6.899E+13	6.910E+13	7.529E+11	6.475E+13		3.450E+12	6.899E+13	0.15%

Table 4-2. Average annual seasonal fecal coliform TMDL allocations for MS4 municipalities

Town	Sub-Watershed	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	2.61E+15	2.06E+14	92.09%
Kennett Square Boro	Red Clay	2.35E+14	1.88E+13	91.98%
Kennett TWP	Red Clay	1.44E+15	1.24E+14	91.38%
New Garden TWP	Red Clay	1.12E+15	9.38E+13	91.60%
Avondale Boro	White Clay	3.81E+13	2.42E+12	93.64%
London Grove TWP	White Clay	1.54E+15	9.27E+13	93.99%
New Garden TWP	White Clay	3.00E+13	2.76E+12	90.82%
West Grove Boro	White Clay	8.48E+13	5.09E+12	93.99%

Town	Sub-Watershed	Non-Swimming Season Baseline (cfu /season)	Non-Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	5.95E+15	2.85E+15	52.08%
Kennett Square Boro	Red Clay	5.45E+14	2.62E+14	51.95%
Kennett TWP	Red Clay	3.65E+15	1.78E+15	51.26%
New Garden TWP	Red Clay	2.76E+15	1.34E+15	51.52%
Avondale Boro	White Clay	5.83E+13	5.53E+13	5.06%
London Grove TWP	White Clay	2.23E+15	2.12E+15	5.04%
New Garden TWP	White Clay	6.59E+13	6.25E+13	5.15%
West Grove Boro	White Clay	1.23E+14	1.17E+14	5.04%

Table 4-3. Average annual seasonal septic system TMDL allocations of fecal coliform bacteria

Sub-Watershed	Estimated number of septic systems	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
Red Clay (R01)	553	6.13E+13	1.26E+11	99.79%
Red Clay (R02)	460	5.09E+13	1.05E+11	99.79%
Red Clay (R03)	779	8.63E+13	1.77E+11	99.79%
White Clay (W04)	224	2.48E+13	5.10E+10	99.79%
White Clay (W07)	42	4.69E+12	9.63E+09	99.79%
Sub-Watershed	**Estimated number of septic systems**	**Non Swimming Season Baseline (cfu/season)**	**Non Swimming Season TMDL (cfu/season)**	**Percent Reduction**
Red Clay (R01)	553	8.79E+13	1.75E+11	99.80%
Red Clay (R02)	460	7.31E+13	1.45E+11	99.80%
Red Clay (R03)	779	1.24E+14	2.46E+11	99.80%
White Clay (W04)	224	3.56E+13	7.06E+10	99.80%
White Clay (W07)	42	6.72E+12	1.33E+10	99.80%

4.1.6.2 *Enterococci* Bacteria

The locations of the stream segments listed as impaired for *enterococci* bacteria in Delaware are shown in Figure 4-1, and comprise most of the Christina River Basin within Delaware. Pennsylvania TMDL allocations for *enterococci* bacteria were determined at the PA-DE state line for Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run and for Maryland at the MD-DE State line for the East and West Branches of the Christina River.

In Delaware, TMDL allocations were determined for each HSPF model subbasin to ensure protection of both the 30-day geometric mean criterion (100 cfu/100mL) also using a five percent MOS. The model run results were compared to a 30-day geometric mean of 95 cfu/100mL. All Delaware loads are average annual loads because Delaware does not have seasonal bacteria criteria.

In Pennsylvania, TMDL allocation results indicate that reductions in bacteria loading from land accumulation and from livestock's direct bacteria loading to streams on the order of 29 to 93 percent, respectively, are necessary to protect the water quality standards for *enterococci* bacteria at the PA-DE state line on Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run. Approximately a 58 percent reduction is required at the MD-DE state line. Allocations are shown in Table 4-4.

The WLA portion of the TMDL allocation includes the contributions from CSO outfalls in the City of Wilmington (see Figure 4-2). The baseline loading for the CSO outfalls was

determined using flow rates simulated by the XP-SWMM model and event mean concentrations (EMC) from CSO monitoring during storm events. Allocation model runs reduced the CSO loads by reducing the EMC but not the CSO volume except for CSOs 27, 28, and 29 on Little Mill Creek. For those three CSOs, the flows were routed through a storage tank to reduce the volume and load. The required total CSO load reduction from baseline conditions is approximately 68 percent as shown in Table 4-5. These reductions are based on the assumption that the Delaware River also meets applicable water quality criteria. See Appendix D for details.

The TMDL CSO load reductions shown in Appendix D, Table D-3, are one scenario of load reductions which, together with other sources' reductions, result in achieving instream water quality criteria throughout the length of the impaired waterbody. It should be noted that other scenarios are possible. In the future DNREC may allow an alternate CSO load reduction scenario, which also demonstrates that water quality standards are met throughout the length of the impaired waterbody.

In 2005 construction of a 2.3 million gallon (mgal) storage tank at Canby Park was completed to help capture overflows from CSOs 27, 28, and 29. Model runs indicate that the 2.3 mgal tank will reduce the average annual *enterococc*i load by 9.90E+13 cfu of the required 1.19E+14 cfu reduction specified by the TMDL. Thus, an additional annual reduction of 1.99E+13 cfu is needed to meet the TMDL in Little Mill Creek.

The non-MS4 point sources in Delaware where not reduced. See Table 2-2 for point source WLAs. Septic system loads were reduced by elimination of failed systems. In the Delaware subbasins, the overall reductions in *enterococci* bacteria from the baseline conditions range from about 29 percent to over 90 percent as shown in Table 4-6. The WLAs include non-MS4 point sources (Table 2-2) and CSO point sources.

Table 4-4. State line average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	Allocation (cfu/yr)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Cr. (at PA-DE Line)	3.12E+15	2.01E+14	93.56%
White Clay Cr. (at PA-DE Line)	6.86E+14	2.06E+14	70.03%
Red Clay Cr. (at PA-DE Line)	2.58E+14	1.08E+14	58.05%
Burroughs Run (at PA-DE Line)	1.85E+13	1.30E+13	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	1.86E+13	7.73E+12	58.40%

Table 4-5. Summary of average annual CSO *enterococci* baseline loads and WLA TMDL

Location	CSO ID Numbers	Baseline (cfu/yr)	WLA (cfu/yr)	Reduction
Little Mill Creek (C05)	27, 28, 29	1.56E+14	3.69E+13	76.32%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	3.54E+14	9.75E+13	72.47%
Brandywine Creek (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	6.89E+14	2.55E+14	63.07%
Total CSO Loads	-	1.20E+15	3.89E+14	67.57%

Table 4-6. Average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Brandywine Creek in Delaware						
Brandywine Cr. (B18)	1.11E+14	0.00E+00	5.55E+12	2.92E+11	5.85E+12	94.75%
Brandywine Cr. (B19)	5.57E+13	3.45E+10	6.31E+12	3.32E+11	6.68E+12	88.00%
White Clay Creek in Delaware						
White Clay Cr. (W11)	4.07E+13	0.00E+00	9.96E+12	5.24E+11	1.05E+13	74.23%
White Clay Cr. (W12)	1.49E+14	4.15E+10	1.79E+13	9.44E+11	1.89E+13	87.31%
White Clay Cr. (W13)	3.01E+13	0.00E+00	3.91E+12	2.06E+11	4.11E+12	86.34%
White Clay Cr. (W14)	3.82E+13	0.00E+00	3.99E+12	2.10E+11	4.20E+12	89.00%
White Clay Cr. (W15)	2.85E+13	0.00E+00	8.95E+12	4.71E+11	9.42E+12	66.90%
White Clay Cr. (W16)	1.02E+14	0.00E+00	1.32E+13	6.95E+11	1.39E+13	86.41%
White Clay Cr. (W17)	2.41E+14	0.00E+00	3.34E+13	1.76E+12	3.52E+13	85.43%
Red Clay Creek in Delaware						
Red Clay Cr. (R04)	5.89E+13	3.00E+12	8.52E+12	4.48E+11	1.20E+13	79.67%
Red Clay Cr. (R05)	2.25E+13	2.07E+10	7.90E+12	4.16E+11	8.34E+12	63.01%
Red Clay Cr. (R06)	1.51E+13	6.22E+08	1.01E+13	5.34E+11	1.07E+13	29.32%
Red Clay Cr. (R07)	6.05E+12	0.00E+00	1.74E+12	9.16E+10	1.83E+12	69.75%
Red Clay Cr. (R08)	7.61E+13	4.84E+11	7.83E+12	4.12E+11	8.73E+12	88.54%
Red Clay Cr. (R09)	2.88E+13	0.00E+00	2.89E+12	1.52E+11	3.04E+12	89.44%
Christina River and Tidal Brandywine Creek						
Christina River (C01)	3.51E+13	0.00E+00	1.27E+13	6.69E+11	1.34E+13	61. 90%
Christina River (C02)	8.16E+13	0.00E+00	2.47E+13	1.30E+12	2.60E+13	68.15%
Christina River (C03)	6.64E+13	0.00E+00	9.35E+12	4.92E+11	9.84E+12	85.18%
Christina River (C04)	8.69E+13	0.00E+00	6.73E+12	3.54E+11	7.09E+12	91.84%
Christina River (C05) *	2.21E+14	3.69E+13	4.84E+12	2.55E+11	4.20E+13	81.01%
Christina River (C06)	7.45E+13	0.00E+00	1.65E+13	8.70E+11	1.74E+13	76.66%
Christina River (C07)	7.16E+13	0.00E+00	1.08E+13	5.70E+11	1.14E+13	84.08%
Christina River (C08)	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
Christina River (C09) *	6.84E+14	9.75E+13	3.54E+13	1.87E+12	1.35E+14	80.30%
Tidal Brandywine Cr. (B34) *	8.23E+14	2.55E+14	1.33E+13	6.98E+11	2.68E+14	67.38%
Sunset Lake	6.39E+13	0.00E+00	1.41E+13	7.46E+11	1.49E+13	76.66%
Beck's Pond	6.27E+13	0.00E+00	9.45E+12	4.99E+11	9.98E+12	84.08%
Smalley's Pond	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
* CSO loads are included in the Baseline and WLA in these subbasins.						

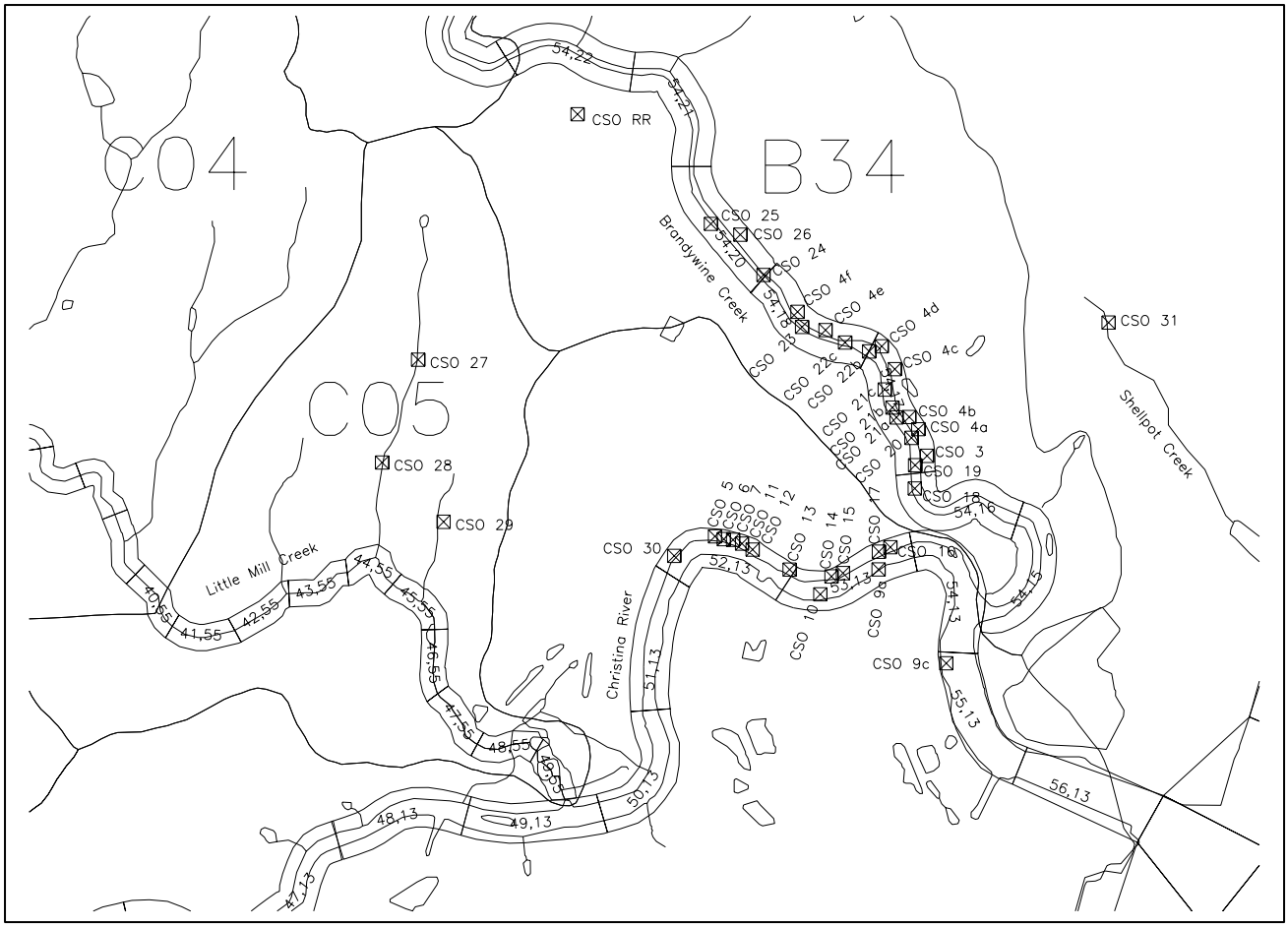

Figure 4-2. Location of CSO discharges in relation to EFDC model grid cells

4.1.7 Consideration of Critical Conditions

Federal Regulations (40 CFR § 130.7c(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. There may be multiple critical conditions depending on the different sources of bacteria. The four-year dynamic modeling addresses varying rainfall, flow, and seasonal variations of bacteria (EPA, 2001). The bacteria TMDLs for Christina River Basin adequately address critical conditions for flow and loading through analysis of a four-year hydrologic simulation that includes typical low and high flow variations in the basin.

The model calibration results for fecal coliform and *enterococci* bacteria show that the bacteria concentrations tend to be higher during the warm weather months. The bacteria concentrations appear to be correlated with cattle grazing behavior and storm events. The calibration results suggest that the highest bacteria concentration in terms of 30-day geometric mean may occur in warm weather following a storm event preceded by a long dry-weather period.

4.1.8 Consideration of Seasonal Variation

The critical conditions for bacteria, or any pollutant washed off the land surface by rainfall runoff, cannot be defined with a fixed flow rate. A long-term continuous simulation is one way to determine when the bacteria concentrations are highest. Therefore, the models were run for a four-year period (October 1, 1994, through October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997 as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin.

4.1.9 Margin of Safety

The CWA and Federal regulations require TMDLs to include a MOS to take into account the relationship between effluent limitations and water quality. EPA guidance suggests two approaches to satisfy the MOS requirement. First, it can be met implicitly by using conservative model assumptions to develop the allocations. Alternately, it can be met explicitly by allocating a portion of the allowable load to the MOS. These TMDLs use an explicit five percent MOS.

4.2 Sediment TMDLs

The following sections discuss the methods used for TMDL development and the LAs, and percent reductions for the sediment-listed Pennsylvania waters. No stream segments are listed as impaired due to sediment in Delaware or Maryland. The stream segments listed for sediment impairment on Pennsylvania's 1996 Section 303(d) list are shown in Figure 4-3, and those on the 1998 Section 303(d) list are shown in Figure 4-4.

4.2.1 Methodology

Sediment and siltation problems tend to occur during wet weather periods when sediment washes off land surfaces and when high flows cause erosion of streambeds and stream banks. Sediment TMDL endpoints for the impaired reaches were developed using a reference watershed approach (see Section 3.2). After the impaired and reference watersheds were matched, the HSPF models were used to simulate the sediment loads from different sources for both the impaired and reference watersheds. The sediment loads calculated for the reference watersheds were used as endpoints for the impaired watersheds. A general description of the approach was previously shown in Figure 3-1.

The HSPF watershed models were used to calculate the TMDL sediment baseline and LAs for the Pennsylvania listed waters. The models were calibrated over a four-year period (October 1, 1994, through October 1, 1998) to include both low and high streamflow. Following calibration, the same four-year period was used for the baseline and TMDL allocation simulations. For the baseline condition, all NPDES point sources were set to their permitted flow and sediment (total suspended solids (TSS)) levels (see Table 2-2). No sediment loads were assigned to septic systems. Sediment yields from different land uses in the watersheds were incorporated into the models. A series of model runs were made in which the sediment loads from land sources were reduced until water quality standards were met. A detailed description of the background, configuration, and calibration of the modeling system is provided in the Modeling Report (EPA, 2005).

4.2.2 TMDL Calculation

TMDLs were established for the stream segments listed on Pennsylvania's Section 303(d) list. Each TMDL consists of point source WLAs, nonpoint source LAs, and a MOS. The basic equation used for TMDLs and allocations to sources is:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The WLA portion of this equation is the total loading assigned to point sources. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent MOS was used for this TMDL.

4.2.3 Waste Load Allocations

Federal regulations (40 CFR § 130.7) require TMDLs to include individual WLAs for each point source. None of the non-MS4 NPDES permitted dischargers in the impaired subbasins was required to reduce their present TSS NPDES permit limits shown in Table 2-2. Based on the available discharge monitoring reports the average discharge of sediment from such facilities in the watershed was usually well below the permitted TSS concentration.

EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from municipal separate storm sewer systems (MS4) as described in Section 2.1.3. MS4s within the Christina River Watershed receive allocations expressed as WLAs, enforceable through the NPDES permitting process.

Sediment loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C, Tables C-5, 6, and 7).

4.2.4 Load Allocations

According to Federal regulations (40 CFR § 130.2(g)), LAs are best estimates of the nonpoint source and background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint sources should be distinguished (EPA, 2001). Model output for the impaired subbasins includes sediment loads from each of the contributing land uses as well as a total sediment load from streambed erosion.

As explained in Section 4.1.3, once a municipality delineates its MS4 area, the sediment loads associated with nonpoint sources may be parsed out of the WLA and moved under the LA portion of the TMDL. Note that the total LA will be unchanged. See Appendix E, Storm Water Permits, Sample Calculations.

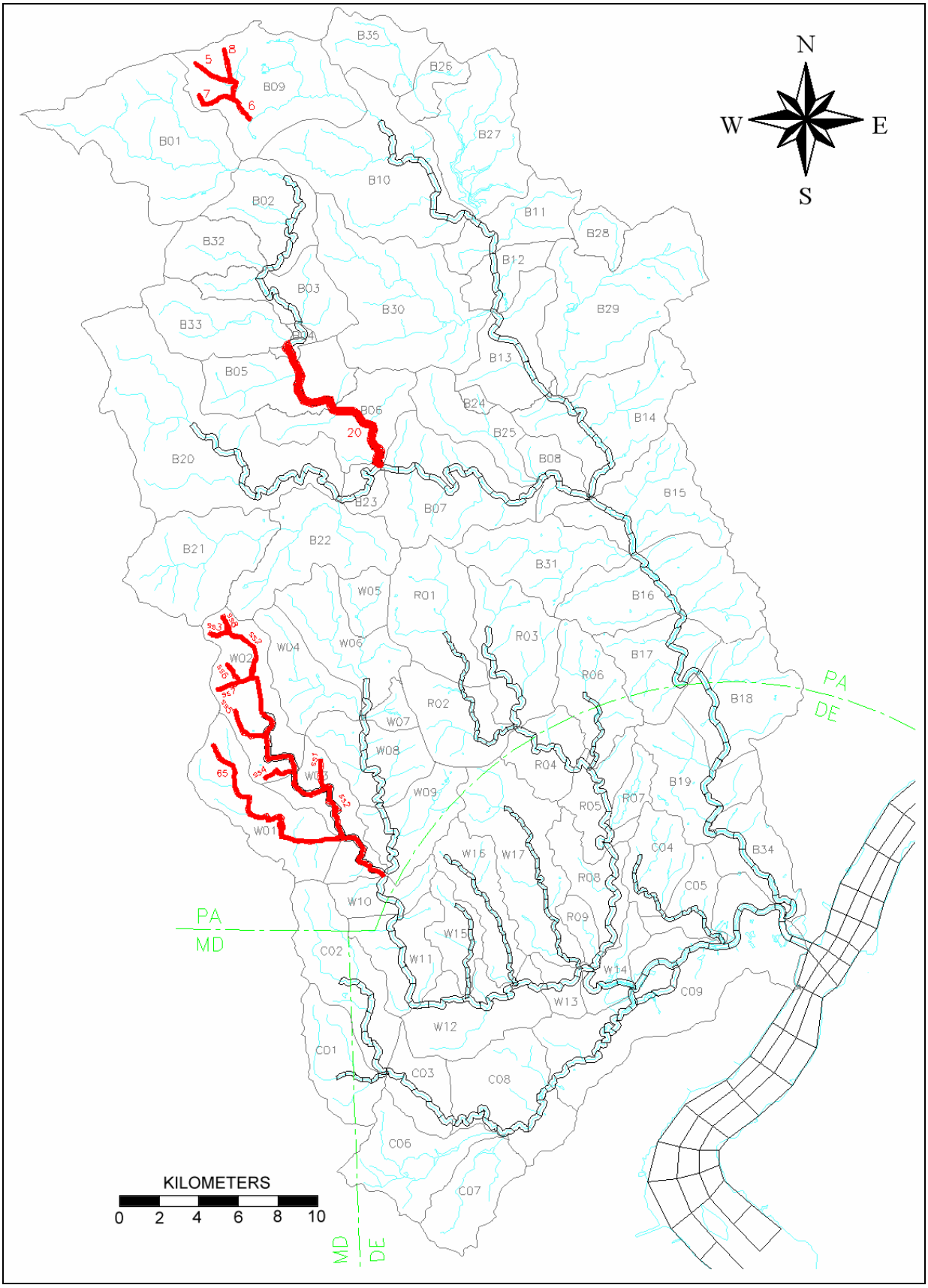

Figure 4-3. Stream segments impaired by sediment on Pennsylvania 1996 Section 303(d) list

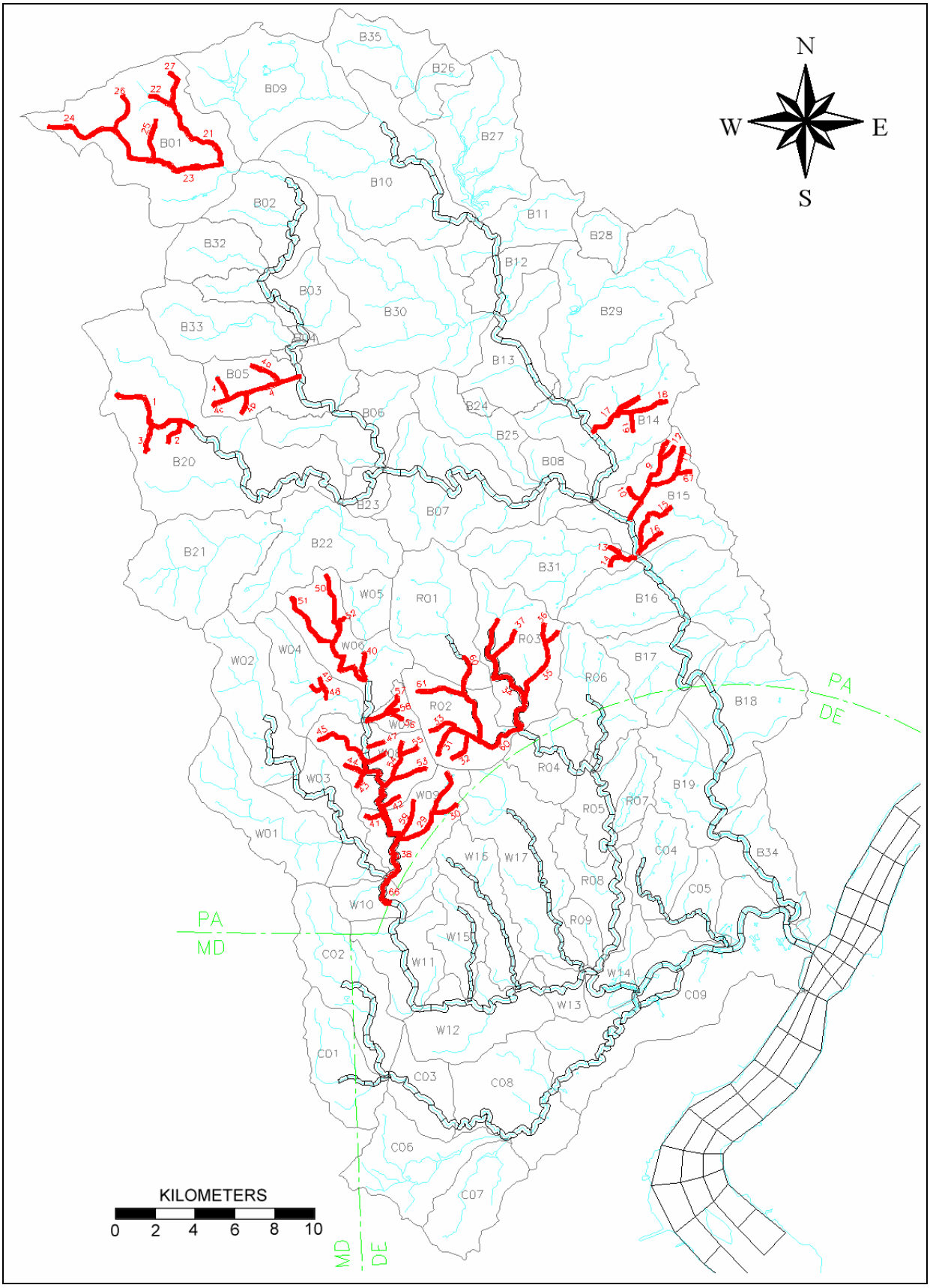

Figure 4-4. Stream segments impaired by sediment on Pennsylvania 1998 Section 303(d) list

4.2.5 TMDL Results and Allocations

The TMDL allocations for sediment in the Christina River Basin are presented in Table 4-7. The NPDES permitted point sources shown in Table 2-2 are summed by subbasin in Table 4-7. The TMDL allocations for the MS4 municipalities in Brandywine Creek, Red Clay Creek, and White Clay Creek Watersheds are listed in Table 4-8, 4-9, and 4-10, respectively.

Table 4-7. Average annual[6] allocations for Christina River Basin sediment TMDL

Subbasin	Baseline Load (ton/yr)			TMDL Allocation (ton/yr)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Brandywine Creek									
B01	29.80	776.03	805.83	29.80	414.16	84.82	27.83	556.61	30.9%
B04	0.00	42.63	42.63	0.00	21.77	-	1.15	22.92	46.2%
B05	246.02	1278.65	1524.67	246.02	421.74	-	35.15	702.91	53.9%
B06	0.08	340.20	340.28	0.08	219.34		11.55	230.97	32.1%
B09	0.04	498.86	498.89	0.04	180.75	218.75	21.03	420.57	15.7%
B14	79.81	1637.50	1717.31	79.81	631.82	-	37.45	749.08	56.4%
B15	9.19	1214.60	1223.79	9.19	509.37	-	27.29	545.85	55.4%
B20	1.68	1119.58	1121.26	1.68	645.94	49.03	36.67	733.31	34.6%
B31	0.04	1189.38	1189.42	0.04	452.25	-	23.80	476.09	60.0%
White Clay Creek									
W01	0.30	5353.56	5353.87	0.30	2940.17	-	154.76	3095.23	42.2%
W02	11.42	7999.18	8010.60	11.42	2283.47	449.21	144.43	2888.53	63.9%
W03	0.00	3168.54	3168.54	0.00	1825.04	-	96.05	1921.10	39.4%
W04	0.00	5187.94	5187.94	0.00	1722.66	58.57	94.49	1875.72	63.8%
W06	2.83	8114.08	8116.92	2.83	1795.34	667.6	129.78	2595.55	68.0%
W07	2.97	1414.61	1417.58	2.97	393.60	-	20.87	417.44	70.6%
W08	2.19	4606.80	4609.00	2.19	2146.83	-	113.11	2262.13	50.9%
W09	0.05	2808.89	2808.95	0.05	1968.74	-	103.62	2072.42	26.2%
Red Clay Creek									
R01	8.45	8424.04	8432.49	8.45	3500.39	329.31	201.96	4040.11	52.1%
R02	50.26	6252.12	6302.38	50.26	2805.45	-	150.30	3006.01	52.3%
R03	6.85	7218.12	7224.97	6.85	3761.33	-	198.33	3966.51	45.1%

The TMDLs in Table 4-7 were not revised. However, where a subbasin is not completely within a MS4 jurisdiction, the TMDL is divided into the MS4 WLA and LA.

[6] See Appendix F for loads in terms of units per day.

Table 4-8. Average annual sediment allocations for towns in Brandywine Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
BIRMINGHAM TWP	310.81	130.35	58.06%
COATESVILLE CITY	231.29	79.76	65.52%
EAST BRADFORD TWP	1185.00	467.17	60.58%
EAST FALLOWFIELD TWP	803.23	426.42	46.91%
EAST MARLBOROUGH TWP	366.70	139.44	61.98%
HIGHLAND TWP	384.80	238.86	37.93%
HONEY BROOK BORO	20.58	13.23	35.70%
HONEY BROOK TWP	813.84	558.76	31.34%
MODENA BORO	27.96	12.46	55.43%
NEWLIN TWP	144.18	59.59	58.67%
PARKESBURG BORO	52.11	32.35	37.93%
PENNSBURY TWP	113.98	43.48	61.85%
POCOPSON TWP	821.21	320.79	60.94%
SADSBURY TWP	289.73	172.13	40.59%
THORNBURY TWP	82.17	34.46	58.06%
VALLEY TWP	485.14	164.64	66.06%
WALLACE TWP	21.74	17.41	19.92%
WEST BRADFORD TWP	283.22	121.60	57.07%
WEST CALN TWP	68.28	43.07	36.92%
WEST GOSHEN TWP	461.32	180.51	60.87%

Table 4-9. Average annual sediment allocations for towns in Red Clay Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
EAST MARLBOROUGH TWP	8791.41	4193.24	52.30%
KENNETT SQUARE BORO	840.10	405.41	51.74%
KENNETT TWP	6751.63	3312.06	50.94%
NEW GARDEN TWP	4709.65	2118.72	55.01%

Table 4-10. Average annual sediment allocations for towns in White Clay Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
AVONDALE BORO	463.65	140.02	69.80%
FRANKLIN TWP	4220.43	2305.87	45.36%
LONDON BRITAIN TWP	2634.66	1620.44	38.50%
LONDON GROVE TWP	13616.33	4842.81	64.43%
NEW GARDEN TWP	6746.50	2986.66	55.73%
NEW LONDON TWP	1913.97	1008.60	47.30%
PENN TWP	3584.76	1410.29	60.66%
WEST GROVE BORO	562.29	192.63	65.74%

4.2.6 Critical Conditions

The HSPF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. The average annual yearly calculations made for the sediment loads shown in the average annual TMDL allocation tables in the previous section were based on the daily model simulation output and summed to get yearly values. Therefore, all flow

conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual loads is protective of the waterbody.

4.2.7 Seasonal Variation

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The HSPF model had for a four-year period (October 1, 1994, through October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997, as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin. The combination of these model features accounts for seasonal variability.

4.2.8 Margin of Safety

The CWA and Federal regulations require TMDLs to include a MOS to take into account any lack of knowledge concerning the relationship between effluent limitations and water quality. EPA guidance suggests two approaches to satisfy the MOS requirement. First, it can be met implicitly by using conservative model assumptions to develop the allocations. Alternately, it can be met explicitly by allocating a portion of the allowable load to the MOS. These TMDLs use an explicit five percent MOS.

5.0 REASONABLE ASSURANCE AND IMPLEMENTATION

EPA's regulations require that there is reasonable assurance that TMDLs can be implemented. Reasonable assurance indicates a high degree of confidence that the goals outlined in the TMDL, whether in the form of WLAs or LAs, can be achieved. In terms of the Christina River High-flow TMDL, various programs exist that can be utilized to help implement TMDLs.

For point sources, Federal regulations at 40 CFR 122.44(d)(1)(vii)(B), require effluent limitations for an NPDES permit to be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of a NPDES permit that is inconsistent with the WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the states' current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint source water quality problems, consider alternative solutions, and recommend control measures.

With regard to LAs for nonpoint sources, programs including Section 319 programs are available. Pennsylvania's Growing Greener funding has provided more than $65 million dollars to environmental initiatives throughout the Commonwealth of Pennsylvania. Section 319 grant funding, supported by the Unified Watershed Assessment and the Watershed Restoration Action Strategies, is designed to focus resources towards the implementation of BMPs for nonpoint source pollutants.

Implementation of BMPs in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of bacteria and sediment reaching the streams can be made through the planning of riparian buffer zones, contour strips, cover crops, or stormwater retention techniques. These BMPs range in efficiency from 20% to 70% for sediment and bacteria reduction. Reductions in instream loads resulting from bank erosion can be made through two plans: (1) stream restoration plans that seek to stabilize stream banks and provide better transport of high storm flows associated with urban areas, and (2) implementation of urban BMPs that reduce peak storm flow through retention or increased infiltration. Such management practices will also address those stream segments listed as impaired due to water/flow variability. Further investigations should be performed in order to assess both the extent of existing BMPs, and to determine the most cost-effective and environmentally protective combination of BMPs required for meeting the bacteria and sediment reductions outlined in this report.

There are state and local policies and regulations in place to help ensure implementation of BMPs. At the state level, PADEP has developed a Proposed Comprehensive Stormwater Management Policy (Appendix A) that encourages implementation of BMPs for stormwater control to reduce pollutant loadings, recharge groundwater tables, enhance stream base flow during drought periods, and reduce the threat of stream bank erosion and flooding. This policy seeks to integrate watershed management plans with permitting programs. Therefore incorporation of TMDL targets at this stage is essential for setting goals for future watershed management plans. Such watershed management plans should be consistent with Stormwater Management Plans developed by counties and implemented by municipalities on a watershed basis, as required by the Pennsylvania Stormwater Management Act (Act 167).

At the Federal level, EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from separate storm sewer systems (MS4s). Due to the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs, and only using numeric limits in unique instances. Such BMP plans should accompany monitoring plans that test the performance of BMPs and provide a basis for revised management techniques. This iterative strategy is consistent with the watershed management approach discussed above, and allows an implementation plan where realistic goals can be set to improve the water quality of the streams through the use of BMPs throughout the watershed. The intention is to implement BMPs as required through the Federal and state policies and regulations described above with the ultimate goal of achieving the WLA. For more information, see the EPA memorandum titled *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs* (November 22, 2002) in Appendix B.

For purposes of this TMDL, WLAs were developed for each municipality holding MS4 permits. Distribution of loads was estimated using land use data within municipal boundaries and application of unit area loadings (lbs/acre/year) determined for subbasins defined in the HSPF model and used for TMDL development. As additional data are collected by the States' storm water programs regarding drainage areas of each storm sewer system in the basin, these WLAs can be refined to more detailed representation of WLAs for each stormwater permit and LAs for areas not bound by such permits. To do this, the drainage area of each storm sewer should be delineated so that the area and distributions of land use can be determined. The land use areas within the stormwater drainage areas can be multiplied by the unit area loadings reported herein to determine the WLA for each MS4 permit and to calculate the load reduction necessary to meet the TMDL. The remaining load in each respective township can then be assigned to LAs. Until such storm water drainage area data are available, the WLAs and required load reductions reported herein are applicable.

The development of TMDLs is only the beginning of the process for stream restoration and watershed management. Load allocations to point and nonpoint sources serve as targets for improvement, but success is determined by the level of effort put forth in making sure that those goals are achieved. The load reductions proposed by the bacteria and sediment TMDLs require specific watershed management measures to ensure successful implementation.

For the Delaware portion of the Christina Basin, the Christina Basin Clean Water Partnership has developed a Watershed Restoration Action Strategy (WRAS), which is intended to provide a guideline for future watershed protection and restoration actions. The WRAS, developed in June 2003, is also designed to interconnect with EPA's earlier low-flow, point source TMDL for the Christina Basin and this high-flow, nonpoint source TMDL. The mission of the Christina Basin Clean Water Partnership is to "conduct a cooperative, interstate effort to restore the water quality of the streams and tributaries in the Brandywine, Red Clay and White Clay Creeks, and Christina River watersheds of Delaware, Maryland, and Pennsylvania to fishable, swimmable, and potable status by 2015." To do so, the Christina Basin WRAS identifies some goals and objectives that are related to this sediment and bacteria TMDL. One goal is to reduce bacteria loads in the streams to meet the Delaware swimmable primary recreation water quality standards of less than 100 cfu/100 mL. Another goal is to reduce

sediment loads from land and stream erosion sources to less than 250 pounds per acre per year. And, regarding stream habitat, the WRAS hopes to improve stream habitat to a “good” rating (above 81% for Habitat Community Index and 61% for Biological Community Index) in the Delaware portion of the Christina Basin.

There are many active watershed groups, in addition to various local and government organizations, that provide watershed stewardship in the Christina Basin. These include: the Brandywine Conservancy, Brandywine Valley Association, Red Clay Valley Association, Delaware Nature Society, White Clay Watershed Association, Stroud White Clay Creek Laboratory, and Christina Conservancy, and Wilmington River-City Steering Committee. Additionally, the Chester County Water Resources Authority and Chester County Conservation District in Pennsylvania, and the University of Delaware, Water Resources Authority, play an active role in coordinating watershed activities and initiatives for the Christina Basin. It is also important to mention that the Chester County and New Castle Conservation Districts have and hopefully will continue to install BMP implementation projects that are in line with the goals of the TMDL. Many of these organizations serve as local co-coordinators or as members of the Christina Basin Clean Water Partnership mentioned above.

6.0 PUBLIC PARTICIPATION

Public participation is not only a requirement of the TMDL process, but is essential to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. Also, EPA must provide a summary of all public comments and responses to those comments to indicate how the comments were considered in the final decision.

Multiple public meetings have been provided throughout all stages of the project to inform and update the public on all aspects of the project as it evolved. The public was encouraged to participate in data collection efforts and provide comments on a report of the data review and proposed TMDL methodology prior to TMDL development.

A first draft of the *Bacteria and Sediment TMDL Under High-Flow Conditions for Christina River Basin, Pennsylvania-Delaware-Maryland* was open for public comment on January 20, 2005. On January 6, 2005, a public meeting was held at the Red Clay Room in Kennett Square, Pennsylvania. Two additional public meetings were held on February 10, 2005, in Newark, Delaware, and February 17, 2005, in West Chester, Pennsylvania.

Following the public comment period, the Christina River Basin Watershed and receiving water models used for development of the bacteria and sediment TMDLs were revised to address the concerns of stakeholders.

For these revised TMDLs EPA held one informational meeting to present details and answer questions regarding the Christina River TMDLs on February 3, 2006, from 9 am to noon in the Red Clay Room, 423 Dalmatian Street, Kennett Square, Pa. 19348. Public notice announcements were published in the *Philadelphia Inquirer* on January 20, 2006, and in the *Wilmington News-Journal* on January 20, 2006. The public notice announcement was also put on the EPA Region III, together will all relevant documents.

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