Total Maximum Daily Loads
of Nutrients and Dissolved Oxygen
Under Low-Flow Conditions
In the Christina River Basin,
Pennsylvania, Delaware and Maryland

United States Environmental Protection Agency
Region III

in cooperation with the
Delaware Department of Natural Resources and Environmental Control
Pennsylvania Department of Environmental Protection
Maryland Department of the Environment
and
Delaware River Basin Commission

January 19, 2001
(revised October 2002)
(revised April 2006)

Previous TMDLs
Approved by:

Signed ____________________ *January 19, 2001* ________
Bradley M. Campbell — Date
Regional Administrator

Signed ____________________ *10-8-02* ________
Jon. M. Capacasa, Acting Director — Date
Water Protection Division

Approved by:

Signed ____________________ *8/23/06* ________
Jon M. Capacasa, Director — Date
Water Protection Division

Errata

April 30, 2007

The 2006 Addendum to the Revisions to the Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, established August 23, 2006, by EPA was not intended to modify wasteload allocations (WLAs) 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 Table 8 are shown in italics below.

Table 8. TMDL Summary by Subwatershed for Christina River Basin

Sum of Individual Waste Load Allocations					
Subwatershed	**CBOD5 lb/day**	**NH3-N lb/day**	**TN lb/day**	**TP lb/day**	**DO lb/day**
Christina River West Branch	75.56	13.57	*125.18*	6.26	37.55
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.56**	**13.57**	***125.18***	**6.26**	**37.55**
Total Waste Load Allocation for Christina River Basin	**2,245.31**	**380.57**	***5,544.44***	**288.32**	**1,080.06**

Table 8 (continued). TMDL Summary by Subwatershed for Christina River Basin

Sum of Load Allocations					
Subwatershed	**CBOD5 lb/day**	**NH3-N lb/day**	**TN lb/day**	**TP lb/day**	**DO lb/day**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.26	0.52	25.38	0.51	186.00
Christina River main stem	34.99	1.65	26.85	0.86	163.06
Christina River Watershed	**72.42**	**2.19**	**53.05**	**1.38**	**355.01**
Total LA for Christina River Basin	563.34	15.70	1,139.81	15.31	4,850.94
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	**2,808.65**	**396.27**	***6,684.24***	**303.63**	**5,931.01**

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
MD0022641	0.7000	12.22	2.00	*20.00*	1.00	6.00	71.387	11.684	*116.836*	5.842	35.051	0.0%	69.0%	0.0%
MD0065145	0.0500	10.00	4.52	*20.00*	1.00	6.00	4.173	1.886	*8.345*	0.417	2.504	0.0%	0.0%	0.0%
	Total Waste Load Allocation						75.559	13.570	*125.181*	6.259	37.554			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01WB	0.15	1.43	0.02	1.00	0.02	7.34	1.158	0.016	0.810	0.016	5.942	0.0%	0.0%	0.0%
Atm. Deposition							0.008	0.003	0.011	0.001				
	Total Load Allocation						1.166	0.019	0.821	0.017	5.942			

Addendum
Revisions to
Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

In August 2002, Region III (Philadelphia, PA) office of the U. S. Environmental Protection Agency (EPA) established Total Maximum Daily Loads (TMDLs) for nutrients and dissolved oxygen (DO) under low-flow conditions in the Christina River Basin. The August 2002 TMDL was a revision of the original low-flow TMDL established on January 19, 2001.

In the August 2002 TMDL, incorrect allocations were included for the small National Pollutant Discharge Elimination System (NPDES) discharges. Also, additional information has become available for NPDES point source discharges and instream phosphorus kinetics, which prompted this revision to the low-flow TMDL. The updated NPDES information is summarized in Table 1. A discussion of the instream phosphorus kinetics follows Table 2.

The proposed revisions to carbonaceous biochemical oxygen demand (CBOD5), total nitrogen, ammonia nitrogen, phosphorus, and effluent concentrations are listed in Table 2 for the small NPDES discharges, having flow rates between 400 and 10,000 gallons per day (gpd). These concentrations are typical treatment levels for small facilities. The water quality model indicates that these proposed revisions to the effluent quality of the small discharge NPDES facilities are protective of water quality standards in all stream reaches in the Christina River Basin model.

Table 1. List of updated NPDES information for Christina River Basin

NPDES Permit	Name (Stream Location)	Description of Change
PA0012416	PA American Water (Rock Run)	New owner (previously owned by Coatesville)
PA0011568-001	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)
PA0011560-016	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)
PA0055492	Andrew and Gail Woods (Indian Run)	New owners (previously owned by John and Jane Topp
PA0051365	PA American Water (E. Br. Brandywine Cr.)	New owner (previously owned by West Chester Area Municipal Authority)
PA0026531	Downingtown Area WWTP (E. Br. Brandywine Cr.)	Flow increase from 7.134 to 7.500 mgd
PA0244031	Chadds Ford Township (Brandywine Cr.)	Replaces PA0047252 (Pantos Corp.). Flow increase from 0.07 to 0.15 mgd
PA0055085	Nancy Winslow (Brandywine Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0036161	Lincoln Crest MHP (Buck Run)	Active during 1994-98 calibration period. No longer exists.
PA0053937	William and Patricia Kratz (Broad Creek)	New owners (previously owned by Ralph and Gayla Johnson)
PA0056952	Sun Company, Inc. (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0052019	Avon Grove Trailer Court (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0029343	Chatham Acres (E.Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0057720-001	Sunny Dell Foods, Inc. (W. Br. Red Clay Cr.)	Flow increase from 0.05 to 0.072 mgd

Table 2. Revisions to NPDES small discharger permit limits

Facility Name	Facility NPDES	Flow mgd	Estimated permit limits used in Low-Flow TMDL					Revised permit limits from PA DEP				
			CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L
Buck Run												
Lincoln Crest Mobile Home Park	PA0036161	0.036	25	2.6	6.29	2	5	No longer active				
Shearer	PA0057231	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Brandywine Creek West Branch												
M. Redmond	PA0053996	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
J. Gramm	PA0053228	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
R. Woodward	PA0053236	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
R. Vreeland	PA0056073	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
R. Mitchell	PA0052990	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Farmland	PA0052728	0.0004	25	1.5	3.63	2	2	25	10	20	10	6
Davidson	PA0057339	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Brandywine Creek East Branch												
McGlaughlin	PA0056171	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Trans-Materials	PA0054747	0	15	1.5	3.63	2	5	Cancelled				
Pope	PA0057282	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Johnson	PA0053937	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Khalife, Paul	PA0055531	0.0007	25	1.5	3.63	2	3	25	10	20	10	6
Hughes	PA0057274	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Unknown	PA0050229	0.0005	10	1.5	3.63	2	6	Delete				
McKenna (new)	PA0057827	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Topp	PA0055492	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Stoltzfus	PA0054691	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Brandywine Creek (main stem)												
Winslow, Nancy	PA0055085	0.0005	10	1.5	3.63	2	6	No longer active				
Keating	PA0055484	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Unionville-Chaddsford	PA0030848	0.0063	25	1.5	3.63	2	3	25	80	90	20	3
Schindler	PA0056120	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Red Clay Creek												
D'Ambro	PA0055425	0.0005	10	1.5	3.63	2	6	25	10	20	10	6
Trans-Materials	PA0054755	0	15	1.5	3.63	2	5	Cancelled				
White Clay Creek East Branch												
Hamilton Oates	PA0052451	0.0012	25	20	48.4	2	2	25	10	20	10	6
Avon Grove Trailer Court	PA0052019	0.0075	25	6	14.52	2	6	No longer active				
Sun Co.	PA0056952	0.0029	30	0.5	4.65	0.3	5	No longer active				
Chadds Ford Inn	PA0040436	0.009	20	3	7.26	2	5	25	10	20	2	6
Stone Barn	PA0040665	0.01	20	3	7.26	2	5	25	10	20	2	6

The water quality model used for the original TMDL was calibrated using a phosphorus half-saturation constant for periphyton growth (KHPm) of 0.132 mg/L, which was based on a laboratory algal assay of limited field measurements (Davis, 1998) in four streams (East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and East Branch White Clay Creek). The field data from the four streams were lumped together to

develop the KHPm constant. The KHPm constant derived from the algal assay was about 26 times higher than the typical value of 0.005 mg/L found in the literature. Knorr and Fairchild (1987) conducted a field investigation on the East Branch Brandywine Creek in which periphyton biomass was measured at six locations during the period July 15 through August 7, 1985. Following establishment of the August 2002 TMDL, discussions with the investigators of the Knorr and Fairchild study revealed that a KHPm constant of 0.005 mg/L would be more appropriate for East Branch Brandywine Creek. Therefore, a KHPm constant of 0.005 mg/L was used in the water quality model for East Branch Brandywine Creek for this proposed revision to the low-flow TMDL. A KHPm value of 0.132 mg/L was used for all other stream reaches in the model.

No other changes are being proposed nor have any changes been made to the technical analysis and modeling used as the basis to develop the Christina River Basin low-flow TMDLs. The Delaware daily average DO freshwater criteria is applicable all year rather than from June through September as stated in the August 2002 TMDL (see Table 5[1]). No changes have been made to the TMDL endpoints used in the TMDL analysis. These proposed revisions are sufficient to protect water quality standards. The following tables and text describing the Level 1 and Level 2 allocation analysis contain the revised TMDL allocation revisions, and supersede the tables and text in the August 2002 TMDL Report.

Table 5.[1] Summary of Applicable Use Designations and DO Criteria

Agency	Designated Use	D.O. Criteria (mg/L)		Comments
		Daily avg.	Minimum	
DEP	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	
	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 from Apr 01 to Jun 15 and Sep 16 to Dec 31

[1] The numbers of Table 5 and following tables correspond to table numbers in the 2002 TMDL Report.

Table 8. TMDL Summary by Subwatershed for Christina River Basin

Sum of Individual Waste Load Allocations					
	CBOD5	**NH3-N**	**TN**	**TP**	**DO**
Subwatershed	**lb/day**	**lb/day**	**lb/day**	**lb/day**	**lb/day**
Brandywine Creek main stem	77.70	21.30	73.51	9.46	32.47
Brandywine Creek East Branch	1,082.22	176.62	3,811.63	167.59	541.36
Brandywine Creek West Branch	600.47	124.87	1,240.87	69.70	257.00
Buck Run	0.10	0.13	0.17	0.04	0.03
Brandywine Creek Watershed	**1,760.50**	**322.92**	**5,126.18**	**246.79**	**830.84**
Christina River West Branch	75.56	13.57	63.84	6.26	37.55
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.56**	**13.57**	**63.84**	**6.26**	**37.55**
Burroughs Run	0.10	0.13	0.17	0.04	0.03
Red Clay Creek West Branch	162.85	19.60	98.49	13.18	72.27
Red Clay Creek main stem	108.95	5.17	19.32	6.79	112.11
Red Clay Creek Watershed	**271.91**	**24.90**	**117.97**	**20.01**	**184.41**
White Clay Cr. Middle Branch	53.83	10.52	25.91	4.51	11.27
White Clay Cr. East Branch	82.77	8.64	149.13	10.73	14.74
Muddy Run	0.00	0.00	0.00	0.00	0.00
Pike Creek	0.00	0.00	0.00	0.00	0.00
Mill Creek	0.00	0.00	0.00	0.00	0.00
White Clay Cr. main stem	0.75	0.03	0.06	0.03	1.25
White Clay Creek Watershed	**137.35**	**19.18**	**175.10**	**15.26**	**27.26**
Total Waste Load Allocation for Christina River Basin	**2,245.31**	**380.57**	**5,483.10**	**288.32**	**1,080.06**

Table 8 (continued). TMDL Summary by Subwatershed for Christina River Basin

Sum of Load Allocations					
Subwatershed	**CBOD5 lb/day**	**NH3-N lb/day**	**TN lb/day**	**TP lb/day**	**DO lb/day**
Brandywine Creek main stem	52.01	1.78	137.29	1.50	497.89
Brandywine Creek East Branch	162.32	3.85	247.98	3.35	1,333.80
Brandywine Creek West Branch	99.17	3.08	262.91	2.77	958.30
Buck Run	34.71	0.96	92.44	0.94	338.71
Brandywine Creek Watershed	**348.20**	**9.67**	**740.61**	**8.55**	**3,128.70**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.26	0.52	25.38	0.51	186.00
Christina River main stem	34.99	1.65	26.85	0.86	163.06
Christina River Watershed	**72.42**	**2.19**	**53.05**	**1.38**	**355.01**
Burroughs Run	4.60	0.10	9.09	0.21	33.65
Red Clay Creek West Branch	20.01	0.40	39.61	0.90	146.85
Red Clay Creek main stem	40.10	0.91	79.24	1.83	291.97
Red Clay Creek Watershed	**64.70**	**1.40**	**127.94**	**2.94**	**472.47**
White Clay Cr. Middle Branch	20.75	0.65	58.02	0.65	237.93
White Clay Cr. East Branch	23.34	0.73	65.27	0.73	267.63
Muddy Run	3.21	0.10	8.97	0.10	36.79
Pike Creek	5.53	0.17	15.46	0.17	63.40
Mill Creek	7.59	0.24	21.23	0.24	87.06
White Clay Cr. main stem	17.61	0.55	49.25	0.55	201.96
White Clay Creek Watershed	**78.02**	**2.44**	**218.21**	**2.44**	**894.76**
Total LA for Christina River Basin	563.34	15.70	1,139.81	15.31	4,850.94
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	**2,808.65**	**396.27**	**6,622.90**	**303.63**	**5,931.01**

Level 1 Allocation Results - Baseline Allocations

The first level of the size-based equal marginal percent removal (EMPR) allocation considered each NPDES discharger individually to determine if water quality standards (WQS) for DO were met. First, all dischargers were set to the baseline conditions in Table 9. This allowed the in-stream flow to remain at 7Q10[2] levels and created no net impact on water quality from the point sources not being considered individually. Then, one at a time, each facility was set to its permit limits and a model run was made starting with the small discharger group. If WQS were not met, then CBOD, nitrogen and phosphorus limits for the individual point source were reduced in five percent increments until standards were achieved.

Of the 89[3] NPDES point sources located in the Christina River Basin, 76 of them are small, with flow rates of 0.25 mgd or less, or are groundwater cleanup discharges, water filtration plant backwash facilities, or non-contact cooling water discharges. In order to avoid making 76 individual model runs to determine whether a Level 1 allocation was needed, all the small NPDES discharges with limits shown in Table 2 or their individual permit limits were grouped into a single model run. The model results for this run indicated that the WQS for daily average and minimum DO were protected at all locations in the Christina River Basin. Thus, if as a group there were no violations of the DO standard for the small dischargers, then individually there would be no violations.

Table 9. Baseline Concentrations of Nitrogen and Phosphorus for Christina Basin TMDL

Subwatershed	Total Nitrogen (mg/L)		Total Phosphorus (mg/L)	
	Baseline	Omernik (1977) (67% range)	Baseline	Omernik (1977) (67% range)
Main Stem and East Branch Brandywine Creek	1.56	0.33 - 6.64	0.01	0.008 - 0.251
West Branch Brandywine Creek	2.44	0.33 - 6.64	0.03	0.008 - 0.251
Red Clay Creek	2.65	0.33 - 6.64	0.05	0.008 - 0.251
White Clay Creek	2.31	0.33 - 6.64	0.02	0.008 - 0.251
Christina River	1.08	0.33 - 6.64	0.02	0.008 - 0.251

Source: STORET data 1988-1998 and Nonpoint Source Stream Nutrient Level Relationships (Omerrnik, 1977)

Next, the remaining 13 large NPDES dischargers were analyzed individually. Of these 13, only three indicated violations of the DO standards:

(1) PA0026531 (Downingtown) on the East Branch Brandywine Creek (minimum DO standard only),
(2) PA0026859 (Coatesville City) on the West Branch Brandywine Creek (daily average and minimum DO standards), and
(3) PA0024058 (Kennett Square) on West Branch Red Clay Creek (daily average and minimum DO standards).

[2] Notation for a seven-day low flow occurring on average once every 10 years.
[3] In 2002 there were 99 NPDES facilities in the Christina Basin. Several facilities no longer discharge reducing the number of active facilities to 89.

These violations are shown on Figures 11 and 12. Analysis for a fourth facility,

(4) MD0022641 - Meadowview Utilities on West Branch Christina River,

indicated EPA water quality criteria for ammonia nitrogen (US EPA 1998; subsequently adopted by the state of Maryland) was not being protected, and was, therefore, also included in the Level 1 allocations. The Level 1 load reductions necessary to achieve compliance with the WQS for these facilities are shown in Table 10.

Table 10. Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0026531	7.5	10	2.0	2.0	8.90	1.78	2.00	11%	11%	0%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	12.30	2.00	1.64	18%	0%	18%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	17.50	2.10	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.00	1.00	0%	69%	0%

* no permit limits, values shown are based on monitoring data
** value shown is BOD5; MD permits list BOD5 instead of CBOD5

PA0026531 - Downingtown Area Regional Authority
PA0026859 - Coatesville City Authority
PA0024058 - Kennett Square
MD0022641- Meadowview Utilities, Inc.

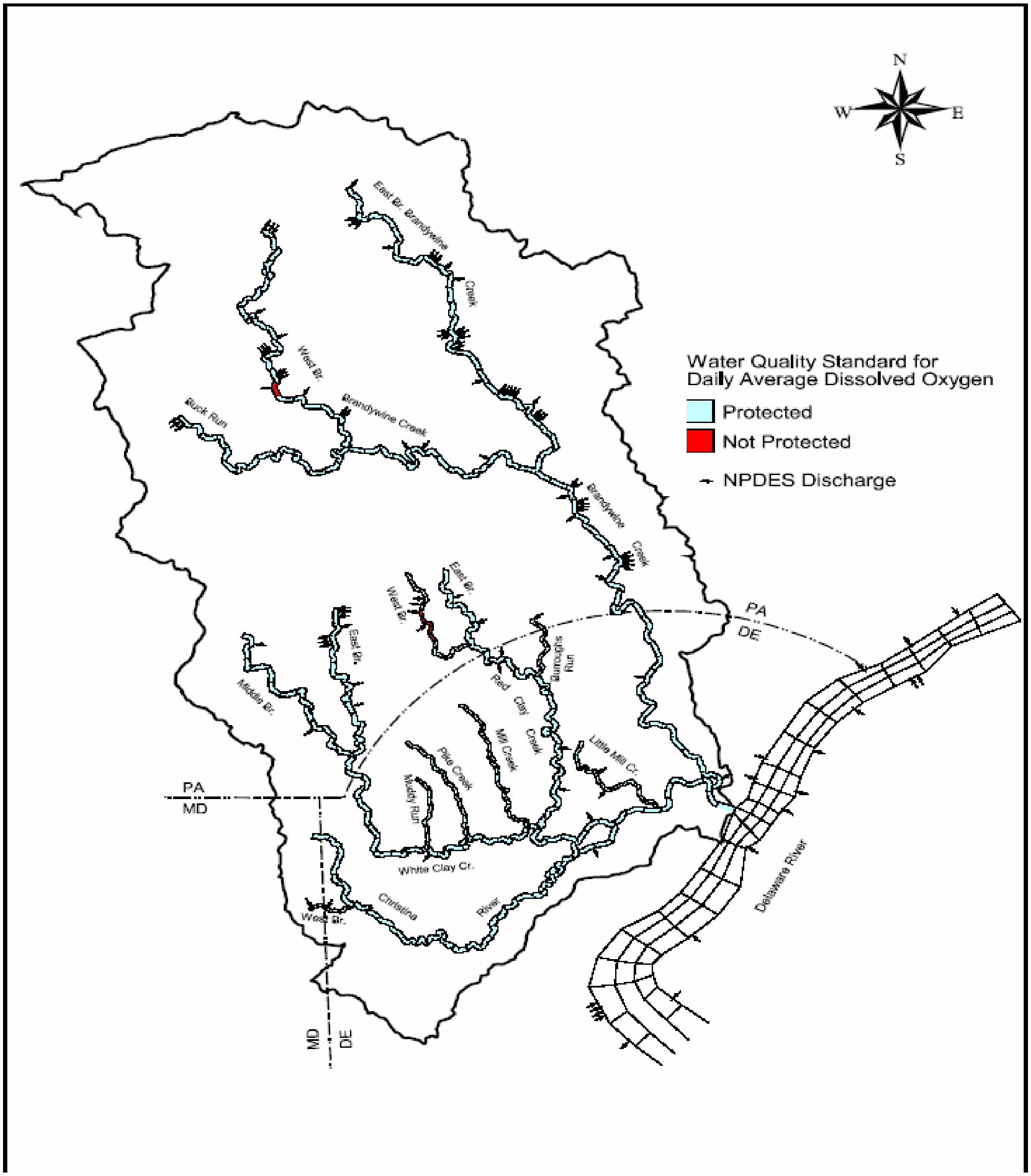

Figure 11. Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on the Level 1 allocation analysis.

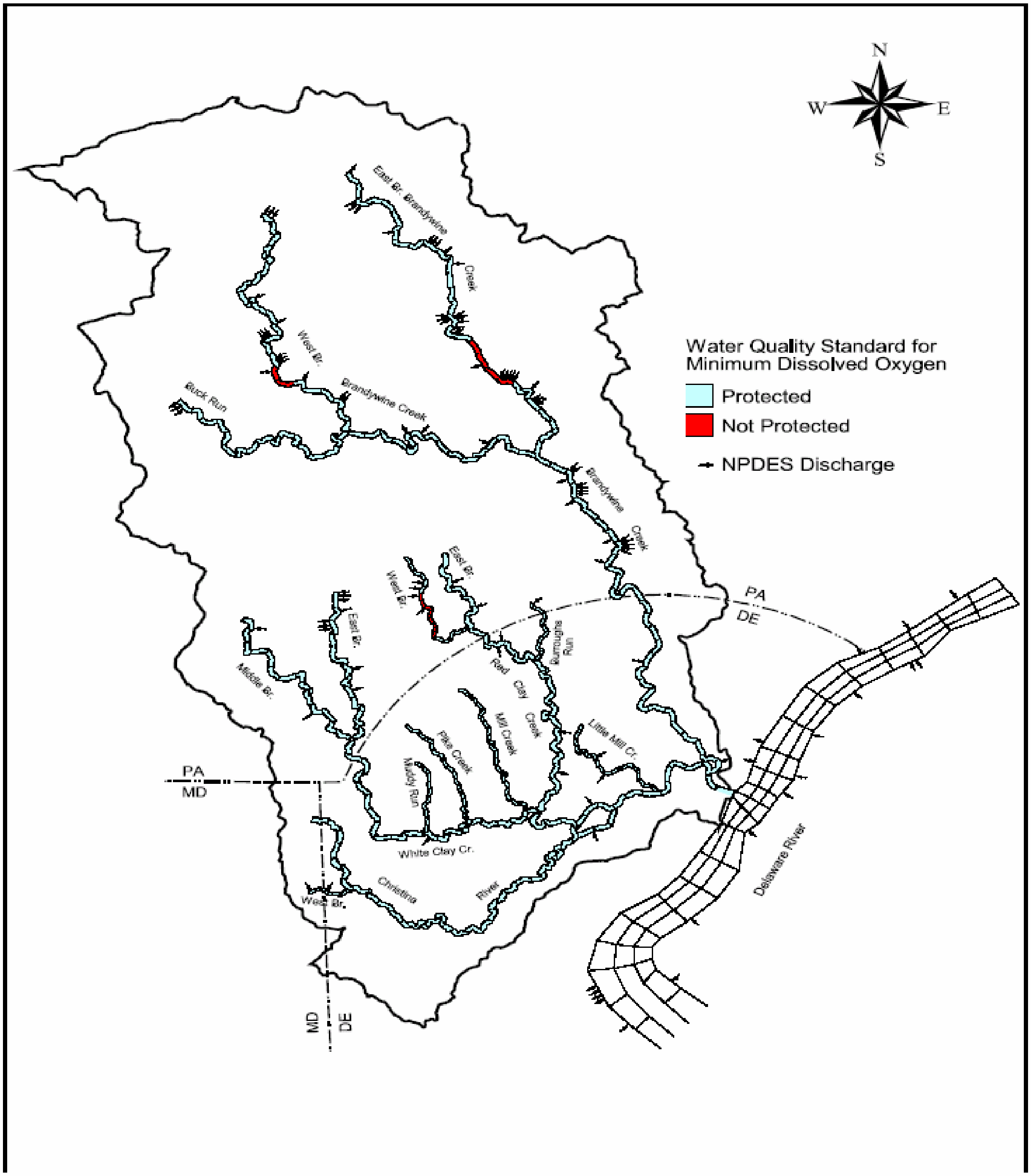

Figure 12. Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 1 allocation analysis.

Level 2 Allocation Results

In the second level of the size-based EMPR allocation strategy, the cumulative effect of the dischargers is determined by adding facilities one at a time back to the model based on the size of Level 1 baseline CBOD load (lb/day), and WLAs were performed for those stream segments indicating violations of the DO WQS. The daily average and minimum DO results of the initial Level 2 run are shown in Figures 13 and 14. The DO WQS are not being met in the East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek and the tidal portion of the Christina River with the two largest dischargers added to each of these stream reaches. The allocation proceeded by running the water quality model in an iterative fashion by reducing CBOD, NH3-N, and TP in five percent intervals for all NPDES dischargers upstream of the farthest downstream model grid cell indicating a DO violation. Once WQS were achieved at the five percent increment level, the allocations were fine tuned in one percent increments. After the allocations were fine tuned, the next largest discharger was added to the stream reach and the process was repeated until all dischargers were included in the analysis.

No allocations were needed for point sources on the main stem Brandywine Creek after bringing the East and West Branches, located upstream, into compliance with WQS. The Level 2 allocation results are presented in Table 11 and are shown in Figures 15 and 16. At Level 2, there are no violations of the daily average or minimum DO criteria inside the Christina River Basin.

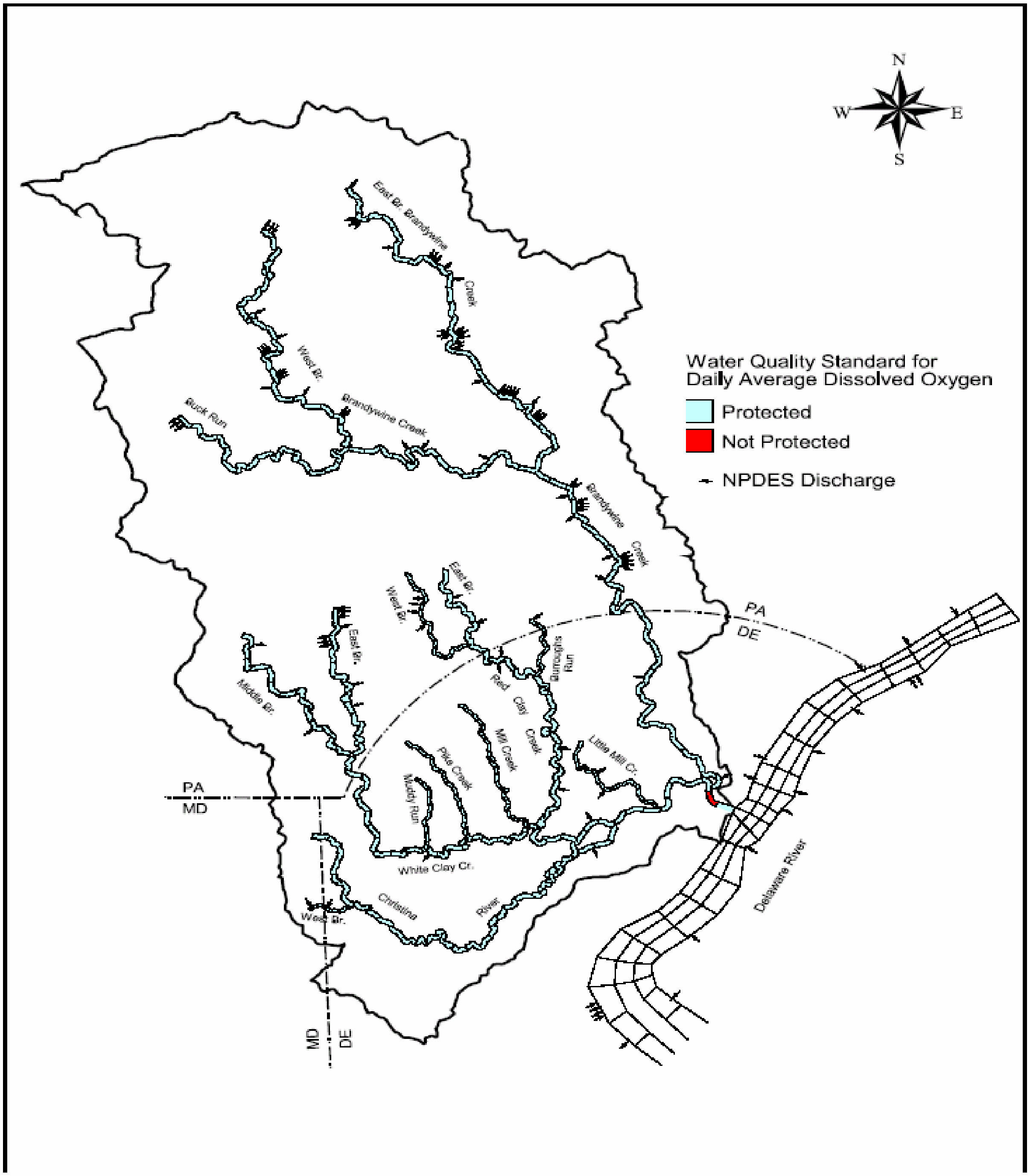

Figure 13. Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on Level 2 allocation analysis.

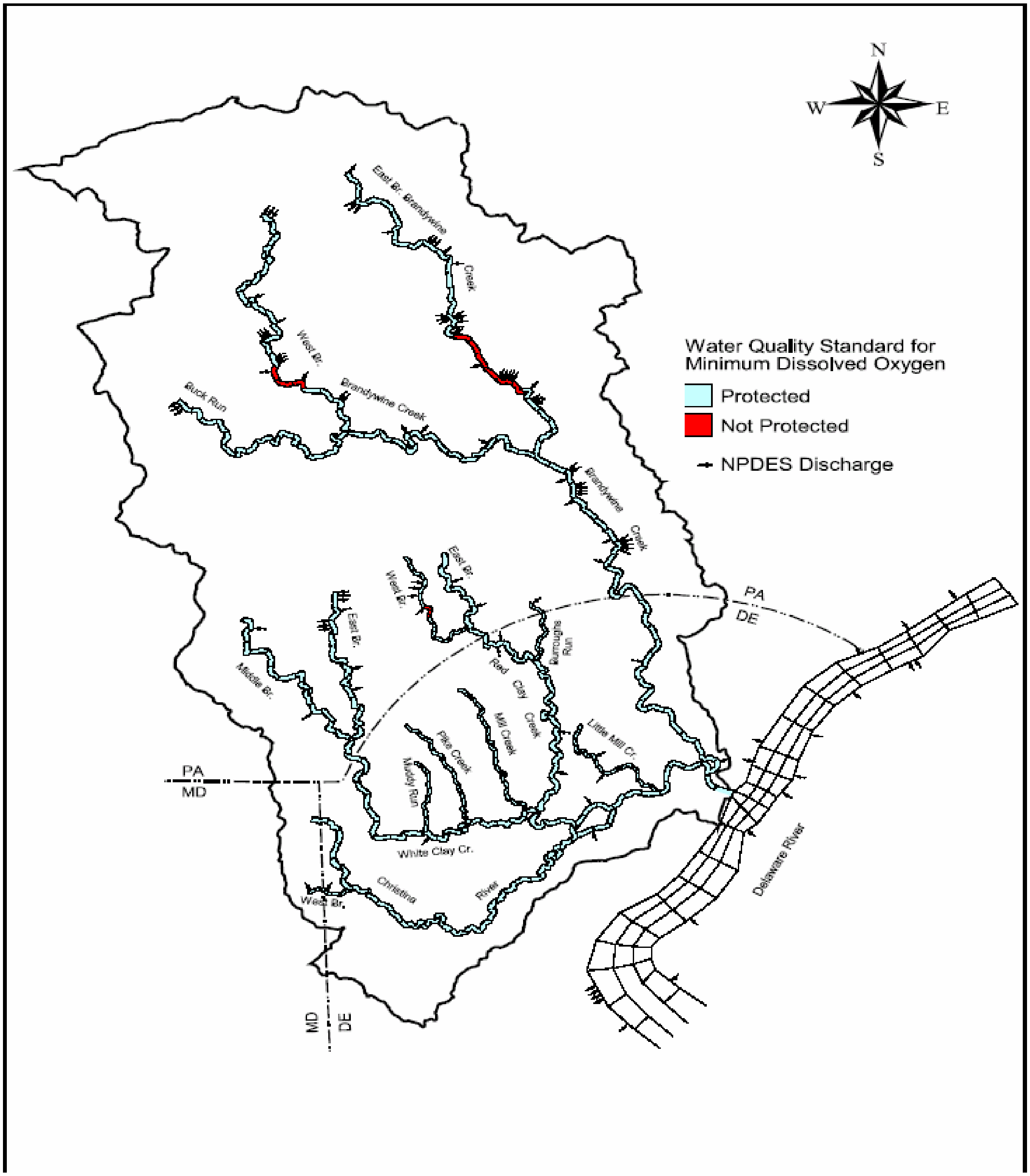

Figure 14. Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 2 allocation analysis.

Table 11. Level 2 Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0043982	0.4	25	2.0*	2.0	21.75	2.00	1.74	13%	0%	13%
PA0012815	1.028	34	6.0	1.0	25.14	4.44	0.74	26%	26%	26%
PA0026531	7.5	10	2.0	2.0	7.00	1.50	2.0	30%	25%	0%
West Branch Brandywine Creek										
PA0026859 **	3.85	15	2.0	2.0	11.07	2.00	1.48	28%	0%	28%
PA0044776	0.6	15	3.0	2.0	13.5	2.70	1.80	10%	10%	10%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.50	1.98	1.28	34%	34%	83%
PA0057720-001	0.072	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

* no permit limits, values shown are based on typical characteristics or monitoring data
** allocation did not change from Level 1 allocation
*** value shown is BOD5; MD permits list BOD5 instead of CBOD5

PA0026531 - Downingtown Area Regional Authority
PA0024058 - Kennett Square
PA0043982 - Broad Run Sewer Co.
PA0057720-001 - Sunny Dell Foods, Inc.
PA0026859 - PA American Water Company
MD0022641- Meadowview Utilities, Inc.
PA0012815 - Sonoco Products
PA0044776 - NW Chester Co. Municipal Authority

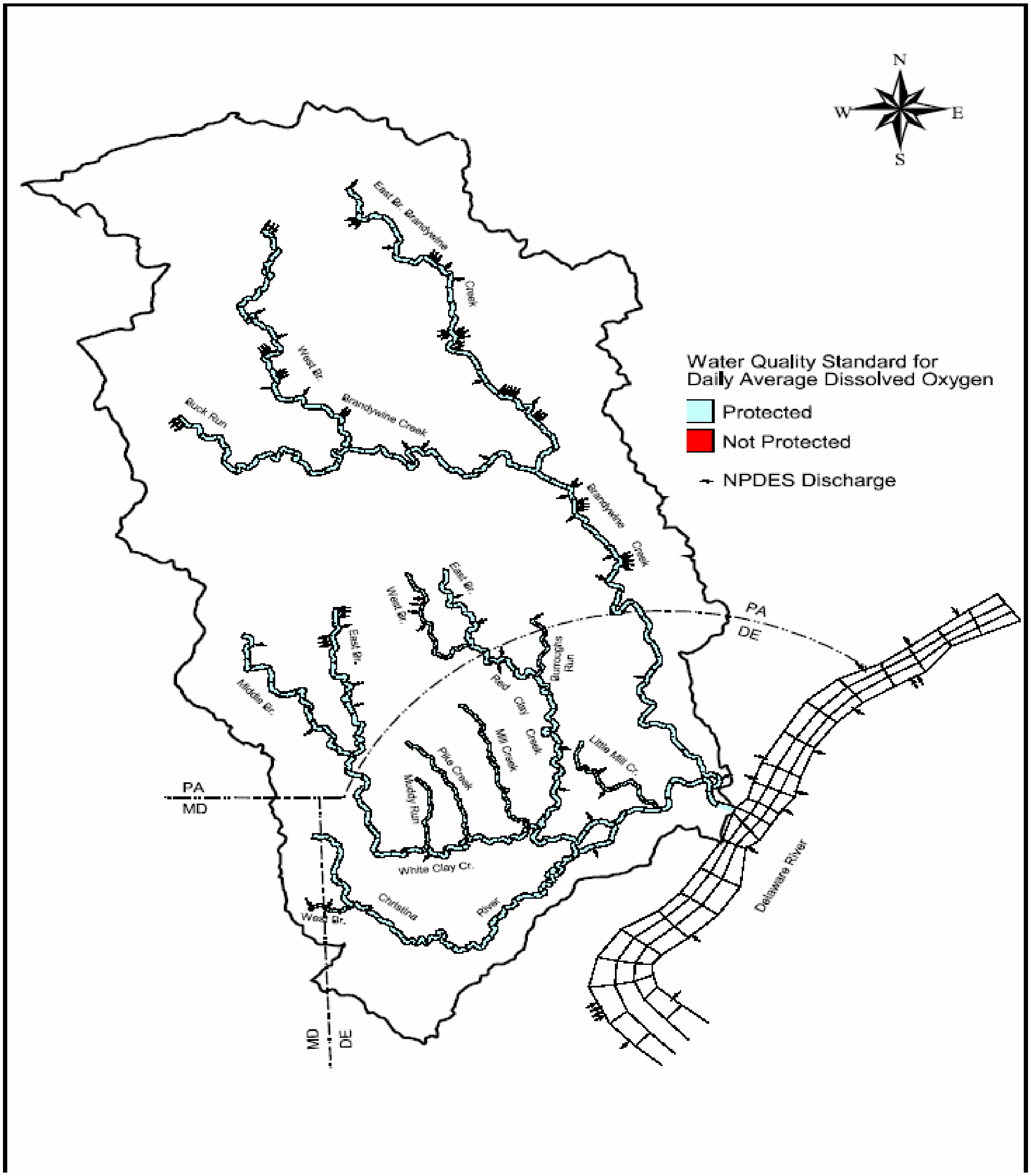

Figure 15. Final Level 2 allocation analysis results which indicate no violations of daily average dissolved oxygen water quality criteria in modeled stream segments.

Permits

The TMDL load reductions shown in this addendum 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 WLAs within an impaired waterbody segment. It is anticipated that any re-allocation of the WLA would be done as part of the NPDES permitting to allow for public participation.

Stormwater permits identified in Table 2, Locations of NPDES point source discharges included in the model, in the *Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland* Report, 2002, are not affected by these low-flow TMDLs. Any stormwater permit WLAs are based on the high-flow TMDLs. See *Revision to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen in the Christina River Basin Watershed, Pennsylvania, Delaware, and Maryland*, 2006, and *Revision to Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Basin Watershed, Pennsylvania, Delaware, and Maryland*, 2006.

Pennsylvania permits PA0054305, PA0053678, and PA0053660 are industrial permits which are assumed to be stormwater permits and are not affected by these TMDLs. A groundwater remediation permit, PA0057126, is assumed not to add nutrients treated groundwater.

Summary

The following tables identify the permitted point source WLAs and nonpoint source load allocations by subbasin.

Table 12. TMDL Summary for Buck Run

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0057231	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.104	0.125	0.167	0.042	0.025			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B05	4.70	0.75	0.02	2.00	0.02	7.34	19.008	0.507	50.687	0.507	186.023	0.0%	0.0%	0.0%
B06	3.86	0.75	0.02	2.00	0.02	7.34	15.602	0.416	41.604	0.416	152.688	0.0%	0.0%	0.0%
Atm. Deposition							0.103	0.038	0.148	0.013				
Total	Total Load Allocation						34.712	0.961	92.440	0.936	338.711			

Table 13. TMDL Summary for Brandywine Creek West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0056561	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0029912	0.1000	25.00	20.00	48.40	2.00	3.00	20.864	16.691	40.392	1.669	2.504	0.0%	0.0%	0.0%
PA0053996	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0053228	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0053236	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0036897	0.3900	25.00	7.00	30.00	2.00	2.00	81.368	22.783	97.641	6.509	6.509	0.0%	0.0%	0.0%
PA0026859	3.8500	11.07	2.00	30.00	1.48	5.00	355.677	64.260	963.894	47.552	160.649	26.2%	0.0%	26.2%
PA0011568-001	0.6400	5.00	0.50	5.30	0.30	5.00	26.705	2.671	28.308	1.602	26.705	0.0%	0.0%	0.0%
PA0011568-016	0.5045	5.00	0.50	12.00	0.30	5.00	21.051	2.105	50.523	1.263	21.051	0.0%	0.0%	0.0%
PA0053821	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0056073	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0012416	0.1400	10.00	0.10*	0.24*	0.10*	5.00	11.684	0.117*	0.280*	0.117*	5.842	0.0%	0.0%	0.0%
PA0052990	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0052728	0.0004	25.00	10.00	24.20	10.00	6.00	0.083	0.033	0.081	0.033	0.020	0.0%	0.0%	0.0%
PA0055697	0.0490	25.00	1.50	10.00	2.00	3.00	10.223	0.613	4.089	0.818	1.227	0.0%	0.0%	0.0%
PA0036412	0.0550	10.00	2.90	10.00	1.90	5.00	4.590	1.331	4.590	0.872	2.295	0.0%	0.0%	0.0%
PA0044776	0.6000	13.50	2.70	10.00	1.80	6.00	67.598	13.520	50.072	9.013	30.043	10.0%	10.0%	10.0%
PA0057339	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						600.468	124.874	1240.872	69.700	256.996			

*Effluent concentration minus influent concentration.

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B01	6.17	0.75	0.020	2.00	0.020	7.34	24.943	0.665	66.514	0.665	244.106	0.0%	0.0%	0.0%
B02	9.06	0.75	0.020	2.00	0.020	7.34	36.655	0.977	97.747	0.977	358.731	0.0%	0.0%	0.0%
B03	4.96	0.75	0.020	2.00	0.020	7.34	20.056	0.535	53.484	0.535	196.285	0.0%	0.0%	0.0%
B04	2.92	0.75	0.020	2.00	0.020	7.34	11.815	0.315	31.507	0.315	115.631	0.0%	0.0%	0.0%
B07	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.866	0.119	43.549	0.0%	0.0%	0.0%
Atm. Deposition							1.249	0.467	1.790	0.159				
	Total Load Allocation						99.168	3.078	262.908	2.770	958.302			

Table 14. TMDL Summary for Brandywine Creek East Branch

NPDES	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
Waste Load Allocations														
PA0056171	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0026018	1.5000	25.00	2.50	10.00	2.00	5.00	312.953	31.295	125.181	25.036	62.591	0.0%	0.0%	0.0%
PA0057282	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0051365	0.3690	2.00	0.10	0.24	0.10	5.00	6.159	0.308	0.739	0.308	15.397	0.0%	0.0%	0.0%
PA0053937	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0056324	0.0440	2.00	0.04	2.10	0.11	5.00	0.734	0.015	0.771	0.040	1.836	0.0%	0.0%	0.0%
PA0056618	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0054305	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053561	0.0360	2.00	0.04	2.10	0.11	5.00	0.601	0.012	0.631	0.033	1.502	0.0%	0.0%	0.0%
PA0043982	0.4000	21.75	2.00	45.00	1.74	2.00	72.605	6.676	150.217	5.808	6.676	13.0%	0.0%	13.0%
PA0012815	1.0280	25.14	4.44	41.26	0.74	5.00	215.678	38.091	353.973	6.349	42.895	26.1%	26.1%	26.1%
PA0026531	7.5000	7.00	1.50	50.00	2.00	6.00	438.134	93.886	3129.526	125.181	375.543	30.0%	25.0%	0.0%
PA0030228	0.0225	7.00	1.00	10.00	3.00	5.00	1.314	0.188	1.878	0.563	0.939	0.0%	0.0%	0.0%
PA0051918	0.1440	2.00	0.10	0.24	0.10	5.00	2.403	0.120	0.288	0.120	6.009	0.0%	0.0%	0.0%
PA0053678	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053660	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0055531	0.0007	25.00	10.00	24.20	10.00	6.00	0.146	0.058	0.141	0.058	0.035	0.0%	0.0%	0.0%
PA0057126	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0054917	0.4750	5.89	0.78	10.00	0.78	6.00	23.348	3.092	39.641	3.092	23.784	0.0%	0.0%	0.0%
PA0057045	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0036374	0.0150	10.00	0.50	10.00	0.50	5.00	1.252	0.063	1.252	0.063	0.626	0.0%	0.0%	0.0%
PA0052949	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0057274	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0050458	0.0351	10.00	3.00	10.00	1.00	6.00	2.929	0.879	2.929	0.293	1.758	0.0%	0.0%	0.0%
PA0057827	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0050547	0.0375	10.00	3.00	10.00	1.00	5.00	3.130	0.939	3.130	0.313	1.565	0.0%	0.0%	0.0%
PA0055492	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0054691	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						1082.221	176.623	3811.632	167.592	541.356			
Load Allocations														
Subwatershed	Flow cfs	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
B08	12.43	0.89	0.020	1.36	0.018	7.34	59.679	1.341	91.195	1.207	492.186	0.0%	0.0%	0.0%
B09	3.02	0.89	0.020	1.36	0.018	7.34	14.502	0.326	22.161	0.293	119.602	0.0%	0.0%	0.0%
B10	3.99	0.89	0.020	1.36	0.018	7.34	19.170	0.431	29.294	0.388	158.100	0.0%	0.0%	0.0%

	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B11	5.62	0.89	0.020	1.36	0.018	7.34	27.000	0.607	41.258	0.546	222.671	0.0%	0.0%	0.0%
B12	5.09	0.89	0.020	1.36	0.018	7.34	24.445	0.549	37.355	0.494	201.606	0.0%	0.0%	0.0%
B13	3.53	0.89	0.020	1.36	0.018	7.34	16.931	0.380	25.872	0.342	139.635	0.0%	0.0%	0.0%
Atm Deposition							0.589	0.220	0.843	0.075				
	Total Load Allocation						162.317	3.854	247.978	3.346	1333.800			

Table 15. TMDL Summary for Brandywine Creek Main Stem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0050962	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0021768	0.0250	15.00	1.50	10.00	2.00	5.00	3.130	0.313	2.086	0.417	1.043	0.0%	0.0%	0.0%
PA0053082	0.0206	10.00	3.00	10.00	2.00	5.00	1.719	0.516	1.719	0.344	0.860	0.0%	0.0%	0.0%
PA0052663	0.0900	10.00	1.00	10.00	2.00	5.00	7.511	0.751	7.511	1.502	3.755	0.0%	0.0%	0.0%
PA0055476	0.0400	10.00	3.00	10.00	2.00	3.00	3.338	1.001	3.338	0.668	1.001	0.0%	0.0%	0.0%
PA0244031	0.1500	10.00	1.50	10.00	0.50	6.00	12.518	1.878	12.518	0.626	7.511	0.0%	0.0%	0.0%
PA0055484	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0030848	0.0063	25.00	80.00	90.00	20.00	3.00	1.314	4.206	4.732	1.052	0.158	0.0%	0.0%	0.0%
PA0056120	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
PA0031097	0.0170	25.00	20.00	48.40	2.00	5.00	3.547	2.837	6.867	0.284	0.709	0.0%	0.0%	0.0%
PA0053449	0.1500	15.00	1.50	10.00	2.00	5.00	18.777	1.878	12.518	2.504	6.259	0.0%	0.0%	0.0%
PA0057011	0.0773	25.00	3.50	10.00	2.00	5.00	16.127	2.258	6.451	1.290	3.225	0.0%	0.0%	0.0%
PA0036200	0.0320	25.00	20.00	48.40	2.00	3.00	6.676	5.341	12.925	0.534	0.801	0.0%	0.0%	0.0%
PA0050005	0.1400	2.00	0.04	2.10	0.11	5.00	2.337	0.047	2.454	0.129	5.842	0.0%	0.0%	0.0%
PA0051497	0.0300	2.00	0.10	0.24	0.10	5.00	0.501	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	Total Waste Load Allocation						77.704	21.301	73.513	9.457	32.467			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B14	2.92	0.75	0.020	2.00	0.020	7.34	11.815	0.315	31.507	0.315	115.631	0.0%	0.0%	0.0%
B15	4.70	0.75	0.020	2.00	0.020	7.34	19.008	0.507	50.687	0.507	186.023	0.0%	0.0%	0.0%
B16	3.86	0.75	0.020	2.00	0.020	7.34	15.602	0.416	41.604	0.416	152.688	0.0%	0.0%	0.0%
B17	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.866	0.119	43.549	0.0%	0.0%	0.0%
Atm. Deposition							1.131	0.422	1.620	0.144				
	Total Load Allocation						52.005	1.779	137.285	1.501	497.891			

Table 16. TMDL Summary for Burroughs Run

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0055425	0.0005	25.00	30.00	40.00	10.00	6.00	0.104	0.125	0.167	0.042	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.104	0.125	0.167	0.042	0.025			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R03	0.85	1.00	0.02	1.98	0.05	7.34	4.584	0.092	9.077	0.206	33.648	0.0%	0.0%	0.0%
Atm. Deposition							0.013	0.005	0.018	0.002				
	Total Load Allocation						4.597	0.097	9.095	0.208	33.648			

Table 17. TMDL Summary for Red Clay Creek West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0053554	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0024058	1.1000	16.50	1.98	10.00	1.28	6.00	151.469	18.176	91.799	11.750	55.080	34.0%	34.0%	83.0%
PA0050679	0.2500	2.00	0.10	0.24	0.10	5.00	4.173	0.209	0.501	0.209	10.432	0.0%	0.0%	0.0%
PA0057720-001	0.0720	9.50	1.90	10.00	1.90	5.00	5.708	1.142	6.009	1.142	3.004	5.0%	5.0%	5.0%
PA0057720-002	0.0900	2.00	0.10	0.24	0.10	5.00	1.502	0.075	0.180	0.075	3.755	0.0%	0.0%	0.0%
	Total Waste Load Allocation						162.852	19.602	98.489	13.176	72.271			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R01	3.71	1.00	0.020	1.98	0.045	7.34	20.007	0.400	39.614	0.900	146.852	0.0%	0.0%	0.0%
Atm. Deposition							0.044	0.016	0.063	0.006				
	Total Load Allocation						20.051	0.416	39.677	0.906	146.852			

Table 18. TMDL Summary for Red Clay Creek Main Stem and East Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000230	0.3500	7.00	0.10	0.24	0.10	5.00	20.446	0.292	0.701	0.292	14.604	0.0%	0.0%	0.0%
DE0021709	0.0150	20.00	1.50	10.00	2.00	5.00	2.504	0.188	1.252	0.250	0.626	0.0%	0.0%	0.0%
DE0050067	0.0015	30.00	30.00	40.00	10.00	6.00	0.376	0.376	0.501	0.125	0.075	0.0%	0.0%	0.0%
DE0000451	2.1700	3.00	0.10	0.24	0.20	5.00	54.329	1.811	4.346	3.622	90.548	0.0%	0.0%	0.0%
PA0055107	0.1500	25.00	2.00	10.00	2.00	5.00	31.295	2.504	12.518	2.504	6.259	0.0%	0.0%	0.0%
	Total Waste Load Allocation						108.949	5.170	19.318	6.793	112.112			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R02	1.39	1.00	0.020	1.98	0.045	7.34	7.499	0.150	14.849	0.337	55.046	0.0%	0.0%	0.0%
R04	1.37	1.00	0.020	1.98	0.045	7.34	7.386	0.148	14.625	0.332	54.215	0.0%	0.0%	0.0%
R05	3.62	1.00	0.020	1.98	0.045	7.34	19.528	0.391	38.665	0.879	143.333	0.0%	0.0%	0.0%
HOOPES	1.00	1.00	0.020	1.98	0.045	7.30	5.394	0.108	10.680	0.243	39.375	0.0%	0.0%	0.0%
Atm. Deposition							0.291	0.109	0.417	0.037				
	Total Load Allocation						40.098	0.905	79.235	1.828	291.968			

Table 19. TMDL Summary for White Clay Creek Middle Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0053783	0.0200	10.00	3.00	10.00	2.00	5.00	1.669	0.501	1.669	0.334	0.835	0.0%	0.0%	0.0%
PA0024066	0.2500	25.00	4.80	11.62	2.00	5.00	52.159	10.014	24.243	4.173	10.432	0.0%	0.0%	0.0%
	Total Waste Load Allocation						53.828	10.515	25.912	4.507	11.266			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W01	2.35	0.64	0.02	1.79	0.02	7.34	8.113	0.254	22.692	0.254	93.049	0.0%	0.0%	0.0%
W02	3.66	0.64	0.02	1.79	0.02	7.34	12.633	0.395	35.333	0.395	144.885	0.0%	0.0%	0.0%
Atm. Deposition							0.054	0.020	0.078	0.007				
	Total Load Allocation						20.800	0.668	58.103	0.655	237.934			

Table 20. TMDL Summary for White Clay Creek East Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0052451	0.0012	25.00	10.00	24.20	10.00	6.00	0.250	0.100	0.242	0.100	0.060	0.0%	0.0%	0.0%
PA0057029	0.1440	2.00	0.04	2.10	0.11	5.00	2.403	0.048	2.524	0.132	6.009	0.0%	0.0%	0.0%
PA0025488	0.3000	25.00	2.00	50.00	4.00	2.00	62.591	5.007	125.181	10.014	5.007	0.0%	0.0%	0.0%
PA0056898	0.0650	25.00	3.50	32.55	0.30	5.00	13.561	1.899	17.657	0.163	2.712	0.0%	0.0%	0.0%
PA0029343	0.0000	20.00	3.00	10.00	10.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0040436	0.0090	25.00	10.00	20.00	2.00	6.00	1.878	0.751	1.502	0.150	0.451	0.0%	0.0%	0.0%
PA0040665	0.0100	25.00	10.00	24.20	2.00	6.00	2.086	0.835	2.020	0.167	0.501	0.0%	0.0%	0.0%
	Total Waste Load Allocation						82.770	8.640	149.126	10.727	14.740			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W03	4.32	0.64	0.020	1.79	0.020	7.34	14.911	0.466	41.705	0.466	171.014	0.0%	0.0%	0.0%
W04	2.44	0.64	0.020	1.79	0.020	7.34	8.424	0.263	23.562	0.263	96.616	0.0%	0.0%	0.0%
Atm. Deposition							0.099	0.037	0.141	0.013				
	Total Load Allocation						23.435	0.766	65.408	0.742	267.630			

Table 21. TMDL Summary for Muddy Run

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W07	0.93	0.64	0.02	1.79	0.02	7.34	3.208	0.100	8.972	0.100	36.791	0.0%	0.0%	0.0%
Atm. Deposition							0.017	0.006	0.024	0.002				
	Total Load Allocation						3.225	0.106	8.996	0.102	36.791			

Table 22. TMDL Summary for Pike Creek

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W06	1.60	0.64	0.02	1.79	0.02	7.34	5.528	0.173	15.460	0.173	63.396	0.0%	0.0%	0.0%
Atm. Deposition							0.039	0.015	0.056	0.005				
	Total Load Allocation						5.567	0.188	15.516	0.178	63.396			

Table 23. TMDL Summary for Mill Creek

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W05	2.20	0.64	0.02	1.79	0.02	7.34	7.591	0.237	21.230	0.237	87.055	0.0%	0.0%	0.0%
Atm. Deposition							0.051	0.019	0.073	0.007				
	Total Load Allocation						7.642	0.256	21.303	0.244	87.055			

Table 24. TMDL Summary for White Clay Creek Main Stem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000191	0.0300	3.00	0.10	0.24	0.10	5.00	0.751	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.751	0.025	0.060	0.025	1.252			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W08	1.72	0.64	0.02	1.79	0.02	7.34	5.938	0.186	16.607	0.186	68.099	0.0%	0.0%	0.0%
W09	2.17	0.64	0.02	1.79	0.02	7.34	7.495	0.234	20.962	0.234	85.954	0.0%	0.0%	0.0%
W10	1.21	0.64	0.02	1.79	0.02	7.34	4.177	0.131	11.682	0.131	47.904	0.0%	0.0%	0.0%
Atm. Deposition							0.348	0.13	0.499	0.044				
	Total Load Allocation						17.957	0.680	49.750	0.594	201.958			

Table 25. TMDL Summary for Christina River West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
MD0022641	0.7000	12.22	2.00	10.00	1.00	6.00	71.387	11.684	58.418	5.842	35.051	0.0%	69.0%	0.0%
MD0065145	0.0500	10.00	4.52	13.00	1.00	6.00	4.173	1.886	5.425	0.417	2.504	0.0%	0.0%	0.0%
	Total Waste Load Allocation						75.559	13.570	63.842	6.259	37.554			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01WB	0.15	1.43	0.02	1.00	0.02	7.34	1.158	0.016	0.810	0.016	5.942	0.0%	0.0%	0.0%
Atm. Deposition							0.008	0.003	0.011	0.001				
	Total Load Allocation						1.166	0.019	0.821	0.017	5.942			

Table 26. TMDL Summary for Little Mill Creek

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000523	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0000566	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.000	0.000	0.000	0.000	0.000			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C04	4.70	1.43	0.02	1.00	0.02	7.34	36.237	0.507	25.340	0.507	185.999	0.0%	0.0%	0.0%
Atm. Deposition							0.028	0.011	0.041	0.004				
	Total Load Allocation						36.265	0.518	25.381	0.511	185.999			

Table 27. TMDL Summary for Christina River Main Stem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000400	0.0000	2.00	0.10	0.24	0.10	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0051004	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.000	0.000	0.000	0.000	0.000			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01	0.60	1.43	0.02	1.00	0.02	7.34	4.625	0.065	3.234	0.065	23.738	0.0%	0.0%	0.0%
C02	0.65	1.43	0.02	1.00	0.02	7.34	5.016	0.070	3.508	0.070	25.746	0.0%	0.0%	0.0%
C03	0.48	1.43	0.02	1.00	0.02	7.34	3.700	0.052	2.587	0.052	18.991	0.0%	0.0%	0.0%
C05	0.80	1.43	0.02	1.00	0.02	7.34	6.164	0.086	4.311	0.086	31.641	0.0%	0.0%	0.0%
C06	1.59	1.43	0.02	1.00	0.02	7.34	12.264	0.172	8.576	0.172	62.949	0.0%	0.0%	0.0%
Atm. Deposition							3.222	1.207	4.630	0.412				
	Total Load Allocation						34.991	1.651	26.846	0.856	163.064			

Table 28. Point and Nonpoint Source Contributions to Delaware River Estuary

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0021555-001	0.5500	12.00	1.50	10.00	2.00	5.00	55.08	6.88	45.90	9.18	22.95	0.0%	0.0%	0.0%
DE0000256-601	13.0000	25.00	12.00	50.00	0.30	5.00	2712.23	1301.87	5424.46	32.55	542.45	0.0%	0.0%	0.0%
DE0000612-001	0.8000	18.00	0.50	4.65	0.30	5.00	120.17	3.34	31.04	2.00	33.38	0.0%	0.0%	0.0%
DE0020001-001	0.6800	14.00	1.50	10.00	2.00	5.00	79.45	8.51	56.75	11.35	28.37	0.0%	0.0%	0.0%
DE0050911-001	0.3000	13.21	1.50	10.00	2.00	5.00	33.07	3.76	25.04	5.01	12.52	0.0%	0.0%	0.0%
DE0020320-001	134.0000	17.00	1.50	10.00	2.00	5.00	19010.65	1677.41	11182.74	2236.55	5591.37	0.0%	0.0%	0.0%
DE0000051-001	5.2000	30.00	0.50	4.65	0.30	5.00	1301.87	21.70	201.79	13.02	216.98	0.0%	0.0%	0.0%
DE0000051-002	3.0000	8.00	0.50	4.65	0.30	5.00	200.29	12.52	116.42	7.51	125.18	0.0%	0.0%	0.0%
DE0000051-003	6.0000	8.00	0.50	4.65	0.30	5.00	400.58	25.04	232.83	15.02	250.36	0.0%	0.0%	0.0%
DE0000655-001	33.3000	17.00	1.20	11.16	0.30	5.00	4724.29	333.48	3101.36	83.37	1389.50	0.0%	0.0%	0.0%
PA0012637-002	52.3500	30.00	0.50	4.65	0.30	5.00	13106.33	218.44	2031.48	131.06	2184.39	0.0%	0.0%	0.0%
PA0012637-101	69.8000	30.00	0.50	4.65	0.30	5.00	17475.11	291.25	2708.64	174.75	2912.52	0.0%	0.0%	0.0%
PA0012637-201	3.3400	52.00	29.00	50.00	0.30	5.00	1449.42	808.33	1393.67	8.36	139.37	0.0%	0.0%	0.0%
PA0027103-001	44.0000	30.00	30.00	50.00	0.30	5.00	11015.83	11015.83	18359.72	110.16	1835.97	0.0%	0.0%	0.0%
NJ0005405-001	1.2700	45.00	35.00	50.00	0.30	5.00	476.94	370.95	529.93	3.18	52.99	0.0%	0.0%	0.0%
NJ0024856-001	1.4450	30.00	1.50	10.00	2.00	5.00	361.77	18.09	120.59	24.12	60.29	0.0%	0.0%	0.0%
NJ0021598-001	2.4650	30.00	35.00	65.00	2.00	5.00	617.14	719.99	1337.13	41.14	102.86	0.0%	0.0%	0.0%
NJ0005100-661	22.9000	30.00	0.50	4.65	0.30	5.00	5733.24	95.55	888.65	57.33	955.54	0.0%	0.0%	0.0%
NJ0021601-001	1.7290	30.00	1.50	10.00	2.00	5.00	432.87	21.64	144.29	28.86	72.15	0.0%	0.0%	0.0%
NJ0024023-001	0.9500	40.00	1.50	10.00	2.00	5.00	317.12	11.89	79.28	15.86	39.64	0.0%	0.0%	0.0%
NJ0024635-001	0.0366	15.00	1.50	10.00	2.00	5.00	4.58	0.46	3.05	0.61	1.53	0.0%	0.0%	0.0%
NJ0004286-001	2.1000	30.00	0.50	4.65	0.30	5.00	525.76	8.76	81.49	5.26	87.63	0.0%	0.0%	0.0%
NJ0027545-001	0.9860	30.00	1.50	10.00	2.00	5.00	246.85	12.34	82.28	16.46	41.14	0.0%	0.0%	0.0%
	Total Waste Load Allocation						80400.64	16988.04	48178.54	3032.70	16699.06			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
none														
Atm. Deposition							117.83	44.01	168.84	15.01				
	Total Load Allocation						117.83	44.01	168.84	15.01				

Updated Model Calibration

The change in the value of the phosphorus half-saturation constant from 0.132 mg/L to 0.005 mg/L only affected East Branch Brandywine Creek. The effect of the change in KHPm on model calibration was subtle. Figures A-3 and A-4 show the revised daily average DO and minimum DO plot along Brandywine Creek East Branch resulting from the change in KHPm. Figure 9-9 in the model report (EPA 2000) showed the calibration of diel dissolved oxygen at three locations: Brandywine Creek at Chadds Ford, East Branch Brandywine Creek downstream of Downingtown, and West Branch Brandywine Creek at Modena. In the revised Figures 9-9 in this addendum, the calibration results look very similar to the original model that used KHPm=0.132 mg/L.

Model-data comparisons were be made by means of longitudinal transect plots from downstream to upstream of East Branch Brandywine. The transect is delineated in river miles referenced to River Mile 74.9 located at the mouth of the Christina River based on EPA REACH FILE 1. Longitudinal transect plots for each water column parameter were presented in Appendix A of the model report (USEPA, 2000) arranged by stream reach. There are 18 transect plots for each reach, representing 18 different water quality parameters. The model results for the transect plots were averaged over the period August 5 through August 20, 1997. The horizontal axis of each plot represents the river mile from the mouth of East Branch Brandywine Creek (mile 95.8) measured along the stream network to mile 113.7 at the upstream extent of the model reach. The vertical axis represents the water column parameter concentration. When there is sufficient observed data, it is shown as "box-and-whisker" symbols indicating the maximum, minimum, 25^{th} percentile, 75^{th} percentile, mean and median statistics. The model output results are represented by three lines, the solid line indicates the mean over the averaging period at a given model grid cell and the two dashed lines represent the minimum and maximum values simulated over the averaging period. Calibration along the East Branch Brandywine Creek transect is shown in Figures A-4 to A-6. Again, the differences between these graphs and those in the original model report (EPA 2000) are subtle, with the largest difference being the macroalgae concentrations, which are closely associated with the KHPm constant. The transect calibration plots for the other stream reaches in the model did not change since no parameters were changed in those reaches.

References

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USEPA. 1998. Update of Ambient Water Quality Criteria for Ammonia. EPA 822-R-98-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2000. Hydrodynamic and Water Quality Model of Christina River Basin. U.S. Environmental Protection Agency, Region III, Philadelphia, PA. December 2000.

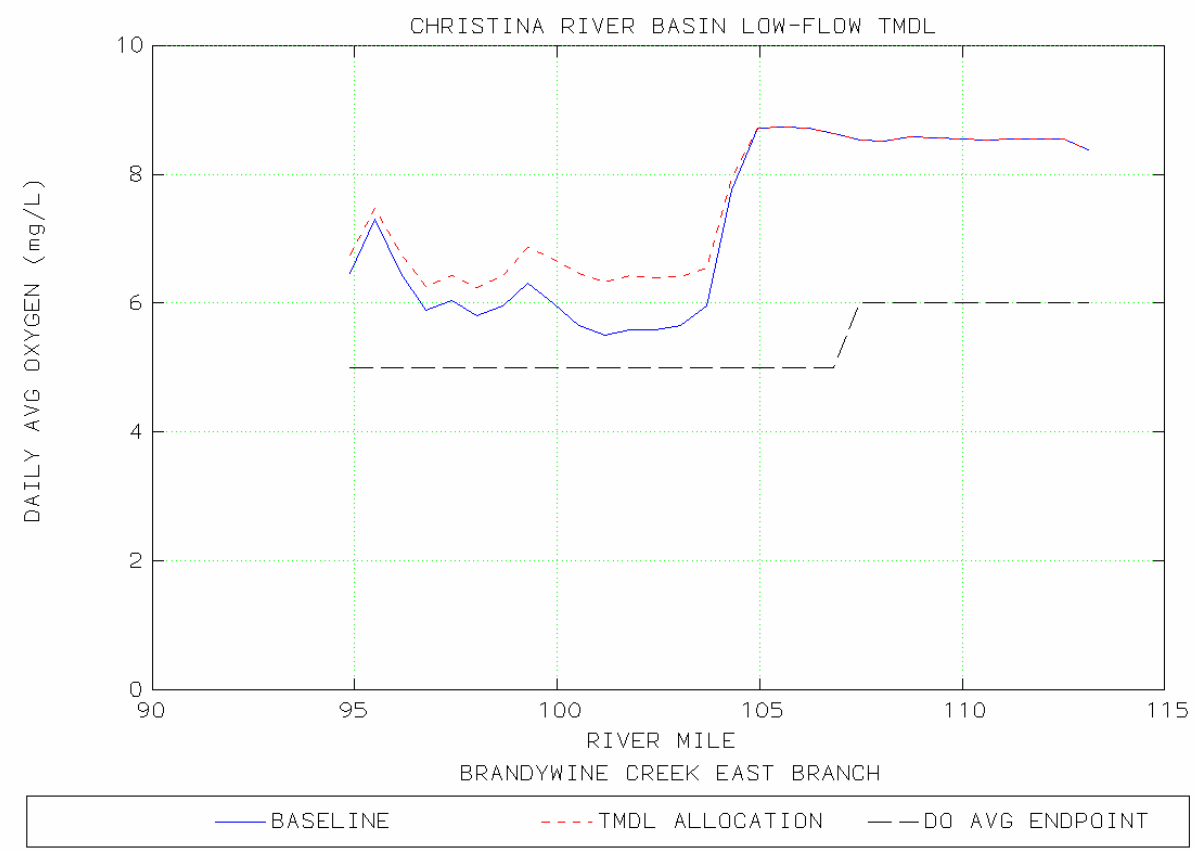

Figure A-3. Brandywine Creek East Branch, daily average DO

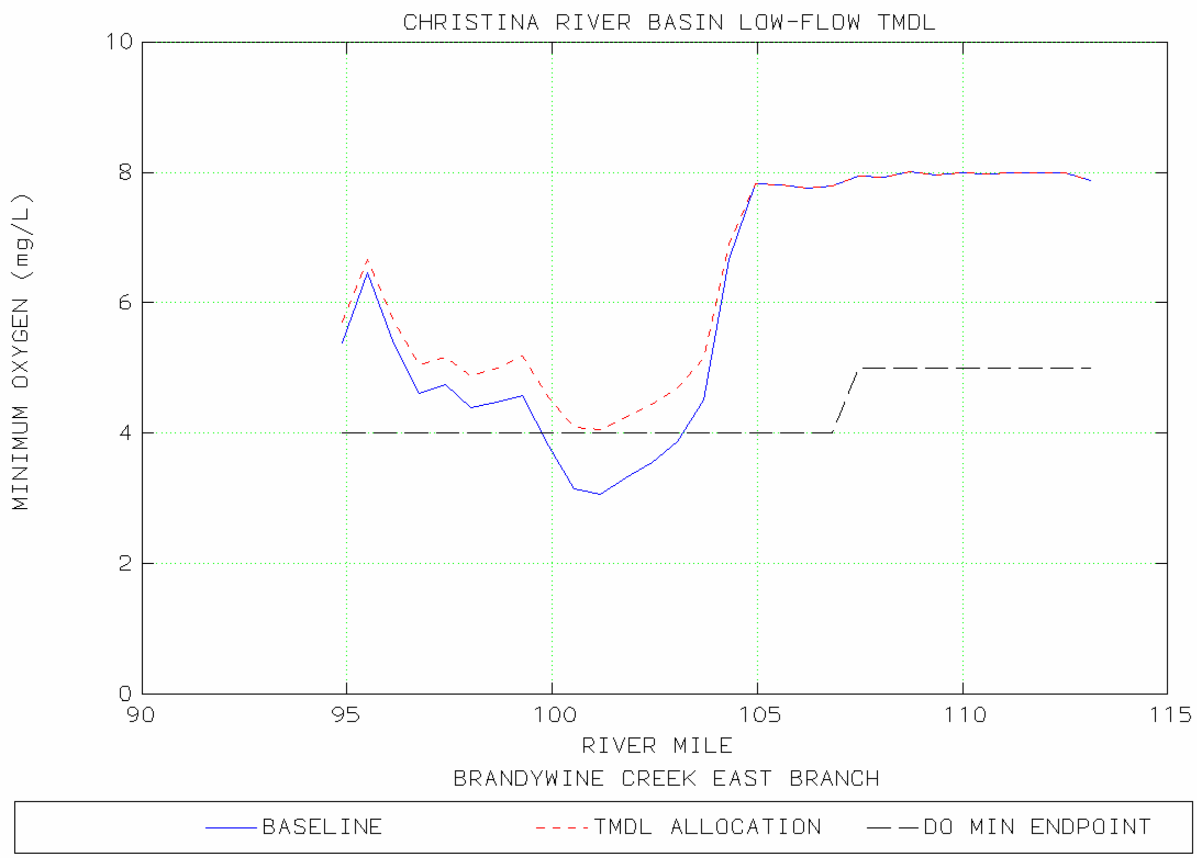

Figure A-4. Brandywine Creek East Branch, minimum DO

Appendix

Executive Summary

Total Maximum Daily Loads of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Introduction

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for nutrients and other oxygen demanding pollutants in order to attain and maintain the applicable Water Quality Standards (WQS) for dissolved oxygen (DO) in the Christina River Basin under low-flow conditions (equivalent to the minimum seven-day low flow expected to occur every 10 years - conditions used to establish National Pollution Discharge Elimination System (NPDES) permits). EPA has established these TMDLs in cooperation with the Pennsylvania Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of the Environment (MDE) and the Delaware River Basin Commission (DRBC). As part of these TMDLs, EPA has allocated specific amounts of nutrients and other oxygen demanding pollutants to certain point and nonpoint sources necessary to restore and maintain the applicable WQS. These TMDLs recommend that eight facilities, seven in Pennsylvania and one in Maryland, have their NPDES permits modified when next reissued to reduce the amounts of pollutants that may be discharged.

During permit reviews for several of the facilities covered by January 19, 2001 TMDLs, it was discovered that flow rates used in the original TMDL calculations were in error. As a result, model runs using updated flow figures for these facilities were performed and revisions to the TMDL recommendations for the Brandywine Creek portion of the Christina River Basin were made.

A related, but separate, effort is underway to establish TMDLs for nutrients, DO and other pollutants causing water quality problems under high-flow conditions. EPA expects these high-flow TMDLs to be completed by December 2004.

Summary of TMDL Development and Public Participation

In 1991, at the request of DNREC and DEP, DRBC agreed to coordinate water management issues in the “interstate” Christina River Basin. The issues included monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum 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. DRBC facilitated a series of meetings with DNREC, DEP, EPA, Chester County Water Resources Authority (CCWA) and the United States Geological Survey (USGS). The two states, DRBC, EPA and other government agencies reached agreement in late 1993 to initiate a

cooperative and coordinated monitoring and modeling approach to develop and establish TMDLs to address water quality problems occurring at low-flow conditions by late 1999.

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. Based on available information, Pennsylvania identified 24 stream segments on its 1998 303(d) lists while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin.

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 Clean Water Act (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 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 expects Delaware to establish the high-flow TMDL by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

Despite best efforts by DRBC, EPA, Delaware and other participants, including the use of expert contractors from Tetra Tech and Widener University, the low-flow TMDLs for the Christina River Basin were not completed by December 1999. EPA thereafter assumed the lead to establish these TMDLs.

EPA held two public information meetings on preliminary draft Christina River Basin TMDLs on July 18-19, 2000 in West Chester, PA and Wilmington, DE respectively. After making appropriate changes, EPA opened the formal public comment period on the proposed TMDLs with two public hearings on August 29-30, 2000, again in West Chester, PA and Wilmington, DE respectively. As advertised in local papers, EPA held the comment period for the draft TMDLs open through October 15, 2000. EPA received numerous comments from both the public hearings and during the public comment period. EPA reviewed and considered those comments in making its final decision for these TMDLs. EPA has prepared a public comment responsiveness summary which accompanies the final TMDL Decision Rationale document.

For the revised TMDLs, EPA issued a public notice of the proposed revisions on March 1, 2002 for a 30-day public comment period. The notice was published in the Chester County

Community Newspaper Group and the Wilmington News-Journal. Copies of the notice were also mailed to each affected point source discharger in the Christina River Basin. One set of comments were received and EPA has prepared a response to those comments which accompanies this revised TMDL Decision Rationale document. Because of the limited changes being made to the TMDLs and the few comments received, EPA determined that the proposed TMDL revisions could proceed without the need for a public hearing.

Applicable Water Quality Standards for TMDLs

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 WQS 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 which have adopted applicable WQS. DEP, DNREC and MDE each have WQS which apply to the stream segments of the Christina River Basin in the respective state. DRBC is an interstate agency which has the authority to establish WQS and regulate pollution activities within the Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins.

Once EPA identifies the applicable use designation and water quality criteria, EPA determines the numeric water quality target or goal for the TMDL. These targets represent a number where the applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at low-flow conditions. EPA has set forth specific targets for DO in the Tables and Figures provided in the TMDL Decision Rationale applicable to each segment. The table below identifies the general numeric water quality targets or endpoints for the Christina River Basin TMDLs.

Summary of TMDL Endpoints*

Parameter	Target Limit	Reference
Daily Average DO, freshwater, Pennsylvania Daily Average DO, freshwater, Delaware DO at any time, freshwater, Maryland	5.0 mg/L 5.5 mg/L 5.0 mg/L	Pennsylvania Water Quality Standards Delaware Water Quality Standards Maryland Water Quality Standards
Minimum DO	4.0 mg/L	Pennsylvania and Delaware Water Quality Standards

* - the state of 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.

In addition to the TMDL DO endpoints summarized in the above table, there are higher DO WQS for certain Christina River Basin segments during the critical conditions time periods considered in these low-flow TMDLs. Generally, these segments were either not listed on 303(d) lists for point source impacts or found not to be impacted by point source discharges in the TMDL evaluations. The results of the TMDL model runs, incorporating the proposed TMDL reductions, indicate that these higher DO WQS will also be protected.

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, Biochemical Oxygen Demand (BOD), Sediment Oxygen Demand (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 (or numeric criteria in the case of Maryland) to support the attainment of the numeric DO criterion. Likewise, to maintain adequate instream levels of DO at low-flow conditions, EPA found it necessary and appropriate to develop as part of these TMDLs waste load allocations for total phosphorus, total nitrogen, ammonia-nitrogen, Carbonaceous Biochemical Oxygen Demand (CBOD) and DO for point sources. 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.

Christina River Basin Water Quality and TMDL Development

As noted above, Pennsylvania identified 24 stream segments on its 1998 303(d) list while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin. The listed stream segments identified various

causes of impairment including excessive nutrients, organic enrichment and low DO. Data appendices prepared for and considered in this report describe in detail the existing water quality during low-flow. These appendices can be viewed at the EPA Region III Christina River Basin TMDL web site (www.epa.gov/reg3wapd/christina).

These TMDLs also address loadings of pollutants from waterbodies or segments which have not been listed as impaired on the states' 303(d) lists. The CWA requires for interstate waters that the water from the upstream state meet the WQS of the downstream state at or before the state line. In this case, these interstate TMDLs not only address the segments listed respectively by Pennsylvania (the upstream state) and Delaware (the downstream state), but also address other water quality problems associated with discharges from non-listed waters necessary to protect the water quality of downstream waters of Delaware during low-flow conditions. In a few cases, including certain segments of the East Branch of the Brandywine River, the TMDL modeling also revealed problems in previously unlisted waters where none had been identified before. In some cases where a segment may not have been previously identified as impaired, these TMDLs allocate pollutant loads that are causing or contributing to the impairment of that water and/or downstream waters. EPA established such waste load allocations in order to attain and maintain the applicable WQS of both upstream and downstream waters consistent with our authority to establish these TMDLs.

As indicated in the data assessment (appendices found at the web site), the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. The data analysis also indicates that DO concentrations within the tidal Christina River violate both the minimum and daily average WQS during low-flow critical conditions. In addition to the influential nutrients loads from tributaries, spatial data analysis indicates that high levels of plant biomass are likely the result of transport from inland tributaries. In any case, the nutrient and biomass loadings from inland tributaries potentially contribute to the DO WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on the states' 303(d) lists.

TMDL Model

In establishing these TMDLs, EPA utilized the EFDC water quality model, a public domain surface water modeling system incorporating fully integrated hydrodynamic, water quality and sediment-contaminant simulation capabilities, to evaluate the linkage between the applicable water quality criteria and the identified sources and to establish the cause-and-effect relationships. The EFDC model has been applied in similar studies including the Peconic Estuary, the Indian River Lagoon/Turkey Creek, and the Chesapeake Bay system and has been used to develop TMDLs in Oklahoma and Georgia.

Summary of TMDL Allocations

The TMDL waste load and load allocations for specific segments are provided in tables at the end of this Executive Summary. The Level 1 allocations result from the evaluation of each individual discharger. For Level 2, the resultant Level 1 allocations were added one at a time in a cumulative assessment of WLA impacts. The Level 2 allocations are the proposed WLAs for the affected dischargers. Tables are also provided that display the total discharge load reductions proposed by the TMDLs to ensure that the DO WQS are met under low-flow conditions in the Christina Basin.

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require that, for an NPDES permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available WLA for the discharger prepared by the state and approved by EPA or established directly by EPA. To ensure consistency with these TMDLs, as NPDES permits are issued for the point sources that discharge the pollutants of concern to the Christina Basin, any deviation from the WLAs described herein for the particular point source must be documented in the permit Fact Sheet and made available for public review along with the proposed draft permit and the Notice of Tentative Decision. The documentation should: (1) demonstrate that the loading change is consistent with the goals of these TMDLs and will implement the applicable WQS, (2) demonstrate that the changes embrace the assumptions and methodology of these TMDLs, and (3) describe that portion of the total allowable loading determined in the TMDL report that remains for other point sources (and future growth where included in the original TMDL) not yet issued a permit under the TMDL.

Discussion of Regulatory Conditions

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight regulatory conditions:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
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 margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

The TMDL Decision Rationale document discusses how these TMDLs satisfy each of these regulatory conditions in Section VII. The Christina River Basin TMDLs for nutrients and DO under low-flow conditions have fulfilled the 40 CFR Section 130 regulatory conditions.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen

Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

TMDL Summary by Subwatershed for the Christina River Basin

Sum of Individual Waste Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day
Brandywine Creek main stem	79.72	16.82	43.04	9.00	26.74
Brandywine Creek East Branch	1,022.79	157.30	3,562.99	118.76	523.97
Brandywine Creek West Branch	600.16	124.15	1,218.68	69.48	257.01
Buck Run	7.55	0.79	1.91	0.61	1.53
Brandywine Creek Watershed	**1,710.22**	**299.06**	**4,826.62**	**197.85**	**809.25**
Christina River West Branch	75.57	13.57	125.33	6.26	37.56
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.57**	**13.57**	**125.33**	**6.26**	**37.56**
Burroughs Run	0.04	0.01	0.02	0.01	0.03
Red Clay Creek West Branch	162.32	19.44	46.94	12.83	71.36
Red Clay Creek main stem	108.96	4.81	11.61	75.52	112.11
Red Clay Creek Watershed	**271.32**	**24.26**	**58.57**	**88.36**	**183.50**
White Clay Cr. Middle Branch	53.83	10.52	25.46	4.51	11.27
White Clay Cr. East Branch	88.78	8.69	149.67	11.23	16.17
Muddy Run	0.00	0.00	0.00	0.00	0.00
Pike Creek	0.00	0.00	0.00	0.00	0.00
Mill Creek	0.00	0.00	0.00	0.00	0.00
White Clay Cr. main stem	0.75	0.03	0.06	0.03	1.25
White Clay Creek Watershed	**143.36**	**19.24**	**175.19**	**15.77**	**28.69**
Total Waste Load Allocation for Point Sources in Christina River Basin	**2,200.47**	**356.13**	**5,185.71**	**308.24**	**1,059.00**

TMDL Summary by Subwatershed for the Christina River Basin

Sum of Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day
Brandywine Creek main stem	52.01	1.78	137.30	1.50	497.95
Brandywine Creek East Branch	162.33	3.85	248.01	3.35	1,333.95
Brandywine Creek West Branch	99.18	3.08	262.94	2.77	958.41
Buck Run	34.72	0.96	92.45	0.94	338.75
Brandywine Creek Watershed	**348.24**	**9.67**	**740.69**	**8.55**	**3,129.05**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.27	0.52	25.38	0.51	186.02
Christina River main stem	34.99	1.65	26.85	0.86	163.08
Christina River Watershed	**72.43**	**2.19**	**53.05**	**1.38**	**355.05**
Burroughs Run	4.60	0.10	9.10	0.21	33.65
Red Clay Creek West Branch	20.05	0.42	39.68	0.90	146.87
Red Clay Creek main stem	40.10	0.91	79.24	1.83	292.00
Red Clay Creek Watershed	**64.75**	**1.43**	**128.02**	**2.94**	**472.52**
White Clay Cr. Middle Branch	20.80	0.67	58.11	0.66	237.96
White Clay Cr. East Branch	23.44	0.77	65.42	0.74	267.66
Muddy Run	3.23	0.11	9.00	0.10	36.80
Pike Creek	5.57	0.19	15.52	0.18	63.40
Mill Creek	7.64	0.26	21.31	0.24	87.06
White Clay Cr. main stem	17.96	0.68	49.76	0.59	201.98
White Clay Creek Watershed	**78.64**	**2.68**	**219.12**	**2.51**	**894.86**
Total for LA Christina River Basin	**564.06**	**15.97**	**1,140.88**	**15.38**	**4,851.48**
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	**2,764.53**	**372.10**	**6,326.59**	**323.62**	**5,910.47**

Note: Totals subject to rounding variations.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0026531	7.134	10	2.0	2.0	8.9	1.78	1.78	11%	11%	11%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	12.3	2.0	1.64	18%	0%	18%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	17.5	2.1	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.0	1.0	0%	69%	0%

Note:WLAs/ permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 - October 31 - DEP)

* no permit limits, values shown are based on monitoring data.
** value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0026859 - PA American Water Co.***
MD0022641- Meadowview Utilities, Inc.

*** - formerly Coatesville City Authority

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Level 2 Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0043982	0.4	25	2.0*	2.0	22.95	2.00	1.88	8%	0%	6%
PA0012815	1.028	34	6.0	1.0	24.41	4.31	0.72	28%	28%	28%
PA0026531	7.134	10	2.0	2.0	6.38	1.28	1.28	36%	36%	36%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	11.07	2.00	1.48	28%	0%	28%
PA0044776	0.6	15	3.0	2.0	13.50	2.70	1.80	10%	10%	10%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.63	2.00	1.28	34%	34%	83%
PA0057720-001	0.05	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

Note: WLAs/permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 - October 31 - DEP)

* no permit limits, values shown are based on typical characteristics or monitoring data.
**allocation did not change from Level 1 allocation.
***value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0043982 - Broad Run Sew. Co.
PA0057720-001 - Sunny Dell Foods, Inc.
**** - formerly Coatesville City Authority
PA0026859 - PA American Water Co. ****
MD0022641- Meadowview Utilities, Inc.
PA0012815 - Sonoco Products
PA0044776 - NW Chester Co. Mun. Auth.

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Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

I. Introduction

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for nutrients and other oxygen demanding pollutants in order to attain and maintain the applicable Water Quality Standards (WQS) for dissolved oxygen (DO) in the Christina River Basin under low-flow conditions (equivalent to the minimum seven-day low flow expected to occur every 10 years - conditions used to establish National Pollution Discharge Elimination System (NPDES) permits). EPA has established these TMDLs in cooperation with the Pennsylvania Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of the Environment (MDE) and the Delaware River Basin Commission (DRBC). As part of these TMDLs, EPA has allocated specific amounts of nutrients and other oxygen demanding pollutants to certain point and nonpoint sources necessary to restore and maintain the applicable WQS. These TMDLs recommend that eight facilities, seven in Pennsylvania and one in Maryland, have their NPDES permits modified when next reissued to reduce the amounts of pollutants that may be discharged.

During permit reviews for several of the facilities covered by the January 19, 2001 TMDLs, it was found that some flow rates used in the original TMDL calculations were in error. As a result, model runs using updated flows were performed and revisions to the TMDL recommendations for the Brandywine Creek portion of the Christina River Basin were made.

A related, but separate, effort is underway to establish TMDLs for nutrients, DO and other pollutants causing water quality problems under high-flow conditions. EPA expects these high-flow TMDLs to be completed by December 2004.

II. Historical Perspective

In 1991, at the request of DNREC and DEP, 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.

The DRBC facilitated a series of meetings with DNREC, DEP, 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 for low-flow conditions by late 1999.

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 firsts, 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 still requiring the development of a TMDL. Based on available information, Pennsylvania identified 24 stream segments on its 1998 303(d) list while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin. 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, any TMDL to achieve the WQS in the Christina River Basin in Delaware requires Pennsylvania waters to meet WQS 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 (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 Rivern 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 expects 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.

In response to the requirement to establish TMDLs, Delaware, in cooperation with the CBWQMC, identified the need for a scientific modeling tool to investigate water quality impairments related to the development of TMDLs in the Christina River Basin. Tetra Tech, already under contract to EPA (Contract No. 68-C7-0018), was asked to provide regional TMDL watershed analysis and support within the Christina River Basin. The original work plan was approved August 28, 1997 to provide a calibrated water quality model for nutrients and DO for the Christina River Basin to be used by DNREC and DEP in establishing TMDLs. The model would be calibrated for critical, low-flow summer period, use all available information and include both point and nonpoint sources. The WASP5[1] model was originally envisioned as the analytical tool, however, EPA ultimately decided to use the EFDC[2] model after considering the complexity of the Christina River Basin and the need to link this model with the HSPF[3] model being developed by the USGS to characterize high-flow conditions. The work plan was further

[1] Ambrose, R.B., T.A. Wool, and J.L. Martin. 1993. The water quality analysis and simulation program, WASP5 version 5.10. Part A: Model documentation. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, GA.

[2] Hamrick, J.M. 1992. A three-dimensional environmental fluid dynamics computer code: theoretical and computational aspects. SRAMSOE #317, The College of William and Mary, Gloucester Point, VA.

[3] Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigan, and R.C. Johanson. 1993. Hydrological Simulation Program-FORTRAN (HSPF): User’s manual for release 10.0. EPA 600/3-84-066. Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

expanded on April 20, 1999 to include additional reaches in Delaware and allow for further validation of the model.

Following DNREC's request for scientific modeling support, a model/technical group was formed to develop the scientific modeling tool within the Christina River Basin. Members who participated in this effort include representatives from DNREC, DEP, EPA, DRBC, USGS and Tetra Tech. Although the Cecil County, Maryland Department of Public Works and MDE were not originally included, once it was discovered that these TMDLs would impact point sources in Maryland, these organizations were contacted and have participated in the development of the TMDLs since May 2000.

After Tetra Tech began providing TMDL watershed analysis and support in 1998, the model/technical group met on a consistent basis in order to develop the modeling tool in support of the requirement to establish TMDLs for low-flow conditions by December 31, 1999. In September 1998, when it became apparent that the model development was behind schedule, and at the request of DNREC and DEP, DRBC agreed, by resolution, to hire Widener University to further assist in the development of TMDLs once the model was completed. Despite best efforts by DRBC, EPA, the states and other participants on the CBWQMC, the low- flow TMDLs for the Christina were not completed by December 1999. EPA thereafter assumed the lead to establish these TMDLs.

III. Christina River Basin Water Quality Perspectives

In addition to the legal, statutory and regulatory requirements of identifying water quality limited segments and establishing TMDLs, there are several compelling reasons why establishing these TMDLs is good public policy to address the water quality of the Christina River Basin: (1) protect water quality uses, (2) protect sources of drinking water, and (3) promote appropriate growth. One goal of the CWA, and other similar legislation, is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. These critical, but often delicate natural resources, can be easily degraded by anthropogenic and other sources of pollution. Polluted waters can affect the quality of life, health and vitality of citizens in the Christina River Basin. Consistent with the goals of the CWA, it is in the public interest to sustain the diverse human, ecological, aesthetic and recreational resources of the watershed.

While it is often difficult to attach a precise economic value to natural resources such as the Nation's waters, the CWA recognizes the benefits gained by restoring and maintaining the Nation's waters. Actions such as these become even more critical where the waterbody serves as the primary source of drinking water for 75% of the residents in New Castle County, Delaware. Many of the water supply withdrawals in Chester County, Pennsylvania originate in waters from the Christina River Basin. Development will continue to occur in the Christina River Basin along with the consequential impacts on water quality. Establishing protective and appropriate water quality targets will allow progress while ensuring water quality integrity.

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. Data appendices prepared for this report describe in detail the existing water quality during low flow. The data assessment developed by Dr. John Davis of Widener University, in draft form for the DRBC TMDL determination, has been included verbatim from the "*Preliminary Draft TMDL Document 5/27/99*" provided to DRBC on June 7, 1999. EPA used this data in developing these TMDLs. These appendices can be viewed at the EPA Region III Christina River Basin TMDL web site (www.epa.gov/reg3wapd/christina).

IV. Basin Summary and Source Assessment

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of 564.06 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware and Cecil County, Maryland (Figure 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 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 portions included in the model appear as thick or outlined segments of the streams in Figure 1.

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 below.

Table 1. 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)

There are 122 NPDES dischargers included in the Christina River Basin TMDL analysis (see Table 2 and Figure 2). The discharges range from single resident discharges (about 500 gallons per day (gpd)) to large industrial and municipal wastewater treatment plants with effluent flow rates in the range of 1 to 7 million gallons per day (mgd). The largest NPDES facilities in

the Christina River Basin are Downingtown (permitted flow of 7.134 mgd), Sonoco (1.028 mgd), West Chester Taylor Run (1.50 mgd), Lukens Steel (1.00 mgd), PA American Water Co. (formerly Coatesville - 3.85 mgd), South Coatesville (0.39 mgd), Kennett Square (1.10 mgd) and Avondale (0.30 mgd). There are seven NPDES facilities with flows above 10 mgd that discharge to the tidal Delaware River portion of the model, the largest being the City of Wilmington (now rated at 134 mgd).

V. Problem Identification and Understanding

In response to the requirements of Section 303(d) of the CWA, DEP and DNREC listed multiple Christina River Basin waterbodies on their 1996 and 1998 303(d) lists of impaired waterbodies based on available information. As noted earlier, Pennsylvania identified 24 stream segments on its 1998 303(d) list (Table 3) while Delaware identified 15 stream segments on its 1998 303(d) list (Table 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 24 listed segments as high priority. A number of monitoring stations are located throughout the Christina River Basin within the listed waters (Figures 3 and 4). Data from these stations were used to determine the impairment and inclusion on the 303(d) lists based on the number of values exceeding WQS for DO. 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, Superfund sites and hydromodification. As noted above, this extensive data assessment is provided in the appendices at the web site (www.epa.gov/reg3wapd/christina).

These TMDLs also address loadings of pollutants from waterbodies or segments which have not been listed as impaired on the states' 303(d) lists. The CWA requires for interstate waters that the water from the upstream state meet the WQS of the down stream state at or before the state line. In this case, these interstate TMDLs not only address the segments listed respectively by Pennsylvania (the upstream state) and Delaware (the downstream state), but also address other water quality problems associated with discharges from non-listed waters necessary to protect the water quality of downstream waters of Delaware during low-flow conditions. In a few cases, including certain segments of the East Branch of the Brandywine River, the TMDL modeling also revealed problems in previously unlisted waters where none had been identified before. In some cases where a segment may not have been previously identified as impaired, these TMDLs allocate pollutant loads that are causing or contributing to the impairment of that water and/or downstream waters. EPA established such wasteload allocations in order to attain and maintain the applicable WQS of both upstream and downstream waters consistent with our authority to establish these TMDLs.

Table 3. Christina River Basin Stream Reaches on the PA 1998 303(d) List

Watershed	Stream ID	Segment ID	Miles	Source of Impairment	Cause of Impairment
Brandywine Creek	00004	27	1.28	other	nutrients
Buck Run	00131	50	1.77	municipal point source	nutrients, low DO
Sucker Run	00202	970930-1437-GLW	6.78	agriculture	nutrients
W.Br. Brandywine Creek	00085	970618-1118-GLW 970618-1340-GLW 970619-1222-GLW 970619-1345-GLW	2.98 3.57 5.51 3.99	agriculture	nutrients
Broad Run	00434	971209-1445-ACW	4.10	hydromodification, agriculture	organic enrichment, low DO, nutrients
E.Br. Red Clay Creek	00413	971023-1050-MRB 971204-1400-ACW	6.53 5.09	agriculture	organic enrichment, low DO
E.Br. White Clay Creek	00432	970409-1130-MRB 970506-1320-MRB 970508-1430-ACE 971113-1335-GLW 971119-1116-GLW 971120-1331-GLW	6.07 8.61 2.44 3.10 1.21 8.12	agriculture	nutrients nutrients organic enrichment, low DO organic enrichment, low DO nutrients nutrients
Egypt Run	00440	970508-1245-ACE	3.66	agriculture	organic enrichment, low DO
Indian Run	00475	115	1.09	agriculture, municipal point source	nutrients
Middle Br. White Clay	00462	115	17.33	agriculture, municipal point source	nutrients
Red Clay Creek	00374	971203-1400-ACW	0.76	agriculture	organic enrichment, low DO
Trout Run	00402	970506-1425-MRB	2.74	agriculture	nutrients
Walnut Run	00435	971209-1445-ACW	1.39	agriculture, hydromodification	organic enrichment, low DO, nutrients
W.Br. Red Clay Creek	00391	971023-1145-MRB	4.58	agriculture	organic enrichment, low DO
White Clay Creek	00373	971216-1230-GLW	1.13	agriculture	nutrients

Source: Excerpt PADEP Final 1998 Section 303(d) List, Submitted August 7, 1998 and Approved by EPA on August 27, 1998

Table 4. Christina River Basin Stream Reaches on the DE 1998 303(d) List

Waterbody ID	Watershed Name	Segment	Miles	Pollutants/Stressor	Probable Sources
DE040-001	Brandywine Creek	Lower Brandywine	3.8	nutrients	PS, NPS, SF
DE040-002	Brandywine Creek	Upper Brandywine	9.3	nutrients	PS, NPS, SF
DE260-001	Red Clay Creek	Main Stem	12.8	nutrients	PS, NPS, SF
DE260-002	Red Clay Creek	Burroughs Run	4.5	nutrients	NPS
DE320-001	White Clay Creek	Main Stem	18.2	nutrients	PS, NPS
DE320-002	White Clay Creek	Mill Creek	16.6	nutrients	NPS
DE320-003	White Clay Creek	Pike Creek	9.4	nutrients	NPS
DE320-004	White Clay Creek	Muddy Run	5.8	nutrients	NPS
DE120-001	Christina River	Lower Christina	1.5	nutrients, DO	NPS, SF
DE120-002	Christina River	Middle Christina River	7.5	nutrients	NPS, SF
DE120-003	Christina River	Upper Christina River	6.3	nutrients	NPS, SF
DE120-003-02	Christina River	Lower Christina Creek	8.4	nutrients	NPS
DE120-005-01	Christina River	West Branch	5.3	nutrients	NPS
DE120-006	Christina River	Upper Christina Creek	8.3	nutrients	NPS
DE120-007-01	Christina River	Little Mill Creek	12.8	nutrients, DO	NPS, SF

PS= point source; NPS = nonpoint source; SF=superfund site

Source: Excerpt DNREC Final 1998 Section 303(d) List, Submitted July 7, 1998 and Approved by EPA on July 17, 1998

EPA developed these TMDLs using the underlying principles of the Watershed Protection Approach. EPA's Watershed Protection Approach is governed by the principle that many water quality and ecosystem problems are best solved at the larger watershed levels rather than on the smaller, individual waterbody or discharger level. The Watershed Protection Approach increases the ability to identify and target priority problems, promotes broader stakeholder involvement, integrates solutions which use all available expertise and provides a better measure of success through the use of data and monitoring. Managing water resources on a watershed basis makes sense environmentally, financially and socially.

As indicated in the data assessment found in the appendices at the Christina TMDL web site, the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. The data analysis also indicates that DO concentrations within the tidal Christina River violate both the minimum and daily average WQS during critical conditions. In addition to the influential nutrients loads from tributaries, spatial data analysis indicates that high levels of phytoplankton biomass are likely the result of transport from inland tributaries. In any case, the nutrient and biomass loadings from inland tributaries contribute to the DO WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on a state's 303(d) list.

Excess nutrients in a waterbody can have many detrimental effects on designated or existing uses, including drinking water supply, recreational use, aquatic life use and fishery use[4]. Eutrophication, a term usually associated with the natural aging process experienced by lakes, describes the excessive nutrient enrichment of streams and rivers which can experience an undesirable abundance of plant growth, particularly phytoplankton (photosynthetic microscopic organisms (algae)), periphyton (attached benthic algae) and macrophytes (large vascular rooted plants). Photosynthesis and respiration of these plants as well as the microbial breakdown of dead plant matter contribute to wide fluctuations in the DO levels in streams. The impact of low DO concentrations or of anaerobic conditions is reflected in an unbalanced ecosystem, fish mortality, odors and other aesthetic nuisances[5]. These types of impairments interfere with the designated uses of waterbodies by disrupting the aesthetics of the river, causing harm to inhabited aquatic communities and causing violations of applicable water quality criteria. Figure 5 below shows the interrelationship of the major processes which affect DO.

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[4] U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. Pg 2-1. EPA 841-B-99-007. Office of Water (4503F). U.S. EPA, Washington D.C. 135pp.

[5] Thomann, R.V., J.A. Mueller. 1987. Principles of Surface Water Quality Modeling. HarperCollins Publishers, Inc. Section 6.1.

The presence of aquatic plants in a waterbody can have a profound effect on the DO resources and the variability of the DO throughout a day or from day to day[6]. Growing plants provide a net addition of DO to the stream on an average daily basis through photosynthesis, yet respiration can cause low DO levels at night that can affect the survival of less tolerant fish and aquatic life species. This is due to the photosynthetic and respiration processes of aquatic plants which can cause large diurnal variations in DO that are harmful to fish and aquatic life. Photosynthesis is the process by which plants utilize solar energy to convert simple inorganic nutrients into more complex organic molecules[7]. Due to the need for solar energy, photosynthesis only occurs during daylight hours and is represented by the following simplified equation (proceeds from left to right):

$6CO_2$	+	$6H_20$	<----------->	$C_6H_{12}O_6$	+	$6O_2$
(Carbon Dioxide)		(Water)		(Sugar)		(Oxygen)

In this reaction, photosynthesis is the conversion of carbon dioxide and water into sugar and oxygen such that there is a net gain of DO in the waterbody. Conversely, respiration and decomposition operate the process in reverse and convert sugar and oxygen into carbon dioxide and water resulting in a net loss of DO in the waterbody. Respiration and decomposition occur at all times and are not dependent on solar energy. Also, if environmental conditions cause a die-off of either microscopic or macroscopic plants, the decay of biomass can cause severe oxygen depressions. Waterbodies exhibiting typical diurnal variations of DO experience the daily maximum in mid-afternoon during which photosynthesis is the dominant mechanism and the daily minimum in the predawn hours during which respiration and decomposition have the greatest effect on DO and photosynthesis is not occurring. Therefore, excessive plant growth, as a result of excessive nutrients, can affect a streams ability to meet both average daily and instantaneous DO standards[8].

Sediment oxygen demand (SOD) is due to the oxidation of organic matter in bottom sediments[9]. The organic matter originates from various sources including wastewater treatment facilities, leaf litter, organic-rich soil or photosynthetically produced plant matter which settles and accumulates. In some instances, SOD can be significant portion of total oxygen demand, particularly in small streams where the effects may be more pronounced during low-flow or high temperature conditions[10].

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[6] Supra, footnote 5. (Thomann, Mueller) Section 6.3.3.

[7] Chapra, S.C. 1997. Surface Water-Quality Modeling. WCB/McGraw-Hill. Section 19.1.

[8] U.S. Environmental Protection Agency. 1997. Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication. Office of Water(4305). EPA 823-B-97-002. Section 4.2.1.2.

[9] Supra, footnote 7. (Chapra) Section 25

[10] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.4.

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen required to stabilize organic matter in wastewater[11]. It is typically determined from a standardized test measuring the amount of oxygen available after incubation of the sample at 20°C for a specific length of time, usually five days. Conceptually, BOD requires a distinction between the oxygen demand of the carbonaceous material in waste effluents and the nitrogenous oxygen demanding component of an effluent[12]. Carbonaceous biochemical oxygen demand (CBOD) involves the breakdown of organic carbon compounds while nitrogenous biochemical oxygen demand (NBOD) involves the oxidation of ammonia to nitrate, referred to as the nitrification process[13].

VI. Christina River Basin Water Quality Model

Thomann and Mueller[14] define a model as "a theoretical construct, together with assignment of numerical values to model parameters, incorporating some prior observations drawn from field and laboratory data, and relating external inputs or forcing functions to system variable responses." In order to evaluate the linkage between the applicable water quality criteria numbers (endpoints) and the identified sources and establish the cause-and-effect relationships, EPA is utilizing the EFDC water quality model. EFDC is a public domain surface water modeling system incorporating fully integrated hydrodynamic, water quality and sediment-contaminant simulation capabilities.

EFDC is extremely versatile and can be applied in 1,2, or 3 dimensional simulation of rivers, lakes and estuaries with coupled salinity and temperature transport. Further capabilities of the model include a directly coupled water quality-eutrophication and toxic contaminated sediment transport and fate models, integrated near-field mixing zone model, as well as pre- and post-processing for input file creation, analysis and visualization. The eutrophication component of EFDC can simulate the transport and transformation of 22 state variables including cyanobacteria, diatom algae, green algae, refractory particulate organic carbon, labile particulate organic carbon, dissolved carbon, refractory particulate organic phosphorus, labile particulate organic phosphorus, dissolved organic phosphorus, total phosphate, refractory particulate organic nitrogen, labile particulate organic nitrogen, dissolved organic nitrogen, ammonia nitrogen, nitrate nitrogen, particulate biogenic silica, dissolved available silica, chemical oxygen demand, dissolved oxygen, total active metal, fecal coliform bacteria and macroalgae. The EFDC model has been used in similar water quality studies including the Peconic Estuary, the Indian River Lagoon/Turkey Creek and the Chesapeake Bay system and the EFDC model was used to develop TMDLs for waterbodies in Oklahoma and Georgia, including Wister Lake, OK (2000), and the St. Mary's and Suwanee Watersheds, GA (2000).

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[11] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.

[12] Supra, footnote 5. (Thomann, Mueller) Section 6.3.1.

[13] Supra, footnote 7. (Chapra) Section 19.4.

[14] Supra, footnote 5. (Thomann, Mueller) Section 1.2.1.

In order to ensure that the EFDC model is adequately representing the hydrodynamic and water quality processes of the Christina River Basin, separate calibration and validation of the model was performed to establish model robustness[15]. Calibration involves adjusting kinetic parameters within the model to achieve a specified level of performance in comparison to actual observed hydrodynamic and water quality data from a basin. Data from a site-specific field study (Davis 1998) were used to establish certain kinetic parameters, e.g., the phosphorus half-saturation constant for periphyton. The model calibration was executed over a period of 143 days from May 1 to September 21, 1997. EPA also validated the Christina River Basin model to confirm and provide additional confidence that the model can be used as an effective prediction tool for a range of conditions other than those in the original calibration. During validation, the kinetic parameters which were adjusted during calibration remain fixed to evaluate the model accuracy in representing the Christina River Basin. The model validation was executed over a period of 143 days from May 1 to September 21, 1995. Point source loads during calibration and validation are representative of actual discharged loads as listed on Discharge Monitoring Reports (DMRs) during the calibration or validation periods. Nonpoint source loads are based on STORET data, USGS water quality data, baseflow sampling, and data from interstate monitoring efforts during the calibration or validation periods. These loads represent contributions from nonpoint sources and form the basis of the load allocations.

EPA also provides an assessment of the calibration and validation quality. There are two general approaches for assessing the quality of a calibration: subjective and objective[16]. The subjective assessment typically involves visual comparison of the simulation with the data, as in time series plots for state variables, while the objective assessment utilizes quantitative measures of quality such as statistical measures of error. EPA included both types of assessment and compared the Christina River Basin model error statistics with those from other similar studies. The Christina River Basin model compares very favorably as discussed in Section 11 of the *Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000.* A complete and more-detailed technical discussion of the EFDC model is available in this report.

The calibrated and validated water quality model was used to confirm that the model was able to simulate the locations of the impaired stream segments on the 303(d) lists. The model results from the 1997 calibration run were plotted on a map view of the Christina River Basin and those model grid cells not meeting the daily average and minimum DO water quality criteria were highlighted (see Figures 6 and 7). The 1997 calibration results indicate that the daily average DO criteria were not met in portions of the tidal Christina River, tidal Brandywine Creek, tidal White Clay Creek, West Branch Red Clay Creek and Little Mill Creek (Figure 6). The 1997 results also indicate that the minimum DO criteria were not protected in portions of the West Branch Red Clay Creek, Little Mill Creek and tidal Brandywine Creek (Figure 7).

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[15] Supra, footnote 7. (Chapra) Section 18.1.5.

[16] Supra, footnote 7. (Chapra) Section 18.3.

A separate analysis was performed to investigate potential WQS violations during critical conditions. During this scenario, 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. Nonpoint source pollutant loads, as computed by multiple data sets, were developed to represent expected conditions and pollutant contributions during critical periods. The use of actual site-specific data to characterize nonpoint sources is appropriate and would essentially act to integrate past pollutant loading events. While the process of calibrating and validating the water quality model was dynamic, the critical condition analysis is representative of steady-state conditions. Tidal elevations at the north and south boundaries on the Delaware River were set using tidal harmonic constants derived from NOAA subordinate tide stations at Chester, Pennsylvania, and Reedy Point, Delaware. Map-view graphics were created to highlight problem areas (see Figures 8 and 9).

The model results for the period August 1 through August 31 when critical stream flows are most likely to occur (while August was used, it is possible for the critical conditions to occur at other times) indicate that the daily average DO criteria will not be satisfied in portions of the West Branch Brandywine Creek, West Branch Red Clay Creek, West Branch Christina River and tidal Christina River (Figure 8). The model results also indicate that the minimum DO criteria will not be achieved in portions of the West Branch Brandywine Creek, East Branch Brandywine Creek below Downingtown and West Branch Red Clay Creek (Figure 9).

The tidal estuary portion of the EFDC model is used to characterize the Delaware River Estuary and consider potential impacts to water quality within the Christina River Basin from pollutant loads to the estuary. Of the 122 NPDES dischargers evaluated in this TMDL assessment, 23 are point sources discharging to the Delaware River which were considered in the linkage analysis. In considering which dischargers to include, the spatial range was limited to about 10 miles above and below the confluence of the Christina River and the Delaware River due to the tidal excursion, which is approximately eight miles.

While this TMDL analysis and subsequent allocation scenarios are designed to address low-flow conditions and the contributions from the primary sources (point sources), the analysis includes land-based nonpoint sources. As discussed further below, because at low-flow conditions there are no significant nonpoint source contributions, the nonpoint source allocation is included as part of the background loading. Addressing this critical condition establishes the baseline condition which point sources within the Christina River Basin must comply with in order to achieve WQS (for example, DEP uses the 7Q10 analysis as the basis for assuring that WQS will be met 99% of the time).

The stream reaches identified by the model as not meeting DO criteria are in general agreement with those on the 303(d) lists. EPA believes that the Christina River Basin model is an appropriate tool for understanding the current water quality problems in the Christina River Basin, evaluating the linkage between cause-and-effect and allocating pollutant loads to identified sources.

VII. Discussion of Regulatory Conditions

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight regulatory conditions:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
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 margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

EPA provides the following information to demonstrate how the Christina River Basin TMDLs meet these eight regulatory requirements.

1) The TMDLs are designed to implement applicable water quality standards.

Target Analysis

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[17].

Within the Christina River Basin, there are four regulatory agencies which have applicable WQS. The DEP, DNREC, and MDE have WQS which apply to those stream segments of the Christina River Basin located in the respective state. The DRBC[18] is an

[17] U.S. Environmental Protection Agency. 1994. Water Quality Standards Handbook: Second Edition. Office of Water(4305). EPA 823-B-94-005a. Section 2.1.

[18] The DRBC was created by compact among Pennsylvania, New Jersey, New York, Delaware and the federal government in 1961.

interstate agency which has the authority to establish WQS and regulate pollution activities within the Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins. Tables 5 and 6 below summarizes the applicable WQS relating to DO and nutrients.

Table 5. Summary of Applicable Use Designations and DO Criteria

Agency	Designated Use	D.O. Criteria (mg/L)		Comments
		Daily avg.	Minimum	
DEP	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	*Average for June-September period shall not be less than 5.5 mg/L
	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 6. Summary of Nutrient Criteria

Parameter Agency	Comments
Ammonia-Nitrogen*	
DEP	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	
DEP	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 303(d) rationale document cites 3.0 mg/L total nitrogen as guidance for determining impairment.
DRBC	No specific numeric criteria.
Phosphorus	
DEP	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 303(d) rationale document cites 0.1 mg/L total phosphorus as guidance for use impairment.
DRBC	No specific numerical criteria.

*** - the state of 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.**

Once EPA identifies the applicable use designation and water quality criteria, EPA determines the numeric water quality target or goal for the TMDL. These targets represent a number where the applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at low-flow conditions. Figure 10 below shows the applicable use designations for stream segments included in the Christina River Basin TMDL. Using Tables 5 and 6 and Figure 10, the numeric water quality targets for DO can be identified for each segment. Table 7 below identifies the general water quality targets or endpoints for the Christina River Basin TMDLs.

Table 7. Summary of TMDL Endpoints

Parameter	Target Limit	Reference
Daily Average DO, freshwater, Pennsylvania	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, freshwater, Delaware	5.5 mg/L	Delaware Water Quality Standards
Daily Average DO, tidal waters, Delaware	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater, Maryland	5.0 mg/L	Maryland Water Quality Standards
Minimum DO	4.0 mg/L	Pennsylvania and Delaware Water Quality Standards

In addition to the TMDL DO endpoints summarized in Table 7, there are higher DO WQS for certain Christina River Basin segments during the critical conditions time periods considered in these low-flow TMDLs. Generally, these segments were either not listed on 303(d) lists for point source impacts or found not to be impacted by point source discharges in the TMDL evaluations. The results of the TMDL model runs, incorporating the proposed TMDL reductions, indicate that these higher DO WQS will be protected. This information is summarized in a series of data plots showing DO levels and WQS for the major segments in the Christina River Basin found in Appendix A1 of this document.

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. Likewise, to maintain adequate instream levels of DO at low-flow conditions, EPA found it necessary and appropriate to develop as part of these TMDLs waste load allocations (WLAs) for total phosphorus, total nitrogen, ammonia-nitrogen, CBOD, and DO for point sources. 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.

One Christina River Basin segment, the East Branch White Clay Creek, has been designated as Exceptional Value waters by Pennsylvania. In addition to TMDL results showing the DO WQS for this segment will be protected, the East Branch White Clay Creek is afforded additional protection of water quality conditions through the regulatory provisions of the Pennsylvania antidegradation program (25 PA Code Chapter 93.4 (c)) and 40 CFR 131.32.

While the ultimate endpoint for this TMDL analysis is to ensure that the WQS for DO are 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 and the Maryland WQS for ammonia-nitrogen. 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 10 mg/l nitrate nitrogen value 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 ammonia-nitrogen WQS in Maryland was not met during the initial point source evaluation and required treatment reductions at one facility in the West Branch Christina River.

Delaware WQS also set a numeric water quality criteria 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.

2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Load

The total allowable load for each portion of the Christina River Basin, as determined by the EFDC model, was calculated based on the segmentation of the model in order to better correspond with the 303(d) listing, ensure the integrity of each stream segment and to allow pollution trading alternatives (for this low-flow TMDL, trading options may be limited to alternate WLA scenarios among affected point source dischargers. See the discussion under Allocation Scenarios on Pages 48-49.) Table 8 below identifies the total allowable load as well as the WLAs, load allocations and margin of safety (MOS) for each of the 16 stream segments of the model.

Deposition from atmospheric sources is also considered in the Christina River Basin water quality model. While atmospheric deposition may not be as important in the narrow stream channels, it could become more important in the open estuary waterbodies in the lower Christina and Delaware rivers. Atmospheric loads are typically divided into wet and dry deposition. Wet deposition is associated with dissolved substances in rainfall. The settling of particulates during non-rainfall events contributes to dry deposition. Observations of concentrations in rainwater are frequently available and dry deposition is usually estimated as a fraction of the wet deposition. The atmospheric deposition rates reported in the Long Island Sound Study (HydroQual 1991) and the Chesapeake Bay Model Study (Cerco and Cole 1994) as well as information provided by DNREC for Lewes, Delaware, were used to develop both dry and wet deposition loads for the EFDC model of the Christina River Basin. Atmospheric deposition loads are included in Tables 12-28 as well as in the summary watershed calculations provided in Table 8.

Size-Based Equal Marginal Percent Removal Allocation Strategy

The general theory of WLAs, and more specifically the size-based equal marginal percent removal (EMPR) allocation strategy that is used for these TMDLs, is discussed in this section. While a complete and detailed understanding of the concepts discussed below is not essential to using the Christina River Basin water quality model, a general appreciation of underlying principles will aid the user in applying the model and interpreting the results. The strategy presented in this section is based largely upon the document *Implementation Guidance for the Water Quality Analysis Model 6.3* (Pennsylvania DEP 1986). While EPA has many ways of allocating pollutant loads, based on this discussion EPA determined the EMPR strategy to be sound, fair and consistent with the goals of the CWA.

The term “waste load allocation” refers to a specific set of circumstances in which two or more point source discharges are in sufficiently close proximity to one another to influence the level of treatment each must provide to comply with WQS. This definition is technically correct since without discharge interaction there is no need to share (i.e., to allocate) the assimilation capacity of the receiving water body. In a single discharge situation, all that needs to be done is to determine the level of treatment that must be provided to comply with WQS. The size-based EMPR analysis does this as a first step: (1) to determine if a WLA situation exists; and if it does, (2) to assign WLAs to each of the discharges that is contributing to the water quality violation. A WLA should have three major objectives: (1) to assure compliance with the applicable WQS; (2) to minimize, within institutional and legal constraints, the overall cost of compliance; and (3) to provide maximum equity (or fairness) among competing discharges.

The first objective, is fundamental to water quality and public health protection. It is an ethical statement that assumes the social, economic and environmental benefits of water pollution control outweigh the associated costs. This is consistent with the goals and requirements of the CWA.

The second objective is a statement of the desirability of economic efficiency. Resources devoted to one purpose are not available for another use. This holds true whether the resources are of a public or a private nature. It therefore behooves a water quality management program to achieve water quality management goals with maximum economic efficiency (i.e., at least cost). It can be shown that maximum efficiency is achieved when the marginal cost of pollution abatement is the same for all participants. The marginal cost of wastewater treatment is related to the marginal rate of removal. If it is assumed that the marginal cost per unit of removal is the same for all discharges, then maximum economic efficiency is achieved when the marginal rate of removal for all discharges is the same. Institutional and legal constraints may prevent water quality programs from achieving optimal economic efficiency. Nevertheless, maximum efficiency within existing institutional and legal constraints should be pursued.

The third objective is a social statement that goes hand in hand with the second objective. Maximizing economic efficiency would by definition, provide for maximum equity. The desirability of equity, especially in a regulatory program, among individual (and potentially competing) members of society is a reasonably well accepted concept. The specific definition of when (or how) equity is to be achieved is, however, open to debate and interpretation. The WLA strategy employed in this TMDL is that of EMPR. It is based on the premise that all dischargers, whether or not they are part of a WLA scenario, should provide sufficient treatment to comply with WQS, and that some dischargers, because they are part of an allocation scenario, must provide additional treatment, due to the cumulative impact that they and nearby dischargers have on the receiving stream.

The strategy is similar in most respects to more traditional uniform treatment approaches, where all dischargers provide the same degree of treatment. The major difference is in the selection of the baseline condition for the WLA process. In most traditional uniform treatment approaches all dischargers that are believed to be part of the WLA start at the same treatment level. The traditional approach introduces economic inefficiencies and inequities into the WLA process because it fails to consider the individual impact that each discharger has on the receiving stream. This individual impact is a function of the discharge size and location. The practical result of failing to take these factors into consideration is to impose unnecessarily stringent treatment requirements on smaller dischargers, solely because they happen to be in the vicinity of a larger discharger. This imposes higher than necessary costs on these smaller dischargers, and in effect, causes them to subsidize dischargers that have a greater impact on water quality. At the same time, uniform treatment does not significantly improve overall water quality.

In the size-based EMPR strategy, the baseline condition for each discharger is the level of treatment the discharge must provide if it is the only discharger to the receiving stream. This level of treatment is water quality based for this TMDL. It is a function of the discharge size and location. In selecting this baseline condition, there are no assumptions made as to whether a discharger is or is not part of an allocation scenario.

Once the baseline condition for each discharger is established, a determination is made of whether additional treatment is needed because of the cumulative impact of multiple discharges. The dischargers are added back into the model one at a time, based on the size of their load (i.e., kg/day of CBOD). The model is then run again. If additional treatment is necessary, then all dischargers contributing to the WQS violations are reduced by equal percentages, starting from their individual levels of treatment at the end of the previous model run. Thus, the marginal rate of removal for all affected dischargers is the same in any given model run, while the overall rate of removal for each may be different.

Another difference between the traditional uniform treatment approach and the size-based EMPR strategy is in the determination of which dischargers are part of the WLA scenario. In the uniform treatment approach, it is commonly assumed that the WLA segment starts at the first discharger that adversely affects in-stream conditions, and extends downstream to the point where the stream returns to background conditions. It is not entirely clear whether this assumption is absolutely required, or is merely a matter of convenience. In either case, the specification of a return to background stream quality tends to extend the allocation segment to include dischargers that may not be part of the allocation at all. This further increases the economic inefficiency and inequity of uniform treatment solutions.

The size-based EMPR WLA does not require any assumptions with regard to a return to background stream conditions. The strategy determines the downstream limit of the allocation problem based on compliance with WQS. These features, combined with the different baseline condition, makes size-based EMPR a more cost-efficient and equitable WLA strategy than the traditional methods.

<u>Christina River Basin Allocation Process</u>

The first consideration is to determine what time period to use for the allocation scenarios. Only the results from the model period August 1-31 were analyzed to determine the daily average DO and minimum DO for comparison to WQS and to direct the allocation scenarios. This time period was selected as most representative of when critical conditions are expected to occur within the system. The model was run for a sufficient period to allow for: (1) the nutrient loads to transport their way through system; (2) the predictive sediment diagenesis model to attain dynamic equilibrium; and (3) the algae to react to the availability of nutrients.

The size-based EMPR allocation process relies on three levels of analysis for the Christina River Basin. Level 1 involves analyzing each NPDES point source individually to determine the baseline levels of treatment necessary to achieve WQS for daily average and minimum DO. The point sources not being considered individually and the tributaries are set to the baseline conditions listed in Table 9 below. This allows the in-stream flow to remain at 7Q10 levels and provides no net impact on water quality from the point sources not being considered individually. Level 2 involves multiple model runs in which the NPDES dischargers are added to the model one at a time based on the size of their CBOD load to determine the WLAs necessary to achieve WQS. If necessary, Level 3 involves analyzing the NPDES

dischargers outside the Christina Basin (i.e., those discharging to the tidal Delaware River) in order to meet WQS in the tidal Christina River.

The ultimate endpoints of these low-flow TMDLs are the daily average and the minimum DO criteria for the various stream segments in the study area. DO concentrations vary throughout the course of a 24-hour day and tend to follow a general sinusoidal pattern with the lowest point occurring just before sunrise and the highest value occurring in the afternoon. In general, controlling CBOD has a greater impact on the daily average DO than on the diel (24-hour period) DO range. Depending on whether a system is nitrogen or phosphorus limited, the available nitrogen or phosphorus influences the diel DO range due to the impact on algae and periphyton growth kinetics. The model calibration and validation indicated that phosphorus is the limiting nutrient in the freshwater streams in the Christina River Basin (*Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000)*. In Section 9.6 of the Model Report, it is noted that there was an abundance of nitrogen available and that phosphorous is the more limiting of the two nutrients based on data at five locations. The five locations were in West Branch Brandywine Creek, East Branch Brandywine Creek, Brandywine Creek (at Chadds Ford), Christina River and West Branch Red Clay Creek. Time-series plots at each location are found in Figures 9-12 through 9-16 in the Model Report.

The allocation process proceeds by reducing the CBOD, nitrogen, and phosphorus loads from the NPDES point sources in equal percentages until the daily average DO criteria are satisfied. After this is accomplished, if the minimum DO criteria have not been met, then the phosphorus loads will be further controlled until the diel DO range is reduced sufficiently to satisfy the minimum DO criteria.

Since these TMDLs deals with low-flow conditions only, by definition very little nonpoint source load from land-based sources will be entering the system during drought conditions. The nonpoint source flows from peripheral tributaries and groundwater sources are considered to be at baseline (i.e., background) conditions. The baseline concentrations for the various water quality parameters were determined from all data in the STORET database for the period 1988 to 1998. The 10th percentile concentration values were assumed to be indicative of the nonpoint source contributions during the 7Q10 low-flow period. The concentrations were within the range of expected values for watersheds in the eastern United States according to Omernik (1977). The baseline concentrations for total nitrogen and total phosphorus are presented in Table 9.

Table 9. Baseline Concentrations of Nitrogen and Phosphorus for Christina Basin TMDL

Subwatershed	Total Nitrogen (mg/L)		Total Phosphorus (mg/L)	
	Baseline	Omernik (1977) (67% range)	Baseline	Omernik (1977) (67% range)
Main Stem and East Branch Brandywine Creek	1.56	0.33 - 6.64	0.01	0.008 - 0.251
West Branch Brandywine Creek	2.44	0.33 - 6.64	0.03	0.008 - 0.251
Red Clay Creek	2.65	0.33 - 6.64	0.05	0.008 - 0.251
White Clay Creek	2.31	0.33 - 6.64	0.02	0.008 - 0.251
Christina River	1.08	0.33 - 6.64	0.02	0.008 - 0.251

Source: STORET data 1988-1998 and Nonpoint Source Stream Nutrient Level Relationships (Omerrnik, 1977)

Level 1 Allocation Results - Baseline Allocations

The first level of the size-based EMPR allocation involved considering each NPDES discharger individually to determine if WQS for DO were met. Those dischargers not considered individually were set to the baseline conditions in Table 9. This allowed the in-stream flow to remain at 7Q10 levels and created no net impact on water quality from the point sources not being considered individually. If WQS were not met, then CBOD, nitrogen and phosphorus for the individual point source were reduced in 5% increments until standards were achieved. Of the 99 NPDES point sources located in the Christina River Basin, 87 of them are small, with flow rates of 0.25 mgd or less. In order to avoid making 87 individual model runs to determine whether a Level 1 allocation was needed, all the small NPDES discharges were grouped into a single model run. The model results for this run indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Thus, if as a group there were no violations of the DO standard for the small dischargers, then individually there would be no violations.

Next, the remaining 12 large NPDES dischargers were analyzed individually. Of these 12, only three indicated violations of the DO standards: (1) PA0026531 (Downingtown) on the East Branch Brandywine Creek (minimum DO standard only), (2) PA0026859 (PA American Water Co. - formerly Coatesville City) on the West Branch Brandywine Creek (daily average and minimum DO standards), and (3) PA0024058 (Kennett Square) on West Branch Red Clay Creek (daily average and minimum DO standards). These violations are shown on Figures 11 and 12. Analysis for a fourth facility, MD0022641 - Meadowview Utilities on West Branch Christina River, indicated the EPA water quality criteria for ammonia nitrogen (US EPA 1998; subsequently adopted by the state of Maryland) was not being protected and was, therefore, also included in the Level 1 allocations. The Level 1 load reductions necessary to achieve compliance with the WQS for these facilities are shown in Table 10.

Table 10. Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0026531	7.134	10	2.0	2.0	8.9	1.78	1.78	11%	11%	11%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	12.3	2.0	1.64	18%	0%	18%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	17.5	2.1	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.0	1.0	0%	69%	0%

Note: WLAs/permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 - October 31 - DEP)
* no permit limits, values shown are based on monitoring data.
** value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
*** formerly Coatesville City Authority

PA0026859 - PA American Water Co.***
MD0022641- Meadowview Utilities, Inc.

Level 2 Allocation Results

The second level of the size-based EMPR allocation strategy involved adding the dischargers one at a time based on the size of Level 1 baseline CBOD allocations (kg/day) and performing waste load allocations to those stream segments indicating violations of the DO WQS. The daily average and minimum DO results of the initial Level 2 run are shown in Figures 13 and 14. It is apparent that the DO WQS are not being met in the East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek and the tidal portion of the Christina River with the two largest dischargers added to each of these stream reaches. The allocation proceeded by running the water quality model in an iterative fashion by reducing CBOD, NH3-N, and TP in 5% intervals for all NPDES dischargers upstream of the farthest downstream model grid cell indicating a DO violation. Once WQS were achieved at the 5% increment level, the allocations were fine tuned in 1% increments. After the allocations were fine tuned, the next largest discharger was added to the stream reach and the process was repeated until all dischargers were included in the analysis.

No allocations were made to point sources on the main stem Brandywine Creek until the stream segments on the East and West Branches were first in compliance with WQS. The small residence dischargers (0.0005 mgd), groundwater cleanup dischargers, and water filtration plant backwash facilities were not included in the allocation analysis since, as noted before, a model run covering all small dischargers indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Furthermore, filtration backwash facilities only discharge as needed and not on a continual basis. The Level 2 allocation results are presented in Table 11 and are shown in Figures 15 and 16 (the Level 2 allocation limits will be applicable to seasonal periods (e.g., May 1 to October 31 in Pennsylvania) covering the design critical conditions time used in the TMDL evaluations). It can be seen that there are no violations of the daily average DO or minimum DO criteria at any point inside the Christina River Basin. Thus, a Level 3 allocation will not be necessary for the tidal Christina River.

Table 11. Level 2 Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0043982	0.4	25	2.0*	2.0	22.95	2.00	1.88	8%	0%	6%
PA0012815	1.028	34	6.0	1.0	24.41	4.31	0.72	28%	28%	28%
PA0026531	7.134	10	2.0	2.0	6.38	1.28	1.28	36%	36%	36%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	11.07	2.00	1.48	28%	0%	28%
PA0044776	0.6	15	3.0	2.0	13.50	2.70	1.80	10%	10%	10%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.63	2.00	1.28	34%	34%	83%
PA0057720-001	0.05	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

Note: WLAs/permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 - October 31 -DEP)
* no permit limits, values shown are based on typical characteristics or monitoring data.
**allocation did not change from Level 1 allocation.
***value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0043982 - Broad Run Sew. Co.
PA0057720-001 - Sunny Dell Foods, Inc.
**** - formerly Coatesville City Authority

PA0026859 - PA American Water Co.****
MD0022641- Meadowview Utilities, Inc.
PA0012815 - Sonoco Products
PA0044776 - NW Chester Co. Mun. Auth.

In Appendix A1 of this document, data plots are presented showing the DO water quality standards, the impacts of existing NPDES permitted loads, and the TMDL model results for the proposed TMDL waste load reductions for each major Christina River Basin stream segment.

Performance data for the year 2000 for the three largest facilities (Downingtown, Coatesville, and Sonoco Products) indicate that these facilities are already achieving generally consistent performance near or below the proposed level 2 reductions. The main exception is the phosphorous discharges at Downingtown and Coatesville. Additional information on performance of major Christina River Basin dischargers is available in the Model Report (Table 7-3, 1997 data used in model calibration) and recent performance information can be obtained from the appropriate state agencies.

Waste Load Allocations (WLAs)

Federal regulations at 40 CFR 130.7 require TMDLs to include individual WLAs for each point source. Tables 12-27 outline the individual WLAs for those dischargers in the Christina River Basin. Of the 122 NPDES facilities considered, only those eight dischargers considered during the Level 1 and Level 2 EMPR analysis require reductions to their NPDES permit limits for those pollutants listed above.

Load Allocations

According to Federal regulation at 40 CFR 130.2(g), load allocations are best estimates of the nonpoint 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. Wherever possible, natural and nonpoint source loads should be distinguished.

Nonpoint source loads within the Christina River Basin model are based on monitoring data from STORET, USGS water quality data, baseflow samples taken in 1997, and interstate monitoring data collection efforts. The loads represent expected low-flow contributions from subwatersheds according to the delineation of the 39 subwatersheds in the HSPF model currently being developed by USGS. This will allow the HSPF model to be directly linked to the EFDC model to investigate seasonality and address high flow situations. Those data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatershed as delineated by the HSPF model. Load allocations were based on actual site-specific data and are broken down by subwatershed in Tables 12-27 below.

Allocations Scenarios

EPA realizes that its determination of the total loads below for carbonaceous biochemical oxygen demand (5-day), ammonia nitrogen, total nitrogen, total phosphorus and DO to the point sources and nonpoint sources is one allocation scenario. As implementation of the established TMDLs proceed, the states and DRBC may find that other combinations of point and nonpoint source allocations are more feasible and/or cost effective. However, any subsequent changes in the TMDLs must conform to gross WLAs and load allocations for each segment and must ensure that the biological, chemical, and physical integrity of the waterbody is preserved.

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require that, for an NPDES permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available WLA for the discharger prepared by the state and approved by EPA or established directly by EPA. EPA has authority to object to the issuance of an NPDES permit that is inconsistent with WLAs established for that point source. To ensure consistency with these TMDLs, as NPDES permits are issued for the point sources that discharge the pollutants of concern to the Christina Basin, any deviation from the WLAs described herein for the particular point source must be documented in the permit Fact Sheet and made available for

public review along with the proposed draft permit and the Notice of Tentative Decision. The documentation should: (1) demonstrate that the loading change is consistent with the goals of these TMDLs and will implement the applicable WQS, (2) demonstrate that the changes embrace the assumptions and methodology of these TMDLs, and (3) describe that portion of the total allowable loading determined in the TMDL report that remains for other point sources (and future growth where included in the original TMDL) not yet issued a permit under the TMDL.

It is also expected that the states will provide this Fact Sheet, for review and comment, to each point source included in the TMDL analysis as well as any local and state agency with jurisdiction over land uses for which load allocation changes may be impacted. EPA believes that this gives flexibility to the state agencies to address point source trading within the NPDES permitting process. However, should these trading activities result in changes to the total loading by basin or subwatershed segment, then EPA would expect that TMDL revisions would be necessary and the states or DRBC would need to follow the formal TMDL review and approval process.

In addition, EPA regulations and program guidance provide for effluent trading. Federal regulations at 40 CFR 130.2 (i) state: “If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then WLAs may be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs.” The states may trade between point sources and nonpoint sources identified in these TMDLs as long as three general conditions are met: (1) the total allowable load to the waterbody is not exceeded, (2) the trading of loads from one source to another continues to properly implement the applicable WQS and embraces the assumptions and methodology of these TMDLs, and (3) the trading results in enforceable controls for each source. Final control plans and loads should be identified in a publicly available planning document, such as the state’s water quality management plan (see 40 CFR 130.6 and 130.7(d)(2)). These final plans must be consistent with the goals of the approved TMDLs. While the design conditions of the low-flow TMDL restrict trading between point and nonpoint sources at the present time, EPA expects that this option will be available when the Christina River Basin high-flow TMDLs are developed.

3) The TMDLs consider the impacts of background pollutant contributions.

Background pollutant contributions are the result of non-anthropogenic sources such as from stream erosion, wild animal wastes, leaf fall, and other natural or background processes[19]. During low-flow, summer conditions baseflow contributions to the river are considered most influential and are representative of background contributions.

In terms of the low flow TMDL analysis, EPA used monitoring data from STORET, USGS water-quality data from monitoring stations, baseflow samples collected in 1997 (Senior, 1999), and data from a field study conducted by Dr. John Davis of Widener University (Davis, 1998). Furthermore, atmospheric loads from both dry and wet deposition are considered. EPA believes that use of actual instream monitoring data and atmospheric data will effectively account for background pollutant contributions.

As previously mentioned, the Christina River Basin drains to the Delaware River Estuary, which is affected by tidal influences. Furthermore, the Christina River, Brandywine Creek and White Clay Creek also experience similar tidal effects. The tides are the movement of water above and below a datum plane, usually sea level, which causes tidal currents[20]. Tides are the result of the gravitational forces of the sun and moon on the earth.

Of particular importance when considering tidal influences is the net estuarine flow which is the flow that flushes material out of the estuary over some period of time. Estuaries typically have complicated flow patterns from tidal motion impacts resulting in vertical stratification where freshwater inflow rides over saline ocean water. In essence then, any discharge of pollutants to the Delaware River above and below the confluence of the Christina River and the Delaware River, within a certain distance, could potentially impact water quality within the tidally influenced portions of the Christina River Basin.

It is important to recognize that these pollutant loads are discharged outside the Christina River Basin. However, increased pollutant loads from these sources could negatively impact water quality within the tidally influenced segments of the Christina River Basin causing violations of WQS. Therefore, EPA included the point source loads for those dischargers on the Delaware River in Table 28 above and EPA considers them as background conditions for the estuary. While sensitivity analyses to determine the exact nature and magnitude of impacts to water quality in the tidal portions of the Christina River Basin from increased or decreased pollutant loads from the Delaware Estuary have not been performed, any changes to pollutant loads from these sources should strive to be consistent with the existing pollutant loads in the estuary.

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[19] Supra, footnote 4. (EPA 1999 Protocol for Developing Nutrient TMDLs) Pg 5-5.

[20] Supra, footnote 5. (Thomann, Mueller) Section 3.

4) The TMDLs consider critical environmental conditions.

Federal regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for streamflow, loading and water quality parameters. The intent of this requirement is to ensure that the water quality of all waterbodies of the Christina River Basin are protected during times when it most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of WQS and will help in identifying the actions that may have to be undertaken to meet WQS.[21] Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that result in attaining and maintaining the water quality criterion and have an acceptably low frequency of occurrence. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low flow (7Q10) design condition as critical because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum. Additionally, the *Technical Support Document for Water Quality-based Toxics Control (EPA 505-2-90-001)* recommends the 1Q10 flow (minimum 1-day flow expected to occur every 10 years) or 7Q10 as the critical design periods when performing water quality modeling analysis. Historically, these so-called "design" flows were selected for the purposes of WLA analyses that focused on instream DO concentrations and protection of aquatic life[22]. Pennsylvania, Delaware and Maryland specify 7Q10 as the design or critical conditions for the application of water quality criteria in their WQS.

The Christina River Basin TMDLs adequately addresses critical conditions for flow through the use of 7Q10 flows during the model period from August 1 to August 31. The 7Q10 values are based on data from 17 USGS stream gages in the Christina River Basin. Table 29 below presents flow statistics from USGS gages in the basin.

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[21] EPA Memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Water Management Division Directors, August 9, 1999.

[22] Supra, footnote 17. (EPA 1994 Water Quality Standards Handbook) Section 5.2.

Table 29. Summary of Flow Statistics from USGS Gages in the Christina River Basin

USGS Gage ID	Drainage Area (mi^2)	Years of Record	Average Flow	Harmonic Mean	7Q10 Flow	1Q10 Flow	7Q1 Flow	1Q1 Flow
01478000	20.5	1944-94	28.21	8.31	1.53	0.54	3.79	1.83
01478500	66.7	1952-79	85.91	47.10	11.00	10.15	24.05	22.38
01478650		1994		38.66				
01479000	89.1	1932-94	114.65	62.19	15.60	14.04	31.23	28.45
01479820		1989-96		24.69				
01480000	47.0	1944-94	63.39	36.51	10.25	8.91	18.38	16.37
01480015		1990-94		41.08				
01480300	18.7	1961-96	26.25	12.83	3.40	3.01	6.62	6.19
01480500	45.8	1944-96	66.33	34.64	8.24	7.34	15.41	14.21
01480617	55.0	1970-96	91.31	52.79	19.02	15.54	24.84	21.63
01480650	6.2	1967-68	6.00	3.51				
01480665	33.4	1967-68	36.36	23.45				
01480700	60.6	1966-96	93.46	50.53	13.86	12.17	21.84	19.87
01480800	81.6	1959-68	86.63	44.81	12.56	11.86	20.57	18.81
01480870	89.9	1972-96	153.43	87.17	28.44	23.62	37.66	34.63
01481000	287.0	1912-96	395.13	234.13	70.63	65.04	117.01	107.14
01481500	314.0	1947-94	477.01	266.73	78.13	71.96	123.45	113.32

Source: USGS

In terms of pollutant loading, the critical conditions for point source loads occur during times when maximum flow and concentrations are being discharged. The maximum flows and loads are based on the NPDES permits for each facility. These conditions for point sources are used in the critical condition analysis and allocation scenarios.

Nonpoint source loads were based on monitoring data from STORET as well as data collected by USGS, baseflow samples collected in 1997 and data collected by DEP and DNREC and are representative of background contributions as well as expected land-based, nonpoint sources during low-flow conditions. During these conditions, land-based nonpoint sources are expected to contribute very little pollutant loadings to the waterbody. Furthermore, the ability of the waterbody to assimilate pollutant loads during these low-flow conditions is at a minimum. Consideration of nonpoint source loads would simply remove assimilative capacity and cause further reductions to point sources in order to achieve WQS. As can be seen from Table 8, in most watersheds point sources are the dominant contributors of pollutant loadings in low-flow

conditions. The data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatersheds as delineated by the HSPF model.

Use of these loads in the model provides the ability to integrate past pollutant loading events. It is recognized that delayed impacts on DO levels from wet-weather events during critical summertime periods may occur. However, Thomann and Mueller observed that "for some rivers and estuaries, the deposition of solids proceeds only during the low flow summer and fall months when velocities are low. High spring flows the following year may scour the bottom clean and reduce the problem until velocities decrease again. Intermediate cases are common where high flows may scour only a portion of the deposit, oxidize a portion, and then redeposit the material in another location."[23] It is likely that the use of site-specific data to characterize nonpoint source loads during critical conditions would consider those sporadic summertime loading events. In addition, both wet and dry deposition of atmospheric loads are included in the EFDC model.

The water quality parameters of concern are DO and nutrients throughout the system. However, as previously discussed, DO can be affected by BOD, SOD, algae and reaeration. These parameters, in addition to nitrogen and phosphorus, are addressed within the linkage analysis to ensure that the pollutant allocation scenario will ensure that WQS are met and maintained throughout the system.

5) The TMDLs consider seasonal environmental variations.

Addressing seasonal variation, similar to critical conditions, is necessary to ensure that WQS are met during all seasons of the year. Seasonal variations involve changes in streamflow as a result of hydrologic and climatological patterns. In the continental United States, seasonal high flow normally occurs during the colder period of winter and in early spring from snowmelt and spring rain, while seasonal low flow typically occurs during the warmer summer and early fall drought periods[24]. Other seasonal variations include reduced assimilative capacity from changes in flow and temperature as well as sensitive periods for aquatic biota. Seasonal fluctuations in both point and nonpoint source loads must also be considered.

In terms of the point source loads, the values used in the model are representative of those loads expected during the summer season based on DMRs, NPDES permit limits or characteristic concentrations. Likewise, the use of data from STORET, USGS and baseflow sampling to characterize expected nonpoint source loads during the summer will effectively consider seasonality.

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[23] Supra, footnote 5. (Thomann, Mueller) Section 6.3.4.

[24] Supra, footnote 8. (EPA 1997 Technical Guidance for Developing TMDLs) Section 2.3.3.

EPA expects that seasonal variations will continue to be addressed through the development of the HSPF model in conjunction with the TMDLs for high-flow conditions. Once this model is linked with EFDC, this will provide EPA with a powerful tool to investigate seasonality, critical conditions and alternate allocation strategies on a larger temporal and spatial scale. However, use of the EFDC model to represent critical low-flow summer conditions prior to development of the HSPF model in no way downgrades the scientific validity or defensibility of the current TMDL analysis and allocation scenario. Regardless, use of the fully integrated and linked model would still require consideration of critical conditions and seasonality. It is reasonable to expect that the allocation scenario from this integrated analysis would reflect the same critical condition and seasonality components in the current low-low analysis and result in similar pollutant loading allocations.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty or lack of knowledge. MOSs may be implicit, built into the modeling process, or explicit, taken as a percentage of the WLA, load allocation, or TMDL.

In consideration of the sheer quality and quantity of data, and the development of the HSPF watershed loading model which will be linked to this EFDC model, EPA is utilizing an implicit MOS through the use of conservative assumptions within the model application. An example of a conservative assumption used in this model is the discharge of point sources located on tributaries directly into the model without consideration of attenuation in the tributary water. The effect is conservative in terms of the main stem river segment since modeling directly to the main stem will not consider potential attenuation between the point of discharge into the tributary and confluence with the downstream main stem segment. This could potentially affect the pollutant allocation scenario. The exact nature of the effect is not known and could be positive or negative. The reverse, however, is not conservative when considering the tributary since negative water quality impacts could be occurring. The ability to model these water quality effects is extremely limited due to lack of resources, time and data and use of this conservative assumption is valid.

Additional factors in the MOS for the TMDLs for the Christina River Basin include:

- All point sources were set to their maximum permitted loads for the TMDL allocations.
- Streamflows were set to critical 7Q10 conditions for the TMDL allocations.
- No shading of the stream due to vegetation canopy was incorporated into the model, therefore, full sunlight conditions reach the stream during daylight hours resulting in maximum photosynthetic activity. Also, no cloud cover was incorporated into the model TMDL allocation runs resulting in maximum solar radiation reaching the stream.

- Stream water temperatures were set to critical high values based on historical data at USGS monitoring stations.

- Finally, all of the above items occur simultaneously resulting in very conservative conditions for the TMDL allocations.

It should be pointed out that this modeling effort relies on data which could be easily characterized as extensive and high-quality. The number of USGS stations and water quality stations, period of record, multiple sources of data, site-specific studies, and comprehensive review and analysis of the model application and techniques all contribute to the confidence EPA has in this TMDL analysis.

7) The TMDLs have been subject to public participation.

Public participation is a requirement of the TMDL process and is vital to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. In addition, EPA must provide a summary of all public comments and the response to those comments to indicate how the comments were considered in the final decision.

For several years, the CBWQMC and the CBWQMC Policy Committee have served as valuable forums to discuss Christina River Basin issues including the low-flow TMDL study. During the past two years as the work on the TMDLs has accelerated and reached completion, updates on the status of the TMDLs have been presented at the following meetings. These meetings, while not explicitly inviting the general public, were nonetheless open to the public:

- CBWQMC Meetings: March 12, 1999, April 22, 1999, August 5, 1999, January 28, 2000, March 30, 2000 and October 12, 2000.

- CBWQMC Policy Committee Meetings: October 29, 1999, May 31, 2000, July 7, 2000, November 3, 2000 and November 30, 2000.

In addition to the above meetings, a Public Outreach Task Force of the CBWQMC, led by Bob Struble of the Brandywine Valley/Red Clay Creek Valley Association, has held regular meetings to discuss Christina River Basin issues, including these TMDLs.

A special meeting of Public Outreach Task Force was held on May 24, 2000. Invitations to the major dischargers in the Christina River Basin were distributed for this meeting and representatives from Northwestern Chester Municipal Authority, Downingtown Area Regional Authority, City of Coatesville Authority, Bethlehem Steel Corporation, West Chester/Taylor Run STP and the Cecil County, MD Department of Public Works were in attendance. Also attending were representatives of Delaware and Maryland and engineers representing facilities in the Christina River Basin. During this meeting, the draft modeling results and allocations from the Christina River Basin TMDL model were presented and discussed. The model results and allocations were also discussed at a May 31, 2000 Public Outreach Task Force meeting and the

May 31, 2000 Policy Committee meeting as well. Additional discharger representatives from Sonoco, Inc. and Kennett Square were present at the May 31 meetings. During the December 1, 2000 Public Outreach Task Force meeting, EPA provided a status report on the Christina River Basin TMDLs.

The CBWQMC has published annual reports summarizing activities and ongoing work for the past several years. The Phase III report, which included a summary of the work completed to date on the Christina River Basin TMDLs and planned future work, was published on August 5, 1999.

A public meeting sponsored by the Delaware Nature Society on the Christina River Basin was held at the Ashland Nature Center in Delaware on June 17, 1999. A presentation on the Christina River Basin TMDLs was included on the agenda.

The proposed Christina River Basin low-flow TMDLs were the subject of two public information meetings on July 18-19, 2000 in West Chester, PA and Wilmington, DE. As result of information received at these meetings, changes were made to the proposed TMDLs and revised draft TMDLs were presented at two formal public hearings on August 29-30, 2000 in West Chester, PA and Wilmington, DE. The public meetings and hearings were the subject of a July 12, 2000 EPA press release and the meetings were advertized in the Wilmington News-Journal, West Chester Local News and the Chester County Papers consortium. EPA held the comment period for the draft TMDLs open through October 15, 2000. As a result of comments received at the public hearings, and during the public comment period, additional changes were made to the Christina River Basin low-flow TMDLs. Comments submitted at the public hearings and prior to the close of the public comment period were reviewed and a public comment responsiveness summary prepared which accompanied the January 19, 2001 TMDL Decision Rationale document.

For the revised TMDLs, EPA issued a public notice of the proposed revisions on March 1, 2002 for a 30-day public comment period. The notice was published in the Chester County Community Newspaper Group and the Wilmington News-Journal. Copies of the notice were also mailed to each affected point source discharger in the Christina River Basin. One set of comments were received and EPA has prepared a response to those comments which accompanies this revised TMDL Decision Rationale document. Because of the limited changes being made to the TMDLs and the few comments received, EPA determined that the proposed TMDL revisions could proceed without the need for a public hearing.

As noted before, EPA Region III established a web site for the Christina River Basin TMDLs to serve as an information clearinghouse for these TMDls. Information related to the proposed TMDLS was posted on this site and included meeting announcements, summaries of presentations and draft TMDL documents. The web site also provided a means for the public to submit comments on the proposed TMDLs

8) There is reasonable assurance that the TMDLs can be met.

There is a high degree of reasonable assurance that each WLA and load allocation for these TMDLs will be implemented. EPA expects the states to implement these TMDLs by ensuring that NPDES permit limits are consistent with the WLAs described herein. The treatment recommendations made by these TMDLs are achievable. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must 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 an NPDES permit that is inconsistent with 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 water quality problems, consider alternative solutions and recommend control measures. This provides further assurance that the pollutant allocations of the TMDLs will be implemented.

In terms of the nonpoint sources, the load allocations are representative of expected pollutant loads during critical conditions from baseflow, atmospheric, and traditional land-based sources. Reasonable assurance that the current load allocations will be met is based on the extensive data set used to characterize the current nonpoint source pollutant loadings. These loadings are not expected to vary significantly. Therefore, reductions from the current load allocations are unnecessary to meet WQS under low-flow conditions.

VIII. References

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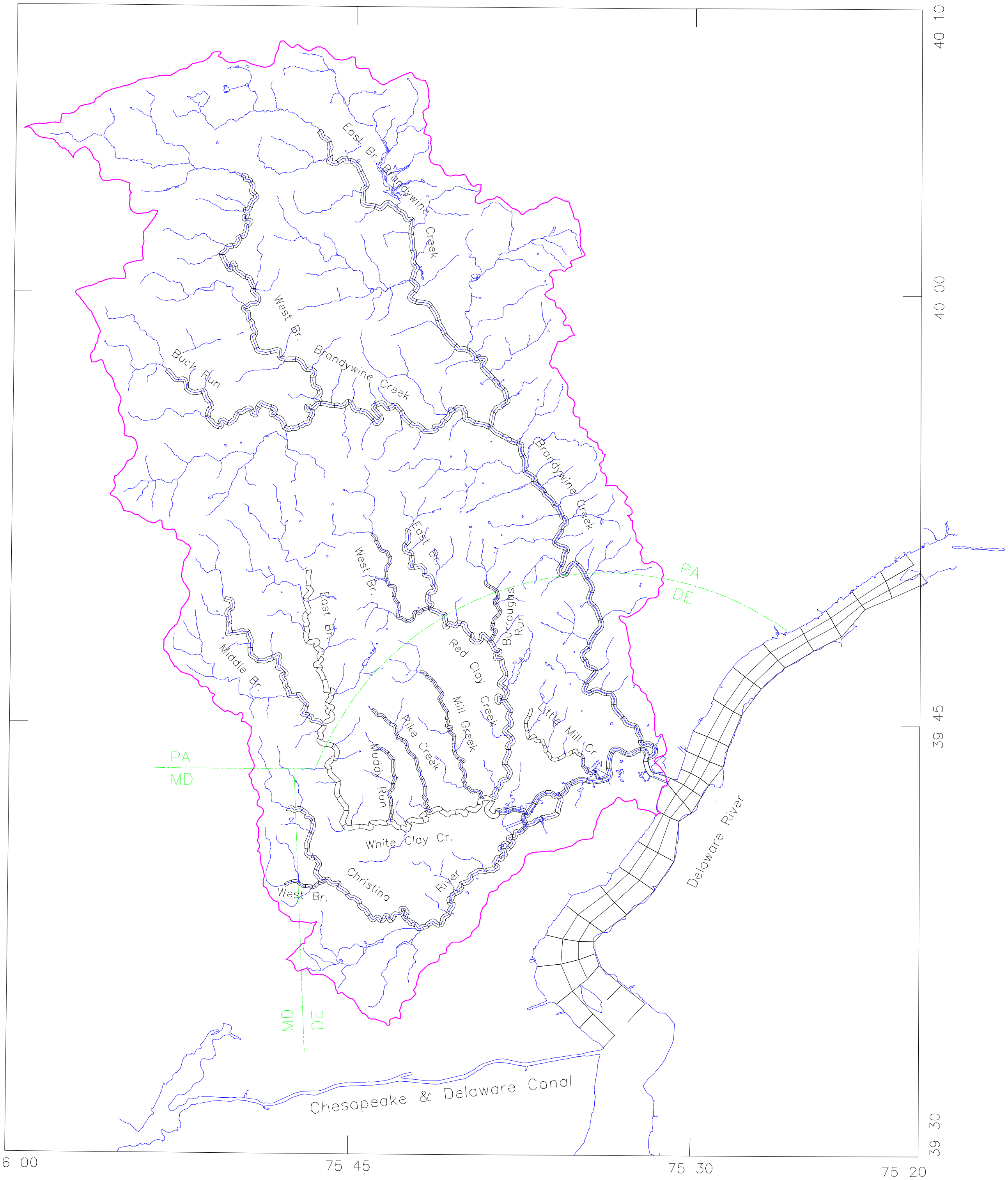

Figure 1. Christina River Basin Study Area

Figure 2. Locations of NPDES discharges in the Christina River Basin

Figure 3. Locations of water quality monitoring stations in the Christina River Basin

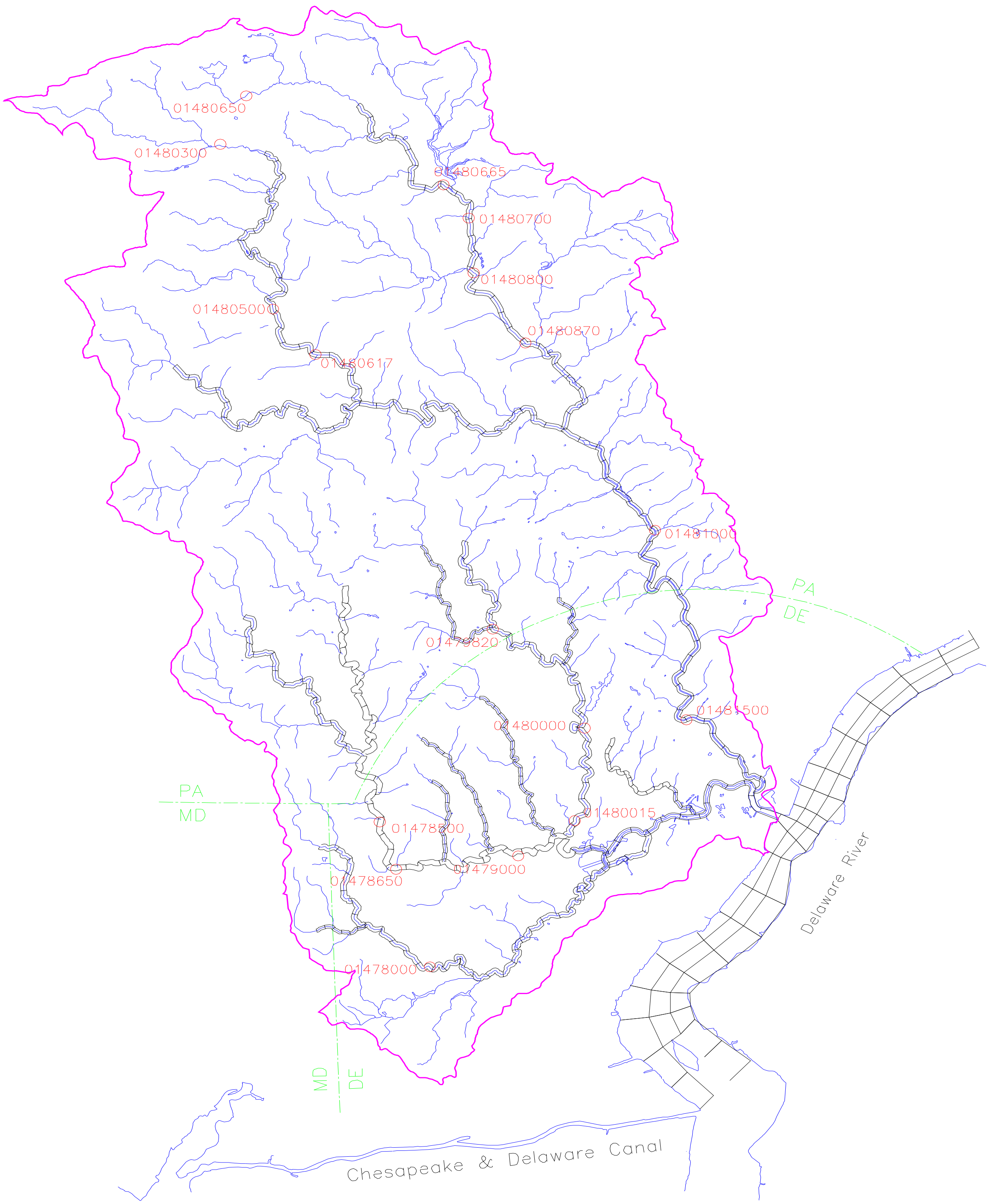

Figure 4. Locations of USGS stream gages in the Christina River Basin

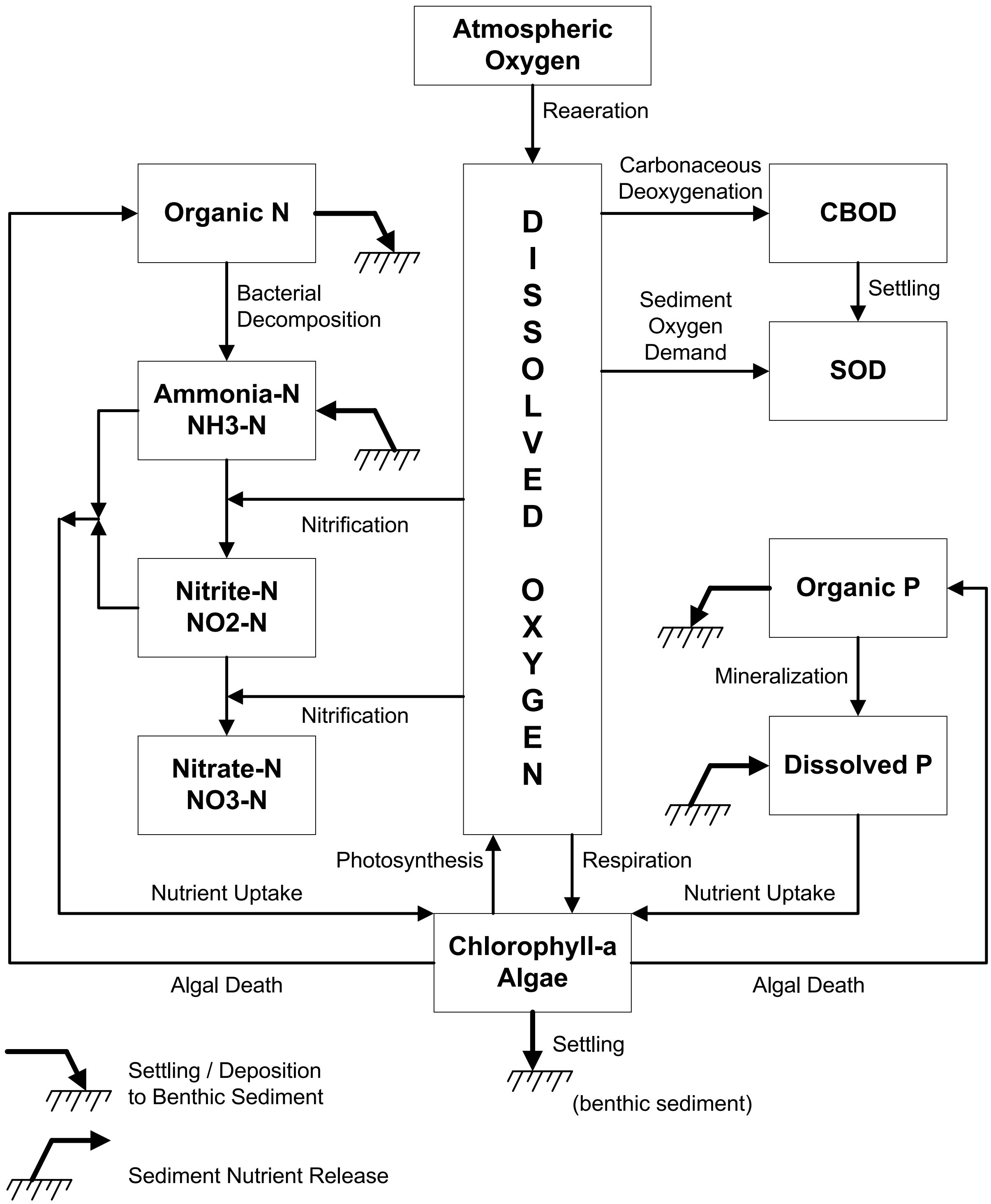

Figure 5. Interrelationship of major kinetic processes for BOD, DO, and nutrients as represented by water quality models (adapted from EPA 823-B-97-002).

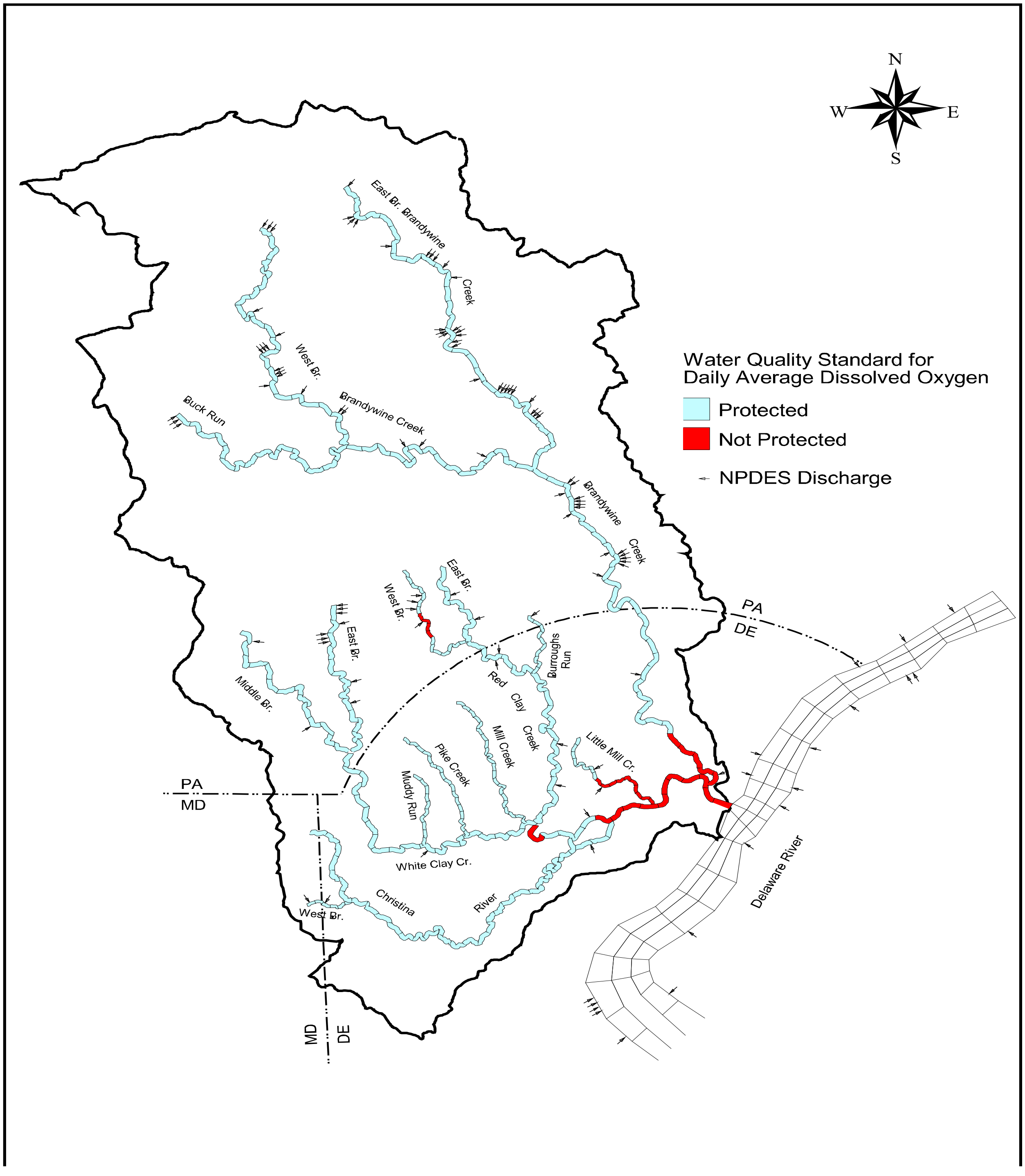

Figure 6. Modeled stream segments violating daily average dissolved oxygen water quality criteria based on the EFDC model using 1997 calibration data.

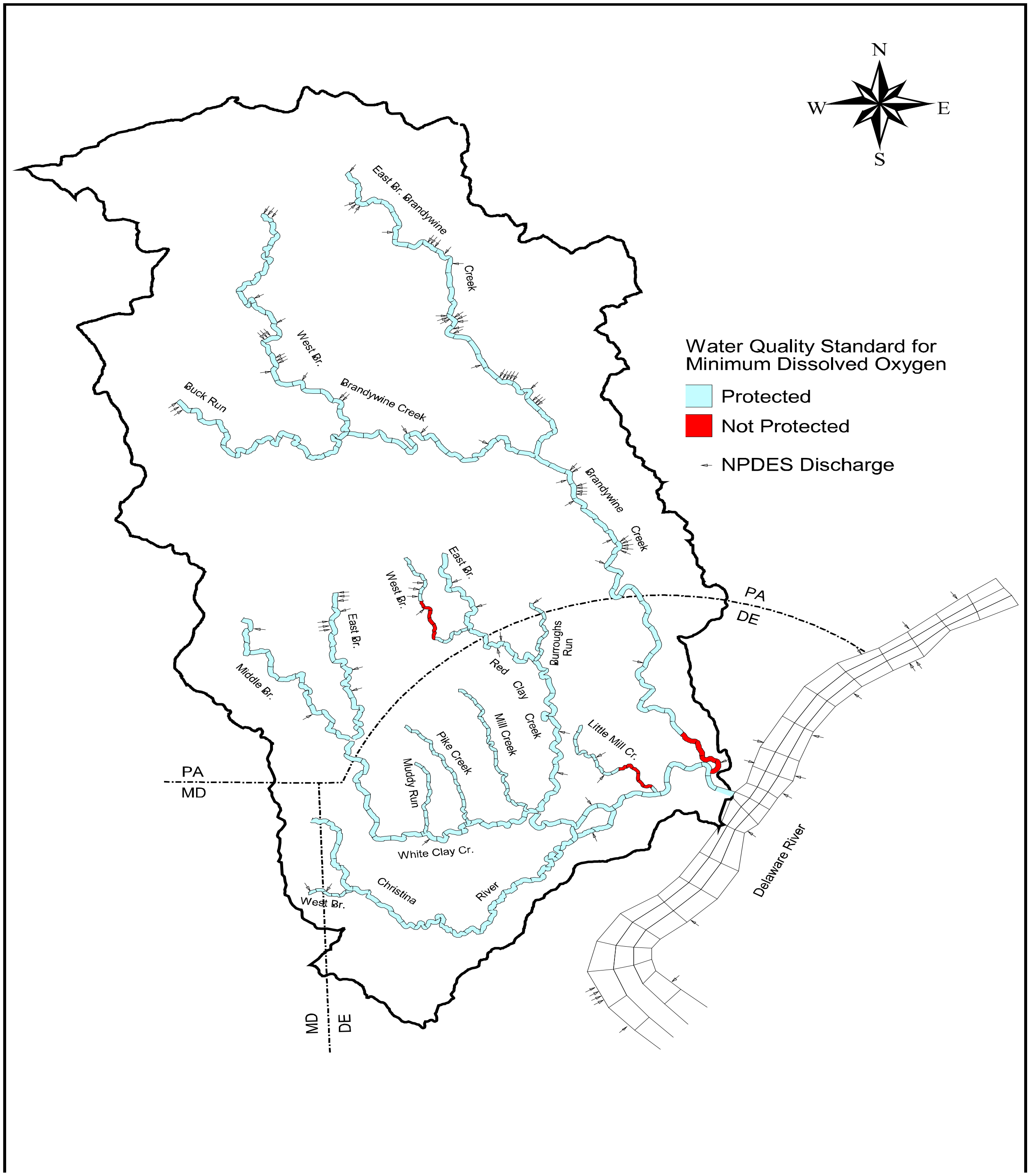

Figure 7. Modeled stream segments violating minimum dissolved oxygen water quality criteria based on the EFDC model using 1997 calibration data.

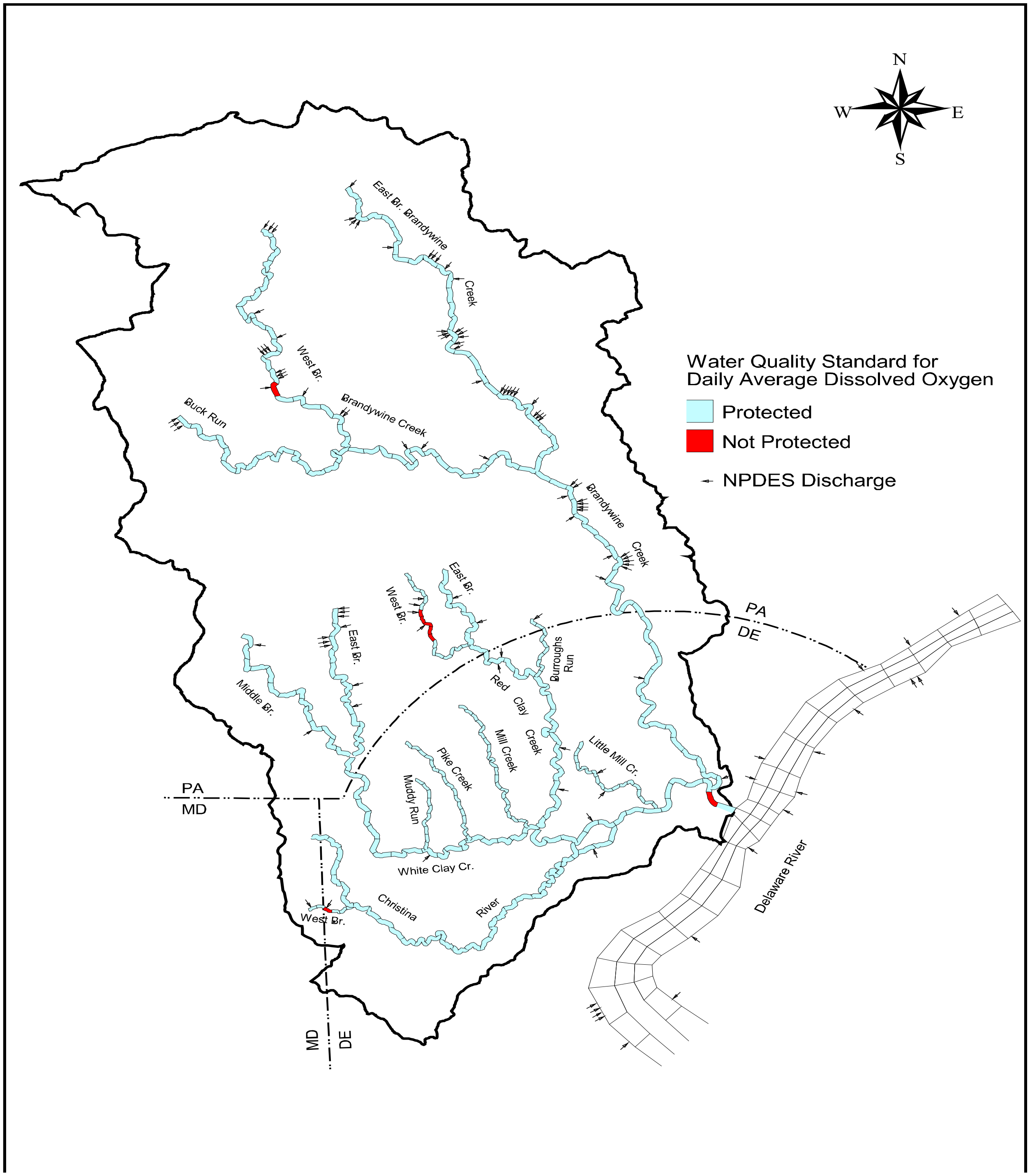

Figure 8. Modeled stream segments violating daily average dissolved oxygen water quality criteria based on the EFDC model during critical conditions.

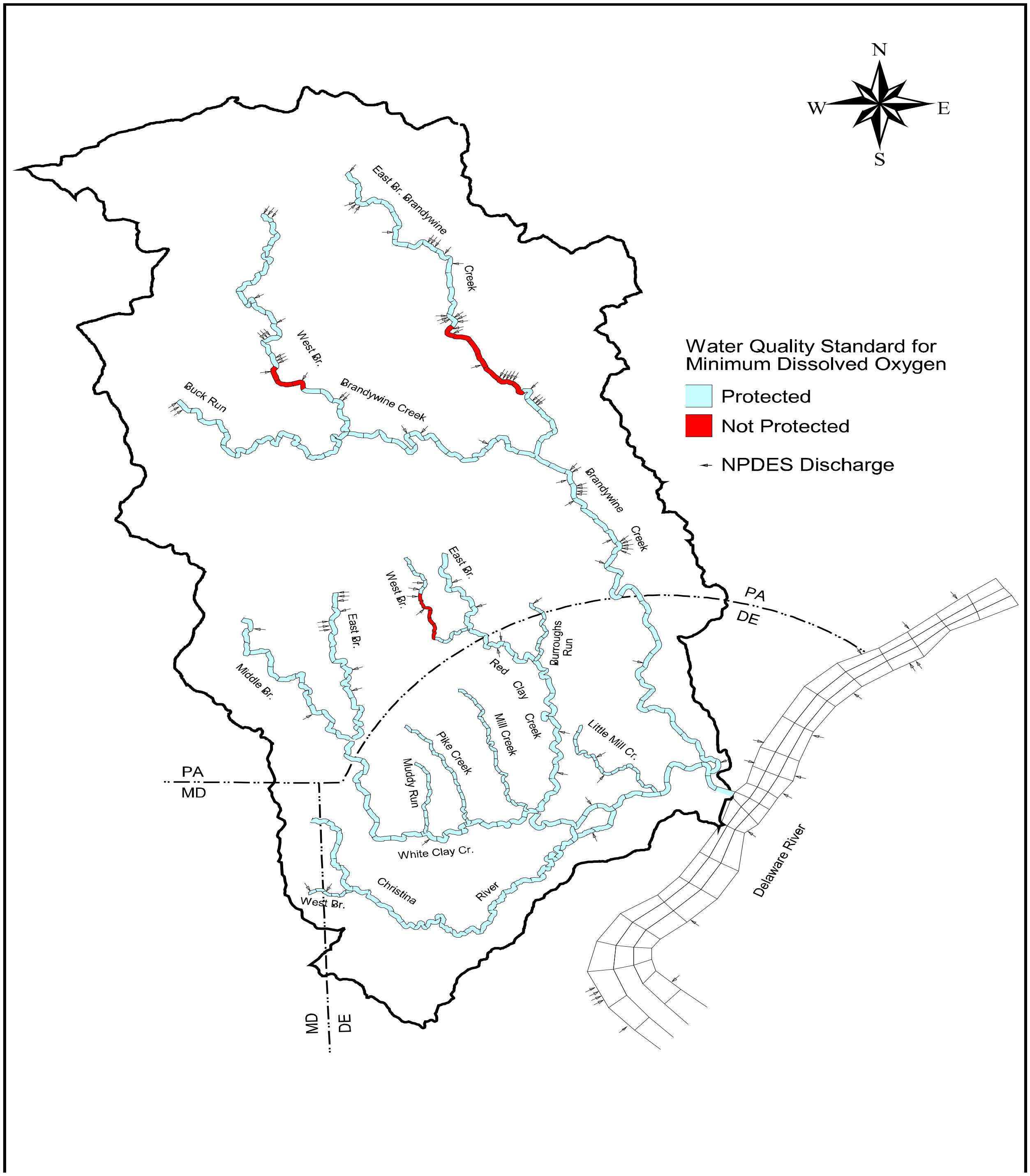

Figure 9. Modeled stream segments violating minimum dissolved oxygen water quality criteria based on the EFDC model during critical conditions.

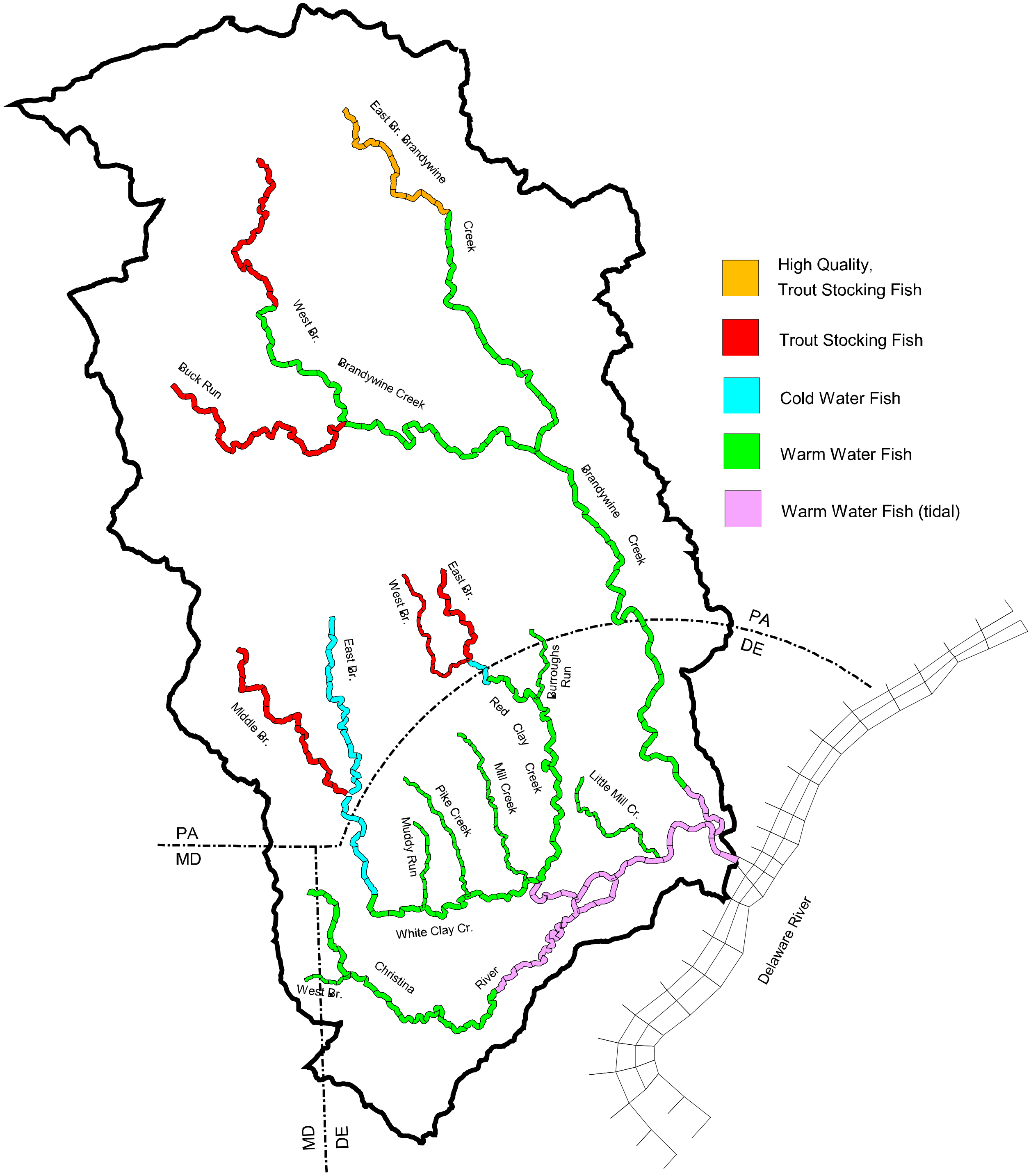

Figure 10. Applicable use designations for stream segments in the Christina River Basin

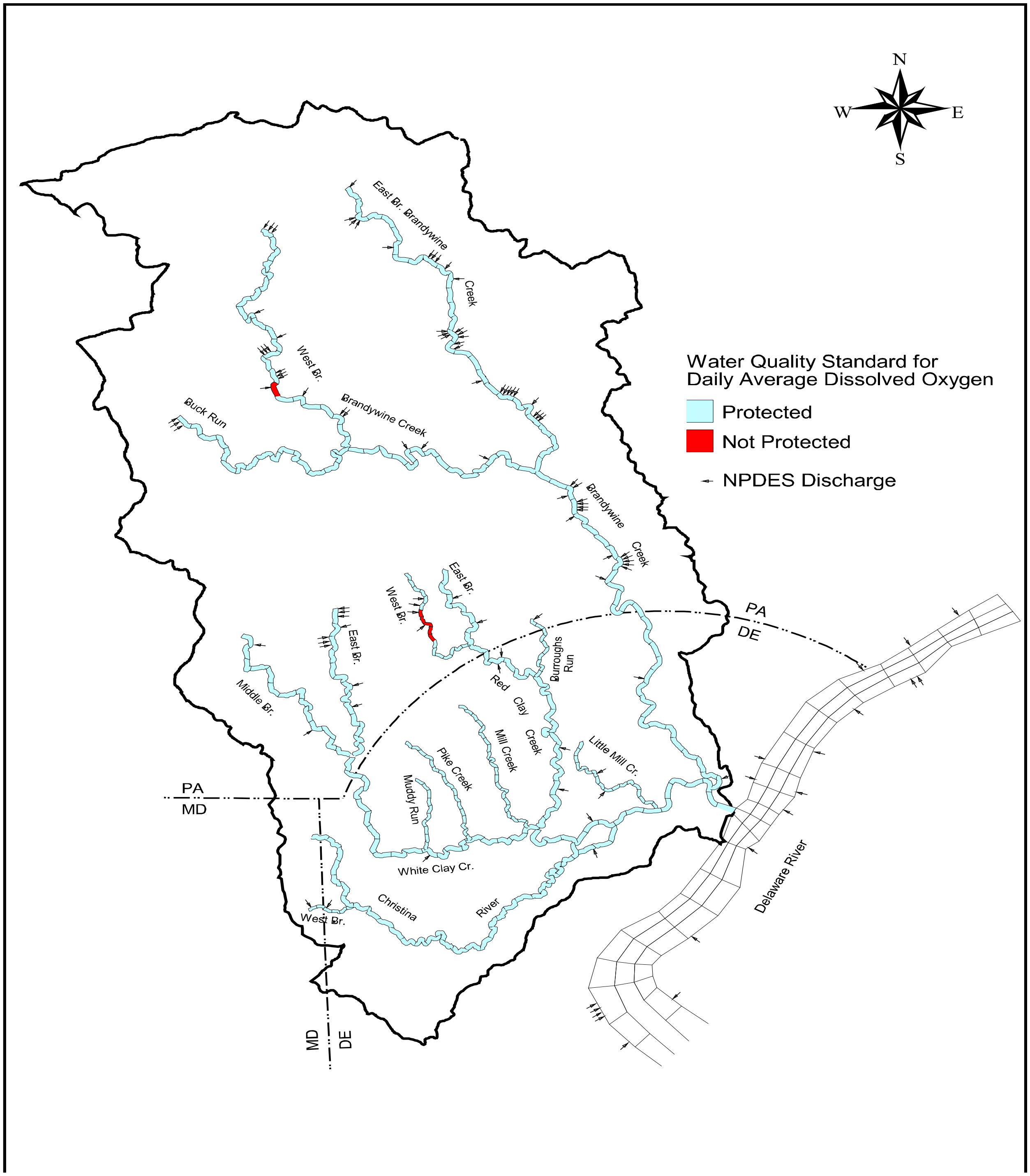

Figure 11. Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on the Level 1 allocation analysis.

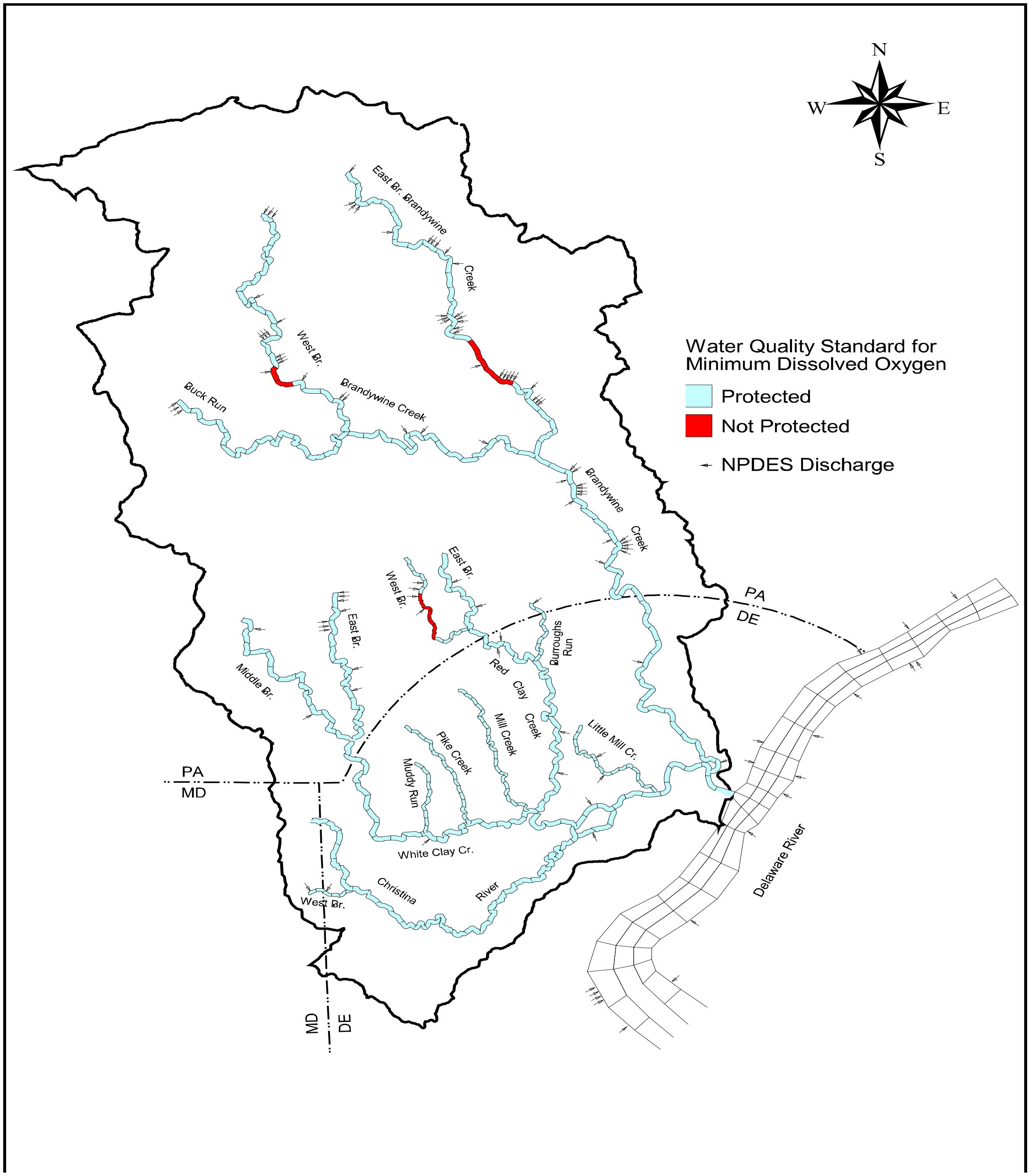

Figure 12. Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 1 allocation analysis.

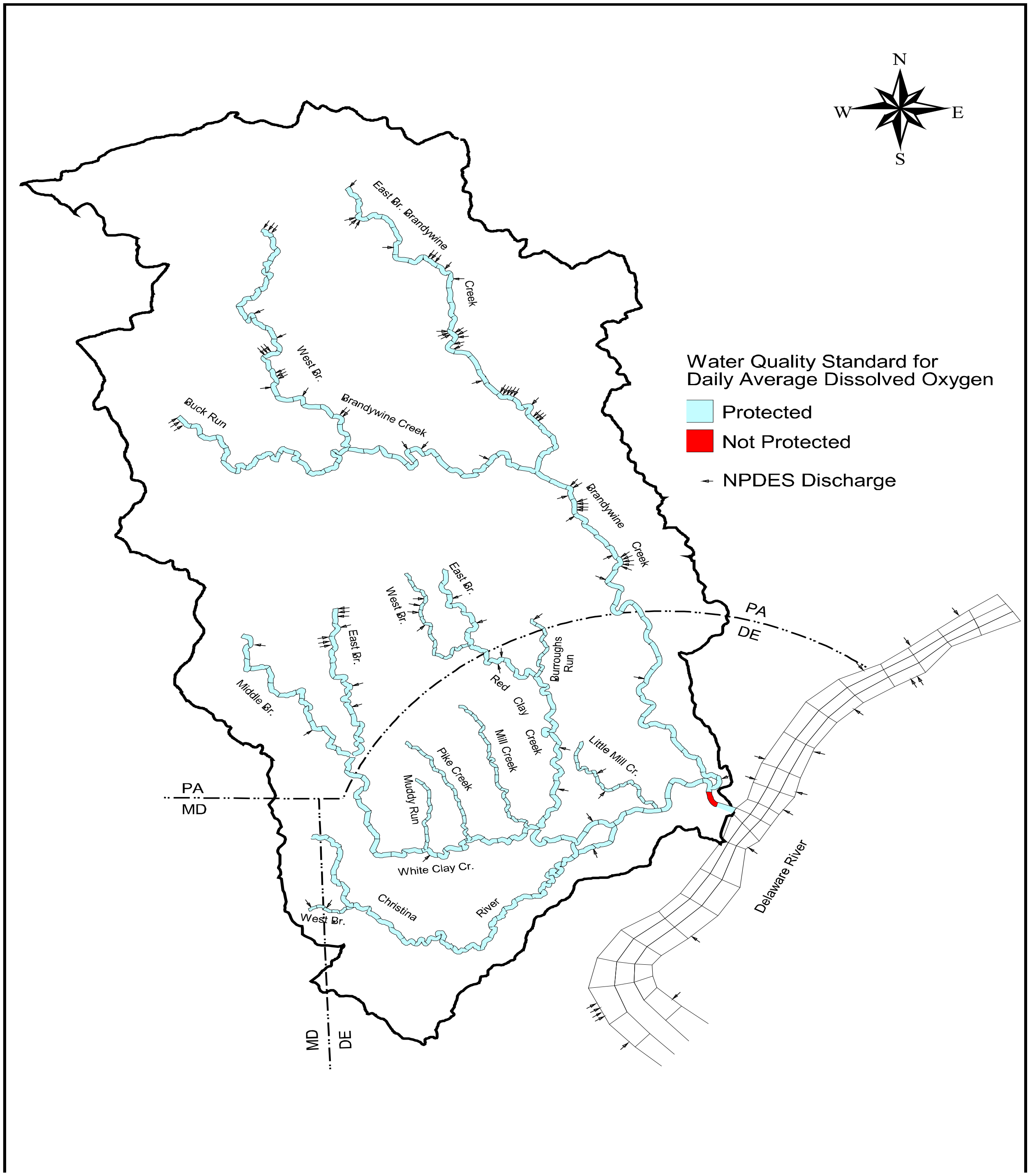

Figure 13. Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on Level 2 allocation analysis.

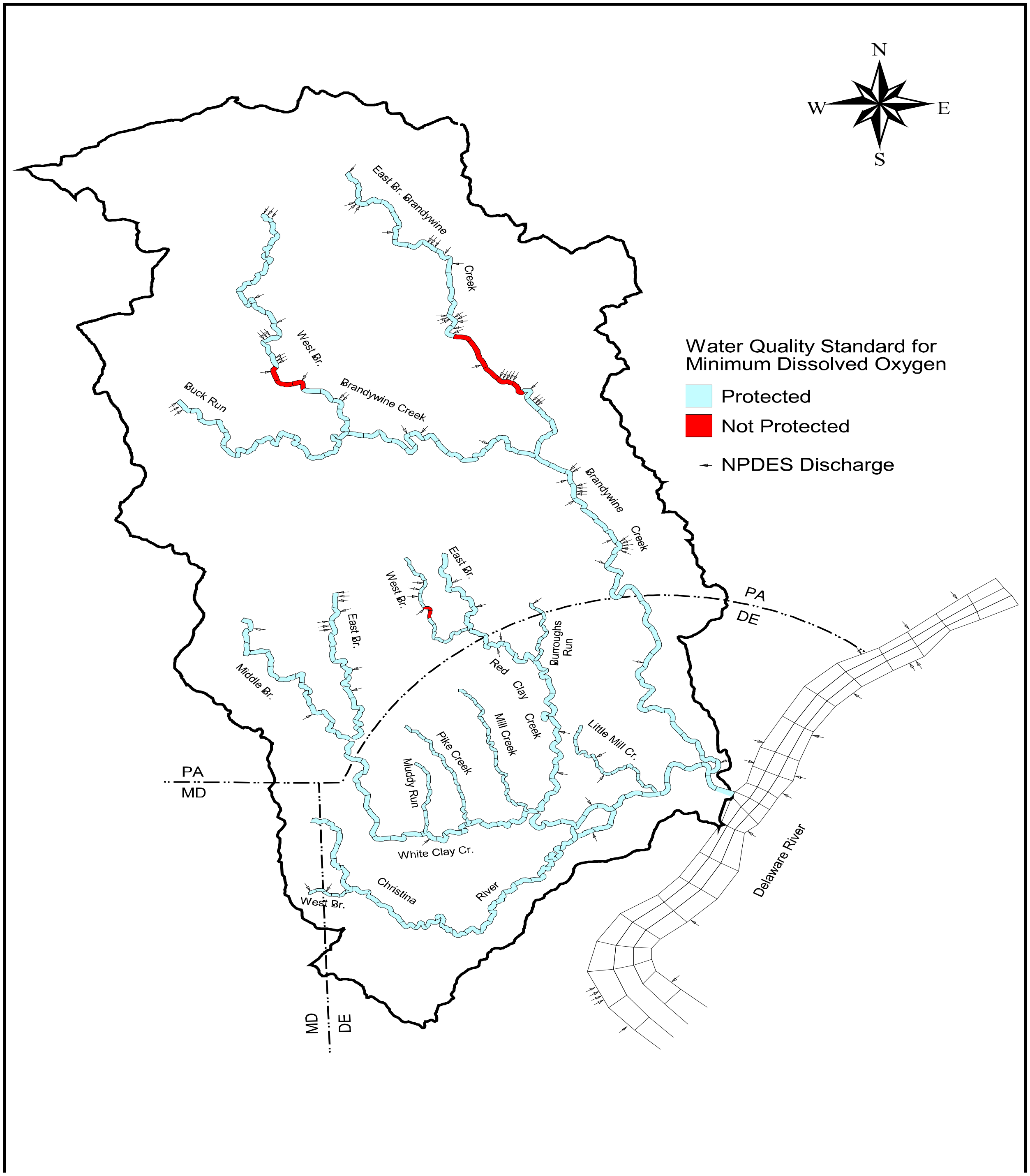

Figure 14. Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 2 allocation analysis.

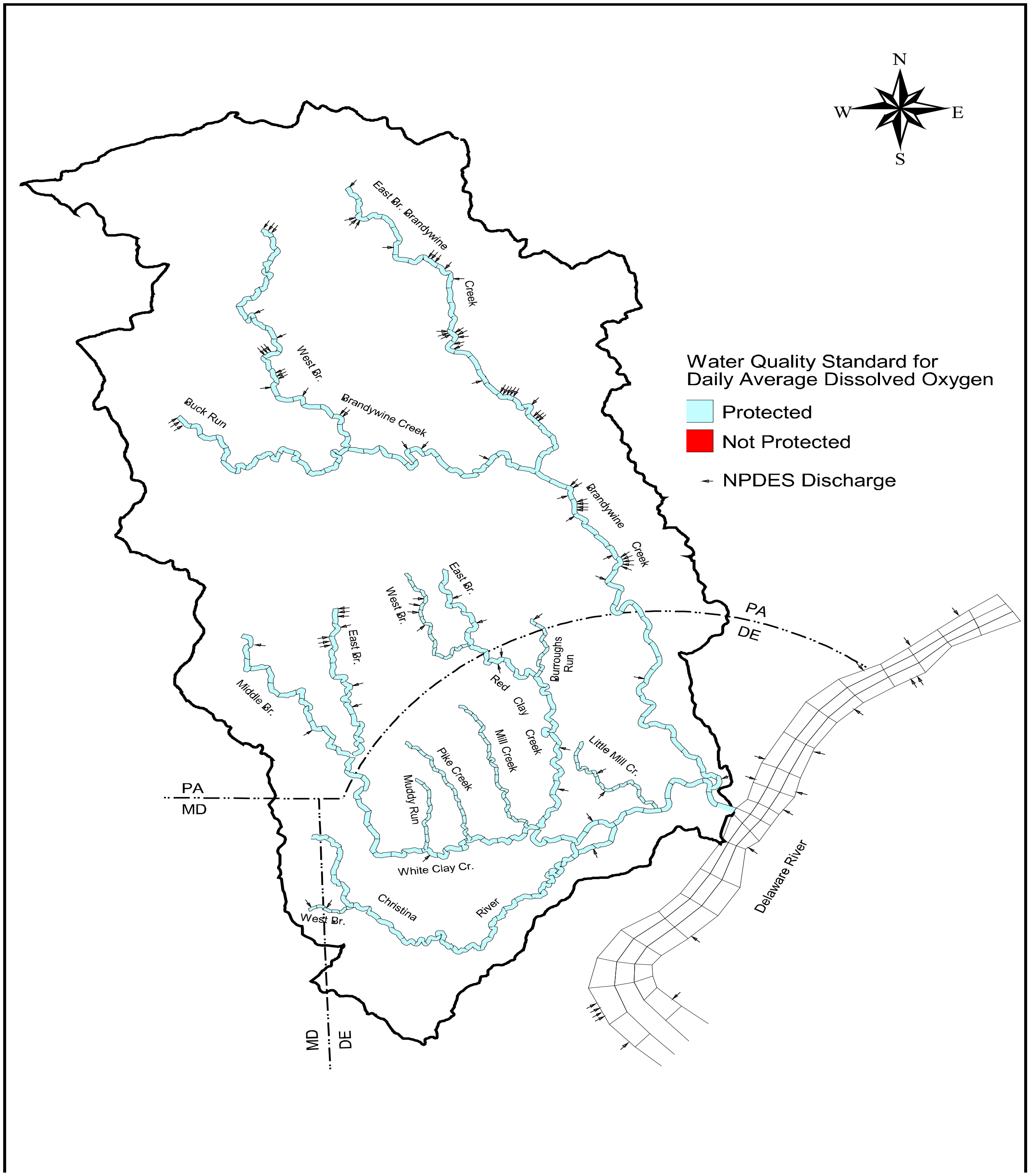

Figure 15. Final Level 2 allocation analysis results which indicate no violations of daily average dissolved oxygen water quality criteria in modeled stream segments.

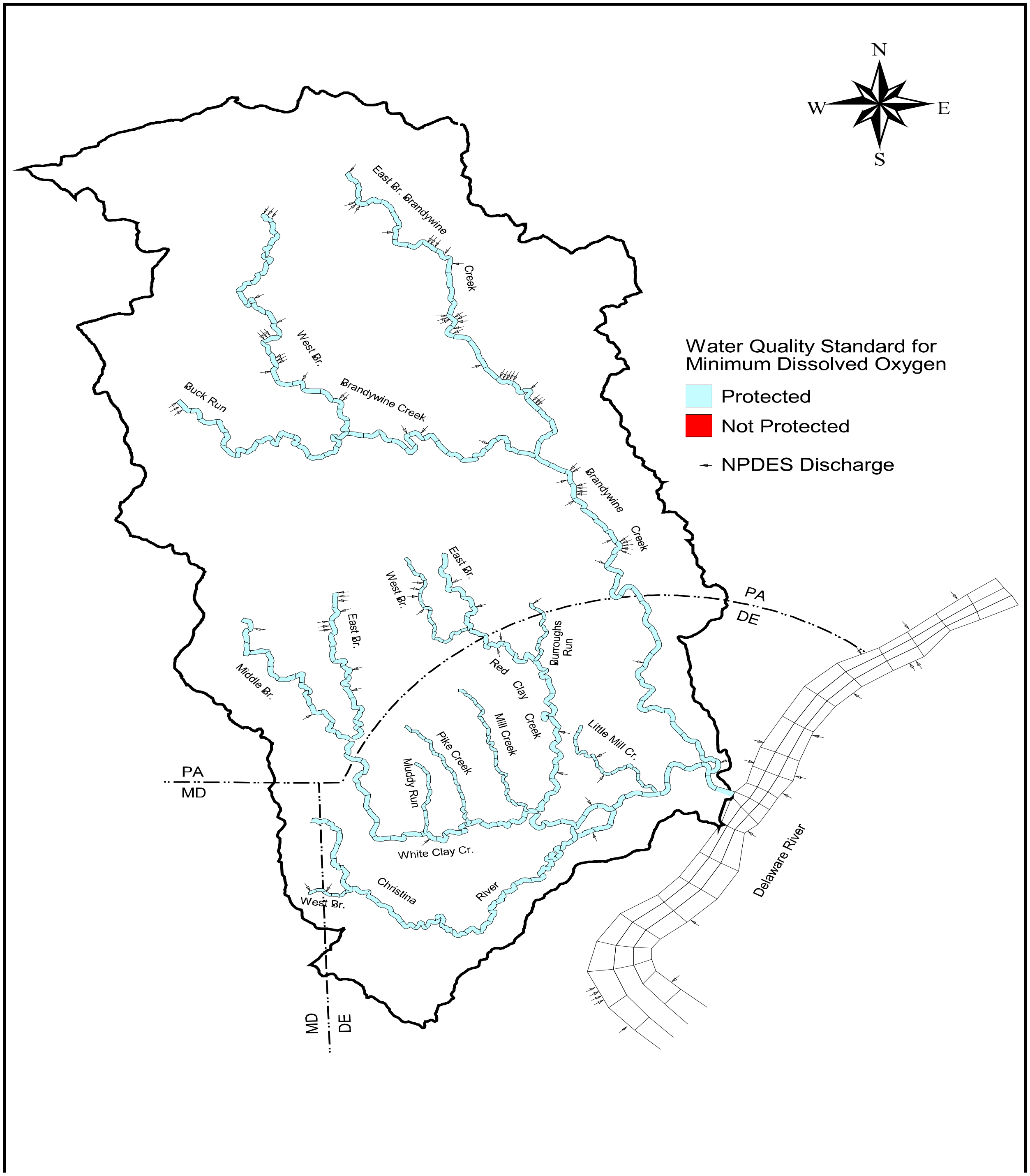

Figure 16. Final Level 2 allocation analysis results which indicate no violations of minimum dissolved oxygen water quality criteria in modeled stream segments.

Table 2. Locations of NPDES point source discharges included in the model.

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	PA0055085	0.0005	SRD	Winslow Nancy Ms.	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0055484	0.0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0047252	0.0700	STP	Pantos Corp/Painters Crossing	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	PA0050005	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	PA0054747	0.0000	SWR	Trans-Materials, Inc.	Taylor Run	Industrial	Stormwater
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	West Chester Area Mun. Auth.	EB Brandywine Creek	Municipal	Ingram's Mill-Backwash
100.535	54,55	PA0053937	0.0005	SRD	Johnson Ralph & Gayla	Broad 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	54,60	PA0012815	1.0280	IND	Sunoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103.682	54,60	PA0026531	7.1340	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	PA0050229	0.0005	SRD	unknown	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	Topp John & Jane	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. Locations of NPDES point source discharges included in the model (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	Lukens Steel Co.	Sucker Run	Industrial	Large STP
111.038	23,79	PA0011568-016	0.5000	IND	Lukens Steel Co.	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	Coatesville Water Plant	Rock Run	Industrial	Water Filtration 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-eliminated 06/10/97
117.041	33,61	PA0036161	0.0360	STP	Lincoln Crest MHP STP	Buck Run	Municipal	Small STP
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
103.255	43,47	PA0054755	0.0000	SWR	Trans-Materials Inc.	EB Red Clay Creek	Industrial	Stormwater
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	0.0500	STP	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Can/Process Water
104.579	28,43	PA0057720-003	0.0900	NCW	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Can/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. Locations of NPDES point source discharges included in the model (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	PA0052019	0.0075	STP	Avon Grove Trailer Court	EB White Clay Creek	Municipal	Small STP
106.560	19,30	PA0056898	0.0650	IND	To-Jo Mushrooms Inc.	Trout Run	Industrial	Small STP-online Jan 98
107.195	19,31	PA0056952	0.0029	IND	Sun Company Inc.	EB White Clay Creek	GWCleanup	Groundwater Cleanup
107.830	19,32	PA0029343	0.0270	STP	Chatham Acres	TB-EB White Clay Creek	Municipal	Small STP
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	134.0000	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	1.2700	IND	Solutia (formerly 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 is based on value used to calculate CBOD5 load in permit

Table 8
TMDL Summary by Subwatershed for the Christina River Basin

Sum of Individual Waste Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day
Brandywine Creek main stem	79.72	16.82	43.04	9.00	26.74
Brandywine Creek East Branch	1,022.79	157.30	3,562.99	118.76	523.97
Brandywine Creek West Branch	600.16	124.15	1,218.68	69.48	257.01
Buck Run	7.55	0.79	1.91	0.61	1.53
Brandywine Creek Watershed	**1,710.22**	**299.06**	**4,826.62**	**197.85**	**809.25**
Christina River West Branch	75.57	13.57	125.33	6.26	37.56
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.57**	**13.57**	**125.33**	**6.26**	**37.56**
Burroughs Run	0.04	0.01	0.02	0.01	0.03
Red Clay Creek West Branch	162.32	19.44	46.94	12.83	71.36
Red Clay Creek main stem	108.96	4.81	11.61	75.52	112.11
Red Clay Creek Watershed	**271.32**	**24.26**	**58.57**	**88.36**	**183.50**
White Clay Cr. Middle Branch	53.83	10.52	25.46	4.51	11.27
White Clay Cr. East Branch	88.78	8.69	149.67	11.23	16.17
Muddy Run	0.00	0.00	0.00	0.00	0.00
Pike Creek	0.00	0.00	0.00	0.00	0.00
Mill Creek	0.00	0.00	0.00	0.00	0.00
White Clay Cr. main stem	0.75	0.03	0.06	0.03	1.25
White Clay Creek Watershed	**143.36**	**19.24**	**175.19**	**15.77**	**28.69**
Total Waste Load Allocation for Point Sources in Christina River Basin	**2,200.47**	**356.13**	**5,185.71**	**308.24**	**1,059.00**

Table 8 (continued)
TMDL Summary by Subwatershed for the Christina River Basin

Sum of Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day
Brandywine Creek main stem	52.01	1.78	137.30	1.50	497.95
Brandywine Creek East Branch	162.33	3.85	248.01	3.35	1,333.95
Brandywine Creek West Branch	99.18	3.08	262.94	2.77	958.41
Buck Run	34.72	0.96	92.45	0.94	338.75
Brandywine Creek Watershed	**348.24**	**9.67**	**740.69**	**8.55**	**3,129.05**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.27	0.52	25.38	0.51	186.02
Christina River main stem	34.99	1.65	26.85	0.86	163.08
Christina River Watershed	**72.43**	**2.19**	**53.05**	**1.38**	**355.05**
Burroughs Run	4.60	0.10	9.10	0.21	33.65
Red Clay Creek West Branch	20.05	0.42	39.68	0.90	146.87
Red Clay Creek main stem	40.10	0.91	79.24	1.83	292.00
Red Clay Creek Watershed	**64.75**	**1.43**	**128.02**	**2.94**	**472.52**
White Clay Cr. Middle Branch	20.80	0.67	58.11	0.66	237.96
White Clay Cr. East Branch	23.44	0.77	65.42	0.74	267.66
Muddy Run	3.23	0.11	9.00	0.10	36.80
Pike Creek	5.57	0.19	15.52	0.18	63.40
Mill Creek	7.64	0.26	21.31	0.24	87.06
White Clay Cr. main stem	17.96	0.68	49.76	0.59	201.98
White Clay Creek Watershed	**78.64**	**2.68**	**219.12**	**2.51**	**894.86**
Total for LA Christina River Basin	**564.06**	**15.97**	**1,140.88**	**15.38**	**4,851.48**
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	**2,764.53**	**372.10**	**6,326.59**	**323.62**	**5,910.47**

Note: Totals subject to rounding variations.

Table 12
TMDL Summary for Buck Run

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0036161	0.0360	25.00	2.60	6.29	2.00	5.00	7.512	0.781	1.890	0.601	1.502	0.0%	0.0%	0.0%
PA0057231	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						7.553	0.787	1.905	0.609	1.527			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B05	4.70	0.75	0.02	2.00	0.02	7.34	19.010	0.507	50.693	0.507	186.044	0.0%	0.0%	0.0%
B06	3.86	0.75	0.02	2.00	0.02	7.34	15.603	0.416	41.609	0.416	152.705	0.0%	0.0%	0.0%
Atm. Deposition							0.103	0.038	0.148	0.013				
	Total Load Allocation						34.716	0.961	92.450	0.936	338.748			

Table 13
TMDL Summary for Brandywine Creek West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0056561	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0029912	0.1000	25.00	20.00	48.40	2.00	3.00	20.866	16.693	40.396	1.669	2.504	0.0%	0.0%	0.0%
PA0053996	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0053228	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0053236	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0036897	0.3900	25.00	7.00	30.00	2.00	2.00	81.377	22.785	97.652	6.510	6.510	0.0%	0.0%	0.0%
PA0026859	3.8500	11.07	2.00	30.00	1.48	5.00	355.716	64.267	964.001	47.557	160.667	26.2%	0.0%	26.2%
PA0011568-001	0.6400	5.00	0.50	5.30	0.30	5.00	26.708	2.671	28.311	1.602	26.708	0.0%	0.0%	0.0%
PA0011568-016	0.5045	5.00	0.50	12.00	0.30	5.00	21.054	2.105	50.529	1.263	21.054	0.0%	0.0%	0.0%
PA0053821	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0056073	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%

PA0012416	0.1400	10.00	0.10	0.24	0.10	5.00	11.685	0.117	0.280	0.117	5.842	0.0%	0.0%	0.0%
PA0052990	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0052728	0.0004	25.00	1.50	3.63	2.00	2.00	0.083	0.005	0.012	0.007	0.007	0.0%	0.0%	0.0%
PA0055697	0.0490	25.00	1.50	3.63	2.00	3.00	10.224	0.613	1.485	0.818	1.227	0.0%	0.0%	0.0%
PA0036412	0.0550	10.00	2.90	7.02	1.90	5.00	4.590	1.331	3.223	0.872	2.295	0.0%	0.0%	0.0%
PA0044776	0.6000	13.50	2.70	6.53	1.80	6.00	67.605	13.521	32.701	9.014	30.047	10.0%	10.0%	10.0%
PA0057339	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						600.160	124.146	1218.680	69.480	257.011			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B01	6.17	0.75	0.020	2.00	0.020	7.34	24.945	0.665	66.521	0.665	244.133	0.0%	0.0%	0.0%
B02	9.06	0.75	0.020	2.00	0.020	7.34	36.659	0.978	97.758	0.978	358.771	0.0%	0.0%	0.0%
B03	4.96	0.75	0.020	2.00	0.020	7.34	20.059	0.535	53.489	0.535	196.306	0.0%	0.0%	0.0%
B04	2.92	0.75	0.020	2.00	0.020	7.34	11.817	0.315	31.511	0.315	115.644	0.0%	0.0%	0.0%
B07	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.868	0.119	43.554	0.0%	0.0%	0.0%
Atm. Deposition							1.249	0.467	1.790	0.159				
	Total Load Allocation						99.179	3.078	262.937	2.770	958.409			

Table 14
TMDL Summary for Brandywine Creek East Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0056171	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0026018	1.5000	25.00	2.50	6.05	2.00	5.00	312.987	31.299	75.743	25.039	62.597	0.0%	0.0%	0.0%
PA0054747	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0057282	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0051365	0.3690	2.00	0.10	0.24	0.10	5.00	6.160	0.308	0.739	0.308	15.399	0.0%	0.0%	0.0%
PA0053937	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0056324	0.0440	2.00	0.04	2.10	0.11	5.00	0.734	0.015	0.771	0.040	1.836	0.0%	0.0%	0.0%
PA0056618	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0054305	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053561	0.0360	2.00	0.04	2.10	0.11	5.00	0.601	0.012	0.631	0.033	1.502	0.0%	0.0%	0.0%
PA0043982	0.4000	22.95	2.00	45.00	1.88	2.00	76.619	6.677	150.234	6.276	6.677	8.2%	0.0%	6.2%
PA0012815	1.0280	24.41	4.31	40.06	0.72	5.00	209.438	36.980	343.716	6.178	42.900	28.2%	28.2%	28.2%
PA0026531	7.1340	6.38	1.28	50.00	1.28	6.00	379.883	76.215	2977.136	76.215	357.256	36.2%	36.2%	36.2%
PA0030228	0.0225	7.00	1.00	2.42	3.00	5.00	1.315	0.188	0.454	0.563	0.939	0.0%	0.0%	0.0%
PA0051918	0.1440	2.00	0.10	0.24	0.10	5.00	2.404	0.120	0.288	0.120	6.009	0.0%	0.0%	0.0%
PA0053678	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053660	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0055531	0.0007	25.00	1.50	3.63	2.00	3.00	0.146	0.009	0.021	0.012	0.018	0.0%	0.0%	0.0%
PA0057126	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0054917	0.4750	5.89	0.78	1.89	0.78	6.00	23.351	3.092	7.493	3.092	23.787	0.0%	0.0%	0.0%
PA0057045	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0036374	0.0150	10.00	0.50	1.21	0.50	5.00	1.252	0.063	0.151	0.063	0.626	0.0%	0.0%	0.0%
PA0052949	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0057274	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0050458	0.0531	10.00	3.00	7.26	1.00	6.00	4.432	1.330	3.218	0.443	2.659	0.0%	0.0%	0.0%
PA0050229	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0050547	0.0375	10.00	3.00	7.26	1.00	5.00	3.130	0.939	2.272	0.313	1.565	0.0%	0.0%	0.0%
PA0055492	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0054691	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						1022.786	157.295	3562.990	118.762	523.972			

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B08	12.43	0.89	0.020	1.36	0.018	7.34	59.686	1.341	91.205	1.207	492.241	0.0%	0.0%	0.0%
B09	3.02	0.89	0.020	1.36	0.018	7.34	14.504	0.326	22.163	0.293	119.616	0.0%	0.0%	0.0%
B10	3.99	0.89	0.020	1.36	0.018	7.34	19.172	0.431	29.297	0.388	158.117	0.0%	0.0%	0.0%
B11	5.62	0.89	0.020	1.36	0.018	7.34	27.003	0.607	41.263	0.546	222.696	0.0%	0.0%	0.0%
B12	5.09	0.89	0.020	1.36	0.018	7.34	24.448	0.549	37.359	0.494	201.628	0.0%	0.0%	0.0%
B13	3.53	0.89	0.020	1.36	0.018	7.34	16.933	0.381	25.875	0.342	139.650	0.0%	0.0%	0.0%
Atm Deposition							0.589	0.220	0.843	0.075				
	Total Load Allocation						162.335	3.855	248.005	3.346	1333.949			

Table 15
TMDL Summary for Brandywine Creek Main Stem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0050962	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0021768	0.0250	15.00	1.50	3.63	2.00	5.00	3.130	0.313	0.757	0.417	1.043	0.0%	0.0%	0.0%
PA0053082	0.0206	10.00	3.00	7.26	2.00	5.00	1.719	0.516	1.248	0.344	0.860	0.0%	0.0%	0.0%
PA0052663	0.0900	10.00	1.00	2.42	2.00	5.00	7.512	0.751	1.818	1.502	3.756	0.0%	0.0%	0.0%
PA0055476	0.0400	10.00	3.00	7.26	2.00	3.00	3.339	1.002	2.424	0.668	1.002	0.0%	0.0%	0.0%
PA0047252	0.0700	25.00	3.00	7.26	2.00	3.00	14.606	1.753	4.242	1.168	1.753	0.0%	0.0%	0.0%
PA0055085	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0055484	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0030848	0.0063	25.00	1.50	3.63	2.00	3.00	1.315	0.079	0.191	0.105	0.158	0.0%	0.0%	0.0%
PA0056120	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0031097	0.0170	25.00	20.00	48.40	2.00	5.00	3.547	2.838	6.867	0.284	0.709	0.0%	0.0%	0.0%
PA0053449	0.1500	15.00	1.50	3.63	2.00	5.00	18.779	1.878	4.545	2.504	6.260	0.0%	0.0%	0.0%
PA0057011	0.0773	25.00	3.50	8.47	2.00	5.00	16.129	2.258	5.465	1.290	3.226	0.0%	0.0%	0.0%
PA0036200	0.0320	25.00	20.00	48.40	2.00	3.00	6.677	5.342	12.927	0.534	0.801	0.0%	0.0%	0.0%
PA0050005	0.1400	2.00	0.04	2.10	0.11	5.00	2.337	0.047	2.454	0.129	5.842	0.0%	0.0%	0.0%
PA0051497	0.0300	2.00	0.10	0.24	0.10	5.00	0.501	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	Total Waste Load Allocation						79.716	16.819	43.042	8.996	26.737			

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B14	2.92	0.75	0.020	2.00	0.020	7.34	11.817	0.315	31.511	0.315	115.644	0.0%	0.0%	0.0%
B15	4.70	0.75	0.020	2.00	0.020	7.34	19.010	0.507	50.693	0.507	186.044	0.0%	0.0%	0.0%
B16	3.86	0.75	0.020	2.00	0.020	7.34	15.603	0.416	41.609	0.416	152.705	0.0%	0.0%	0.0%
B17	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.868	0.119	43.554	0.0%	0.0%	0.0%
Atm. Deposition							1.131	0.422	1.620	0.144				
	Total Load Allocation						52.011	1.779	137.300	1.501	497.947			

Table 16
TMDL Summary for Burroughs Run

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0055425	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.042	0.006	0.015	0.008	0.025			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R03	0.85	1.00	0.02	1.98	0.05	7.34	4.585	0.092	9.078	0.206	33.652	0.0%	0.0%	0.0%
Atm. Deposition							0.013	0.005	0.018	0.002				
	Total Load Allocation						4.598	0.097	9.096	0.208	33.652			

Table 17
TMDL Summary for Red Clay Creek West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0053554	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0024058	1.1000	16.63	2.00	4.83	1.28	6.00	152.679	18.362	44.344	11.752	55.086	33.5%	33.5%	82.9%
PA0050679	0.2500	2.00	0.10	0.24	0.10	5.00	4.173	0.209	0.501	0.209	10.433	0.0%	0.0%	0.0%
PA0057720-001	0.0500	9.50	1.90	4.60	1.90	5.00	3.965	0.793	1.920	0.793	2.087	5.0%	5.0%	5.0%
PA0057720-002	0.0900	2.00	0.10	0.24	0.10	5.00	1.502	0.075	0.180	0.075	3.756	0.0%	0.0%	0.0%
	Total Waste Load Allocation						162.319	19.439	46.945	12.828	71.361			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R01	3.71	1.00	0.020	1.98	0.045	7.34	20.009	0.400	39.618	0.900	146.869	0.0%	0.0%	0.0%
Atm. Deposition							0.044	0.016	0.063	0.006				
	Total Load Allocation						20.053	0.416	39.681	0.906	146.869			

Table 18
TMDL Summary for Red Clay Creek Mainstem and East Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000230	0.3500	7.00	0.10	0.24	0.10	5.00	20.449	0.292	0.701	0.292	14.606	0.0%	0.0%	0.0%
DE0021709	0.0150	20.00	1.50	3.63	2.00	5.00	2.504	0.188	0.454	0.250	0.626	0.0%	0.0%	0.0%
DE0050067	0.0015	30.00	1.50	3.63	2.00	5.00	0.376	0.019	0.045	0.025	0.063	0.0%	0.0%	0.0%
DE0000451	2.1700	3.00	0.10	0.24	4.00	5.00	54.335	1.811	4.347	72.446	90.558	0.0%	0.0%	0.0%
PA0055107	0.1500	25.00	2.00	4.84	2.00	5.00	31.299	2.504	6.059	2.504	6.260	0.0%	0.0%	0.0%
PA0054755	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	Total Waste Load Allocation						108.961	4.814	11.607	75.518	112.112			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
R02	1.39	1.00	0.020	1.98	0.045	7.34	7.500	0.150	14.851	0.338	55.052	0.0%	0.0%	0.0%
R04	1.37	1.00	0.020	1.98	0.045	7.34	7.387	0.148	14.626	0.332	54.221	0.0%	0.0%	0.0%
R05	3.62	1.00	0.020	1.98	0.045	7.34	19.530	0.391	38.669	0.879	143.349	0.0%	0.0%	0.0%
HOOPES	1.00	1.00	0.020	1.98	0.045	7.30	5.394	0.108	10.681	0.243	39.379	0.0%	0.0%	0.0%
Atm. Deposition							0.291	0.109	0.417	0.037				
	Total Load Allocation						40.103	0.905	79.244	1.829	292.001			

Table 19
TMDL Summary for the White Clay Creek Middle Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0053783	0.0200	10.00	3.00	7.26	2.00	5.00	1.669	0.501	1.212	0.334	0.835	0.0%	0.0%	0.0%
PA0024066	0.2500	25.00	4.80	11.62	2.00	5.00	52.165	10.016	24.246	4.173	10.433	0.0%	0.0%	0.0%
	Total Waste Load Allocation						53.834	10.516	25.458	4.507	11.268			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W01	2.35	0.64	0.02	1.79	0.02	7.34	8.114	0.254	22.694	0.254	93.059	0.0%	0.0%	0.0%
W02	3.66	0.64	0.02	1.79	0.02	7.34	12.634	0.395	35.337	0.395	144.901	0.0%	0.0%	0.0%
Atm. Deposition							0.054	0.020	0.078	0.007				
	Total Load Allocation						20.803	0.668	58.109	0.655	237.960			

Table 20
TMDL Summary for the White Clay Creek East Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0052451	0.0012	25.00	20.00	48.40	2.00	2.00	0.250	0.200	0.485	0.020	0.020	0.0%	0.0%	0.0%
PA0057029	0.1440	2.00	0.04	2.10	0.11	5.00	2.404	0.048	2.524	0.132	6.009	0.0%	0.0%	0.0%
PA0025488	0.3000	25.00	2.00	50.00	4.00	2.00	62.597	5.008	125.195	10.016	5.008	0.0%	0.0%	0.0%
PA0052019	0.0075	25.00	6.00	14.52	2.00	6.00	1.565	0.376	0.909	0.125	0.376	0.0%	0.0%	0.0%
PA0056898	0.0650	25.00	3.50	32.55	0.30	5.00	13.563	1.899	17.659	0.163	2.713	0.0%	0.0%	0.0%
PA0056952	0.0029	30.00	0.50	4.65	0.30	5.00	0.726	0.012	0.113	0.007	0.121	0.0%	0.0%	0.0%
PA0029343	0.0270	20.00	3.00	7.26	2.00	5.00	4.507	0.676	1.636	0.451	1.127	0.0%	0.0%	0.0%
PA0040436	0.0090	20.00	3.00	7.26	2.00	5.00	1.502	0.225	0.545	0.150	0.376	0.0%	0.0%	0.0%
PA0040665	0.0100	20.00	3.00	7.26	2.00	5.00	1.669	0.250	0.606	0.167	0.417	0.0%	0.0%	0.0%
	Total Waste Load Allocation						88.784	8.694	149.671	11.231	16.166			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		

Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W03	4.32	0.64	0.020	1.79	0.020	7.34	14.913	0.466	41.710	0.466	171.033	0.0%	0.0%	0.0%
W04	2.44	0.64	0.020	1.79	0.020	7.34	8.425	0.263	23.564	0.263	96.627	0.0%	0.0%	0.0%
Atm. Deposition							0.099	0.037	0.141	0.013				
	Total Load Allocation						23.437	0.766	65.415	0.742	267.660			

Table 21
TMDL Summary of Muddy Run

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W07	0.93	0.64	0.02	1.79	0.02	7.34	3.208	0.100	8.973	0.100	36.795	0.0%	0.0%	0.0%
Atm. Deposition							0.017	0.006	0.024	0.002				
	Total Load Allocation						3.225	0.106	8.997	0.102	36.795			

Table 22
TMDL Summary of Pike Creek

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W06	1.60	0.64	0.02	1.79	0.02	7.34	5.528	0.173	15.462	0.173	63.403	0.0%	0.0%	0.0%
Atm. Deposition							0.039	0.015	0.056	0.005				
	Total Load Allocation						5.567	0.188	15.518	0.178	63.403			

Table 23
TMDL Summary of Mill Creek

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W05	2.20	0.64	0.02	1.79	0.02	7.34	7.591	0.237	21.232	0.237	87.065	0.0%	0.0%	0.0%
Atm. Deposition							0.051	0.019	0.073	0.007				
	Total Load Allocation						7.642	0.256	21.305	0.244	87.065			

Table 24
TMDL Summary of White Clay Creek Mainstem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000191	0.0300	3.00	0.10	0.24	0.10	5.00	0.751	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.751	0.025	0.060	0.025	1.252			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
W08	1.72	0.64	0.02	1.79	0.02	7.34	5.938	0.186	16.609	0.186	68.107	0.0%	0.0%	0.0%
W09	2.17	0.64	0.02	1.79	0.02	7.34	7.495	0.234	20.964	0.234	85.964	0.0%	0.0%	0.0%
W10	1.21	0.64	0.02	1.79	0.02	7.34	4.177	0.131	11.684	0.131	47.910	0.0%	0.0%	0.0%
Atm. Deposition							0.348	0.13	0.499	0.044				
	Total Load Allocation						17.959	0.680	49.756	0.594	201.980			

Table 25
TMDL Summary for the Christina River West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
MD0022641*	0.7000	12.22	2.00	20.00	1.00	6.00	71.395	11.685	117.0	5.842	35.055	0.0%	69.0%	0.0%
MD0065145*	0.0500	10.00	4.52	20.00	1.00	6.00	4.173	1.886	8.33	0.417	2.504	0.0%	0.0%	0.0%
	Total Waste Load Allocation						**75.568**	**13.571**	**125.33**	6.260	**37.558**			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01WB	0.15	1.43	0.02	1.00	0.02	7.34	1.158	0.016	0.810	0.016	5.943	0.0%	0.0%	0.0%
Atm. Deposition							0.008	0.003	0.011	0.001				
	Total Load Allocation						**1.166**	**0.019**	**0.821**	**0.017**	**5.943**			

*** - the equivalent BOD5 values are: MD0022641 - 128.4 lbs/day and MD0065145 - 6.3 lbs/day; total BOD5 waste load allocation of 134.7 l.bs/day. There are no BOD5 reductions at these facilities recommended by this TMDL.**

Table 26
TMDL Summary for Little Mill Creek

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000523	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0000566	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.000	0.000	0.000	0.000	0.000			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C04	4.70	1.43	0.02	1.00	0.02	7.34	36.241	0.507	25.343	0.507	186.020	0.0%	0.0%	0.0%

Atm. Deposition							0.028	0.011	0.041	0.004				
	Total Load Allocation						36.269	0.518	25.384	0.511	186.020			

Table 27
TMDL Summary of the Christina River Main Stem

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000400	0.0000	2.00	0.10	0.24	0.10	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0051004	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.000	0.000	0.000	0.000	0.000			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01	0.60	1.43	0.02	1.00	0.02	7.34	4.625	0.065	3.234	0.065	23.741	0.0%	0.0%	0.0%
C02	0.65	1.43	0.02	1.00	0.02	7.34	5.016	0.070	3.508	0.070	25.748	0.0%	0.0%	0.0%
C03	0.48	1.43	0.02	1.00	0.02	7.34	3.700	0.052	2.588	0.052	18.994	0.0%	0.0%	0.0%
C05	0.80	1.43	0.02	1.00	0.02	7.34	6.165	0.086	4.311	0.086	31.644	0.0%	0.0%	0.0%
C06	1.59	1.43	0.02	1.00	0.02	7.34	12.265	0.172	8.577	0.172	62.956	0.0%	0.0%	0.0%
Atm. Deposition							3.222	1.207	4.630	0.412				
	Total Load Allocation						34.994	1.651	26.848	0.856	163.083			

Table 28
Point and Nonpoint Source Contributions to the Delaware River Estuary

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0021555-001	0.5500	12.00	1.50	3.63	2.00	5.00	55.09	6.89	16.66	9.18	22.95	0.0%	0.0%	0.0%
DE0000256-601	13.0000	25.00	12.00	50.00	0.30	5.00	2712.53	1302.02	5425.07	32.55	542.51	0.0%	0.0%	0.0%
DE0000612-001	0.8000	18.00	0.50	4.65	0.30	5.00	120.19	3.34	31.05	2.00	33.39	0.0%	0.0%	0.0%
DE0020001-001	0.6800	14.00	1.50	3.63	2.00	5.00	79.46	8.51	20.60	11.35	28.38	0.0%	0.0%	0.0%
DE0050911-001	0.3000	13.21	1.50	3.63	2.00	5.00	33.08	3.76	9.09	5.01	12.52	0.0%	0.0%	0.0%
DE0020320-001	134.0000	17.00	1.50	3.63	2.00	5.00	19012.77	1677.60	4059.79	2236.80	5591.99	0.0%	0.0%	0.0%
DE0000051-001	5.2000	30.00	0.50	4.65	0.30	5.00	1302.02	21.70	201.81	13.02	217.00	0.0%	0.0%	0.0%
DE0000051-002	3.0000	8.00	0.50	4.65	0.30	5.00	200.31	12.52	116.43	7.51	125.19	0.0%	0.0%	0.0%
DE0000051-003	6.0000	8.00	0.50	4.65	0.30	5.00	400.62	25.04	232.86	15.02	250.39	0.0%	0.0%	0.0%
DE0000655-001	33.3000	17.00	1.20	11.16	0.30	5.00	4724.82	333.52	3101.70	83.38	1389.65	0.0%	0.0%	0.0%
PA0012637-002	52.3500	30.00	0.50	4.65	0.30	5.00	13107.79	218.46	2031.71	131.08	2184.63	0.0%	0.0%	0.0%
PA0012637-101	69.8000	30.00	0.50	4.65	0.30	5.00	17477.06	291.28	2708.94	174.77	2912.84	0.0%	0.0%	0.0%
PA0012637-201	3.3400	52.00	29.00	50.00	0.30	5.00	1449.58	808.42	1393.82	8.36	139.38	0.0%	0.0%	0.0%
PA0027103-001	44.0000	30.00	30.00	50.00	0.30	5.00	11017.06	11017.06	18361.76	110.17	1836.18	0.0%	0.0%	0.0%
NJ0005405-001	1.2700	45.00	35.00	50.00	0.30	5.00	476.99	370.99	529.99	3.18	53.00	0.0%	0.0%	0.0%
NJ0024856-001	1.4450	30.00	1.50	3.63	2.00	5.00	361.81	18.09	43.78	24.12	60.30	0.0%	0.0%	0.0%
NJ0021598-001	2.4650	30.00	35.00	65.00	2.00	5.00	617.21	720.07	1337.28	41.15	102.87	0.0%	0.0%	0.0%
NJ0005100-661	22.9000	30.00	0.50	4.65	0.30	5.00	5733.88	95.56	888.75	57.34	955.65	0.0%	0.0%	0.0%
NJ0021601-001	1.7290	30.00	1.50	3.63	2.00	5.00	432.92	21.65	52.38	28.86	72.15	0.0%	0.0%	0.0%
NJ0024023-001	0.9500	40.00	1.50	3.63	2.00	5.00	317.16	11.89	28.78	15.86	39.64	0.0%	0.0%	0.0%
NJ0024635-001	0.0366	15.00	1.50	3.63	2.00	5.00	4.58	0.46	1.11	0.61	1.53	0.0%	0.0%	0.0%
NJ0004286-001	2.1000	30.00	0.50	4.65	0.30	5.00	525.81	8.76	81.50	5.26	87.64	0.0%	0.0%	0.0%
NJ0027545-001	0.9860	30.00	1.50	3.63	2.00	5.00	246.88	12.34	29.87	16.46	41.15	0.0%	0.0%	0.0%
	Total Waste Load Allocation						80409.59	16989.93	40704.74	3033.04	16700.92			

Load Allocations														
Subwatershed	Flow cfs	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction		
												CBOD5	NH3-N	TP
none														
Atm. Deposition							117.83	44.01	168.84	15.01				
	Total Load Allocation						117.83	44.01	168.84	15.01				

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Appendix A1

Presented in this appendix are longitudinal transect graphs showing the daily average and minimum dissolved oxygen for each of the following 12 stream reaches:

1. Brandywine Creek main stem
2. Brandywine Creek East Branch
3. Brandywine Creek West Branch
4. Buck Run
5. Christina River (tidal reach downstream of Smalleys Pond)
6. Christina River (non-tidal reach upstream of Smalleys Pond)
7. Christina River West Branch
8. Red Clay Creek main stem and East Branch
9. Red Clay Creek West Branch
10. White Clay Creek main stem and Middle Branch
11. White Clay Creek East Branch
12. Delaware River (from Reedy Point, DE to Chester, PA)

Each longitudinal graph shows the following:

- DO average or minimum Water Quality Standard (i.e., TMDL endpoint)
- Model results for NPDES discharges at their existing permit loads
- Model results for NPDES discharges at their final TMDL allocation loads
- Stream flow is in the downstream direction, i.e., from higher to lower river mile

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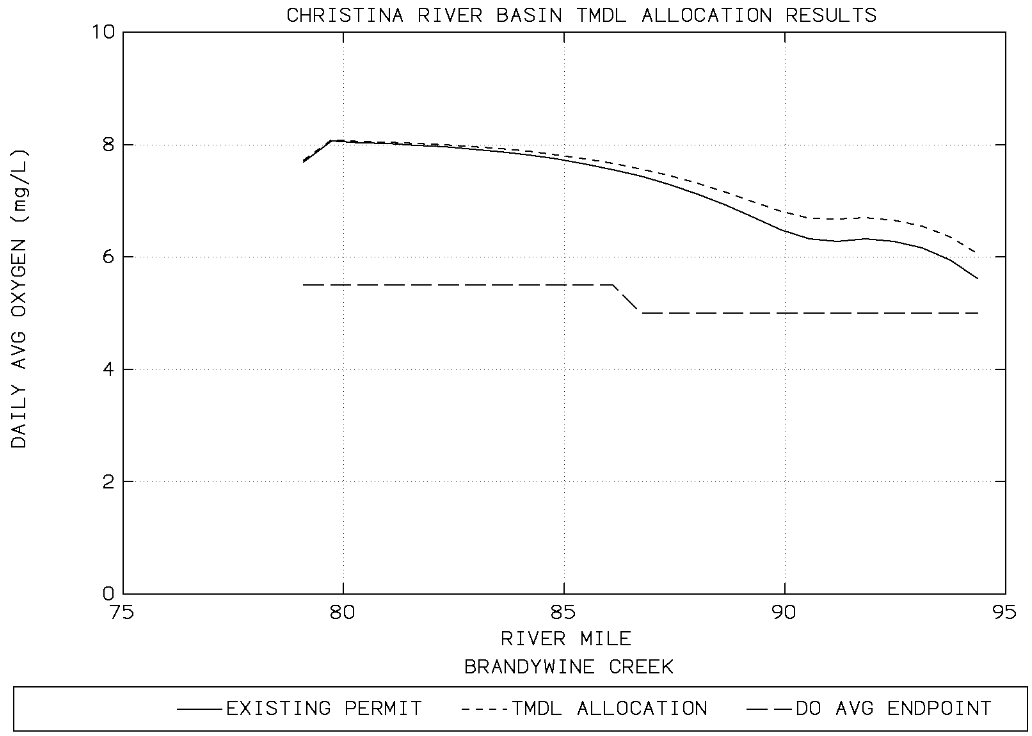

Figure A-1. Brandywine Creek main stem, daily average DO.

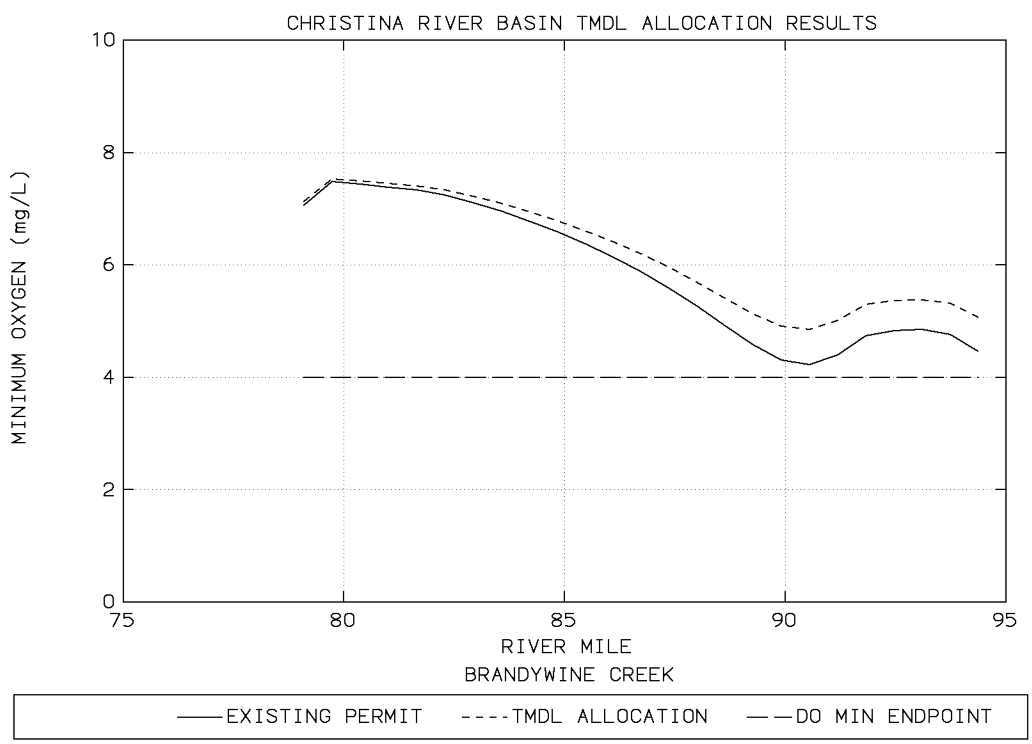

Figure A-2. Brandywine Creek main stem, minimum DO.

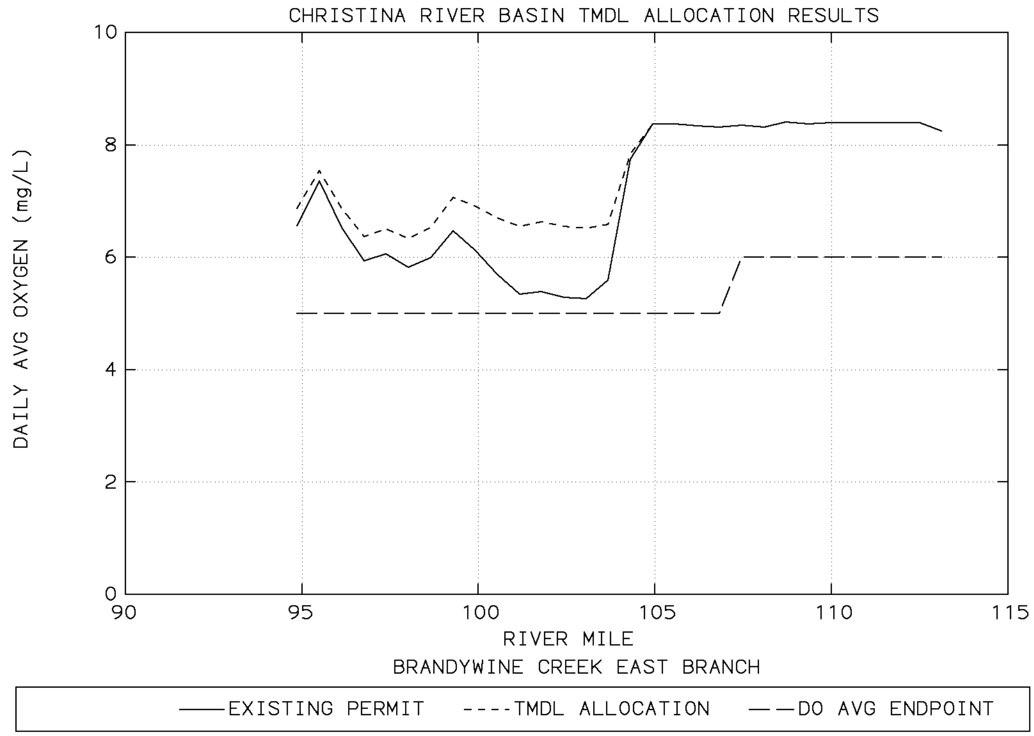

Figure A-3. Brandywine Creek East Branch, daily average DO.

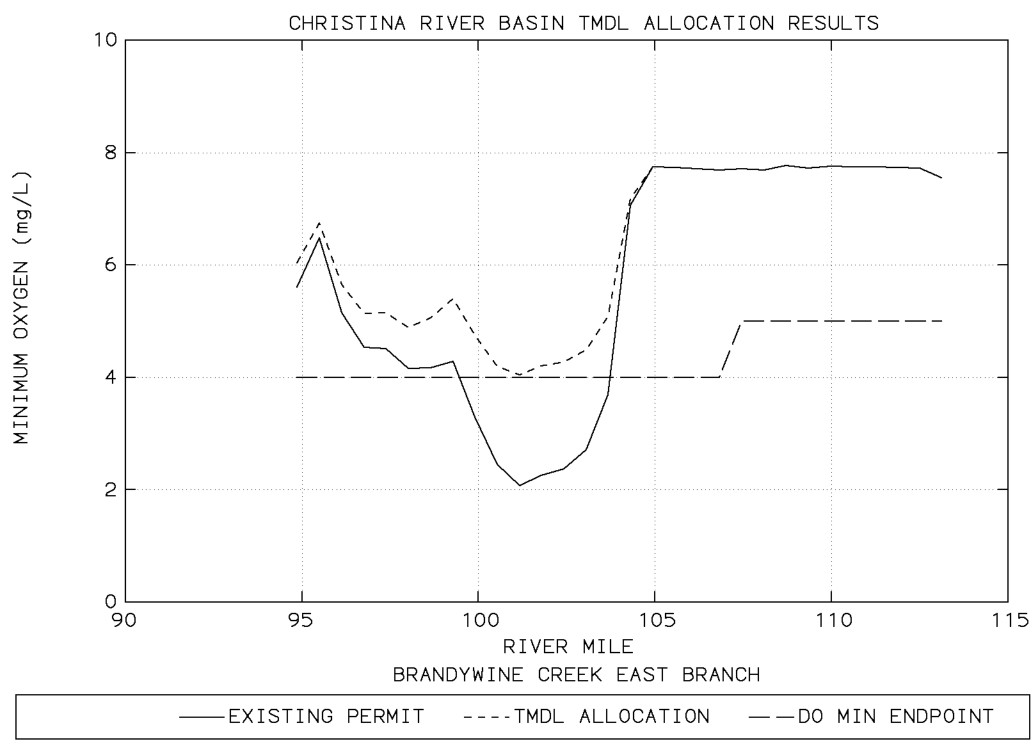

Figure A-4. Brandywine Creek East Branch, minimum DO.

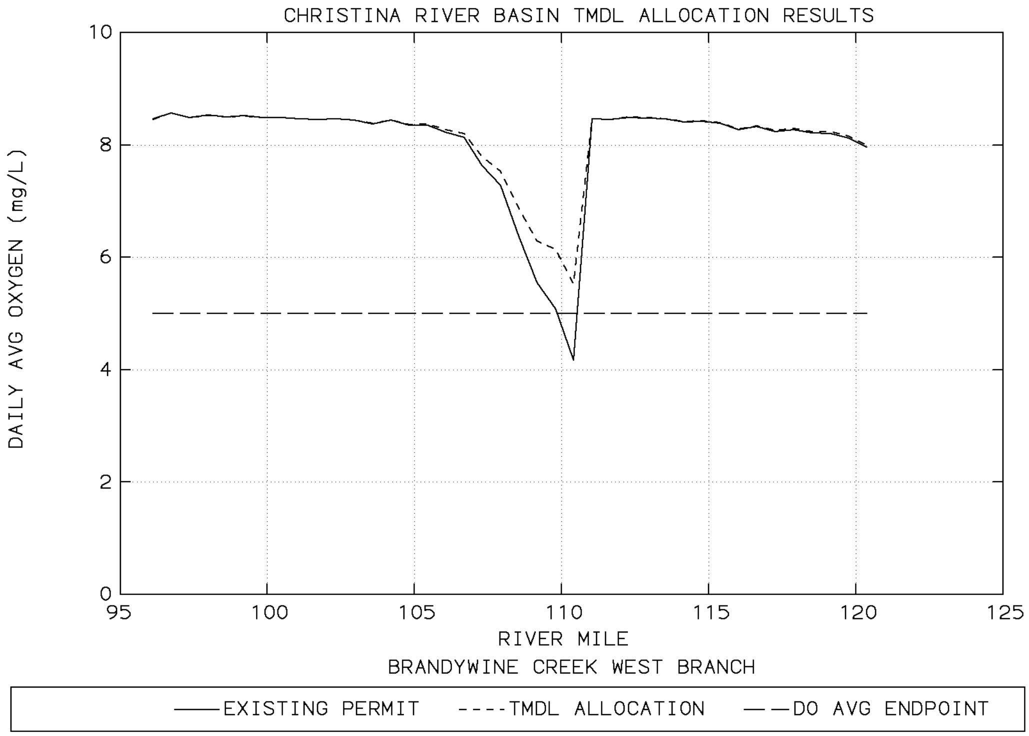

Figure A-5. Brandywine Creek West Branch, daily average DO.

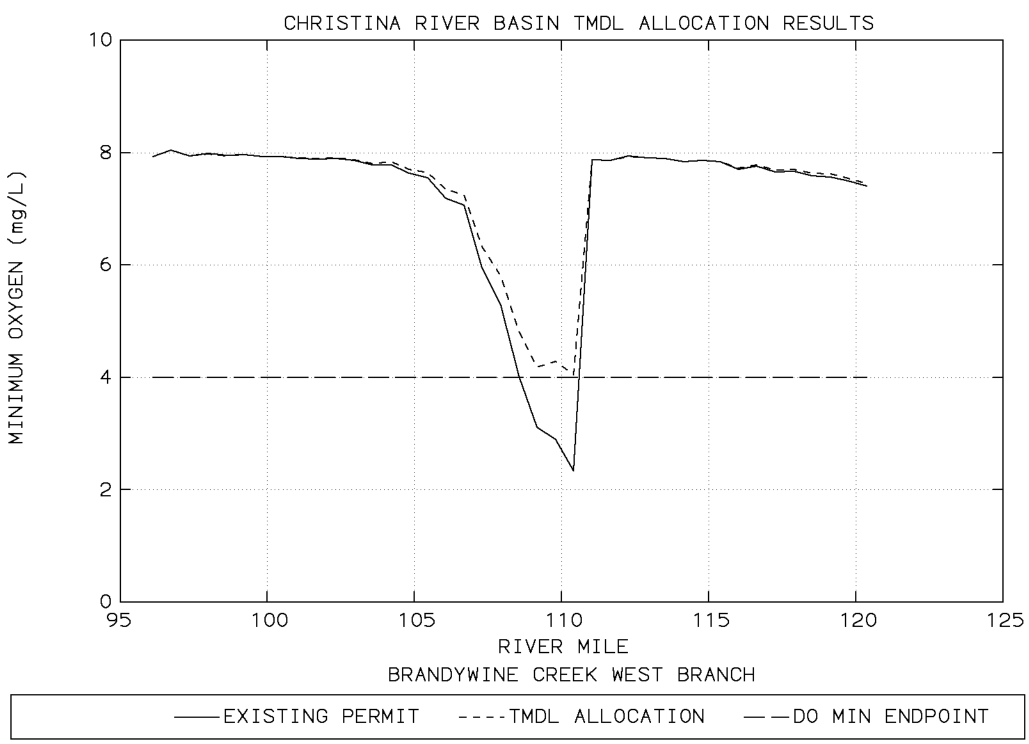

Figure A-6. Brandywine Creek West Branch, minimum DO.

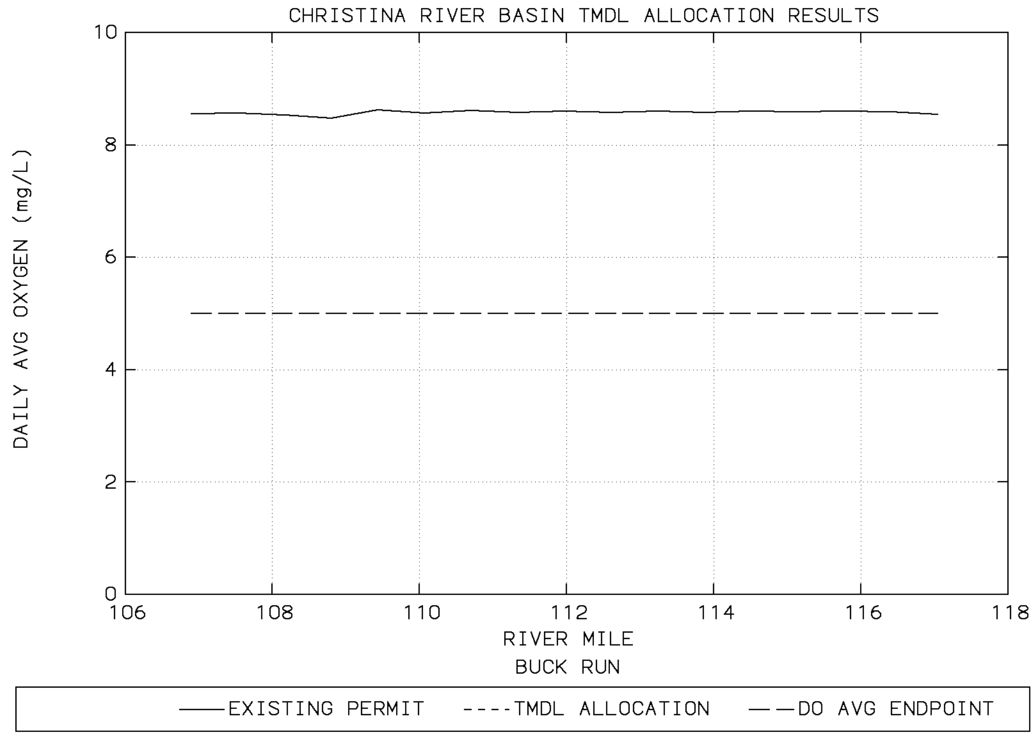

Figure A-7. Buck Run, daily average DO.

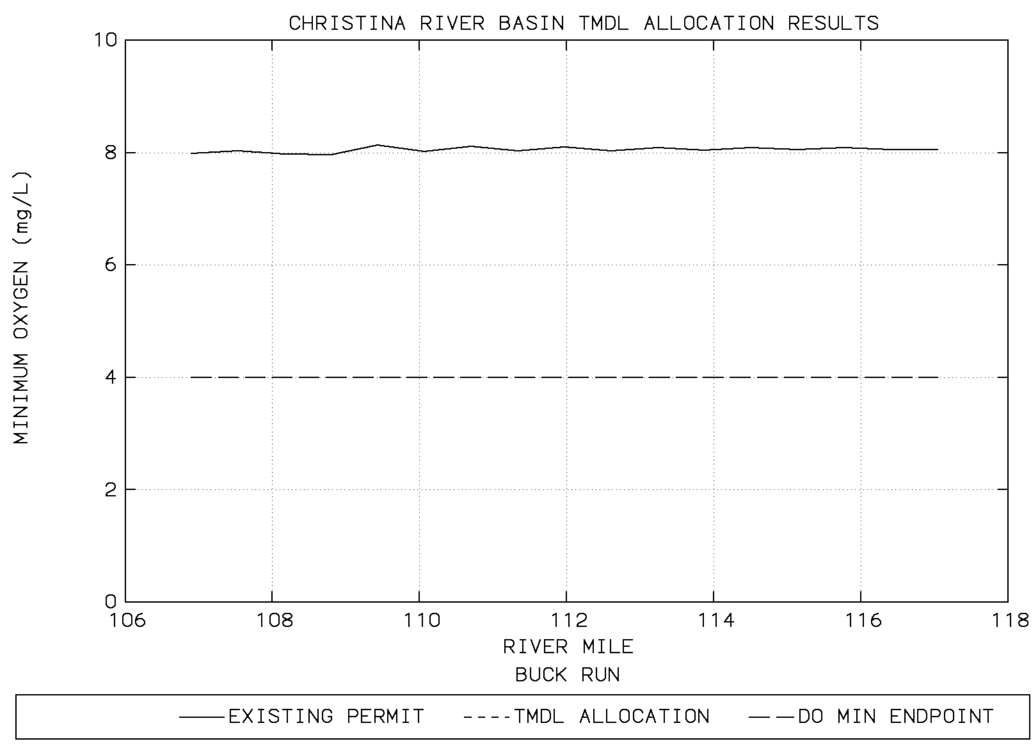

Figure A-8. Buck Run, minimum DO.

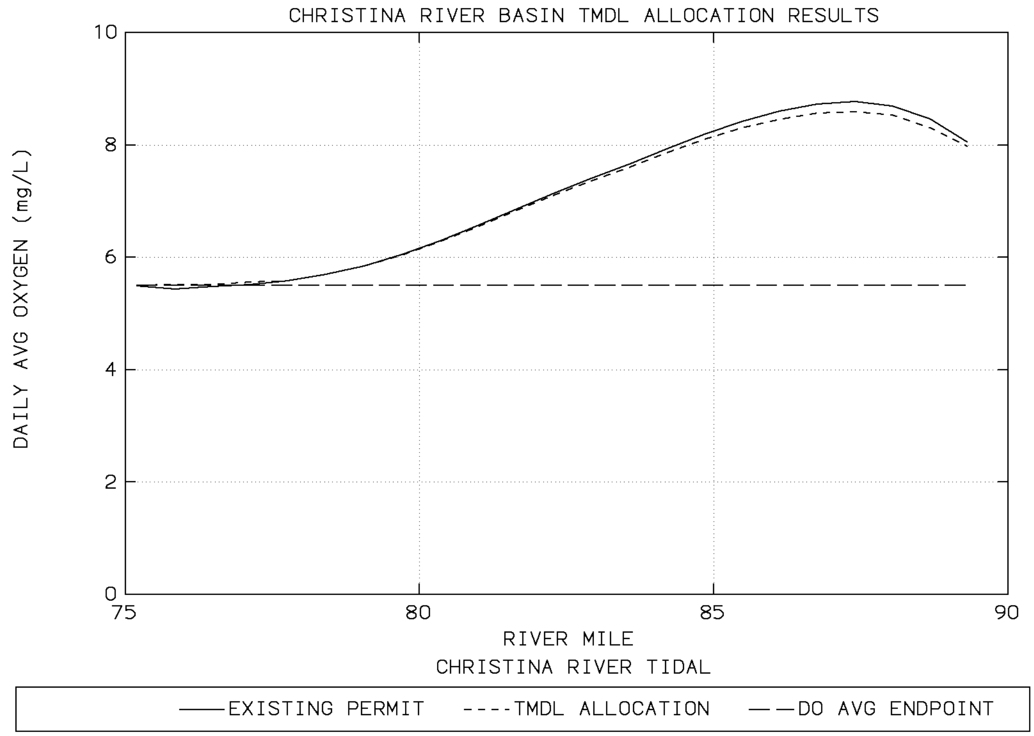

Figure A-9. Christina River (tidal), daily average DO.

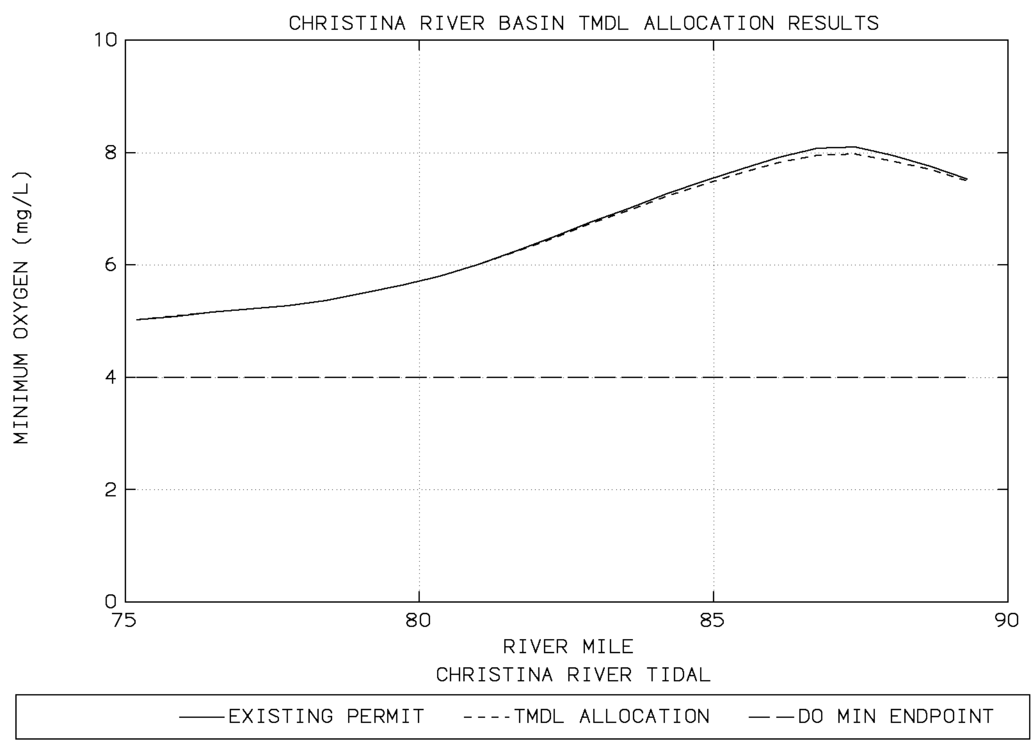

Figure A-10. Christina River (tidal), minimum DO.

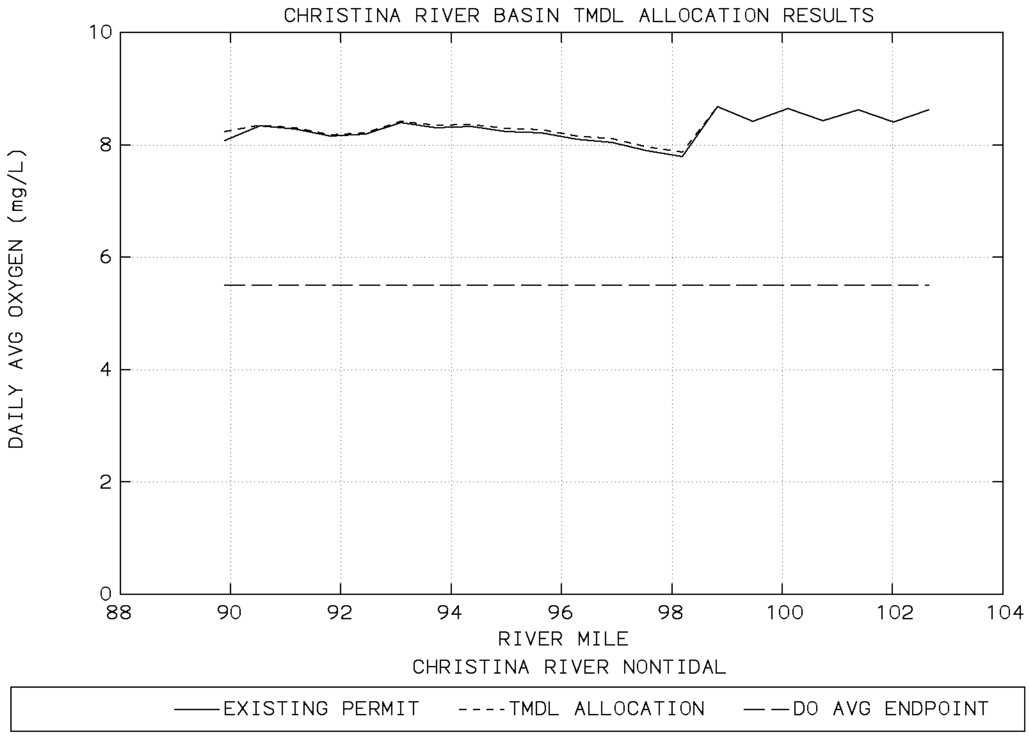

Figure A-11. Christina River (non-tidal), daily average DO.

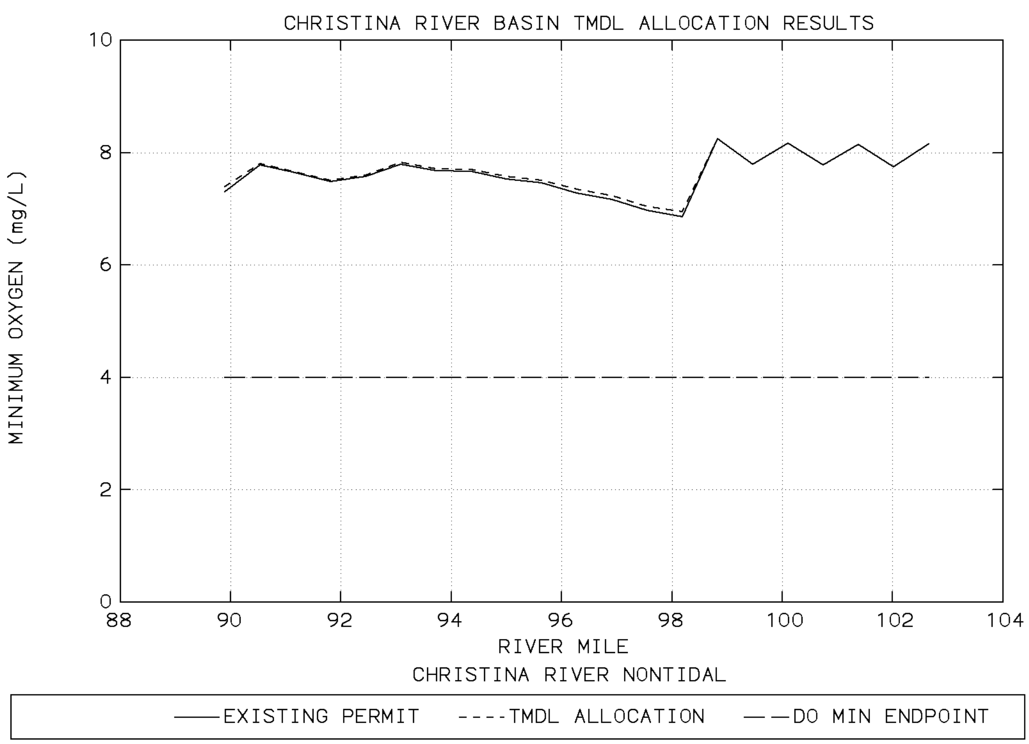

Figure A-12. Christina River (non-tidal), minimum DO.

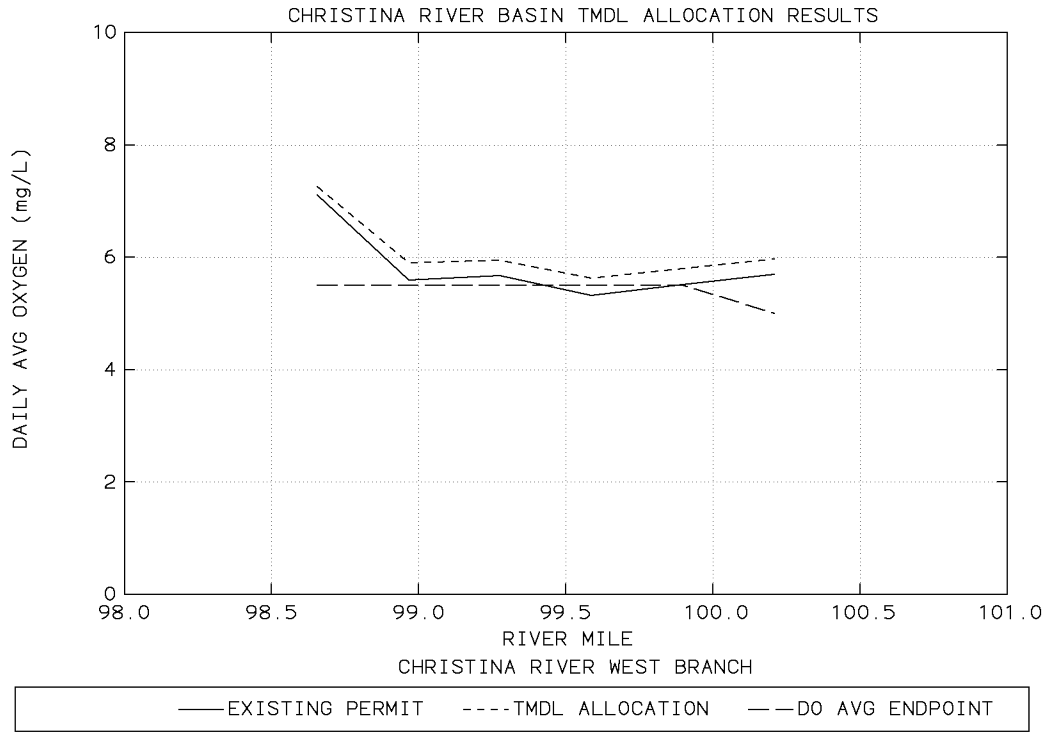

Figure A-13. Christina River West Branch, daily average DO.

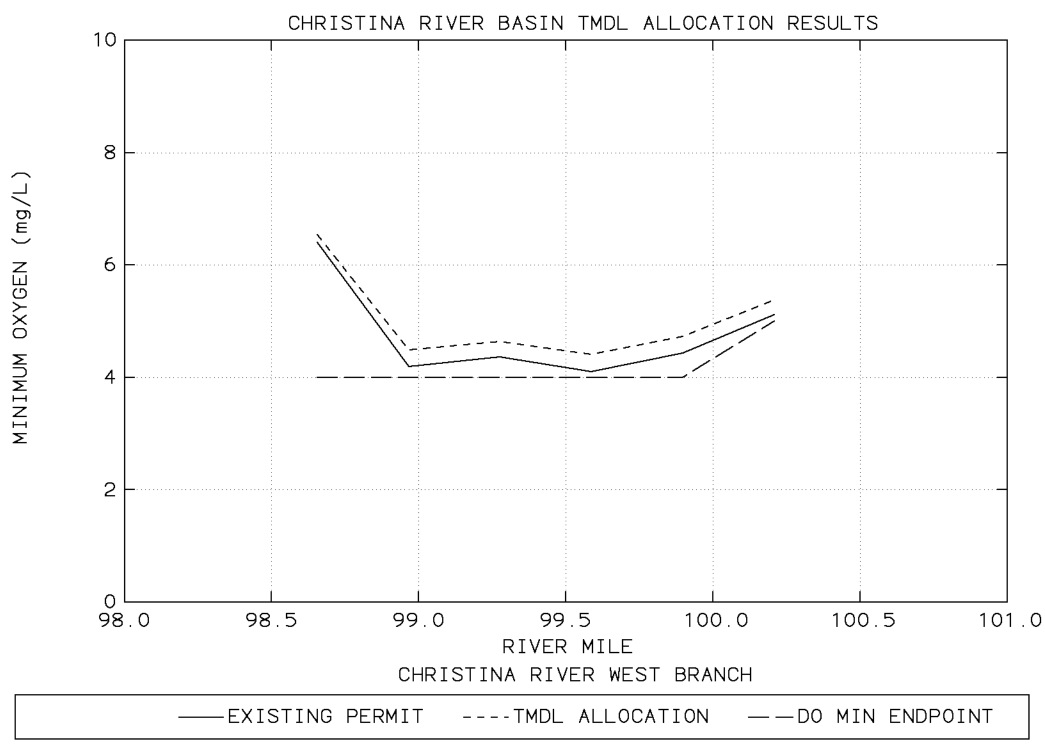

Figure A-14. Christina River West Branch, minimum DO.

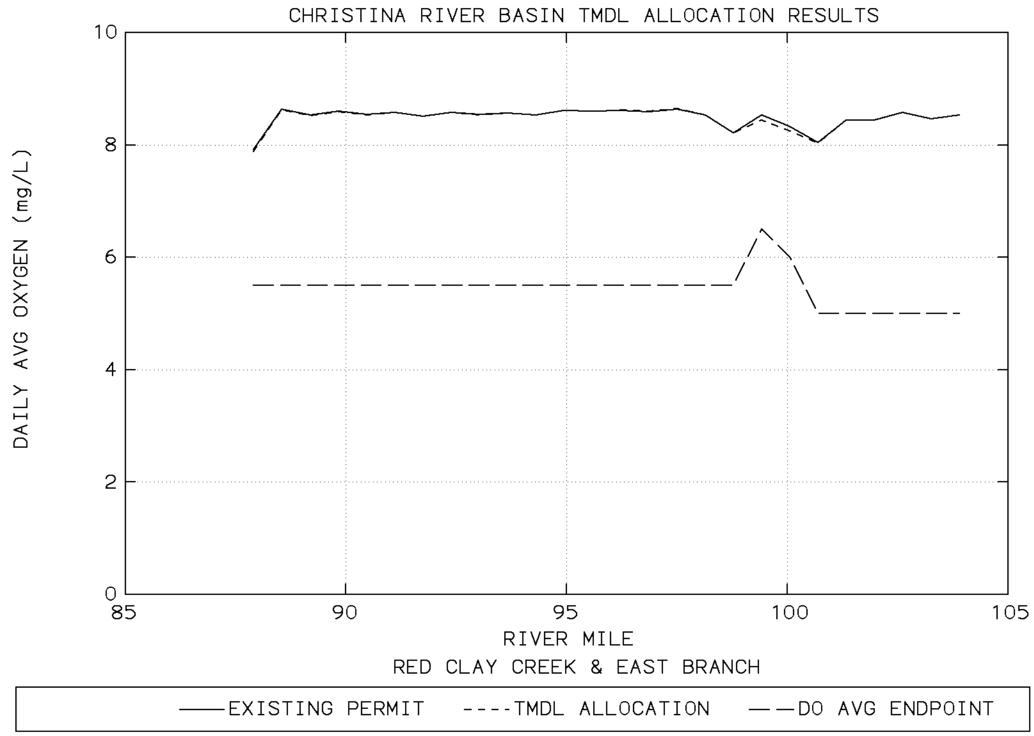

Figure A-15. Red Clay Creek main stem and East Branch, daily average DO.

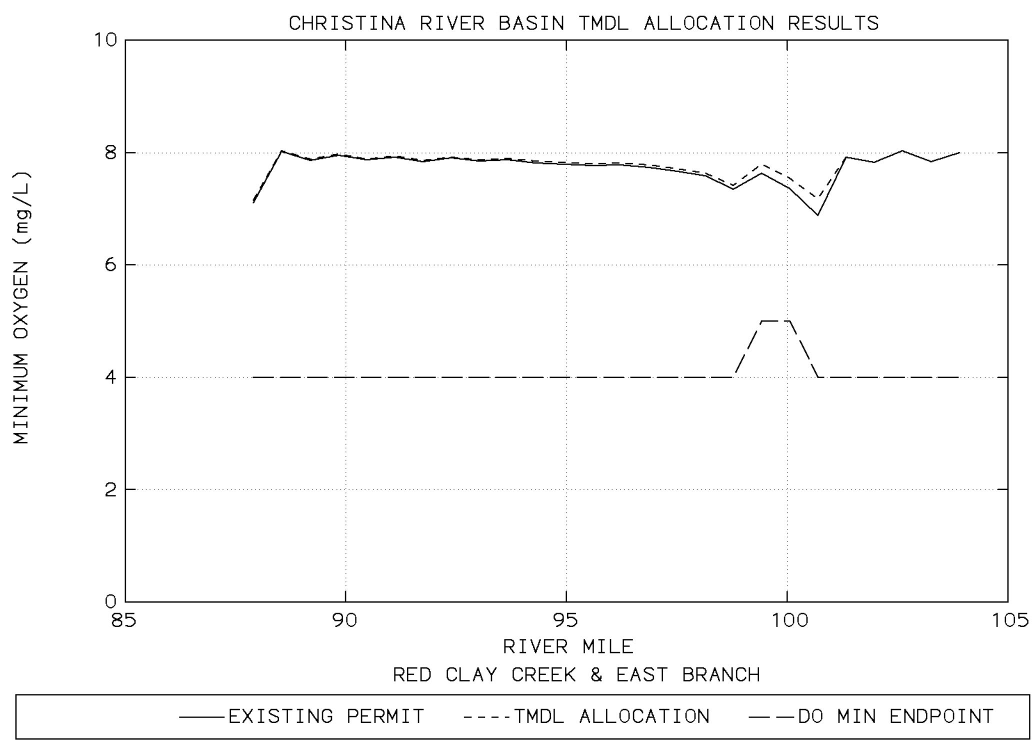

Figure A-16. Red Clay Creek main stem and East Branch, minimum DO.

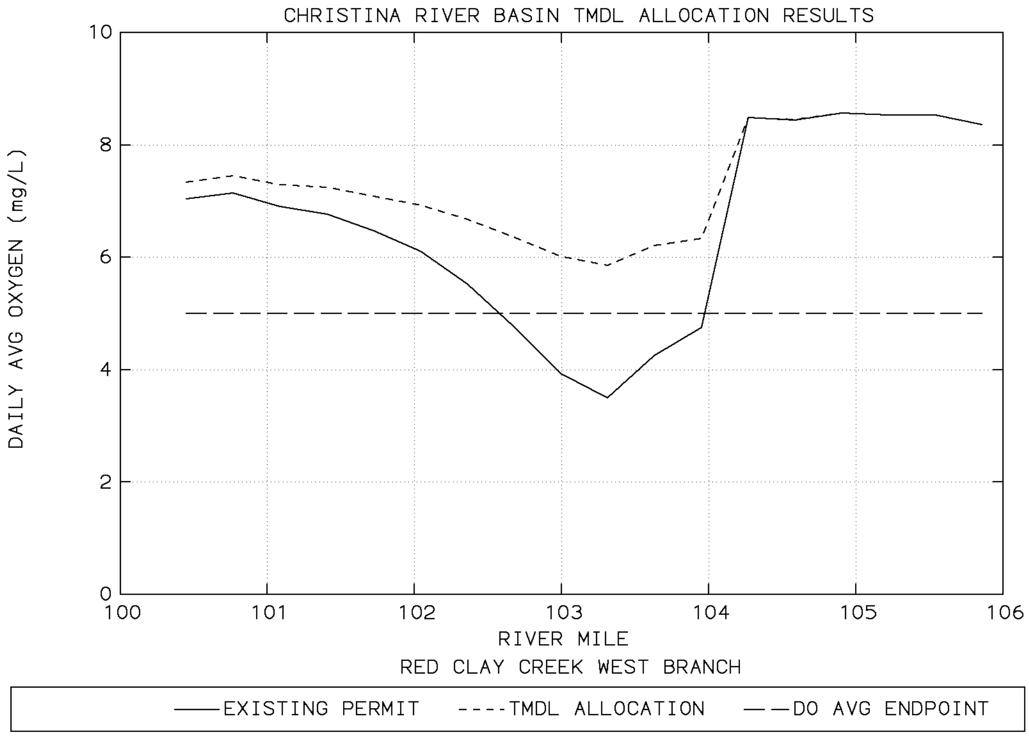

Figure A-17. Red Clay Creek West Branch, daily average DO.

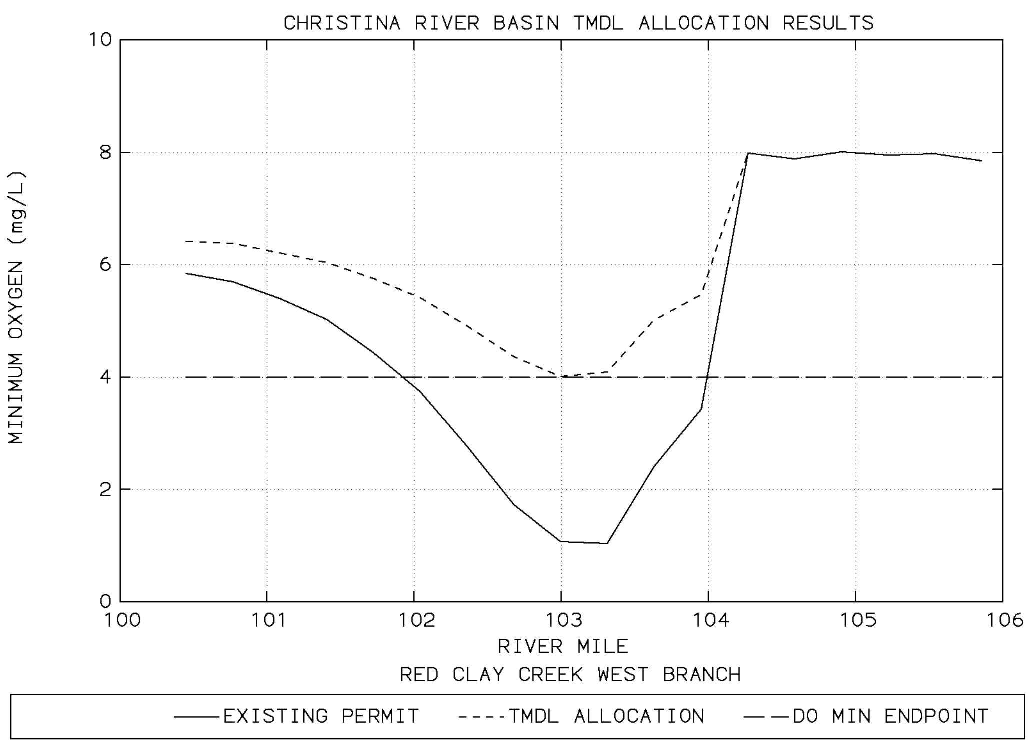

Figure A-18. Red Clay Creek West Branch, minimum DO.

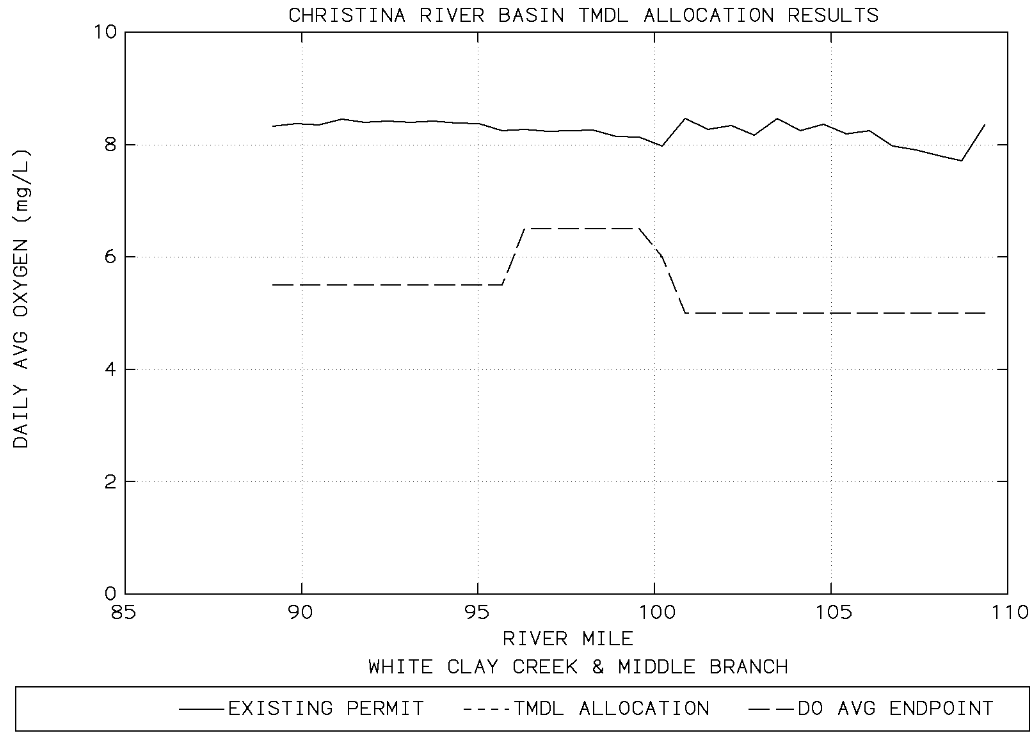

Figure A-19. White Clay Creek main stem and Middle Branch, daily average DO.

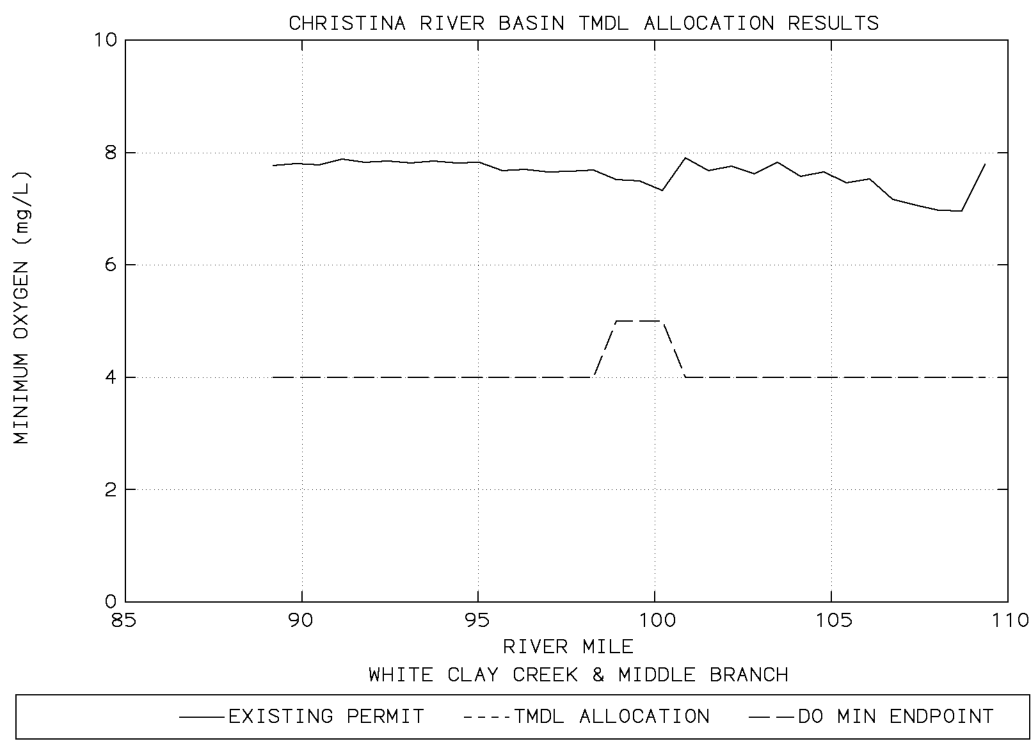

Figure A-20. White Clay Creek main stem and Middle Branch, minimum DO.

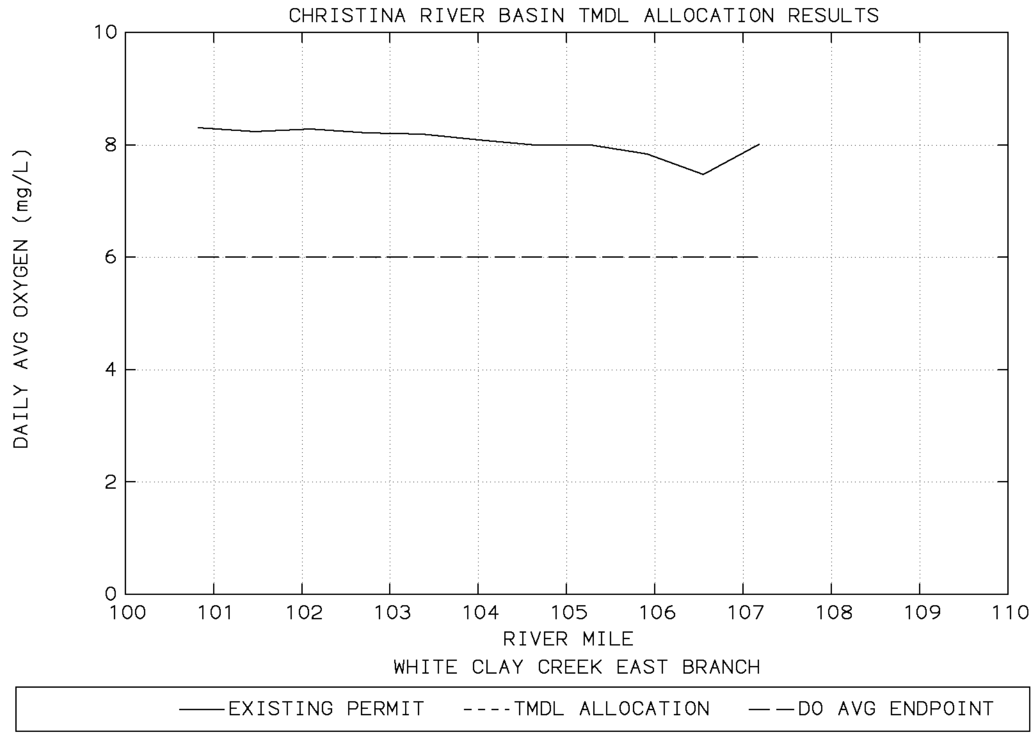

Figure A-21. White Clay Creek East Branch, daily average DO.

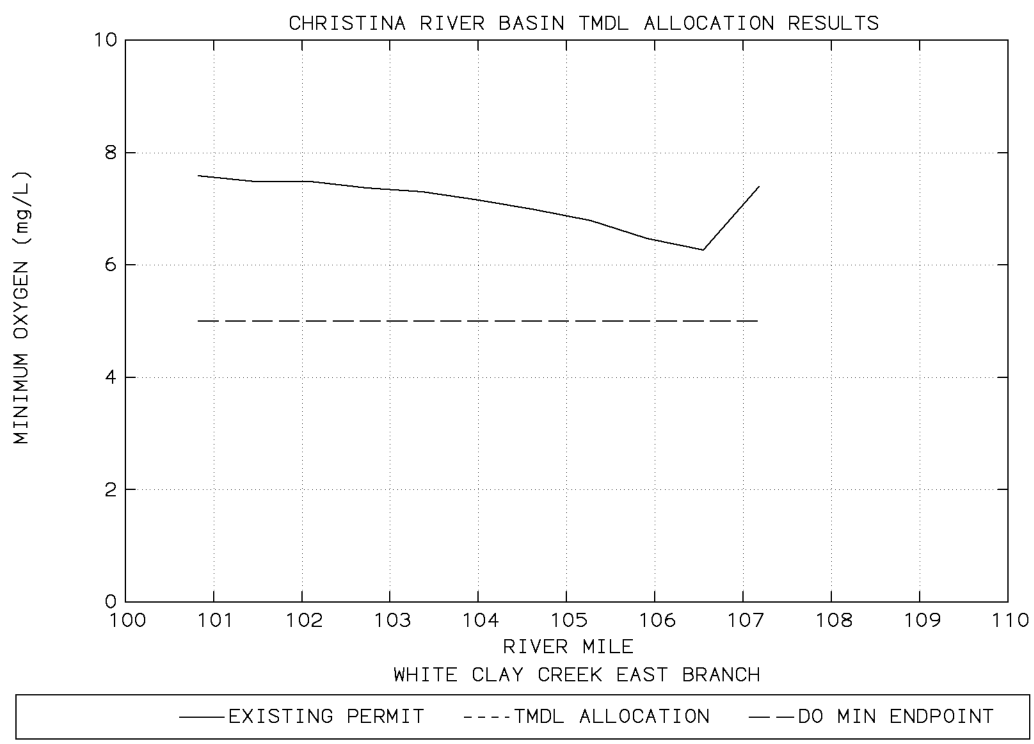

Figure A-22. White Clay Creek East Branch, minimum DO.

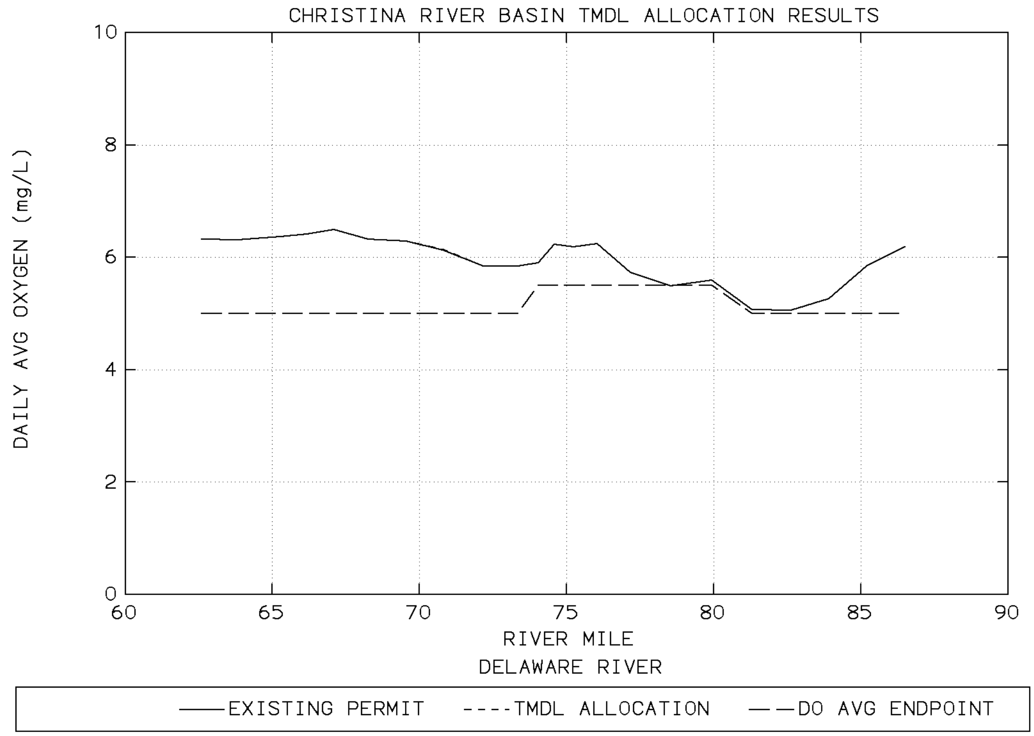

Figure A-23. Delaware River (Reedy Point to Chester), daily average DO.

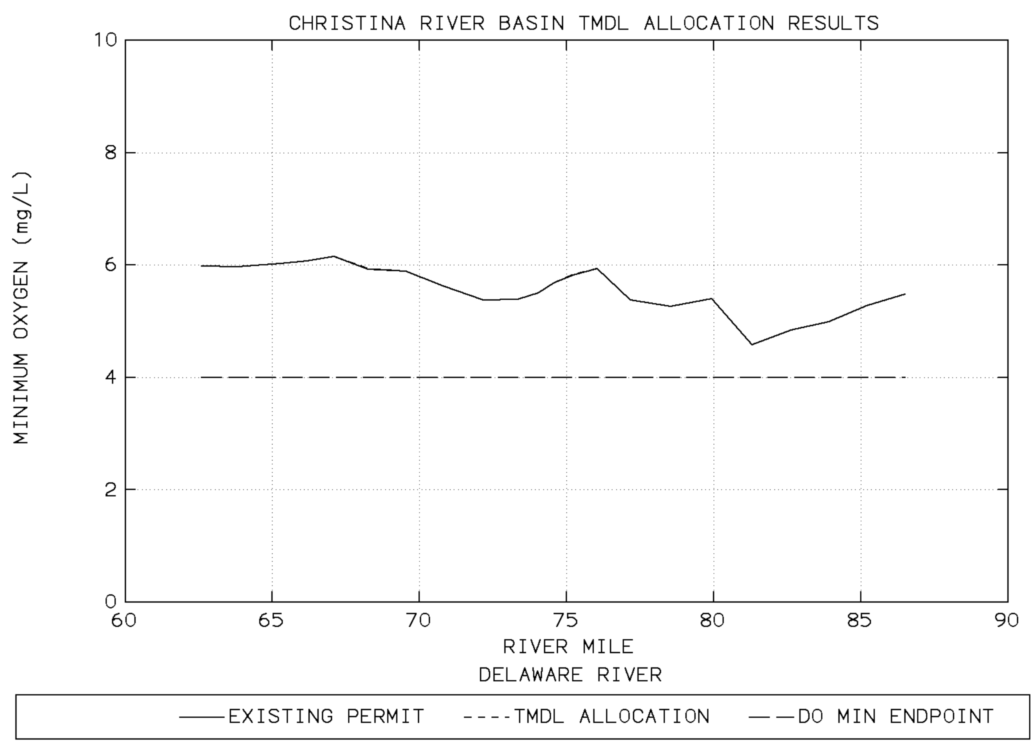

Figure A-24. Delaware River (Reedy Point to Chester), minimum DO.

Christina Comments and Responses

TMDL ID #	Comment	Commenter	Response
01-A-01	However, since the DRWPCC effluent is of exceptional quality satisfying all permit requirements, it is apparent that it is not the source of the existing nutrient problems in the Christina basin. Therefore, further restrictions on the nutrients discharged by the DRWPCC will have no impact on the current nutrients-impaired portions of the Christina River basin.	Herbert J. May	The TMDL model results show that reductions at the Downingtown plant are required, both at the Level 1 and Level 2 assessments, to meet Dissolved Oxygen (DO) standards in the Christina River Basin and specifically protect the DO water quality standard for the East Branch Brandywine Creek. As part of the reductions necessary to meet the DO standards, the model results and the TMDL call for a reduction in the amount of nutrients discharged by Downingtown under design flow conditions. While Downingtown may not be the sole source of existing nutrient problems in the Christina River Basin, any source which discharges nutrients is a contributor of nutrients to the Christina River Basin and must be included in the TMDL analysis and allocation.
01-A-02	The Christina River basin lower reaches are not only impaired during low stream flows, but continuously, indicating a non-point source connection. In order to have any meaningful impact on the problem, priority must be given to identifying and remedying all of the conditions causing the current impairments, whether of point or non-point origin. Once that is done, a strategy for dealing with future conditions can be developed and the model can be refined.	Herbert J. May	EPA agrees that there may be additional problems with water quality in the Christina River Basin other than the low flow problems addressed in this TMDL. There are segments on the states 303(d) lists in the Christina River Basin where problems identified under high flows are identified. As outlined in the TMDL document, a decision was made to proceed first with a low flow TMDL and then perform a high flow TMDL evaluation. The high flow model will be integrated with the low flow model, allowing the assessment requested in this comment to be available. However, the low flow TMDL prepared for these low flow critical conditions described in the TMDL document is unlikely to be changed by the high flow TMDL.

TMDL ID #	Comment	Commenter	Response
01-A-03	It is a documented fact that non-point sources are causing the majority of lingering water quality problems nationally and locally, especially with regard to excess nutrient discharges. The low-flow point source model developed by the USEPA does not address this problem. It is a point source model that computes the need for point source reductions of carbonaceous biochemical oxygen demand ("CBOD5"), ammonia nitrogen ("NH3-N"), and total phosphorus ("P") based on critical low-flow conditions, i.e., when the maximum flow from the DRWPCC is discharged to a stream flowing at or near its minimum 10-year, seven-day average flow. Such a scenario is extremely unlikely, as stream and wastewater treatment influent/effluent flows nearly always mirror each other as both are greatly influenced by local precipitation cycles. Therefore the maximum DRWPCC flows occur when stream flows are at or near their maximum, and vice-versa. Even if it were possible for the high discharge low stream flow condition to occur, its contribution to the overall stream quality impairment may be less than the frequent non point source contributions that occur in a stream.	Herbert J. May	EPA agrees with some of these comments. EPA acknowledges that this TMDL does not address special water quality problems from high flow critical conditions. That will be the subject of the high flow TMDL evaluation for the Christina River Basin. For this low flow TMDL, 40 CFR Section 130.7(c)(1) states “Determinations of TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters.” The critical condition can be thought of as the “worst-case” scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutants of concern will continue to meet water quality standards. This critical condition analysis is necessary to ensure the chemical, physical, and biological integrity of the waterbody. Data analysis indicated that critical conditions in the Christina River Basin occur during summer and early fall drought periods when stream flow is reduced and temperatures are warmer. Point sources are the dominant contributor of pollutants during these times. EPA characterizes low flow through use of the 7Q10 statistic which is defined as the 7-day average low flow occurring once in 10 years. Since point sources are allowed to discharge at levels specified in NPDES permits, current maximum permitted levels (monthly average discharge limitations) are maximum used during the critical condition analysis. Therefore, it is appropriate to use 7Q10 to characterize reduced steam flows and current permitted levels to define maximum allowable loads within the context of the critical conditions analysis. See 10-J-05.

TMDL ID #	Comment	Commenter	Response
01-A-04	A more probable scenario is that nutrients are entering the receiving stream in large quantities through non-point sources such as agricultural and urban storm runoff during rain events. Nitrogen and phosphorus compounds entering the stream during these events then pass through swifter upstream reaches to be caught in the slower, wider streams of the lower reaches. The Christina River non-point source TMDL ("high-flow model") is being developed separately from the current document to address this problem; however, it is several years away from completion and adoption. Since it is clear that nonpoint,sources are a major factor in the excess nutrient problem, the high-flow model must be completed and the results of that effort compared to those provided by the low-flow model before any assumptions can be made regarding the problem.	Herbert J. May	EPA, the states and the Delaware River Basin Commission (DRBC) intend to complete the high flow TMDL and make recommendations for reductions from those sources assessed in the high flow evaluation as appropriate. However, based on currently available information the low flow TMDL prepared for critical conditions described in the Decision Rationale document is unlikely to be changed by development of a TMDL to address high flow critical conditions.
01-A-05	Predictions made by the low-flow model for the East Branch Brandywine Creek as shown in Appendix H greatly under estimate the dissolved oxygen levels of the receiving stream and over estimate the pollutant loadings to the receiving stream when compared to actual observed levels (Figs. H07-H08). Its ability to predict the impacts of the point source discharges during critical conditions is therefore questionable and needs further review.	Herbert J. May	EPA disagrees. The Figures in Appendix H of the Hydrodynamic and Water Quality Model of Christina River Basin, EPA, May 31, 2000 ('Model Report') show the model results under critical conditions with the NPDES facilities discharging at their existing permitted flows and loads. These figures are not the calibration or validation results. The observed data displayed on these figures are from the period August 1 to September 21, 1997 (the calibration period) and are shown for reference only and are not an indication of model performance.

TMDL ID #	Comment	Commenter	Response
01-A-06	The Authority has been told that the development and implementation of the low-flow model is being accelerated to meet the terms of a Consent Decree reached between the USEPA, the state of Delaware and several environmental groups. However, the Consent Decree only mandated the timely development of a TMDL for those impaired water bodies listed on the state of Delaware's 303d list. It did not impose such requirements for Pennsylvania. The East Branch Brandywine Creek is located entirely within Pennsylvania. Therefore, there is no legal basis for imposing further restrictions on point source nutrient discharges within the East Branch Brandywine Creek.	Herbert J. May	As discussed in the proposed TMDL and enclosed final TMDL Decision Rationale document, EPA has prepared this low flow TMDL using the Watershed Protection Approach consistent with EPA's authority to establish TMDLs under Section 303(d) of the Clean Water Act and 40 CFR 130.7. Based on available water quality data, conditions in the downstream segments of the Christina River Basin are impacted by tributary loads from upstream segments including the East Branch Brandywine Creek. The Watershed Protection Approach calls for an evaluation of all relevant loads in a defined watershed. To address downstream Delaware impairments for DO, EPA along with participating state agencies and DRBC decided to establish a watershed TMDL. EPA believes this is the most equitable, most resource efficient and most environmentally prudent course of action available. EPA has therefore decided that the TMDL for the Christina River Basin must include the full watershed, including the East Branch Brandywine Creek.

TMDL ID #	Comment	Commenter	Response
01-A-07	Rapid urbanization of the County and within the East Branch Brandywine Creek basin have caused the Pennsylvania Department of Environmental Protection to list the receiving stream on its 303d list as an "impaired water body" due to increased siltation, flow and habitat alterations, and hydromodification. None of 303d-listed sources of impairment for this stream relate to point source discharges. Therefor the state of Pennsylvania has established no technical basis for developing the nutrients TMDL under the 303 regulations. One is required. Section 130.51 of USEPA's recently-revised Water Quality Planning and Management Regulations states that water quality planning must be based on initial water quality management plans produced in accordance with sections 208 and 303(e) of the Clean Water Act and certified and approved updates to those plans. That section further states that the annual water quality planning should focus on priority issues and geographic areas identified in the latest 305(b) reports. Since a nutrients requirement for the East Branch Brandywine Creek is apparently not included on the state of Pennsylvania's current water quality management plan, this condition is not met. Developing a TMDL for an unlisted condition diverts funding and efforts away from the priority areas of the list.	Herbert J. May	EPA did recently enact new TMDL regulations but those regulations are not yet effective. See 65 Federal Register 43586-43670, specifically 43660 (7/13/00). This TMDL was developed under current regulations at 40 CFR 130.7. Therefore, this comment and reference is not appropriate for this particular TMDL. However, Delaware has identified nutrients as pollutants of concern in the Christina River Basin. In order to consider and address all potential sources of nutrients to Delaware's waters, it was necessary to include the potential sources originating in Pennsylvania. The analysis performed for this TMDL revealed that there were local nutrient concerns in Pennsylvania as well as in Delaware. This water quality modeling analysis was then used to establish necessary controls in order to address the local impacts as well as any impacts that may be occurring in the tidal Christina River. Note that the existing implementing regulations identify water quality modeling results as a data source for identifying waters for listing on the section 303(d)list of waters (40 CFR 130.7 (b) (5) (ii).
01-A-08	If the state of Pennsylvania has developed a Water Quality Management Plan for East Branch Brandywine Creek, does it include the mandatory requirements for such plans as detailed in sections 130.51(c).3 and 4, i.e., financial arrangements for any municipal and industrial waste treatment works, including facilities for treatment of storm water-induced combined sewer overflows, and a description of the regulatory and non-regulatory programs, activities and best management practices which the agency has selected as the means to control nonpoint source pollution where necessary to protect or achieve approved water uses?	Herbert J. May	The comment references an EPA regulation citation that is not yet effective. See response to 01-A-07. Under current regulations at 40 CFR 130.6, a TMDL is one of several elements of a Water Quality Management Plan (WQMP). Whether the state has a WQMP or not does not relieve the state or EPA from completing the necessary TMDLs. As a WQMP is developed these completed TMDLs then would become a part of that plan.

TMDL ID #	Comment	Commenter	Response
01-A-09	130.51(c).5 also requires management agencies to demonstrate the legal, institutional, managerial and financial capability and specific activities necessary to carry out their responsibilities in accordance with section 208(c)(2)(A) through (1) of the Act. Has this requirement been met? ,	Herber J. Mays	The comment references an EPA regulation citation that is not yet effective. See response 01-A-07. Under Current regulation at 40 CFR 130.6, the comment describes a required element of a WQMP, just as a TMDL is an element of a WQMP. Development of such elements as described by this comment is not a pre-requisite of completing a necessary TMDL
01-A-10	The USEPA has developed the low flow TMDL model on behalf of the state of Delaware, and applied the results of that model to Pennsylvania. Since it has developed the TMDL, the USEPA is also responsible for providing the reasonable assurance described in 40 CFR Part 130.2(p). Specifically, the USEPA has failed to show reasonable assurance that management measures or other control actions to implement the non point source load allocations developed in the subsequent high flow model will be implemented as expeditiously as practical, will be accomplished through reliable and effective delivery mechanisms, and will be supported by adequate funding. Will the USEPA assume the duties of Pennsylvania in that regard including those listed in paragraphs 5 and 6 above? The PADEP has not even confirmed a nutrients control priority/strategy for the East Branch Brandywine Creek as required by the 303d list.The USEPA must demonstrate such reasonable assurance before the TMDL can be implemented. That would seem difficult now, as the high flow model is not yet developed.	Herbert J. May	EPA agrees that it would be difficult to develop a reasonable assurance for implementing a TMDL that has yet to be completed. As has been described, this TMDL for the Christina River Basin has been developed for low flow (or dry weather) critical conditions. Therefore the reasonable assurance discussion for this TMDL in Section VII. 8 of the Decision Rationale document appropriately addresses those specific conditions and control requirements. Expecting EPA to develop a reasonable assurance for a TMDL that will address another critical condition and that is not yet complete is inappropriate. The commenter may be confused between nonpoint source impacts at low flow and nonpoint source impacts during wet weather, higher flow conditions, as well as the relative importance of point source contributions. The commenter is referred to several other comments (e.g., 12-L-10) and their responses regarding this issue.
01-A-11	TMDL simulations indicate that the model greatly under estimates dissolved oxygen levels within the receiving stream and over estimates the levels of ammonia nitrogen, nitrate, total phosphorus, orthophosphate, and dissolved and total organic carbon caused by worst-case point source discharges (figures H07- H08).	Herbert J. May	EPA disagrees. The figures in Appendix H of the Model Report show the model results under critical conditions with the NPDES facilities discharging at their existing permitted flows and loads. These figures are not the calibration or validation results. The observed data displayed on these figures are from the period August 1 to September 21, 1997 (the calibration period) and are shown for reference only and are not an indication of model performance

TMDL ID #	Comment	Commenter	Response
01-A-12	STORET data is quoted as the source for much of the background water quality data used in model calibration and verification, yet the STORET data obtained by the Authority from USEPA to date is extremely limited for the East Branch Brandywine Creek below Downingtown, including as little as one data point for the various nitrogen and phosphorus parameters. The 10th percentile base line concentrations used in the model appear low when compared to the STORET data reviewed by the Authority. Additional data is needed to support any background concentrations, assumptions on nonpoint source contributions, etc.	Herbert J. May	EPA disagrees that additional data is necessary to support the TMDL calculations. Additional monitoring data is always useful for water quality modeling studies. The analysis for this TMDL was performed using available data consistent with 40 CFR 130.7 and drew upon several special monitoring studies performed by agencies in the Christina River Basin for this TMDL.
01-A-13	In the absence of the high-flow model, the model developers have assumed certain background concentrations that are multiplied by unit flow values to compute non-point source load allocations for each reach. Developing the load and waste load allocations in this manner neglects to account for the improvements in the non-point source discharge quality that will result from non-point source controls (i.e., the background concentrations should be reduced through non-point source control).	Herbert J. May	The TMDL was conducted for low-flow summer conditions during which little runoff or loading is expected from nonpoint sources. Nonpoint source controls will have impacts on improving water quality for high flows that occur during rainfall events, but will not have significant effects during low-flow conditions. Nonpoint source issues due to variable flow will be considered under the high flow TMDL.
01-A-14	Was Q30-10 used in developing the ammonia nitrogen limits per PA Chapter 96?	Herbert J. May	The allocated ammonia limits for all Pennsylvania NPDES dischargers in the Christina River Basin were protective of the ammonia toxicity criteria at the 7Q10 flow rates, so there was no need to check the criteria at the higher 7Q30 flow rates. The ammonia reductions in Pennsylvania were made to allow the receiving stream to achieve the DO water quality standard.

TMDL ID #	Comment	Commenter	Response
02-B-01	The Authority believes the USEPA has failed to sufficiently prove a link between the current discharge of nutrients by the point source dischargers and the ongoing nutrients/DO problems occurring near Wilmington, yet through this low-flow model, it is pursuing additional point source reductions based on projected future conditions;	Herbert J. May	EPA disagrees. Under the baseline condition in which all NPDES facilities were set to discharge at their existing maximum allowable permit flows and loads, the model indicated that a small portion of the tidal Christina River was not achieving the daily average dissolved oxygen standard (see Figure 8 in the TMDL Decision Rationale document). In addition, various stream segments in East and West Branches of the Brandywine Creek, Red Clay Creek, and West Branch Christina River were also not achieving the dissolved oxygen standards according to the TMDL model. The TMDL allocations were made using the equal marginal percent removal (EMPR) strategy explained on pages 34 - 41 of the TMDL Decision Rationale document. After the Level 1 and Level 2 allocations of the EMPR strategy were made to the NPDES facilities inside the Christina River Basin, the model indicated all freshwater streams as well as the entire tidal Christina River were meeting the dissolved oxygen standards. Therefore, the TMDL model does, indeed, indicate a link between the discharge of nutrients from point sources inside the Christina River Basin and the DO impairment in the Christina River near the mouth of Brandywine Creek.
02-B-02	The proposed reductions in point source discharges within the basin have been developed by the USEPA using "worst-case" assumptions that have very little chance of occurring, while the development of a high-flow model that will address the frequent non-point source discharges that do occur is potentially years away from completion;	Herbert J. May	The design conditions employed in this low flow TMDL are standard methodologies, and as noted in the TMDL Decision Rationale document, used by all states in the Christina River Basin as the design or critical conditions for the application of water quality criteria in their Water Quality Standards. See 01-A-03. This approach also provides an implicit margin of safety. The high flow TMDL will be completed by December 2004.

TMDL ID #	Comment	Commenter	Response
02-B-03	The East Branch Brandywine Creek is not listed on the state of Pennsylvania's 303d list as being nutrient-impaired. Developing a TMDL for an unlisted condition diverts funding and efforts away from higher priority projects on the list.	Herbert J. May	As discussed in the Decision Rationale document, EPA has prepared this low flow TMDL using the Watershed Protection Approach consistent with EPA's authority to establish TMDLs under Section 303(d) of the Clean Water Act. Based on available water quality data, conditions in the downstream segments of the Christina River Basin are impacted by tributary loads from upstream segments such as the East Branch Brandywine Creek. The Watershed Protection Approach calls for an evaluation of all relevant loads in a defined watershed. To address downstream Delaware impairments for DO, EPA along with participating state agencies and DRBC decided to establish a watershed TMDL. EPA believes this is the most equitable, most resource efficient and most environmentally prudent course of action available. Also, using the model shows that portions of the East Branch of the Brandywine Creek would experience DO violations at critical conditions. See Figure 8 in Decision Rationale document. EPA has therefore decided that the TMDL for the Christina River Basin must include the full watershed, including the East Branch Brandywine Creek.
02-B-04	The USEPA supports its accelerated development of the low-flow TMDL under the basis that it is required by a Consent Decree. However, the Consent Decree does not include Pennsylvania.	Herbert J. May	EPA is exercising its discretionary authority to establish a watershed TMDL for the Christina River Basin low flow problems of DO and nutrients using the Watershed Protection Approach. See 01-A-06 or 02-B-03.
02-B-05	The USEPA has failed to develop the TMDL in accordance with its recently-revised Water Quality Planning and Management Regulations which require the preparation and submittal of a water quality management plan by the states prior to development of a TMDL.	Herbert J. May	EPA did recently enact new TMDL regulations but those regulations are not yet effective. See 65 Federal Register 43586-43670, specifically 43660 (7/13/00). This TMDL was developed under current regulations at 40 CFR 130.7. Therefore, this comment and reference is not appropriate for this particular TMDL.
02-B-06	The mandatory contents for such water quality plans, such as demonstrating that sufficient financial arrangements for any municipal or industrial waste treatment works or regulatory and non-regulatory programs, activities and best management practices are in place, have not been provided.	Herbert J. May	These items are not required elements of an approvable TMDL under current regulations at 40 CFR 130.7 and therefore do not need to be addressed in an approved TMDL.

TMDL ID #	Comment	Commenter	Response
02-B-07	The USEPA has failed to provide reasonable assurance that management measures or other control actions necessary to implement the non-point source load allocations to be developed in the subsequent high flow model will be implemented as expeditiously as practical, will be accomplished through reliable and effective delivery mechanisms, and will be supported by adequate funding.	Herbert J. May	EPA believes that it would be difficult to develop a reasonable assurance for implementing a TMDL that has yet to be completed. As has been discussed on numerous occasions, this TMDL for the Christina River Basin has been developed for low-flow critical conditions. Therefore the reasonable assurance discussion appropriately addresses those specific conditions and control requirements. Expecting EPA to develop a reasonable assurance for a TMDL that is not yet complete is inappropriate. The commenter is referred to several other comments (e.g. 11-L-10) and their responses regarding this issue.
02-B-08	Future funding for the TMDL rule is in jeopardy based on the current political climate in Washington, and lacking such future funding, the USEPA will be unable to complete the highflow model and only point source reductions will be implemented. Such goals are contrary to the purpose of the TMDL Rule.	Herbert J. May	Funding speculation related to the future of TMDL development cannot be factored into the decisions affecting TMDL completion. At this date, EPA fully expects the high flow model to be completed by December 2004. The low flow TMDL calculations are applicable to their design critical conditions and would remain applicable even if the high flow TMDL can not be completed.
03-C-01	We have seen no evidence that point source discharges are the primary cause of the water quality problems in the Christina River Basin; however, the emphasis for correction appears to be the point source discharges.	Thomas Brown	This low flow TMDL addresses the impacts of point source discharges in the Christina River Basin. Section 303(d) lists submitted by states in the Christina River Basin have identified point sources as a contributor to water quality problems in the Christina River Basin. The TMDL model runs conducted in the establishment of this TMDL confirmed that point sources evaluated at their existing permit limits under the design conditions used in this TMDL would produce violations of DO standards. See e.g. Figure 8 of Decision Rationale document.

TMDL ID #	Comment	Commenter	Response
03-C-02	On the Pennsylvania 303(d) list of impaired streams, the East Branch Brandywine Creek is not listed as an impaired stream, yet TMDLs are being set for the East Branch Brandywine Creek.	Thomas Brown	As discussed in the Decision Rationale document, EPA has prepared this low flow TMDL using the Watershed Protection Approach consistent with EPA's authority to establish TMDLs under Section 303(d) of the Clean Water Act and 40 CFR 130.7. Based on available water quality data, conditions in the downstream segments of the Christina River Basin are impacted by tributary loads from upstream segments such as the East Branch Brandywine Creek. The Watershed Protection Approach calls for an evaluation of all relevant loads in a defined watershed. To address downstream Delaware impairments for DO, EPA along with participating state agencies and DRBC decided to establish a watershed TMDL. EPA believes this is the most equitable, most resource efficient and most environmentally prudent course of action available. EPA has therefore decided that the TMDL for the Christina River Basin must include the full watershed, including the East Branch Brandywine Creek.
03-C-03	On the Pennsylvania 303(d) list of impaired streams within the Christina River Basin, the most prominently listed source of stream impairment is "agriculture". In fact, agricultural lands comprise 40% of the Pennsylvania land use within the Christina River Basin. However, the focus of the Step 1 TMDLs is point source discharges, rather than agriculture.	Thomas Brown	EPA does not dispute that "agriculture" has been identified by the states on their 303(d) lists as a prominent source of stream impairment. Siltation, a separate pollutant from those being evaluated under this low flow TMDL is cited for a number of segments with agricultural use as a likely source. As discussed in the Decision Rationale document, nonpoint source loads, including agricultural, are assessed and a background contribution load is calculated under the critical conditions of low flow used in this TMDL. No reductions of these backgrounds are determined necessary to meet water quality standards under the critical conditions addressed by this low flow TMDL. Agricultural sources will undergo further evaluation during the development of the TMDL addressing high flow critical conditions for the Christina River Basin.

TMDL ID #	Comment	Commenter	Response
03-C-04	In section VII, item 8) of the EPA document entitled "Draft Total Maximum Daily Load of Nutrients and Dissolved Oxygen in the Christian River Basin, Pennsylvania, Delaware, and Maryland", EPA discussed the reasonable assurances that TMDL can be met. EPA gives assurances that point source discharge limits will be met through the NPDES permitting program. With respect to nonpoint source TMDLs EPA states: "Reductions from the current load allocations are unnecessary." "The feasibility of control measures necessary to reduce current non-point source pollutant loadings is highly questionable." In other words, it appears that EPA is conceding that the burden of water quality improvement will be placed on point source discharges rather than spreading the burden over both point and non point source discharges. We believe that this is contrary to the purpose of the TMDL regulations.	Thomas Brown	Revisions will be made to the Decision Rationale document to clarify these statements. The context of the statement on the feasibility of control measures for nonpoint sources was intended for the background nonpoint source loads assessed in this low flow TMDL. EPA contends that controls on nonpoint sources are feasible and expects that the high flow TMDL and its subsequent implementation plan will make this clear.
03-C-05	Non-point source discharges, for all practical purposes, will be addressed in the Step 2 TMDL process, which is in progress and not required to be completed until December 2004. We Believe that Step 1 and Step 2 modeling should be done concurrently, as non-point source loadings have an impact on the stream quality, even during dry weather.	Thomas Brown	EPA, the states and the DRBC will complete the high flow TMDL and make recommendations for reductions from those sources assessed in the high flow evaluation as appropriate. However, the low flow TMDL prepared for critical conditions described in the Decision Rationale document is unlikely to be changed by the high flow TMDL. The low flow TMDL can be completed independent of the high flow TMDL as different critical conditions are employed. Assessment of nonpoint source loads during dry weather have been incorporated in the low flow TMDL through the assessment of background nonpoint source contributions.
03-C-06	The Step 1 model used by EPA is unrealistically conservative, resulting in point source discharge limits that are more stringent than necessary.	Thomas Brown	The TMDL model itself is not unrealistically conservative. It incorporates the best available science into the hydrodynamic and biochemical processes that describe the oxygen-carbon-nitrogen-phosphorus cycle.

TMDL ID #	Comment	Commenter	Response
03-C-07	The Brandywine River and its tributaries impact the water quality of only a small portion of the Christina River. That portion of the Christina is tidal. The water quality of the tidal portion of the Christina River is also impacted by the Delaware River and the point source discharges to the Delaware. The contaminant loads contributed by the 23 point source discharges in the limited segment of the tidal portion of the Delaware River considered by EPA are substantially greater than the contaminant loads contributed by the Brandywine River. However, there are no contaminant load reductions proposed for any of the Delaware River discharges.	Thomas Brown	Under the baseline condition in which all NPDES facilities were set to discharge at their existing permit flows and loads, the TMDL model indicated that a small portion of the tidal Christina River was not achieving the daily average DO standard (see Figure 8 in the TMDL Decision Rationale document). As noted in the Decision Rationale document, the tidal estuary portion of the TMDL model was able to consider potential impacts within the Christina River Basin from pollutant loads from the applicable portion of the Delaware River. Various stream segments in Brandywine Creek, Red Clay Creek, and West Branch Christina River were also not achieving the dissolved oxygen standards according to the model. However, in the Delaware River, the TMDL model did not indicate any problems with the Delaware River segments achieving DO standard. The TMDL allocations were made using the equal marginal percent removal (EMPR) strategy explained on pages 34 - 41 of the TMDL Decision Rationale document. After the Level 1 and Level 2 allocations of the EMPR strategy were made to the NPDES facilities inside the Christina River Basin, the TMDL model indicated all freshwater streams as well as the entire tidal Christina River were meeting the DO standards. Therefore, there was no need for any further allocations to NPDES facilities discharging to the Delaware River outside the Christina River Basin. See responses to 05-E-01-A, -B and -C.
03-C-08	If the Tier 2 TMDLs are implemented, as proposed, the cost to upgrade the Downingtown treatment plant will probably cost millions of dollars, which will place a substantial financial burden on the users of the Uwchlan Township sewer system. We believe that is unfair and inequitable since other discharges to the Christina River Basin, namely the non-point source discharges and the major point source discharges into the Delaware River, are not also required or probably will not be required to reduce their pollutant loadings into the Christina River basin.	Thomas Brown	Speculation on the costs for any planned improvements at facilities in the Christina River Basin as a result of the low flow TMDL are premature. An implementation plan to achieve the requirements of the TMDL will be developed after the TMDL is established. Cost estimates for any required improvements will be evaluated at that time.

TMDL ID #	Comment	Commenter	Response
04-D-01	First, we found the organization of the draft TMDL to detract from its purpose. The most crucial aspects of the TMDLs should be identified early in the document, and not relegated to latter pages. For example, the document does not even identify applicable water quality standards and waste load allocations until pages 27 and 32, respectively.	Bonnie Dahl	To assist in an organization of critical aspects of the TMDL, EPA has prepared an Executive Summary and included it in the Decision Rationale document.
04-D-02	The "Historical Perspective" and discussion of public participation, we submit are gratuitous, and at times simply wrong. They should be removed, or in the least, demoted to an appendix, if anything.	Bonnie Dahl	EPA contends these sections are helpful, and in the case of the discussion of public participation, one of the regulatory requirements for the establishment of TMDLs. These sections will remain in the Decision Rationale document and revised as necessary.
04-D-03	Second, inexplicably, the document fails to identify the existing actual relevant total loads and observed DO and nutrient concentrations under critical conditions in the Christina basin. Given that it is a basin-wide TMDL, the document should identify the basin-wide loads that affect DO and nutrients.	Bonnie Dahl	Tables 12 through 27 in the TMDL Decision Rationale document provide specific waste load allocations for dischargers in the basin as well as load allocations for subwatersheds in the Christina River Basin.
04-D-04	Third, the draft TMDL does not adequately account for model uncertainty. The underlying water quality model used to generate the TMDL is flawed in at least three important respects.	Bonnie Dahl	See responses 04-D-04A, 04-D-04B, 04-D-04C and 04-D-04A.
04-D-04-A	It assumes that full sunlight is available to all the stream segments throughout the watershed. To the contrary, most riparian stream reaches, particularly in the upper portions of the basin, are at least partially shaded. This incorrect assumption accordingly skews all of the DO and nutrient calculations by overestimating photosynthesis rates.	Bonnie Dahl	The underlying TMDL model is not flawed with respect to its treatment of available sunlight. The TMDL model incorporates a shade factor which can be applied individually to each grid element to account for shading effects. Canopy cover data for all stream reaches in the Christina River Basin were not available. It was decided to assume full sunlight everywhere in the basin to represent worst-case critical conditions and add to the implicit margin of safety.
04-D-04-B	It at times also underestimates photosynthesis rates for systems that are saturated with phosphorus and other nutrients, such as the Red Clay Creek below Kennett Square. Assuming that there is room for any additional loading is simply unsupportable.	Bonnie Dahl	EPA disagrees. The photosynthesis rates downstream of the Kennett Square WWTP are apparently represented very well in the TMDL model as depicted in the dissolved oxygen shown in Figure A22. In this figure, it is apparent that the model minimum and maximum dissolved oxygen matches almost exactly the observed minimum and maximum concentrations downstream of Kennett Square (river mile 103.2).

TMDL ID #	Comment	Commenter	Response
04-D-04-C	It incorrectly predicts that benthic algae biomass growth peaks during the vernal period, and reaches a minimum during the summer. This is just plain wrong, and correspondingly predicts much higher allowable loading levels than clearly is the case.	Bonnie Dahl	The starting conditions for the benthic algal biomass (day 121) for the TMDL model calibration and validation runs may have been initialized higher than one might expect. However, no observed data were available to confirm or deny this starting condition. Also, the TMDL model was calibrated for the late summer (August-September) critical period, not the starting period in May. The first month of the calibration and validation periods was considered as the model spin up period when the various model parameters were moving toward their "dynamic equilibrium" conditions. If one ignores the first month of the simulation, the benthic algae shown in the figures in Appendix B of the Model Report indicate a fairly steady biomass from June (day 152) through mid-August (day 225) with an increase during late summer at most locations. An example of how the benthic algae in the model responds to loading levels can be seen by comparing Figures B15 and B16 (West Branch Red Clay Creek) with the results on Figures B31 and B32 (Pike Creek). At the West Branch Red Clay Creek location, the available phosphorus and nitrogen concentrations are high and the corresponding benthic algae biomass is also large (about 1000 ug/L). Conversely, at the Pike Creek location the phosphorus and nitrogen concentrations are low and the benthic algae is also very low (less than 10 ug/L).
04-D-04-D	It grossly under reports the effect of sediment activities. The model was developed for estuaries systems of the Chesapeake Bay. It is not appropriate for the rocky, sandy or granular sediment components existing in the freshwater systems throughout the basin.	Bonnie Dahl	There is no basis for implying that the TMDL model "grossly under reports the effect of sediment activities." The Christina River Basin TMDL model accounts for potential sediment effects on DO through the use of the Sediment Oxygen Demand (SOD) variable. SOD is accounted for during the TMDL analysis and allocation scenarios and is based on literature values as well as site-specific SOD data gathered by DNREC. The sediment diagenesis submodel of the TMDL model is applicable to both estuary and fresh water systems. Please refer to section 5.3.5 in the Model Report for documentation on how the model utilizes either methane or sulfate depending on whether the overlying water column is a saline or fresh water system.

TMDL ID #	Comment	Commenter	Response
04-D-05	The insufficiency of the model is displayed by noting that it does not predict water quality impacts well when compared to actual, available, significant databases.	Bonnie Dahl	The TMDL model was calibrated using data collected in 1997 and validated using data collected in 1995 with both years experiencing low-flow periods comparable to 7Q10 conditions used for the low flow TMDL. The results of the calibration and validation are presented in the Model Report. As presented in Section 11 of the Model Report, relative error statistics for dissolved oxygen, carbon, nitrogen, and phosphorus are within the acceptable guidance for water quality models published in Technical Guidance Manual for Performing Waste Load Allocations, EPA, 1990.
04-D-06	Fourth, the draft TMDL ignores important influences on allowable loadings. For example, there is no discussion of violations of pH on the East and West Branch Brandywine. These violations are a product of changes in algal photosynthesis, which in turn affects nutrient concentrations. Yet inexplicably the report does not account for these pH violations, thus predicting even greater allowable loadings than what is the case in the basin.	Bonnie Dahl	Water Quality Standards for DO, not pH, are appropriately used as the water quality target of this TMDL. EPA believes that the pH criteria violations are directly coupled with photosynthesis and respiration which occurs in the stream in response to excess nutrient loading. EPA further believes that controls on nutrients as established in this TMDL will address the pH violations.

TMDL ID #	Comment	Commenter	Response
04-D-07	Last, the draft TMDL contains several gratuitous, debatable, and erroneous comments about the legal underpinnings of TMDLs, and often misquotes or misconstrues existing legal requirements. It assumes that there are not control measures to reduce nonpoint contributions. It assumes, without discussion, that pollutant reductions are not economically practicable for several point sources. It assumes an implied margin of safety, but provides no actual margin. It assumes no water quality violations for many stream reaches, even though actual and recent data show otherwise.	Bonnie Dahl	As previously stated, EPA does believe that nonpoint source control mechanisms, such as BMPs, must be implemented to control overland sources of pollutant loadings during precipitation events and high flow periods. The final sentence in part 8 (Reasonable Assurance) of Section VII (discussion of Regulatory Conditions) of the Decision Rationale document is applicable within the context of the critical conditions of this TMDL. The lack of precipitation events, as is typical during critical low-flow conditions, causes one to question the effectiveness of traditional BMP measures which are designed on the premise of overland flow. This statement is also meant to clarify why EPA believes that reductions in point sources are necessary during critical conditions to provide reasonable assurance that the TMDL can be met. The Decision Rationale document will be revised to clarify this issue. Economic feasibility did not specifically determine the nature and magnitude of pollutant reductions in the Christina River Basin. Without knowing which specific point sources the commenter refers to, EPA can not provide a more specific response. The requirement to include a margin of safety (MOS) stems from the need to account for uncertainty in the modeling process. Accounting for uncertainty can be done either through an explicit or implicit approach. Neither method is more appropriate than the other. It is more important to consider and address uncertainty than it is to use a particular method. EPA believes that use of implicit MOS within this model is appropriate. The nature of implicit margins of safety precludes quantifying an actual MOS load. Please refer to the response to comment 11-L-48 regarding modeled segments and related 303(d) listed segments.

TMDL ID #	Comment	Commenter	Response
05-E-01	The Brandywine River and its tributaries impact the water quality of only a small portion of the Christina River. That portion of the Christian River is tidal. The water quality of the tidal portion of the Christina River is also impacted by the Delaware River and the point source discharges to the Delaware River, as acknowledged by EPA in the draft TMDL document (Section VII, Item). We have several concerns.	Doug Hanley	The Decision Rationale document states that any discharge into the Delaware River above and below the confluence of the Christina River and the Delaware River could potentially impact water quality within the tidally influenced portions of the Christina River Basin. As discussed in the responses to 03-C-07 and 05-E-01B, a planned Level 3 evaluation for facilities within the defined portion of the Delaware River proved unnecessary.
05-E-01-A	When considering the impact of the Delaware River and its point source discharges on the tidal portion of the Christina River, EPA considered only a small portion of the Delaware River watershed (10 miles above and below the confluence of the Christina with the Delaware), which includes 23 point source discharges. No other Delaware River basin point source or non-point source discharges were considered.	Doug Hanley	Point sources in the Delaware River were considered within an approximate 10-mile distance from the mouth of the Christina River. The tidal excursion zone in this area of the Delaware River is about 8 miles. Therefore, it was decided to locate the upstream and downstream boundaries of the Delaware River at least one tidal excursion length from the mouth of the Christina River. All point sources located within the model domain were also included in the TMDL model.
05-E-01-B	The volume of contaminant discharged by the 23 point source discharges within the 20 mile segment of the Delaware River are many times greater than the volume of contaminants discharged by the point source discharges into the Brandywine River. However, even though contaminant loads from Brandywine River discharges must be reduced, none of the 23 Delaware River point source discharges will be required to reduce contaminant loads (refer to EPA Table 28).	Doug Hanley	As outlined in the Decision Rationale document, EPA proceeded through a Level 1 and then a Level 2 discharge evaluation of facilities that discharge within the physical boundaries of the Christina River Basin. Reductions from this evaluation were deemed adequate to protect DO standards and a planned Level 3 evaluation for facilities within the defined portion of the Delaware River proved unnecessary. See 03-C-07.
05-E-01-C	In the draft TMDL document, with respect to the impact of Delaware Estuary pollutant loads on the Christina River, EPA states "...explicit analyses to determine the exact nature and magnitude of impacts to water quality in the tidal portions of the Christina River Basin from increased or decreased pollutant loads from the Delaware Estuary has not been performed. "It appears, therefore, that a major of pollution impact on the tidal portion of the Christina River (the Delaware Estuary), is being ignored or glossed over, while imposing more stringent requirements on the discharges into the East Branch Brandywine Creek. We believe this is inequitable.	Doug Hanley	EPA did consider pollutant impacts from dischargers on the Delaware River in the TMDL and are included in the TMDL analysis and allocation scenarios. Those loadings are included in table 28. EPA believes it was not necessary nor appropriate to include these as waste load allocations since they are located outside of the Christina River Basin. However, the impact of those pollutant loadings are considered within the TMDL model. The statement was meant to indicate that sensitivity analyses have not been performed to determine the effects from varied loadings of Delaware River discharges on water quality of the tidal portions of the Christina River Basin.

TMDL ID #	Comment	Commenter	Response
05-E-02	We have seen no evidence that point source discharges are the primary cause of the water quality problems in the Christina River Basin; however, the emphasis for correction appears to be the point source discharges.	Doug Hanley	This low flow TMDL addresses the impacts of point source discharges in the Christina River Basin. Section 303(d) lists submitted by states in the Christina River Basin have identified point sources as a contributor to water quality problems in the Christina River Basin. The TMDL model runs conducted in the preparation of this TMDL confirmed that point sources evaluated at their permit limits under the design conditions used in this TMDL can produce violations of DO standards. For an example of evidence of water quality impairment due to a point source discharge, refer to Figure A22 for the West Branch Red Clay Creek. Notice the observed dissolved oxygen concentrations at river mile 103.2. The observed minimum DO is 2.0 mg/L whereas the minimum DO water quality standard is 4.0 mg/L in this stream. The location of this monitoring station is downstream of the Kennett Square WWTP (PA0024058).
05-E-03	On the Pennsylvania 303(d) list of impaired streams, the East Branch Brandywine Creek is not listed as an impaired stream, yet TMDLs are being set for the East Branch Brandywine Creek.	Doug Hanley	As discussed in the Decision Rationale document, EPA has prepared this low flow TMDL using the Watershed Protection Approach consistent with EPA's authority to establish TMDLs under Section 303(d) of the Clean Water Act.. Based on available water quality data, conditions in the downstream segments of the Christina River Basin are impacted by tributary loads from upstream segments such as the East Branch Brandywine Creek. The Watershed Protection Approach calls for an evaluation of all relevant loads in a defined watershed. To address downstream Delaware impairments for DO, EPA along with participating state agencies and DRBC decided to establish a watershed TMDL. EPA believes this is the most equitable, most resource efficient and most environmentally prudent course of action available. EPA has therefore decided that the TMDL for the Christina River Basin must include the full watershed, including the East Branch Brandywine Creek. See 02-B-03.

TMDL ID #	Comment	Commenter	Response
05-E-04	On the Pennsylvania 303(d) list of impaired streams within the Christina River Basin, the most prominently listed source of stream impairment is "agriculture". In fact, agricultural lands comprise 40% of the Pennsylvania land use within the Christina River Basin. However, the focus of the Step 1 TMDLs is point source discharges, rather than agriculture.	Doug Hanley	EPA does not dispute that "agriculture" has been identified by the states on their 303(d) lists as a prominent source of stream impairment. Siltation, a separate pollutant from those being evaluated under this low flow TMDL is cited for a number of segments with agricultural use as a likely source. As discussed in the Decision Rationale document, nonpoint source loads, including agricultural, are assessed and a background contribution load is calculated under the critical conditions of low flow used in this TMDL. No reductions of these backgrounds are determined necessary for this low flow TMDL. Agricultural sources will undergo further evaluation during the development of the high flow TMDL for the Christina River Basin.
05-E-05	In Section VII, Item 8 of the EPA document entitled "Draft Total Maximum Daily Load of Nutrients and Dissolved Oxygen in the Christina River Basin, Pennsylvania, Delaware, and Maryland". EPA discussed the reasonable assurances that TMDLs can be met. EPA gives assurances that point source discharge limits will be met through the NPDES permitting program. With respect to non-point source TMDLs, EPA states:"Reductions from the current load allocations are unnecessary." "The feasibility of control measures necessary to reduce current nonpoint source pollutant loadings is highly questionable." In other words, it appears that EPA is conceding that the burden of water quality improvement will be placed on point source discharges rather than spreading the burden over both point and non-point source discharges. We believe that this is contrary to the intent of the TMDL regulations, which is that TMDLs address all discharges (point source and non-point source) into a water body.	Doug Hanley	Revisions will be made to the Decision Rationale document to clarify these statements. The context of the statement on the feasibility of control measures for nonpoint sources was intended for the background nonpoint source loads assessed in this low flow TMDL. EPA contends that controls on nonpoint sources are feasible and expects that the high flow TMDL and its subsequent implementation plan will make this clear.

TMDL ID #	Comment	Commenter	Response
05-E-06	Non-point source discharges, for all practical purposes, will be addressed in the Step 2 TMDL process, which is in progress and not required to be completed until December 2004. We believe that Step 1 and Step 2 modelling should be done concurrently, as non-point source loadings have an impact on the stream quality, even during dry weather.	Doug Hanley	EPA, the states and the DRBC intend to complete the high flow TMDL and will make recommendations for reductions from those sources assessed in the high flow evaluation as appropriate. However, the low flow TMDL prepared for critical conditions described in the TMDL Decision Rationale document is unlikely to be changed by the high flow TMDL. The low flow TMDL can be completed independent of the high flow TMDL as different critical conditions are employed. Assessment of nonpoint source loads during dry weather have been incorporated in the low flow TMDL through the assessment of background nonpoint source contributions.
05-E-07	The Step 1 model used by EPA is unrealistically conservative, resulting in point source discharge limits that are more stringent than necessary.	Doug Hanley	The TMDL model itself is not unrealistically conservative. It incorporates the best available science into the hydrodynamic and biochemical processes that describe the oxygen-carbon-nitrogen-phosphorus cycle.
05-E-08	If the Tier 2 TMDLs are implemented, as proposed, the cost to upgrade the Downingtown Treatment Plant will cost millions of dollars, which will place a substantial financial burden on the users of the Uwchlan Township sewer system. We believe that is unfair and inequitable since other discharges to the Christina River Basin, namely the non-point source discharges and the major point source discharges into the Delaware River, are not also required or probably will not be required to reduce their pollutant loadings into the Christina River basin.	Herbert J. May	Speculation on the costs for any planned improvements at facilities in the Christina River Basin as a result of the low flow TMDL are premature. Cost estimates for any required improvements will be evaluated during the implementation process.
06-F-01	We are in support of additional public participation in determination of the allocations.The affected dischargers should be given adequate time to evaluate the model and wasteload allocation scenarios before the TMDL is finalized.	J. Newbold	In response to requests received, EPA granted an additional 30 days to the public hearing record to allow more time for public review of and comment on the proposed TMDL.
06-F-02	The document title should be revised to say that this is the Step 1 TMDL for low-flow conditions, as reflected in the last sentence of the Introduction paragraph, the sentence beginning at the bottom of page 2 and the last paragraph on page 3.	J. Newbold	EPA will modify the TMDL Decision Rationale document title and appropriate text to clarify that this a TMDL for low-flow conditions.

TMDL ID #	Comment	Commenter	Response
06-F-03	A statement should be included in the document to say that implementation of the TMDL by the states (or of this first step of the two-step TMDL) can be deferred or postponed where appropriate until after completion of the second step, which will model and characterize high-flow conditions.	J. Newbold	EPA regulations at 40 CFR 122.44 (d) (1) (vii) (B) require that reissued permits must be consistent with any established TMDL. Once the low flow Christina River Basin TMDL is established, a reissued permit must be consistent with the loading requirements established by the TMDL. Inclusions of reopener clauses in reissued permits for possible future adjustments in the TMDL and a compliance schedule that offers a facility a period of time to meet the requirements of the TMDL within the period of the permit may be acceptable.
06-F-04	The document should clarify that where point sources on tributaries were involved in allocations, the allocations were actually determined at the confluence with the main stem stream segment, not at the point of effluent discharge to the tributary.	J. Newbold	The TMDL Decision Rationale document discusses the treatment of tributary discharges (allocations determined at the main stem) in the explanation of a conservative assumption used in the TMDL model (Section vii. 6.)
06-F-05	In the case of the West Chester-Taylor Run STP, we reviewed previous results from the Department model which was used in developing existing effluent limits to protect Taylor Run, our review indicated that the instream concentrations (14.5 mg/1 CBODS, 1.9 mgll NH3N) at the confluence with East Branch Brandywine Creek will be less than the draft allocation limits. Although our modeling didn't include phosphorus, available DMR data has shown that the discharge is consistently less than the existing permit limit of 2 mg/l. Using a log-normal distribution the 1997-1998 suggests an average monthly concentration of 1.9 mg/1 at the discharge point.	J. Newbold	See response to 06-F-06 below.

TMDL ID #	Comment	Commenter	Response
06-F-06	During our review it was also noted that the permitted annual average discharge flow is 1.5 mgd. This flow should be used for modeling purposes, instead of 1.8 mgd, which is the maximum monthly flow, to be consistent with flows used for other discharges. We recommend that EPA rerun the EFDC model using 1.5 mgd and conservative input values of CBODS=15 mg/l, NH3N=1.9 mgJl and P=1.9 mg/1 at the confluence to determine the impact on other discharges in the main stem East Branch Brandywine.	J. Newbold	An incorrect flow rate for the West Chester Taylor Run facility (PA0026018) was used in model runs reported in the draft TMDL Decision Rationale document. A monthly average flow rate of 1.8 mgd was used based on information from the 1995 Discharge Monitoring Report (DMR) data sheet provided by the Brandywine Valley Association. However, we understand that the permitted monthly average flow rate changed to 1.5 mgd in 1996. We have re-done the TMDL model allocation runs using the corrected flow rate of 1.5 mgd and revised allocations will be reported in the final TMDL Decision Rationale document. We also conducted a TMDL model run using a flow rate of 1.5 mgd as well as the lower parameter concentrations suggested in this comment (i.e., CBOD5=15 mg/L, NH3N=1.9 mg/L, and TP=1.9 mg/L). However, using the lower parameter concentrations did not impact the allocations in the East Branch Brandywine Creek. Therefore, we have decided to use the original concentrations (CBOD5=25 mg/L, NH3N=2.5 mg/L, and TP=2.0 mg/L) for the TMDL allocation runs in order to retain a consistent methodology with the other facilities in the study.
06-F-07	The implicit margin of safety assumption in the TMDL should not be affected by revisions due to West Chest-Taylor Run STP, a conservative assumption still exists because all other point sources are modeled using the theoretical situation of design flow and permit limits, all at Q7-10 stream flow.	J. Newbold	This comment is correct. The basic assumptions regarding implicit margin of safety still apply since we are only correcting an error in the flow rate at the West Chester Taylor Run facility.
07-G-01	The TMDL fails to account for: Leaf litter (soluble as well as SOD component),wetlands,lake turnover,& malfunctioning septic systems ... which are significant nutrient sources during fall low flow periods (background assumption and evaluation period error).	William Glover	Leaf litter, wetlands, lake turnover, and malfunctioning septic systems were not explicitly considered in the model. No information was available or provided on malfunctioning septic systems and the subject was never broached at any of the TMDL public meetings. The trend of increasing Total Organic Carbon concentrations in the main stem Brandywine Creek in the downstream direction may be due to the impacts of leaf litter.

TMDL ID #	Comment	Commenter	Response
07-G-02	The TMDL fails to account for: STPs perform better at low flow & below design loadings (TMDL calibration error).	William Glover	The use of maximum allowable permit (design) flows and loads has historically been the appropriate method for determining waste load allocations under steady-state conditions. Under dynamic conditions it is acceptable to determine waste load allocations using the statistical procedures outlined in the Technical Support Document for Water Quality-based Toxics Control, EPA605/2-90-001, 1991 (TSD). Since this low flow TMDL was determined for steady-state conditions, it is reasonable to use maximum allowable permit flows and loads. Dynamic conditions and variable flow will be considered under the high flow TMDL. See 01-A-03.
07-G-03	The TMDL fails to account for: Projected climate change will negate need to protect to high water quality standard.	William Glover	EPA is unaware of any agreed upon projected climate change that would negate the need to protect water quality standards.
07-G-04	The TMDL fails to account for: Where is there consideration for existing or new STP service area extensions which would reduce raw sewage discharge and septic system problem nutrient loadings? The cost to upgrade the STPs will discourage the connection of sewerage problem areas and contribute to the potential failure of this effort. Land use changes such as the elimination of forest areas or natural changes other than climate adjustments may negate this TMDL effort.	William Glover	The TDML is established based on existing maximum allowable permit limits for flow and loads, which in most cases, would allow for increases in flows to accommodate new connections by dischargers in the Basin. Speculation on the impacts of any costs to upgrade facilities in the Christina River Basin is unfounded until implementation plans are developed. This TMDL establishes limits under the design conditions which will continue to have to be met regardless of land use changes in the Christina River Basin.

TMDL ID #	Comment	Commenter	Response
08-H-01	I run the Broad Run wastewater treatment facility owned by Utilities, Inc. in Downingtown, Pa. I attended an informational meeting on July 18, 2000 and was informed of the new limits that would be imposed on this particular system for improved water quality for the Christina River Basin. At this meeting I raised concern that. the limit for Ammonia for this particular system would be 0.1 mg/l, This limit I feel is much too low and leaves no room for error. Both groups attending from EPA and DEP agreed that a 0.1 was rather low. They had used data that was from 1997 when for whatever reason my ammonia results were very good. A George Goliday was given ammonia data from 1996 through 1999 which gave a more accurate idea of how this system handled removal of ammonia. He said be would take this data and get back to me to see if these limits could be raised. I contacted George about the middle of September and he said they were looking at bringing these limits up to maybe 0.4mg/1 to 0. 5mg/1. I told him that I was still uncertain that my system would be able to meet these limits and asked if there was any way that they could be put at 2.O mg/l. He said he would send the info to others and see if it could be done in conjunction with the lowering of other parameters. He also said that he would be leaving and said that a person to talk to would be Mike Morten. I now would like to submit that I would be much more comfortable if ny ammonia limit was placed at 2.Omg/1. When we first took over this system in August 1992 the DEP permit for ammonia was monitor only. Because (I guess) that my ammonia was low the new DEP permit issued in Jan. 1999 removed the ammonia limit completely. Now all of a sudden because of the Christina River Basin EPA comes along and wants to put my ammonia limit at 0. 1mg/l.	J.Hawkes, Jr	The TMDL analysis was revised to reflect new ammonia nitrogen limits of 2.0 mg/L for the Broad Run Sewer District WWTP (PA0043982). The TMDL allocation results presented in Table 11 of the TMDL Decision Rationale document reflect the revised ammonia nitrogen limit of 2.0 mg/L.
09-I-01	A "Total Maximum Daily Load" is a process, many years delayed and now being carried out under a deadline resulting from litigation, to determine how the Christina is impacted by pollutants, and what reductions in those pollutants would be needed to achieve some degree of compliance with the (very weak and inadequate) water quality standards adopted by Delaware and Pennsylvania under authority delegated by the EPA under the Clean Water Act.	Muller& Collins	EPA does not agree with the description of the Pennsylvania and Delaware water quality standards, approved by EPA, described in this comment. The standards established by the states, and the DRBC, provide the basis for the TMDL process and are subject to their own, separate public review procedures. EPA has no basis to question the standards employed in the development of the Christina River Basin TMDL.

TMDL ID #	Comment	Commenter	Response
09-I-02	The proposed TMDL apparently applies only to "point" sources, calls for only small reductions, does not contain explicit safety factors, and assigns all the reductions to Pennsylvania and Maryland, although everyone in Delaware knows that water quality in the Christina is severely impacted by discharges in and near the City of Wilmington. This is absurd, and likely to lead to a situation in which Pennsylvania officials are understandably reluctant to make reductions.	Muller& Collins	The basis for this TMDL is a point source evaluation under design low flow conditions. Impacts of other sources in the Christina River Basin will be evaluated through the high flow TMDL. The TMDL model runs used in the development of the TMDL pinpointed the dischargers where reductions are necessary.
09-I-03	At the "public meeting" the presenter was unable to say how the recent 50% permitted increase from the City of Wilmington POTW was treated in the model. Thus, we doubt the model in this and other respects reflects reality.	Muller& Collins	After presentation of this statement at the Wilmington public information meeting on July 19, 2000, EPA asked its Christina River Basin TMDL model consultant to evaluate the impacts of the revised Wilmington STP permit. This analysis was performed and the conclusion reached that the revised permit had no impacts on the Christina River Basin TMDL.
09-I-04	There appears to have been no meaningful public participation in the development of the TMDL. Rather, cosmetic, public-relations-oriented activities were set up to distract members of the public from participation in the actual formulation and calibration of the model. We object very strongly to this bogus form of public participation, and the management of it by Mr. Robert Struble, who represents organizations now or formerly under the influence of major dischargers and environmental offenders such as NVF Corp. As shown by material released under a Freedom of Information Act request, Mr. Struble has been meeting with "dischargers"and apparently helping them to coordinate objections to reductions. On the other hand, Struble asked to be taken off Green Delaware's mailing list, and took us off his mailing list for his dubious activities. To have hired Mr. Struble, with all his potential conflicts of interests, mocks the most basic concepts of good faith, and has contaminated the integrity of the entire process. What should have been done includes this: Those involved in the technicalities of model development should have identified the judgement calls and assumptions they were considering, and sought public input on same.	Muller& Collins	EPA disagrees with the characterization of the public participation process for the Christina River Basin TMDL as described in this comment. As discussed in the Decision Rationale document, EPA, with the assistance of several participating agencies, conducted an open process throughout the development of the Christina River Basin TMDL. Numerous public meetings were scheduled and the public meeting process culminated in the general information meetings on July 19 and 20. EPA also developed and publicized an internet web site (www.epa.gov/reg3wapd/christina) where many documents relevant to the Christina River Basin TMDL were made available and opportunity provided for submission of comments. In addition, EPA has no basis to object to the involvement of Mr. Robert Struble in the public participation efforts pertaining to the Christina River Basin TMDL. Mr. Struble provided assistance in arranging very productive sessions with representatives of many Christina River Basin dischargers and acted in a neutral manner in conveying an objective summation of the concerns of these dischargers.

TMDL ID #	Comment	Commenter	Response
09-I-05	Recognizing that hydrodynamic and water quality modeling of a river basin is a complex process, we are concerned that the complexity of the process, in and of itself, tends to obscure the reality of a polluted waterway that will remain polluted. To put it another way, the EPA seems to have long since lost touch with the original intent and purpose of the Clean Water Act.	Muller& Collins	EPA acknowledges that establishment of a TMDL is a complex and highly technical process, especially when done in an interstate watershed such as the Christina River Basin . However, establishment of TMDLs is a core element of the Clean Water Act, being a statutory requirement since 1972. The establishment of TMDLs is clearly part of the intent and purpose of the Clean Water Act.
09-I-06	We received a strong impression, from both the "public meeting," and the "public hearing," that EPA was unlikely to pay serious attention to comments received from the public on this matter. Certainly DNREC has neither sought not considered public opinion on this project.	Muller& Collins	EPA disagrees with this comment. During the public meetings and hearings, EPA made it clear that it welcomed comment on the proposed TMDL and would revise the TMDL as necessary based on comments received. In fact, numerous changes were made in the proposed TMDL between the public meetings and public hearings based on information received at the public meetings. Additional changes have been made to the TMDL in response to comments received following the public hearings. The role of the Delaware Department of Natural Resources and Environmental Control (DNREC) in the public participation process was that of a supporting agency as initially the DRBC Commission and then EPA were responsible for the administrative portions of the TMDL development. DNREC has provided considerable support to both the DRBC and EPA in the development of the TMDL and attended nearly all the public meetings and hearings and provided comments and responses to questions as necessary.
09-I-07	In conclusion, we recommend that the proposed TMDL not be adopted at this time. We conclude that neither DNREC nor EPA have complied with the settlement agreements under which this work went forward, nor would the work product, as it now stands, reasonably lead to compliance with the Clean Water Act.	Muller& Collins	EPA respectfully disagrees on both points. In establishing the Christina River Basin TMDL, EPA and DNREC are also complying with settlement agreement reached in response to the Delaware 303(d) lawsuit. EPA also asserts that the establishment of this low flow TMDL is an important milestone for compliance with the Clean Water Act in the Christina River Basin.

TMDL ID #	Comment	Commenter	Response
10-J-01	Model Results Confirm that Discharges to the East Branch of Brandywine Creek do not Adversely Affect the Christina River, therefore no TMDL is necessary. The problem identification section of the TMDL identified the tidal Christina River as the region experiencing water quality problems due to nutrient loading, while other tributaries (such as the East Branch of Brandywine Creek) are not impaired (@ pg. 11). This assessment is supported by the 1997 calibration evaluation illustrated in Figures 6 and 7 of the report for average and minimum dissolved oxygen levels. However, the TMDL evaluation, under design conditions, demonstrates that no water quality excursions are expected in the tidal portions of Brandywine Creek at the confluence with the Christina River (Figures 8 and 9 of the report). This result is a clear indication that point source nutrient loads to the East Branch are not responsible for water quality excursions in the tidal Christina River. Thus, EPA has demonstrated that regulation of upstream sources is not required under this TMDL action.	William Hall	Refer to Figure 8 and Figure 9 in the TMDL Decision Rationale document. These figures present model results indicating the locations where the water quality standards for daily average DO (Figure 8) and the minimum DO (Figure 9) are not protected during critical summer low-flow conditions with NPDES sources discharging at their existing monthly average permit limits. These two figures indicate that a large portion of the East Branch Brandywine Creek are indeed adversely affected by nutrient loads under assumed critical conditions. In Figures 6 and 7, TMDL model results are presented showing the locations were water quality standards for daily average DO and minimum DO are not protected during the August 1997 calibration period. The TMDL model indicates the daily average DO in a portion of the tidal Christina River does not meet the water quality criteria of 5.5 mg/L. A smaller portion of the Christina River does not meet water quality standards under the critical conditions TMDL model run (Figure 8). This is somewhat misleading because a point source in Little Mill Creek was active for the 1997 calibration period, but is no longer active today and was not included in the critical conditions model run (Figure 8). The loads from that point source were influencing the tidal Christina River in the vicinity of the mouth of Little Mill Creek during the calibration runs but not during the critical conditions run.

TMDL ID #	Comment	Commenter	Response
10-J-02	Figures 8 and 9 suggest that water quality problems will occur in the East Branch of Brandywine Creek under design conditions. However, this is not the basis for the TMDL, and PADEP has not identified these reaches as not attaining water quality standards. These sources are currently regulated under water quality-based permits that PADEP considers sufficient to attain all applicable water quality objectives. A probable reason for this difference in opinion is that the TMDL critical conditions combine multiple worst-case assumptions that represent a highly improbable condition with a remote probability of occurrence. PADEP, not EPA, has delegated authority on such decisions. If EPA believes that additional restrictions may be necessary, it may raise such issues at NPDES reissuance. EPA does not have any jurisdiction to impose a more restrictive water quality-based limit at this time.	William Hall	EPA has the authority to establish waste load allocations, as called for in the TMDL regulations and consistent with agreements reached with affected state and other parties. NPDES permits and associated limits are not automatically changed with the establishment of a TMDL. Any changes to NPDES permits will afford additional opportunities for comment and review. Any NPDES permits reissued after the establishment of such TMDL waste load allocations must contain effluent limits 'consistent with' the applicable waste load allocation (40 CFR 122.44 (d) (1) (vii) (B)).
10-J-03	TMDL Model Uses Wrong Effluent Flows from POTWs. The critical condition analysis used by EPA in the TMDL was based on drought flow conditions in the Christina River Basin with point source discharges at their design flow rates. Specifically, the discharge for the Authority's wastewater treatment facility, the Downingtown Regional Water Pollution Control Center ("DRWPCC") was set at the facility design flow rate of 7.0 mgd (see Table 14 of report) while the East Branch flow was approximately 19 cfs. EPA did not present any information regarding the type of condition represented by the plant design flow (e.g., wet, dry, average, etc.). The report defines this critical condition analysis as representative of steady-state conditions expected to occur through the month of August (@ pg. 23). However, the relevant performance data confirm that use of the design flow is not representative of conditions expected to occur in August, or any other month when drought conditions exist in the Christina River Basin.	William Hall	The maximum allowable monthly average permit flows and loads for the NPDES facilities were used for the TMDL model runs. There are no provisions in the NPDES permits requiring that these facilities are to discharge less mass loading during low-flow conditions. Therefore, it is appropriate for EPA to use the maximum allowable permitted flows in developing the TMDL since they represent the allowable loading from the facility under any stream flow condition. Such assumptions are reasonable and appropriate to ensure a TMDL that will attain and maintain water quality standards. See 01-A-03 and 10-J-05.

TMDL ID #	Comment	Commenter	Response
10-J-04	DMR data for the DRWPCC between 1997 and 2000 indicate that the monthly average flows ranged from 3.97 mgd to 4.63 mgd for the month of August, with an average August flow of 4.25 mgd. The highest monthly average flow (4.63 mgd) occurred in the year 2000, which was a year with higher than average rainfall. The lowest monthly average flow, 3.97 mgd, occurred in 1999 (a period experiencing drought conditions). These data clearly indicate that the design flow, 7.0 mgd, is not appropriate for modeling steady-state conditions in August. The design flow used for characterizing stream impacts does not reflect low flow conditions. The fact that EPA used the design flow when such a flow is inconsistent with the other modeling conditions violates the Agency's own policy and practice in this matter (see letter from James F. Pendergast to Gary Stenhouse, September 20, 1996, Attachment 1 hereto). The model should have incorporated the effluent flows anticipated in August for drought conditions along with the loads corresponding to these flows.	William Hall	The purpose of the TMDL was to determine the allowable loading from all sources to the impacted stream segments. The existing maximum allowable permit limits were used as a base condition to determine the existing allowable loading from the NPDES facilities. EPA has no policy on this issue. Mr. Pendergast's response to the questions posed him from Mr. Stenhouse does not refer to policy or regulations that require the use of seasonal flows or conditions. Mr. Pendergast uses terms such as "no requirement in the Clean Water Act...", "EPA encourages permitting authorities...", "an alternative is steady-state modeling.", "states may require...", and "the Clean Water Act and EPA regulations do not specify an effluent flow that must be used...". Mr. Pendergast notes that EPA 'encourages' states to use a dynamic model. EPA does not require it. Mr. Pendergast also notes that steady state modeling is an acceptable alternative to dynamic modeling if a state chooses not to model dynamically. Mr. Pendergast's response states that tiered permits are acceptable under the CWA and implementing regulations, but he does not say that they are mandatory under any circumstances. What Mr. Pendergast's response does refer to is the need to meet state water quality standards. Pennsylvania's standards apply to the 7Q10 low flow and above. Therefore it is imperative to assure that any allocation that is developed will meet these conditions. Please note that the process used to develop low flow TMDLs for the Christina River Basin study is no different than the process used by Pennsylvania statewide for developing permit condition, the use of low flow critical conditions at effluent design flow conditions. The only difference is that the TMDL was based on more detailed environmental data and detailed modeling and also overlapping impacts of various dischargers were necessary. We suspect that Downingtown's existing permit conditions were developed no differently but with less stream data and a less sophisticated model. Another point is that Downingtown does not now have seasonal effluent limits for flow. Under the NPDES permit now held by Downingtown, the maximum flow can legally be 7 MGD at any time of the year. We have developed this TMDL based on the legal limitations for flow and other environmental conditions. Downingtown has the option of pursuing the option of

seasonal flows with the state as the facility's permit is renewed.

TMDL ID #	Comment	Commenter	Response
10-J-05	TMDL Based on Overestimated Loads from POTWs Loads used in the steady-state analysis were based on the design flow and the permitted effluent concentration. For the DRWPCC, these permit limits are 10 mg/1 (CBOD5), and 2.0 mg/1 (ammonia nitrogen and phosphorus). As indicated above, use of the design flow to set wasteloads is inappropriate for modeling purposes. In addition, use of the permit limit concentrations is inconsistent with limit derivation processes and actual performance. For a facility to be in compliance with its permit, typical performance must be significantly better than the permit limit. The Agency considers the permit level to represent (at the minimum) the 95th percentile concentration within the frequency distribution of a POTW's performance. The steady-state modeling results, if otherwise computed properly, should represent average loads under drought conditions. The modeling results could then be used to project effluent limits as values greater than the average loads, using the statistical procedures contained in the Technical Support Document for Water Quality-based Toxics Control ("TSD"); EPA, 1991). The TMDL study, however, did not treat the results as average loads under critical conditions. The results were treated as though the permit limits should be set at the reduced levels. This approach is overly conservative because it presumes that every discharger will discharge at the 95th percentile concentration, simultaneously. This scenario has a very low probability and should not serve as the basis for a scientifically justified study. The performance expected under warm weather, low flow conditions should be much better than the permit limit. A review of Downingtown's performance over the past four years confirms this situation. Downingtown Area Regional Authority Summary of August Performance Data (mg/1) YearBOD5AmmoniaPhosphorus 19972.40.11.4 19983.00.11.3 19992.00.11.4	William Hall	The use of maximum allowable permit (design) flows and loads has historically been the appropriate method for determining waste load allocations under steady-state conditions. Consistent with EPA guidance, under dynamic conditions it is acceptable to determine waste load allocations using the statistical procedures outlined in the Technical Support Document for Water Quality-based Toxics Control, EPA605/2-90-001, 1991 (TSD). Since this low flow TMDL was determined for steady-state conditions, it is reasonable to use maximum allowable permit flows and loads. Dynamic conditions and variable flow will be considered under the high flow TMDL.

TMDL ID #	Comment	Commenter	Response
	20002.00.11.5 The August performance data are representative of expected facility performance throughout the summer and for most of the year. By comparison, the TMDL model used loading rates that were factors of: five higher for BODS; 35 higher for ammonia; and two higher for phosphorus. It is no wonder that the model predicted water quality problems in the East Branch of Brandywine Creek. The actual loads from Downingtown were less than the TMDL Level 2 Allocations for CBODS and ammonia-nitrogen presented in Table 11 (@ pg. 47), confirming that the discharge does not, in any way, cause water quality impairment.		
10-J-06	Actual Data Confirm that No Problem Exists in the East Branch of Brandywine Creek. The critical condition analysis for this TMDL concluded that daily average DO criteria and minimum DO criteria will not be achieved in portions of the East Branch Brandywine Creek below Downingtown (@ pg. 23). In contrast to this finding, the draft TMDL report noted that no DO criteria violations occurred in the East Branch of Brandywine Creek for the period from 1988 through the present. This lack of DO criteria violations was attributed to improved wastewater treatment effective in 1988 and served as the basis for not listing the East Branch Brandywine on the 303(d) list. Given this long history of meeting water quality standards for DO, it is inappropriate for the Agency to predict extensive areas of non-compliance by exaggerating the loads that actually reach the receiving waters.	William Hall	The TMDL has been developed for critical conditions expected during times of low flow. The critical conditions analysis is in accordance with standard practices employed in establishing permit limitations. The TMDL model runs for the Downingtown facility clearly indicate DO impacts under these critical conditions. It is likely that the period of time referenced when the East Branch Brandywine Creek did not evidence DO violations did not provide any comparable occurrence of the design conditions used to develop the TMDL. Note: the East Branch Brandywine Creek is on Pennsylvania's 303(d) list as a result of siltation, flow alterations and other habitat alterations. Modeling work performed in development of a TMDL is a valid basis for a 303(d) listing (40 CFR 130.7 (b) (5) (ii).

TMDL ID #	Comment	Commenter	Response
10-J-07	Nutrient Reduction Not Supported by Data for the East Branch of Brandywine Creek. The Level 2 Allocations for the DRWPCC (@ pg. 47) specify an allocation limit of 5.90 mg/1 for CBOD5, 1.18 mg/1 for ammonia-nitrogen, and 0.73 mg/1 for total phosphorus when the Christina River Basin is experiencing drought flow conditions and the discharge is at the design rate of 7.0 mgd. Historical performance for August indicates that the facility flow rate is approximately 4.25 mgd, and effluent quality is better than the allocation limits for CBOD5 and ammonia-nitrogen. Given the high effluent quality of the discharge, there is no reason to believe that reductions in phosphorus beyond the current limit of 2.0 mg/1 are required to achieve DO standards in the East Branch. Based on this more detailed review outlined above, and the comments previously submitted by DARA, we believe that the allocations specified for loads to the East Branch of Brandywine Creek are unjustified. With specific reference to the DRWPCC, no adjustments to the permit limits for BOD5, ammonia-nitrogen, or total phosphorus are justified.	William Hall	There is no provision in the NPDES permit for the Downingtown facility requiring that phosphorus discharge concentrations are to be less than 2.0 mg/L during low-flow conditions. Therefore, it was appropriate for EPA to consider the maximum allowable permit limit concentrations for developing the waste load allocation portion of the TMDL. The Level 1 and Level 2 allocation results of the TMDL model indicate there is reasonable justification for reducing the CBOD, ammonia nitrogen, and phosphorus concentrations from the Downingtown facility in order to protect the dissolved oxygen water quality standards in East Branch Brandywine Creek and downstream waters.
11-L-01	The point source "TMDLs" are based on average monthly discharge limits, and are therefore more accurately called "Total Monthly Average Loads," not "Total Maximum Daily Loads."	J.R.May	Point sources have been evaluated using existing NPDES effluent limitations and associated water quality data. Limits contained in the permits, and in the proposed point source reductions, provide an accurate estimate of the expected daily load from each discharger based on a monthly average. The resulting summation of the point source loads do in fact comprise the daily waste load component of a TMDL. Please refer to Table 8 in the Decision Rationale document.

TMDL ID #	Comment	Commenter	Response
11-L-02	In addition, because the allocated loads do not account for maximum permit conditions, the TMDLs will not protect the stream from further violations of the minimum Dissolved Oxygen water quality standard.	J.R.May	Because the TMDL sets waste load allocations assuming maximum allowable discharge of pollutants, the TMDL is protective of applicable DO water quality standards. The existing permit limits, and the proposed reductions in effluent limits for selected facilities as represented in the waste load allocations, are shown by TMDL model runs to be sufficiently protective to prevent violations of the minimum DO water quality standard. Data plots showing the protection of the minimum DO water quality standard will be added to the Decision Rationale document as an Appendix.
11-L-03	While reductions from the 12 point sources may result in improved water quality on those three water bodies, and on waters downstream, it cannot possibly improve water quality on the remaining impaired waters on the Pennsylvania and Delaware 303 (d) lists (see Table 3 and Table 4 in the TMDL document). No explanation is provided for how reductions in only these 12 point sources will address the impaired water quality of these "upstream" water bodies.	J.R.May	This TMDL is for low-flow critical conditions. Data plots for the TMDL allocation run show that DO water quality standards throughout the Basin, including 'upstream' water bodies, will be protected as a result of reductions specified in this TMDL for the low-flow critical condition. This information will be added to the Decision Rationale document as an Appendix.
11-L-04	In addition, many streams on the 303(d) lists list only nonpoint sources such as agriculture as the source of impairment; unbelievably, the proposed TMDL requires no reductions from current nonpoint source loads. (See Table B below.)	J.R.May	This TMDL is for low-flow conditions. Nonpoint source loads assessed as background conditions are incorporated in the low-flow TMDL. A full evaluation of nonpoint source loads under high flow conditions will be made in the high flow TMDL.
11-L-05	The failure to address nonpoint source loading in the TMDL automatically renders the TMDL inadequate to address water quality problems in a significant portion of the Christina River Basin. In addition, the failure of the model to predict impairment in these stream segments demonstrates the inadequacy of the model used to develop the TMDL.	J.R.May	This TMDL is developed to address low-flow conditions outlined in the Decision Rationale document and the waste load and load allocations have been prepared to protect DO standards in the Christina River Basin under those design conditions. See 01-A-03 and 11-L-10.

TMDL ID #	Comment	Commenter	Response
11-L-06	The commentors also note that the model fails to predict impairment from low DO for the Red Clay Creek, East Branch Red Clay Creek, East Branch White Clay Creek, Buck Run, and Little Mill Creek, even though these streams are specifically listed as impaired from this cause on the PA and DE 303(d) lists.	J.R.May	The Red Clay Creek, East Branch Red Clay Creek, East Branch White Clay Creek and Little Mill Creek segments do not identify point sources as a basis for the 303(d) listing decisions. Buck Run did identify point sources as a basis. However, a review of dischargers on Buck Run shows that the largest discharger to Buck Run, Parkesburg Borough Authority WWTP, ceased discharge to Buck Run in June 1997. Two other small dischargers to Buck Run were evaluated and the results did not indicate any DO violations.
11-L-07	Also puzzling is the fact that point sources listed as the source of impairment for Buck Run, Middle Branch White Clay Creek, and mainstem White Clay Creek (DE) are not reduced by the TMDL.	J.R.May	Point sources were identified in the 303(d) listing for Buck Run. However, a review of dischargers on Buck Run shows that the largest discharger to Buck Run, Parkesburg Borough Authority WWTP, ceased discharge to Buck Run in June 1997. Two other small dischargers to Buck Run were evaluated and the results did not indicate any DO violations. Dischargers to the Middle Branch White Clay Creek and main stem White Clay Creek (DE) were evaluated and the results did not indicate any DO violations.
11-L-08	During critical, lowflow conditions, the amount the water body can absorb is affected significantly by the amount of nutrients already present in the water body because of loading during storms or high flow periods. Therefore, the model used to calculate the low-flow TMDL must account for nonpoint source loads from storm events or high flows in order to produce an adequate TMDL during low-flow	J.R.May	The amount of nutrients present in the waterbody would be accounted for as background contributions. EPA utilized data from STORET, USGS, DEP, and DNREC to characterize background pollutant contributions. In addition, baseflow samples from USGS are used to characterize the nature of pollutant loadings from baseflow. EPA believes that the model adequately considers pollutant contributions from nonpoint sources. See 11-L-10.

TMDL ID #	Comment	Commenter	Response
11-L-09	To reasonably assure that water quality standards will be met during low-flow conditions, the low-flow TMDL must set maximum daily loads of nutrients from both point sources and nonpoint sources.	J.R.May	Table 8 of the Decision Rationale document sets forth waste load allocations for point sources and load allocations for nonpoint sources broken down by watershed for the Christina River Basin. Tables 12-27 specify individual waste load allocations for point sources in specific subwatersheds as well as load allocations for nonpoint sources broken down into 39 subwatersheds. These load allocations specify the maximum pollutant loads for carbonaceous biochemical oxygen demand (measured during a 5-day period), ammonia nitrogen, and total phosphorus for all 122 point source dischargers and the 39 subwatersheds in the basin. The Decision Rationale document specifically states why EPA believes that the Christina River Basin TMDL meets the requirements for TMDLs.

TMDL ID #	Comment	Commenter	Response
11-L-10	If nonpoint source loads from storm events or higher flow periods are not adequately accounted for in the model (and the commentors contend that the model does not adequately account for NPS loads or nutrients in stream sediment), the TMDLs assigned to point sources during low flow will be too high to achieve water quality standards.' If further reductions in nutrient pollution from point sources become impractical during low-flow, or if no point sources are present on an impaired stream segment, then measures to reduce nonpoint source loading during storm events and higher flow periods must be implemented to achieve water quality standards during low-flow.	J.R.May	Nonpoint source loads are adequately accounted for in the Christina River Basin TMDL model. EPA utilized existing data from STORET, United States Geological Survey (USGS), Pennsylvania Department of Environmental Protection (DEP) and DNREC to develop characteristic nonpoint source loads for parameters of concern from each of the 39 subwatersheds during critical low-flow conditions. These characteristic loads are used by the model during development of the allocation scenarios to represent nonpoint source pollutant contributions. Furthermore, those characteristic loads are representative of baseflow contributions (considered the dominant nonpoint source during critical low flow conditions) as well as expected land-based, nonpoint source during critical low-flow conditions. The Christina River Basin model also accounts for potential sediment effects on DO through the use of the Sediment Oxygen Demand (SOD) variable. SOD is accounted for during the TMDL analysis and allocation scenarios and is based on literature values as well as site-specific SOD data gathered by DNREC. Critical conditions in the Christina River Basin, as indicated by data characterization performed by Dr. John Davis (Preliminary Draft TMDL Document 5/27/99 - Report to DRBC) and confirmed through modeling, occur during relatively dry late summer and early fall months when streamflow is reduced and temperatures are high. During these times, the assimilative capacity of waterbodies are at a minimum. Point sources are the dominant contributor of pollutant loadings during these critical conditions. Land-based nonpoint sources, on the other hand, contribute very little loading during the late summer and early fall drought periods. However, contributions from nonpoint sources are reflected in the data used to develop characteristic nonpoint source loads during critical conditions. As discussed in the Decision Rationale document, an implicit margin of safety was provided in the TMDL through the use of conservative assumptions in the TMDL model.

TMDL ID #	Comment	Commenter	Response
11-L-11	In Section 1.1 of the model report, the scope of the Phase I model is narrowly focused on those stream segments impaired by point sources only: "The stream segments shown in [figure identifying segments impaired by point source only] will be the primary focus of this initial phase of the TMDL for low-flow conditions." This narrow focus leaves out the entire Christina River, the East and West Branches of the Brandywine Creek, the East and West Branches of the Red Clay Creek, and the East Branch of the White Clay Creek-in other words, most of the Christina River Basin.	J.R.May	Consistent with the Watershed Protection Approach advocated by EPA, the Christina River Basin TMDL addresses those segments indicated as impaired on both Pennsylvania and Delaware's 1998 303(d) lists as well as waterbodies which are not listed. While it is true that a significant amount of effort was focused on those segments impaired by point sources, the Christina River Basin TMDL does not focus exclusively on those segments. All waterbody segments in the basin are represented within the model and considered during the TMDL analysis. Tables 12 through 27 in the TMDL Decision Rationale document contain summary waste load and load allocations for all of the segments mentioned in this comment.
11-L-12	T. H. Cahill, P.E., confirms this basic flaw in the TMDL as proposed: "A major portion of the nutrient and organic loadings experienced into this watershed occurs during wet weather periods, when transport from the watershed land surface can increase nutrient concentrations by two orders of magnitude. This flux of nutrients through the drainage system, which occurs on only some 30 days in an average year, comprises a significant part of the accumulated benthic food supply. In effect, any type of Mass Load Analysis that wishes to determine (and hopefully reduce) the root cause of water quality impacts must consider the wet weather input as well as the daily residual produced from multiple sewage treatment plants in the drainage ....Even though the most severe water quality conditions are experienced during the drought periods, the source(s) of these problems are generated throughout the full hydrologic cycle. Only a model that considers the total water balance (and chemical balance) can produce guidance on the potential benefit of both point and nonpoint reduction strategies."	J.R.May	Nonpoint sources were adequately considered in this TMDL through development of characteristic nonpoint source loads during critical conditions. The data used to characterize nonpoint source loads and background contributions acts to integrate the impacts of past loading events into the TMDL calculations. During low-flow conditions, nutrient laden sediments would release nutrients into the overlying water column. Samples gathered during these conditions would reflect levels of nutrients present in the waterbody which would include contributions from nutrient laden sediments as well as other nonpoint sources. Impacts of precipitation events on nutrients will be considered in the high flow TMDL. See 11-L-10.

TMDL ID #	Comment	Commenter	Response
11-L-13	In addition, as discussed previously in these comments, these load allocations only account for loads actually flowing into the waters during low-flow, not for nutrients that have entered the stream during storm events or high-flow periods and remain in the sediment and in downstream waters during low-flow periods. The best the EPA does in the TMDL is say that it is "likely" that the background data collected during critical conditions accounts for the loading during storm events. It provides no support for this statement and fails to explain what "likely" means.	J.R.May	As previously stated, EPA believes the Christina River Basin TMDL adequately considers nonpoint source pollutant contributions during low flow. The TMDL considers specific pollutant loads from baseflow contributions, atmospheric deposition, natural background contributions, as well as land-based contributions. Background data is likely to incorporate past loading events based on the following argument: 1) following deposition of sediment from a storm event, nutrients may begin to move from the sediments into the overlying water column; and 2) once in the water column, sampling would capture that portion of nutrient contributions from the sediment and it would be reflected in the sample value for the parameter of concern. See 11-L-10, 11-L-31 and 11-L-32.
11-L-14	The TMDL misconstrues the term "seasonality" to allow it to defer considerations of nonpoint source pollution improperly to the Stage II TMDL.	J.R.May	Seasonality refers to the need to consider how changes in hydrologic and climatological patterns may affect the TMDL. Within the context of the critical condition of low flow that EPA identified as the appropriate flow regime for this TMDL, EPA considered how warmer conditions and reduced flow typical of late summer and early fall drought periods would impact TMDL development and allocation scenarios. EPA appropriately considers seasonality by incorporating these seasonal variations into the TMDL analysis and allocation scenarios. Nonpoint source loads are considered by incorporating characteristic pollutant contributions in the TMDL developed from available data gathered during these critical conditions. Those characteristic loads, which represent pollutant contributions from baseflow, background, and land-based sources, are subsequently used in the TMDL analysis and allocation scenarios.
11-L-15	However, deferral of the TMDL for high-flow periods to Stage II does not allow EPA to ignore or diminish the effects of nonpoint source pollution on water quality during the critical condition period that is the subject of the Phase I TMDL. Because storm events occur during the low-flow "season," and nutrients accumulated in the sediment during higher flow "seasons" continue to affect water quality during low-flow, the lowflow TMDL must account for the effects of these storm events and sediment deposits on water quality.	J.R.May	As stated in the response to 11-L-10, EPA does adequately account for nonpoint source loads during critical conditions. See also 11-L-31 and 11-L-32.

TMDL ID #	Comment	Commenter	Response
11-L-16	Until high flow scenarios and NPS load estimates are refined through the HSPF model, . modelers must estimate NPS load from the best available information. In addition, the EPA must incorporate a substantial margin of safety into the final TMDL.	J.R.May	EPA has utilized best available information to assess the nonpoint source load as discussed in 11-L-10. As discussed in the Decision Rationale document, an implicit margin of safety was provided in the TMDL through the use of conservative assumptions in the model.
11-L-17	The TMDL endpoints-daily average and minimum DO values selected to quantify stream impairment during modeling (Table 7 in TMDL document) are appropriate for only those stream segments with designated uses of Fresh Waters (DE), Warm Water Fish (WWF), Marine Waters (DE), and Trout Stocking Fishery Aug 1-Feb 14 (PA). These endpoints do not satisfy water quality standards for stream segments with designated uses of Cold Water Fish (PA, DE)', Trout Stocking Fishery Feb 15-Jul 31 (PA), and High Quality Trout Stocking Fishery (PA). Several stream segments in the Christina River Basin must meet these higher standards for DO concentration. (See Figure 10 in TMDL document.)	J.R.May	Data plots for the TMDL allocation run shows that the higher DO standards for these identified segments will be protected during the critical conditions evaluated during the development of this TMDL. This clarification will be added to the TMDL Decision Rationale document as an Appendix.
11-L-18	Because it used the less stringent standards as the basis for the TMDL model, the EPA cnnot assert that the resulting TMDL will protect those stream segments with more stringent water quality requirements.	J.R.May	Data plots for the TMDL allocation run shows that the higher DO standards for these identified segments will be protected during the critical conditions evaluated during the development of this TMDL. The TMDL is protective of applicable DO standards in the Christina River Basin. See 11-L-17.
11-L-19	Pennsylvania has also designated at least one stream segment in the Basin (East Branch White Clay Creek) as Exceptional Value waters. The TMDL makes no mention of this designation or its implications for water quality management in the Basin.	J.R.May	The TMDL Decision Rationale document will be revised to take note of this designation. The results of the TMDL model runs indicates that the DO standards for the East Branch White Clay Creek will be maintailned and protected consistent with antidegradation requirements. The Exceptional Value waters designation will provide additional protection of water quality conditions through the regulatory provisions of the Pennsylvania antidegradation program (25 PA Code Chapter 93.4(c)) and 40 CFR 131.32.

TMDL ID #	Comment	Commenter	Response
11-L-20	This guidance is consistent with EPA's long-standing recommendation for allowable phosphorus in flowing waters. Nevertheless, WLAs for total phosphorus in the Draft TMDL will cause these widely accepted phosphorus criteria to be exceeded by wide margins throughout the Christina River basin. Mass balance calculations demonstrate that low flow phosphorus concentrations resulting from the Draft phosphorus WLAs will be 0.3 to 0.4 mg/1 in Brandywine Creek, 0.3 to 0.5 mg/1 in main stem White Clay Creek, and 0.8 to 1.0 mg/1 in main stem Red Clay Creek and Christina River West Branch.	J.R.May	The identified value for phosphorous cited in the comment is not an applicable water quality criterion by any regulatory agency in the Christina River Basin, simply a guidance value. As discussed in the Decision Rationale document, controls on the discharge of phosphorous is part of an overall strategy to achieve attainment of applicable DO water quality standards. The guidance value has utility when site-specific data are not available. In this TMDL, data were available upstream and downstream of major dischargers, which indicates that phosphorous levels less than 0.1 mg/l are not necessary to ensure attainment of DO criteria during critical low-flow conditions.
11-L-21	The TMDL fails to account for or address the pH criteria violations that continue to occur in the Brandywine Creek despite lower levels of phosphorous as compared to the 1980s. (See data). The TMDL simply ignores the pH criteria violations and fails to provide any assurance that the reductions in point source loads will end these water quality violations.	J.R.May	Water Quality Standards for DO, not pH, are appropriately used as the water quality target of this TMDL. EPA believes that the pH criteria violations are directly coupled with photosynthesis and respiration which occurs in the stream in response to excess nutrient loading. EPA further believes that controls on nutrients as established in this TMDL will address the pH violations.
11-L-22	Also significant is the concurrent increase in nitrate-nitrogen concentrations in the past decade, though no analysis of the relationships is provided in the document.	J.R.May	Nitrate-nitrogen values were assessed in the data plots for the TMDL allocation run. The only instances where the 10 mg/l value 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, additional reduction is not necessary to meet the standard. This information will be added to the TMDL Decision Rationale document.
11-L-23	Insufficient attention is paid to whether phosphorus or nitrogen is the limiting nutrient in each stream segment of the Christina River basin	J.R.May	In Section 9.6 of the Model Report, it is noted that there was an abundance of nitrogen available and that phosphorous is the more limiting of the two nutrients based on data at five locations. The five locations were in West Branch Brandywine Creek, East Branch Brandywine Creek, Brandywine Creek (at Chadds Ford), Christina River and West Branch Red Clay Creek. Time-series plots at each location are found in Figures 9-12 through 9-16 in the Model Report. The information presented in the TMDL Decision Rationale document on this subject will be expanded.

TMDL ID #	Comment	Commenter	Response
11-L-24	Nonpoint sources are cited as the only source of impairment for several of the streams listed on the PA and DE 303(d) lists, and are cited as a primary source of impairment for virtually all the other streams listed. Despite this, the Christina River Basin TMDL provides little discussion of the limiting nutrient and its importance in properly addressing the nutrient pollution problems in the watershed.	J.R.May	This TMDL is established to address the critical condition of low flow. Nonpoint source loads assessed as background conditions are incorporated in the TMDL (see 11-L-10). A full evaluation of nonpoint source loads under high flow conditions will be made in the high flow TMDL. The limiting nutrient issue under low-flow conditions is discussed in the Decision Rationale document. See 11-L-23.
11-L-25	The TMDL model used to develop the proposed TMDLs is too flawed to be relied on for the Christina River Basin TMDLs	J.R.May	EPA disagrees. The TMDL model was calibrated using data collected in 1997 and validated using data collected in 1995 with both years experiencing low-flow periods comparable to 7Q10 conditions used for the low flow TMDL. The results of the calibration and validation are presented in the Model Report. As presented in Section 11 of the Model Report, relative error statistics for dissolved oxygen, carbon, nitrogen, and phosphorus are within the acceptable guidance for water quality models published in Technical Guidance Manual for Performing Waste Load Allocations, EPA, 1990.
11-L-26	According to section 3.1 of the model report, the EFDC model was originally developed for estuarine and coastal applications.The commentors believe the model developer needs to provide more assurance that the model is indeed appropriate for simulating the Christina River Basin.	J.R.May	The TMDL model was originally applied to estuary situations. However, it is a general water quality model applicable to both freshwater and estuarine waterbodies. A full description of the processes incorporated in the model can be found in Sections 3, 4, and 5 of the Model Report. The EFDC model has been applied to support nutrient and dissolved oxygen analysis for TMDLs and water quality studies in the following freshwater systems: Yazoo River, Mississippi; Ochlockonee River Basin, Georgia; Satilla River Basin, Georgia; Suwanee River Basin, Georgia; St. Marys River Basin, Georgia; Lake Tenkiller, Oklahoma; Lake Wister, Oklahoma; Los Angeles River, California; and East Fork Little Miami River, Ohio.
11-L-27	However, the model document provides little assurance that the sediment model used here is appropriate for simulating the actual conditions in the Christina River Basin.	J.R.May	A complete description of the processes incorporated in the sediment diagenesis model is described in Section 5 of the Model Report.

TMDL ID #	Comment	Commenter	Response
11-L-28	However, to calibrate the model, the modelers inappropriately used the characteristic low-flow/background concentrations of pollutants (that is, the lowest concentrations from NPS) and assumed that this background concentration remained constant over time, even though the flow rate in the model calibration was varied based on flow-rate data collected in 1997.	J.R.May	The TMDL model was calibrated for summer low-flow conditions, therefore EPA determined it appropriate to use low-flow (background) concentrations of pollutants for the nonpoint source inputs to the model. The intent of the low flow TMDL was to focus on the critical condition of low flow. The high flow TMDL will consider variable flow conditions and will incorporate varying nonpoint source loads.
11-L-29	By keeping the NPS concentrations set to a constant minimum throughout the model calibration, the model must have significantly underestimated the amount of nutrients contributed from nonpoint sources.	J.R.May	Since actual monitoring data were used to determine nonpoint source loads, the estimates of amount of nutrients contributed from nonpoint sources are as accurate as any watershed runoff model would provide during low-flow drought conditions. The nonpoint source loads are kept at a constant minimum as this TMDL is established for critical low-flow condition when nonpoint source loads should not vary from the estimated values incorporated in the model.
11-L-30	Even though the HSPF model is not yet available, the modelers are still responsible for making sure a realistic estimate of NPS loading was included in the model calibration. Using the bare minimum concentration as the "constant" value is completely inappropriate and certainly not a "conservative" assumption. The commentors assert that without a realistic estimate of NPS nutrient concentrations, the model calibration is invalid.	J.R.May	EPA disagrees. Actual monitoring data were used to determine nonpoint source loads for the TMDL model during the summer low-flow steady-state conditions. This method for estimating nonpoint source loads is reasonable and accurate for low-flow conditions.
11-L-31	Section 5.6.2 on "Boundary and Initial Conditions" for the Sediment Model also raises concern, because the boundary conditions used in the sediment model include the overlying water conditions taken from the water column water quality model.	J.R.May	Large storm events tend to scour the stream bed and wash away large amounts of deposited sediment and organic material. During low-flow periods, the locations of sediment deposition are primarily in the nearby vicinity of point sources. The TMDL model has shown that these deposition areas exist in the vicinity of the larger point source facilities (see the sediment flux results in Appendix D of the Model Report).
11-L-32	The commentors question whether the assumptions made in the model result in a severe underestimate the amount of nutrients in the sediment.	J.R.May	No sediment monitoring data were available to corroborate the TMDL model estimates of benthic nutrient flux rates with the exception of three sediment oxygen demand samples in the tidal Christina River. Based on previous applications of this TMDL model, the benthic nutrient flux rates calculated by the model are reasonable.

TMDL ID #	Comment	Commenter	Response
11-L-33	The TMDL inappropriately uses average NPDES permit limits for analysis of in-stream minimum DO levels rather than maximum permit limits. Where values are given for permit limits or allocations, it is never stated how the numbers are applied--that is as average or maximum. With DO, average discharge values should be used in assessing compliance with average standards, and maximum discharge values used for minimum standards. While the draft TMDL document states that NPDES point source permits were analyzed based on maximum flows and concentrations (see draft TMDL pages 23 and 67), a review of additional information reveals that this is not the case.	J.R.May	Monthly average permit flows and loads for the NPDES facilities were used for the TMDL model runs. The use of monthly average NPDES permit limits for the TMDL analysis is appropriate for the low-flow, steady-state conditions. The daily maximum permit limits are intended to enforce compliance with meeting reasonable loads during periods of when the inherent variability of effluent conditions are considered. This inherent variability stems from a number of factors, including fluctuations in wasteflow or waste strength and changes in operating efficiency as a result of changes in temperature, equipment operating characteristics, etc. During drought summer conditions, it is not reasonable to expect that the daily maximum permit flows and loads would ever occur since by definition a drought is a condition absent of significant rainfall. The analysis of the daily average and minimum DO water quality standards do not depend on the average and maximum permit values. The minimum DO is a function of the diel (24-hour period) photosynthesis and respiration processes in the stream. A quick transient increase in loading from a NPDES facility (i.e., the daily maximum load) will not have a significant impact on either the daily average DO or the diel oxygen range. It is the persistent long-term average load that drives the algae growth and hence the photosynthesis and respiration. The TMDL was properly determined using monthly average permit limits.

TMDL ID #	Comment	Commenter	Response
11-L-34	Using the example of the Kennett Square (NPDES permit No. PA0024058) discharge to West Branch Red Clay Creek, the CBOD5 limit is given in the draft TMDL as 25 mg/l, but it is never stated if this is the monthly or weekly average limit, or the daily maximum. The flow is given as 1.1 mgd, but this too is not defined in terms of average or maximum. The commentor obtained a copy of relevant portions of the permit and found that in fact, the 25 mg/1 limit for CBOD5 is the monthly average, with a weekly average limit of 40 mg/l. The permit also contains a CBOD5 limit of 50 mg/1 as "Inst. Max" (which is not defined), and the daily maximum column for this parameter in the permit is blank. It thus appears that a more accurate representation of the maximum permitted concentration for the draft TMDL to be using for CBOD5 is 50 mg/l. As presently modeled with the 25 mg/! value, the daily maximum load would be underestimated by a factor of 50%. The same is true of other permitted parameters, such as ammonia.	J.R.May	Monthly average permit flows and loads were consistently used for all the NPDES facilities in this TMDL. The monthly average value of 25 mg/l CBOD5 for Kennett Square is the appropriate value for the TMDL analysis. See 11-L-33 for a discussion of the daily maximum permit limits.
11-L-35	Other permits associated with these TMDLs have not been similarly reviewed, but it is likely that this problem persists for all. In general, when comparing standards, permit limits, and TMDL allocations, consistency should be used so as to avoid "apple and orange" comparisons and to avoid underestimations of daily.maximum load impacts as allowed by permit limits and TMDLs.	J.R.May	Monthly average permit flows and loads were consistently used for all the NPDES facilities in this TMDL as discussed in 01-A-03, 11-L-33 and 11-L-34.
11-L-36	The Christina River Basin EFDC Model simulates the hydrodynamics of the basin reasonably well. Its water quality simulation, however, misses by a wide mark the important biochemical processes under the critical 7Q10 low flow condition for which the Draft TMDL was developed. This model failure is manifested in underestimating of downstream accumulations of organic carbon produced by photosynthesis in upstream tributaries, and overestimating of dissolved oxygen at these downstream locations. The differences between observed data and model estimates in transect plots for the August 1995 model verification show how the model failed to accurately predict photosynthesis and DO levels.	J.R.May	Thank you for the positive comment on the TMDL model simulation of Christina River Basin hydrodynamics. Regarding the comment on biochemical processes, EPA does not agree that this TMDL model "misses by a wide mark the important biological processes..." The overall relative error for DO in the August 1995 validation was 6.3%. This is well within the acceptable guidance (15%) for water quality models published in Technical Guidance Manual for Performing Waste Load Allocations, EPA, 1990.

TMDL ID #	Comment	Commenter	Response
11-L-37	In Figure E01, model estimates for dissolved oxygen and total organic carbon diverge substantially from the observed contemporaneous data at downstream river miles 78, 82, and 87 on the main stem Brandywine Creek.	J.R.May	EPA disagrees. In Figure E01 of the Model Report, the TMDL model DO agrees very well with the 4 of the 5 observation locations on the main stem Brandywine Creek. The model maximum total organic carbon (TOC) follows the observed trend of increasing concentration in the downstream direction. Since the observed data are grab samples, not averages, it is reasonable to assume that the model envelope defined by the minimum and maximum values capture the essence of the observed TOC trend.
11-L-38	In Figure E13, total organic carbon is underestimated throughout the tidal Christina River and, in Figure E16, dissolved oxygen is overestimated at the downstream non-tidal Christina River at miles 89.5 and 96.5	J.R.May	EPA disagrees. In Figure E13, the DO average and minimum/maximum range follows the observations extremely well throughout the tidal Christina River. Total organic carbon simulated by the TMDL model is slightly less than the observations near mile 81 on the tidal Christina River. The reason for this is thought to be due to organic material originating in Churchman's Marsh which was not included in the TMDL model.
11-L-39	The same overestimation of dissolved oxygen and underestimating of organic carbon by the model are seen in Figure E19 for main stem Red Clay Creek at downstream river miles 88 and 92.5, and in Figure E25 for White Clay Creek at downstream river miles 89, 91, and 100.5. It is seen again in Figure E31 for river mile 74 on the Delaware River.	J.R.May	In Figure E19 in the Model Report, at the downstream location on main stem Red Clay Creek, the TMDL model DO is slightly higher than the observations for the 1995 validation run. However, for the 1997 calibration run, the DO observations fall within the TMDL model diel range (Figure A19). Also, the TMDL model simulation of total organic carbon agrees with the observations better in the 1997 calibration run than the 1995 validation run. When assessing model performance, both the calibration and validation should be considered together. In Figure E25 (validation) and Figure A25 (calibration), the TMDL model agrees well with dissolved organic carbon. In Figure A25, the model DO agrees with the observed data at all four sampling locations on White Clay Creek. In the Delaware River, the model DO agrees very well with the observed data during the 1997 calibration (Figure A31) and is slightly less than the observations in the 1995 validation run (Figure E31).

TMDL ID #	Comment	Commenter	Response
11-L-40	Associated with this model's failure to simulate biochemical processes critical to water quality in the Christina River basin, concentrations of ammonia-nitrogen are consistently and significantly underestimated for the downstream stations (Figures E02, E 14, E 17, E20, E26, E32).	J.R.May	EPA disagrees. The TMDL model simulates the concentrations of ammonia nitrogen well for the downstream stations as shown in Figures A05, A20, A29, A32, E08, and E20. As presented in Section 11 of the Model Report, relative error statistics for DO, carbon, nitrogen, and phosphorus are within the acceptable guidance for water quality models published in Technical Guidance Manual for Performing Waste Load Allocations, EPA, 1990.

TMDL ID #	Comment	Commenter	Response
11-L-41	As mathematically and computationally complex as is EFDC and related water quality simulation models, their representations of dynamic biological processes are still simplistic approximations of the natural reality. It is an arduous and time consuming task to fit these models' mathematical estimations to the uncooperative data from the natural world. With all the demonstrable uncertainties and opportunities for error inherent in these models, the commentors question whether this effort is an appropriate application of resources to TMDL development	J.R.May	Those who do not fully understand the concepts of water quality modeling often mistakenly assume that the more sophisticated the model is the less useful it is due to the increase in data needs. We disagree with the misconception. Some of those same people would recommend a very simple approach to the development of all TMDLs by using an oversimplified mass balance approach. We believe that the level of model sophistication should be based on several factors including the type of pollutant, the data available, the problem to be solved and the implications the resolution will have on the sources of the pollutant. While the more sophisticated approach attempts to quantify and identify various instream processes through the use of environmental data, the oversimplified approach takes nothing into consideration, except the very basic concept of dilution. One may recommend a simple mass balance for phosphorous for example to address the nutrient problem. This has many problems such as the lack of water quality standards for the pollutant and the fact that no instream processes, with respect to either the contributions of the pollutant from other sources (point, nonpoint or sediment) or the loss of the pollutant through instream processes, are factored into the calculations. Simplifying the TMDL process down to a very simple calculation based on no local environmental data does disservice to both the environmental goals as well as the point source and land owners that must commit resources to meet the TMDL. Modeling dynamic biological processes is a long history of success. EPA firmly believes that the approach used in this TMDL, even with some limitations, outweighs by a large margin, the oversimplified, pedestrian approach of back-of-the-envelope approach advocated by those not fully knowledgeable in the concepts of water quality modeling.

TMDL ID #	Comment	Commenter	Response
11-L-42	Development of the proposed TMDL focuses wrongly on the carbon-oxygen cycle in water quality determinations. This view of photosynthesis and respiration as the production and oxidation of simple sugars may be in a limited way technically correct, but it is entirely misleading from the biochemical processes that occur in natural waters. A more usefully complete description of photosynthesis and respiration processes in the Christina River basin should include the critical role of the problematic nutrients that control these processes.	J.R.May	The model used for this TMDL considered the impacts of carbon, nitrogen, and phosphorus on oxygen (see Section 4 of the Model Report for a more detailed description).
11-L-43	The Draft TMDL appears to satisfy the TMDL targets for dissolved oxygen only because the TMDL was developed from a "critical condition analysis" in which the critical condition was a steady-state, i.e., photosynthesis and respiration were assumed to be occurring steadily and simultaneously (though perhaps fluctuating diurnally) at each place in the basin. For this assumed condition, dissolved oxygen production and depletion balance out over the day with little calculated impact on daily averaged levels of dissolved oxygen. But this is an artificial and unstable condition for nutrient-enriched waters. The appropriate critical condition for these waters is not the low flow steady-state week of bright sunshine, but the following several days of low flow and cloudy overcast weather. During these critical days, the accumulated steady-state growth will cease, decompose, and rapidly consume oxygen without replenishment by photosynthesis. During these critical days, the 38,780 pounds of oxygen demand stimulated by the phosphorus load in the Christina River TMDL will be exerted. During these critical days, the Draft TMDL targets for dissolved oxygen will be widely missed.	J.R.May	EPA disagrees with certain assumptions of this comment, and therefore its conclusion. Algae growth responds to both direct and diffuse solar radiation. On cloudy days, diffuse solar radiation reaches algae in the stream and growth continues, although at a slower rate. To imply that all algal matter in a stream will cease growing and decompose due to overcast conditions is not reasonable nor accurate. The algal growth rate will slow to a certain extent, but the entire algal biomass will certainly not suddenly decompose and exert its entire demand on oxygen.

TMDL ID #	Comment	Commenter	Response
11-L-44	Though many portions of the streams in the Christina River Basin are shaded by canopy cover, the model-assumes no shade in the entire basin due to a lack of data on canopy cover. (Model report, Section 12.4, p. 12-4.) As the model report admits, "[v]egetative cover shields many portions of the stream reaches from direct sunshine, which can have a profound effect on localized chlorophyll photosynthesis." (Model report, p. 12-4.) This affects the resulting DO levels in the shaded areas of the stream and skews the DO levels predicted by the model. As a result, model results which predict compliance with DO standards after TMDL implementation are unreliable.	J.R.May	The TMDL model incorporates a shade factor which can be applied individually to each grid element to account for shading effects. It was decided to assume no shade anywhere in the Christina River Basin to represent worst-case critical conditions and increase the implicit margin of safety. See 04-D-04A.
11-L-45	The model appears to indicate a peak biomass in early May and late September, rather than during the height of the growing season in mid-summer. This is further evidence of the model's ineffectiveness in modeling the Christina River Basin for low-flow, late summer conditions, when the risk of water quality violations related to excess biomass is at its highest.	J.R.May	As noted in the comment, the TMDL model correctly estimates peak biomass in the month of September which corresponds to the period of low-flow that usually occurs in late summer and early fall. See 04-D-04C.
11-L-46	The modelers could not calibrate or validate the Buck Run segment or validate the White Clay Creek East Branch segment because no actual data was available for comparison to the model. Despite this, the modelers state that "[c]omparisons of predicted and observed data for all parameters were considered to be reasonable in all 11 major stream reaches included in the model." (Section 12.3 of model report.) Contrary to the modelers' assertion, no reasonable basis exists for believing the Buck Run and White Clay Creek East Branch segments of the model reflect actual conditions.	J.R.May	This comment correctly states that no observed data were available for Buck Run during either the calibration or validation periods, therefore, it cannot be conclusively stated that the simulation results are reasonable in this stream segment. However, the kinetic rates and hydraulic parameters developed for Buck Run were similar to the other stream segments in the TMDL model, so there is reason to believe the simulation results should behave similar to the other streams in the model. Also, the comment correctly states that no observed data were available for East Branch White Clay Creek during the validation period. However, data were available in East Branch White Clay Creek during the calibration period and model-data comparisons were reasonable during that time period.

TMDL ID #	Comment	Commenter	Response
11-L-47	The EPA should consider alternative approaches to developing the TMDL, particularly since the HSPF model for nonpoint source pollution is not yet available. For example, a more reliable and straightforward approach to an effective Christina River Basin TMDL would be to first establish the allowable total phosphorus loadings that would achieve a target instream criterion of 0.1 mg/1 total phosphorus during the critical low flow condition in main stem reaches of Brandywine, Red Clay, and White Clay Creeks and the Christina River.	J.R.May	EPA is confident that the approach used in developing this TMDL is appropriate. The suggested use of 0.1 mg/l phosphorous value would not be appropriate as this value is not an applicable water quality criterion, nor is necessary to achieve and maintain DO water quality standards. See 11-L-20.
11-L-48	The commentors are concerned about the numerous conclusory statements made without providing any supporting data or explanation, or in some cases, made in contradiction to the data or figures presented. For example, on page 20 of the main TMDL document the statement is made that the calibrated and validated water quality model confirmed "that the model was able to simulate the locations of the impaired stream segments on the 303(d) list." However, as pointed out in Section I of these comments, the model in fact did NOT predict low DO in several stream segments specifically listed for low DO on the PA and DE 303(d) lists.	J.R.May	The available monitoring data for some of the streams listed for low DO on the state 303(d) lists did not indicate any impairment of the water quality standards for DO. For example, no monitoring data were available for Buck Run to confirm that the DO concentrations were below the water quality standards. Therefore, without supporting monitoring data it was not possible or desirable to configure the model to predict violations of the DO standard
11-L-49	Another statement made without support or explanation is the brief mention of water quality criteria for nitrate-nitrogen and ammonia-nitrogen on p. 29. The text claims that the pollutant load reductions necessary to maintain the criteria for dissolved oxygen result in the Christina River basin also meeting state criteria for nitrate-nitrogen and ammonia-nitrogen. No explanation for how or why this is true is included anywhere in the TMDL.	J.R.May	Following pollutant load reductions necessary to maintain applicable water-quality standards for DO, the TMDL model was run to determine the resulting levels of ammonia-nitrogen and nitrate-nitrogen in the model segments at those discharge levels. The TMDL model indicated that at pollutant loading levels necessary to maintain DO standards, the applicable water quality criteria for nitrate-nitrogen and ammonia-nitrogen are also maintained. The purpose of this exercise was to ensure that nutrient-related parameters, for which numeric water quality criteria exist, are maintained in the Christina River Basin.

TMDL ID #	Comment	Commenter	Response
11-L-50	The TMDLs as summarized in Table 8 and Tables 12 through 28 fail to provide any comparison of the proposed TMDLs to current loading conditions. The only comparisons are to percent reductions from permit limits, not actual loads. Since some point sources operate well below their permit limits, the percentages provided are deceptive.	J.R.May	Current actual loading conditions for point sources are used during the calibration and validation stages of developing the water quality model. Current maximum allowable permit limits for point sources, on the other hand, are used during the critical condition analysis and form the baseline loading levels from which EPA makes reductions to point sources in order to meet water quality criteria for DO during low-flow conditions. Therefore, it is appropriate to include percent reductions to current permitted levels since these are used as the basis for point source loads during TMDL analysis and allocation.
11-L-51	The commentors request that the final TMDL present a comparison of TMDLs to current permit limits and to current operating levels to provide a fairer comparison of current loads to proposed reductions in loads. The commentors also request that complete point source discharge data used in model calibration be included in the TMDL document.	J.R.May	The revised Level 1 and Level 2 Point Source Allocations table summarizing the proposed TMDL reduction that is included in the Executive Summary, and incorporated in the Decision Rationale document contains the current monthly average permit limits for all facilities. A brief summary of recent performance data for the major dischargers in the Christina River Basin from this list has been added to the TMDL Decision Rationale document. Complete information on all discharger limits is provided in the Model Report.
11-L-52	The main TMDL document provides pages and pages of "filler" material that is not specific to the Christina River Basin or the actual TMDL proposed by the EPA. For example, the first section provides only historical background to the TMDL development process, and many later sections contain long paragraphs that discuss EPA strategies and goals for water quality modeling and allocation procedures. While this may be useful background material, it belongs in a separate policy document or in an appendix. The body of the TMDL needs to provide more detailed, more specific information about this watershed, this model, and this TMDL.	J.R.May	EPA believes that the Decision Rationale document provides all required information necessary to justify the decision regarding the Christina River Basin TMDL. The Decision Rationale document is not intended to be a technical document and is meant to provide the reader with information necessary to determine if EPA has adequately addressed its legal, regulatory, and statutory obligations. Historical information and other background material is necessary to justify the time period used to develop this TMDL. The Decision Rationale document also contains citations to additional technical documents available for further information.

TMDL ID #	Comment	Commenter	Response
11-L-53	In addition, more specific information about the water quality problems in the Christina River Basin should be provided in the main TMDL document, for example, an explanation of how nutrient impairment manifests itself in the streams identified in the 303(d) lists (algae blooms, toxicity to fish, etc.). Currently, only general educational information about nutrient impairment is provided. The information should be tailored to explain the problems experienced in the Christina River Basin and how TMDL implementation will improve the water quality.	J.R.May	The Decision Rationale document provides references to the technical reports used to develop the TMDL including the water quality characterization report developed by Dr. John Davis. These documents are available upon request. EPA does not feel it is necessary to include the majority of this highly technical information in the Decision Rationale document. Summaries and references to these documents are provided throughout the Decision Rationale document.
11-L-54	Critical information about the model used and the underlying assumptions made during TMDL development are not anywhere in the TMDL document or its appendices. This information is found only in the Hydrodynamic and Water Quality Model of Christina River Basin final report published May 31, 2000, a document which is not easily available to the public for review. Key information from this report should be summarized and explained in the main TMDL document.	J.R.May	The Decision Rationale document adequately summarizes the TMDL model. EPA provided an overview of the TMDL model at both public information meetings. On several occasions, EPA announced that copies of the Model Report would be provided to any one wishing to have a copy. All requests for copies of the Model Report were honored.
11-L-55	In addition, the TMDL needs to provide much more extensive discussion of the sources of nonpoint source pollution in the Basin, including agricultural runoff, urban runoff, septic systems, and groundwater, and how these loads affect water quality during low-flow conditions.	J.R.May	The TMDL Decision Rationale document provides an adequate discussion of nonpoint source loads and their resulting impacts on low flow conditions. Nonpoint source loads are adequately accounted for in the Christina River Basin water-quality TMDL model. EPA utilized data from STORET, USGS, DEP, and DNREC to develop characteristic nonpoint source loads for parameters of concern from each of the 39 subwatersheds during critical low flow conditions. These characteristic loads are used by the model during development of the allocation scenarios to represent nonpoint source pollutant contributions. Furthermore, those characteristic loads are representative of baseflow contributions (considered the dominant nonpoint source during critical low-flow conditions) as well as expected land-based, nonpoint source during critical low-flow conditions. See 11-L-10.

TMDL ID #	Comment	Commenter	Response
11-L-56	The TMDL also fails to calculate existing loads for each impaired stream segment and fails to identify the current WLAs and LAs in these segments.	J.R.May	Tables 12 through 27 in the TMDL Decision Rationale document provide specific waste load allocations for dischargers in the Christina River Basin as well as load allocations for subwatersheds in the Christina River Basin. All segments identified in TMDL modeling work with DO concerns from point source impacts or under low flow conditions are included in these tables.
11-L-57	It also fails to identify whether any reserve capacity exists in the Christina River Basin.	J.R.May	This TMDL has been prepared under the current and effective requirements of the regulations in place. The requirement to provide for reserve capacity in the TMDL calculations is found in the recently revised regulations which are not yet effective. (65 Federal Register 43586-43670 7/13/00) Sincse they are not yet effective, the Christina River Basin TMDL does not have to include this. See the discussion at 65 Federal Register 43660 on the effective date of the revised regulations.
11-L-58	The presentation of Level 1 and Level 2 allocations is confusing, especially because two of the point sources in the Level 1 allocation (Table 10) are not listed in the Level 2 allocation (Table 11). All 12 point sources that receive allocations should be listed in Table 11, with an indication that two of the sources were not reduced further in Level 2.	J.R.May	To clear up any confusion, EPA has prepared a new summary table and has included it in the Executive Summary of the Decision Rationale document.
11-L-59	The discussion of effluent trading between nonpoint sources and point sources (pp. 48-49) should be deleted from this TMDL since by the EPA's own admission it cannot be implemented until the Stage II (high-flow) TMDL is complete.	J.R.May	EPA believes it is important to specify that opportunities for effluent trading between point and nonpoint sources may become available following development of the high flow TMDL. Excluding this from the document may have caused some to believe that this type of trading would never be applicable.
11-L-60	A very helpful discussion of the relevant state and DRBC water quality standards, regulations, and guidance pertaining to DO and nutrients was present in a 5/27/99 draft of the TMDL ("Chapter I" of what is now in Appendix A) but deleted in the final draft TMDL. The commentors suggest that this information be included in the final version of the TMDL.	J.R.May	Information on relevant state and DRBC standards on DO and nutrients is provided in Section VII.1 of the Decision Rationale document. (Note: the document cited in this comment was not a draft of the TMDL Decision Rationale document. The document was a draft report on water quality conditions in the Christina Basin prepared by a consultant for DRBC. Material from this document was incorporated in the draft TMDL Decision Rationale document issued by EPA, as well as provided at the Christina TMDL web site. The document cited was never issued by either the DRBC or EPA.)

TMDL ID #	Comment	Commenter	Response
11-L-61	The commentors also note that pH criteria were included in the 5/27/99 draft, but deleted from the final draft TMDL, despite numerous pH criteria violations in the Brandywine Creek watershed. This significant deletion requires explanation.	J.R.May	Water Quality Standards for dissolved oxygen, not pH, are used as the water quality target of this TMDL. EPA believes that the pH criteria violations are directly coupled with photosynthesis and respiration which occurs in the stream in response to excess nutrient loading. EPA further believes that controls on nutrients as established in this TMDL will address the pH violations.
11-L-62	Although the document states that atmospheric deposition rates are considered in the model and the resulting TMDL, it does not specify whether the atmospheric loads are included in the load allocations in Table 8.	J.R.May	The Decislion Rationale document has been revised to include specific data on atmospheric loads. Tables 12-28 now contain an entry for atmospheric loads in the load allocations for each watershed. The summary totals in Table 8 for load allocations now include the atmospheric loads.
11-L-63	The implementation strategies discussed in the TMDL document are deficient because they lack any nonpoint source pollution controls and require no load reductions from any but 12 point sources.	J.R.May	Under current and effective TMDL regulations, there are presently no requirements for inclusion of implementation strategies in this TMDL (see notation in 11-L-57on the revised TMDL regulations). EPA has outlined the probable mechanism (the NPDES permit process) for accomplishing the required point source reduction.
11-L-64	In addition, the commentors strongly recommend that the implementation plan include an extensive monitoring program to measure the effectiveness of this TMDL in meeting water quality standards and to improve the data available for the next phase of TMDL development.	J.R.May	As this low flow TMDL deals principally with point source dischargers and their effects on water quality in the Christina River Basin, compliance monitoring for the point source dischargers and ongoing ambient efforts by the states should address the request made by this comment to expand monitoring.

TMDL ID #	Comment	Commenter	Response
11-L-65	The TMDL requires no reductions from current low-flow loads and assumes no increase in loads in the foreseeable future, despite data showing increasing nitrogen-nitrate loads through the 1990s. The final sentence in the TMDL makes the outrageous, unsupportable statement that "the feasibility of control measures necessary to reduce current nonpoint source pollutant loadings is highly questionable. "The commentors are perplexed at the EPA's position on the effectiveness of nonpoint source-pollution control measures, particularly in light of recent efforts by the states, encouraged by the EPA, to implement BMPs to reduce nonpoint source pollution. Even if this statement is intended to apply only to NPS loads during critical low flows, when NPS loads may be predominantly from difficult-to-control sources such as groundwater, the EPA must clarify its position and acknowledge that nonpoint source controls must be implemented in order to reduce over-land pollutant loads during storm events and high-flow periods.	J.R.May	EPA believes that nonpoint source control mechanisms, such as BMPs, must be implemented to control overland sources of pollutant loadings during precipitation events and high flow periods. The statement "the feasibility of control measures necessary to reduce current nonpoint source pollutant loadings is highly questionable" is applicable within the context of the critical conditions of this TMDL. The lack of precipitation events, as is typical during critical low-flow conditions, causes one to question the effectiveness of traditional BMP measures which are designed on the premise of overland flow. This statement is also meant to clarify why EPA believes that reductions in point sources are necessary during critical conditions to provide reasonable assurance that the TMDL can be met. The Decision Rationale document will be revised to address this issue.
11-L-66	As discussed earlier in these comments, nonpoint source pollution contributes significantly to water quality impairment in the Christina River Basin, and in some stream segments is the only source of impairment. As a result, NPS controls must be part of the implementation plan in order to provide reasonable assurance that water quality standards will be met. The implementation of point source reductions alone does not provide reasonable assurance these standards will be met, particularly for those stream segments solely or significantly impaired by nonpoint sources of pollution.	J.R.May	As this TMDL is for specific low-flow conditions and nonpoint source loads have been adequately accounted for as background conditions, the TMDL will not call for additional nonpoint controls. Many nonpoint source BMPs have been installed in the Christina River Basin voluntarily. Additional nonpoint source controls will be considered in the high flow TMDL.
11-L-67	The feasibility of implementing controls on small point sources should not be discounted from the implementation plan. One option is to prohibit further individual home sewage discharges, especially to small tributary streams.	J.R.May	The Decision Rationale document contains a discussion of an analysis of 87 small point sources (less than .25mgd each). These dischargers were grouped and evaluated in a single run of the TMDL model. Average and minimum DO standards were shown to be protected throughout the watershed as a result of this model run. Any possibility of a ban on future small dischargers in Christina River Basin is beyond the scope of this TMDL.

TMDL ID #	Comment	Commenter	Response
11-L-68	The only way to improve this TMDL in the future and to improve the model used for future TMDL development is to measure the effectiveness of this TMDL in meeting water quality standards. To do this, an extensive monitoring program should be required as part of the TMDL implementation.	J.R.May	Specific features of the implementation plans for the Christina TMDL will be provided subsequently by the states. As this low flow TMDL deals principally with point source dischargers and their effects on water quality in the Christina River Basin, compliance monitoring for the point source dischargers and ongoing ambient efforts by the states should address the request made by this comment.
11-L-69	The comments above demonstrate why the TMDL does not, in fact, incorporate conservative assumptions. As a result, it is inappropriate for the EPA to claim that a margin of safety is implicit in the TMDL. The inability of the model to predict current impairment, the lack of data to calibrate or validate portions of the model, the failure to adequately account for nonpoint loads, and the lack of stream canopy data all make the TMDL unreliable. As a result, an explicit margin of safety must be included in this TMDL to account for the inadequacies of the model and the data.	J.R.May	EPA disagrees with the commenter's assertion that an explicit margin of safety must be used in this TMDL. EPA does not agree with some of the claims contained within this comment. We do not agree that the model does not predict existing impairment and that the model does not include nonpoint source loads. We have addressed the canopy issue elsewhere. EPA guidance suggests that the margin of safety (MOS) can be either explicitly or implicitly or both. Considering the MOS through the implicit approach is based on the use of conservative assumptions within the modeling activities. These conservative assumptions can include the use of the design effluent flows, the 95th percentile stream temperature, low flow stream flow, etc. This modeling activity uses the implicit approach. EPA believes that this use of conservative assumptions in this case adequately addresses the MOS requirement.
11-L-70	Commentor Dr. Barry Sulkin recommends using the relative error values as a basis for establishing explicit MOS values. (See page 11-3 of the model report.) In addition, Dr. Sulkin notes that errors in the model's predictions of maximum and minimum DO levels for the low-flow calibration and validation periods should be quantified and used to establish an explicit MOS.	J.R.May	The use of the relative error for establishing an explicit margin of safety (MOS) would be appropriate if the TMDL analysis was conducted using a dynamic modeling approach rather than a steady-state approach. An explicit MOS may be appropriate for the high flow TMDL.
12-M-01	The TMDL offers a fair and reasonable mechanism to reduce permitted discharges that have long been known to contribute to the degradation of the basins waters. And as mandated in Federal regulations, the TMDL appropriately addresses critical low flow conditions, at which water quality aquatic life are most vulnerable. To insure that water quality standards are met and provide feedback on the reliability of the model used to set the TMDL, the Society requests a carefully structured compliance in monitoring the system be instituted.	C. Brown	EPA appreciates the positive comment. As this low flow TMDL deals principally with point source dischargers and their effects on water quality in the Christina River Basin, it is reasonable to assume that compliance monitoring for the point source dischargers and ongoing ambient efforts by the states will cover the request made by this comment.

TMDL ID #	Comment	Commenter	Response
12-M-02	Although seemingly ignored in the draft TMDL documents, the problems of pH excursions beyond water quality standards are linked to excessive phosphorus levels has been documented at locations in the basin. We recommend that the monitoring include pH and stream flow at fifteen minute intervals immediately downstream of major dischargers to insure compliance with pH water quality standards.	C. Brown	Specific features of the monitoring requirements for major dischargers will be established through the NPDES permitting process and through the ambient monitoring networks of the states. EPA will review these permits in accordance with the provisions of NPDES delegation agreements. Decisions on pH monitoring will be made by the states. It is unlikely that the monitoring networks will be able to take pH and flow readings at 15 minute intervals below major dischargers. Such readings are being made by USGS on several segments below major dischargers
12-M-03	To increase public confidence in the TMDL, the Society also requests that EPA provide from the final TMDL document clarification of the conservative assumptions used in the application of the model. This is necessary to support the assertion in the draft TMDL report that the implicit margin of safety used is appropriate rather than an explicit numerical margin of safety.	C. Brown	Response to this comment is contained in various other responses (e.g., 11-L-69). Some of the conservative assumptions used in this model and discussed in other responses include, percent cover, the design stream flow, the use of design effluent flow, the design stream temperature and sediment contributions.
12-M-04	Finally, the society urges that in the future the EPA will carefully consider the readers and reviewers of documents available for public review. Aspects of the draft TMDL report and the Christina TMDL website are very confusing because that information is of such a highly technical nature to be presented to the general public in an unambiguous manner to promote meaningful public participation.	C. Brown	EPA acknowledges that the complexity of this highly technical TMDL process makes it difficult to provide clear and concise documents for the general public. Prior to the completion of the final Decision Rationale document, EPA will make efforts to make the document easier to read and comprehend. An Executive Summary will be included in the final Decision Rationale. However, the technical nature of this subject and the need to offer a complete basis for EPA's decision will still dictate a great portion of the content of the final document.

TMDL ID #	Comment	Commenter	Response
13-N-01	Unfortunately, my experience suggests that the public participation that has come of this TMDL has not been carried out in good faith. I won't comment although I agree with Ms. Dahl's comments on what's also needed in the report. I commented last week on the employment of Mr. Robert Struble of the Brandywine Valley Association to in effect operate the public participation comment. I pointed out that he's associated with organizations that are funded by and under the influence of major dischargers. I observe that this is an objection that I have raised over a period of several years to officials of Delaware's Department of Natural Resources who all told me they feel comfortable and would do it over again. Now, the information that I've received as a result of my request of Mr. Merrill, confirmed and I'm also reporting on a conversation I had with Mr. Struble and I will have some exhibits which will be sent to you to appear on the record before the closing of the record on the 15th.	Alan Muller	EPA has no basis to object to the involvement of Mr. Robert Struble in the public participation efforts pertaining to the Christina TMDL. Mr. Struble provided assistance in arranging very productive sessions with representatives of many Christina River Basin dischargers and acted in a neutral manner in conveying an objective summation of the concerns of these dischargers. EPA is, in the end, responsible for the public participation process. EPA has held a full and open process that meets all federal regulatory requirements.
13-N-02	But more to the point it shows no effort to involve public participation into actual key decisions into the development of this hydrodynamic model. Now, what ought to be done if public participation was intended in good faith, was an effort ought to have been made to identify the key decision points or judgment calls associated with the development of the modeling process and involved the public in making those decisions. Rather than making those decisions behind the scenes, obscuring them in pages and pages of obtuse terminology, data and leaving those people who consider themselves advocates for the water quality are essentially non participants and now at the end of the process are forced to say that they find the results unacceptable.	Alan Muller	EPA disagrees with the characterization of the public participation process for the Christina River Basin TMDL as described in this comment. As discussed in the TMDL document, EPA, with the assistance of several participating agencies, conducted an open process throughout the development of the Christina River Basin TMDL. Numerous public meetings were scheduled and the public meeting process culminated in the general information meetings on July 19 and 20, 2000. Public hearings were then held on August 29 and 30, 2000. EPA also developed an internet web site (www.epa.gov/reg3wapd/christina) where many documents relevant to the Christina River Basin TMDL were made available and opportunity provided for submission of comments.
13-N-03	Now, I'm not here to comment in length on the details on the fluid dynamics. But even a superficial examination suggest many problems including the absence of a quantified safety margin, including as I pointed out before that there was no clear response to my question about whether they permitted a twenty-five percent increase in pollutant discharges from the City of Wilmington was considered a model at all. Now, these are serious defects.	Alan Muller	After presentation of this statement at the Wilmington public information meeting on July 19, 2000, EPA asked its Christina River Basin model consultant to evaluate the impacts of the revised Wilmington STP permit. This analysis was performed and the conclusion reached that the revised permit had no impacts on the Christina River Basin TMDL.

TMDL ID #	Comment	Commenter	Response
13-N-04	Let's look at if what we have here seems intuitively acceptable and reasonable. I would like to open a panel here and perhaps the record can show that this is a map that was provided by the Water Resources Agency and shows the location of thirty-eight -- sewers existing on the Brandywine Christina Rivers within the City of Wilmington. Now, we've been involved as advocates in trying to get these hooked up and it's a matter of common knowledge in the City of Wilmington if you go down to the river front which is not very far from where we are now, many times the water will be brown and will have a fecal odor and condoms floating by. One can also in other places in the city see fecal in the water. Now, you're telling us that no reductions are required and you're suggesting, in fact, that the water quality in the Christina fundamentally originated down in Coatesville. Now, they do to a degree, but it's intended to imply and I'm afraid that the implication of this is to support an argument of reductions from these gross dischargers that are occurring in Delaware and that are having immediately harmful local effects and a water quality issue and to us that's nonsensical and completely unacceptable.	Alan Muller	The effects of combined sewer overflows in the Christina River Basin will be considered during the development of the high flow TMDL. Under the critical conditions employed in this low flow TMDL, the effects of combined sewer overflows are not present.
13-N-05	Now, the City of Wilmington which has conducted a long drawn out and unscrupulous campaign to avoid the abatement of CSOs indicates in the reports of its own consultants that an overflow is likely to occur at a rate of rainfall of one tenth of an inch per pound. I mention that because it is obviously possible that the overflow in a situation that would not necessarily constitute a high flow condition for the water in the basin at all. So the failure to address this particular impact or even acknowledge the existence of it in the documentation that I've seen strikes us as a serious defect.	Alan Muller	The effects of combined sewer overflows in the Christina River Basin will be considered during the development of the high flow TMDL. Under the critical conditions employed in this low flow TMDL, the effects of combined sewer overflows are not present.

TMDL ID #	Comment	Commenter	Response
13-N-06	So because of the manner in which you all tend to compartmentalize the implementation of the Clean Water Act, there's an implication in all of this that perhaps dissolved oxygen is the only thing that is at real issue here. If we would solve that problem that the river would be fine and that's clearly not true. Even if we invest all of the issues that are called out as water quality limitations and TMDL, we'll still have disastrous impaired watershed.	Alan Muller	EPA does not dispute that there are other water quality concerns in the Christina River Basin. This low flow TMDL, however, focuses appropriately on the DO standards for affected segments and establishes reductions necessary to protect these standards under the critical conditions described in the TMDL Decision Rationale document. Additional Christina River Basin concerns will be assessed as part of the high flow TMDL evaluation but EPA asserts that the low flow TMDL establishes a necessary baseline for improvements in the Christina River Basin and the protection of DO standards under the design conditions.

Response to Comments - Proposed Christina Low-Flow TMDLs Revision

On March 1, 2002, EPA Region III issued a public notice for a proposed revision of the Christina River Basin Total Maximum Daily Loads (TMDLs) under Low-Flow Conditions. The proposed revisions to the TMDLs established by EPA on January 19, 2001 were announced in newspapers in Wilmington, DE and Chester County, PA. Copies of the proposed revisions were mailed to affected wastewater treatment dischargers in the Christina River Basin.

In the public notice, EPA stated that a decision on whether to hold a public hearing on the proposed TMDL revisions would be based on comments submitted on the revisions. Comments by letter dated March 28, 2002 were received from just a single party, Hall & Associates, representing the Downingtown Area Regional Authority. EPA has reviewed these comments and 1) prepared the attached response, and 2) made a determination that the comments do not constitute a need to schedule a public hearing on the proposed revisions. EPA's response to comments follows the order in which the comments were made.

Response to Hall & Associates March 28, 2002 Comments - Proposed Christina Low-Flow TMDLs Revision (March 1, 2002)

A. Periphyton Model Fundamentally Flawed

The comments in this section raise issues on periphyton growth projections and how they were used in the Christina River Basin TMDL water quality model in assessing minimum dissolved oxygen values in the watershed, notably the East Branch of Brandywine Creek.

In response to these comments, EPA's contractor for the development of the Christina River Basin TMDL Environmental Fluid Dynamics Code water quality model provided a detailed review of the issues raised. EPA provides this review as its response to these comments as an attachment to this document.

B. Modeling Assumptions Do Not Reflect Relevant Conditions

The comments in this section include three points: 1) assumptions used in the revised TMDLs will occur less frequently than one percent of the time and PADEP regulations (25 PA Code 96.3) set a compliance goal of 99 percent to achieve WQS; 2) the revised flow figure of 7.134 mgd used for the Downingtown facility incorporates wet weather flows and would not be appropriate for the conditions used to set the revised TMDLs and 3) the design conditions, particularly the permitted limits for each parameter, used as the basis for the TMDL are inappropriate for the critical conditions analysis used to develop the revised TMDLs.

EPA Response:

Several of these points and related issues were made in comments submitted on the Christina River Basin Low-Flow TMDL issued by EPA on January 19, 2001. In the Responsiveness Summary prepared for the public hearing and open comment period, comments (and responses) 01-A-03, 02-B-02, 07-G-02 and 10-J-05 are pertinent to some of the issues raised by these comments and are hereby incorporated here by reference.

On the question of the PADEP 99% compliance goal, PADEP interprets this goal in the context of setting NPDES effluent limitations as equivalent to a 7Q10 (7-day average flow occuring once in 10 years) low-flow analysis. Limits set on this basis are considered to ensure that WQS are maintained 99% of the time. As EPA used a 7Q10 analysis in calculating the TMDLs, the recommended limits do not impose a greater WQS compliance requirement than employed in PADEP regulations.

The revised flow figure for the Downingtown Area Regional Authority of 7.134 mgd (one of the flow figures that was found in error in the original TMDL calculation - 7.0 mgd was previously used) is the permitted flow value used in establishing NPDES permit limits for the Downingtown facility. EPA used maximum permitted flow values in calculating the TMDLs. As was explained in comments on the original Christina TMDL, this is standard EPA practice and is a consideration in establishing a reasonable Margin of Safety in the TMDL calculations.

Regardless of how the flow would be comprised, Downingtown is permitted to discharge 7.134 mgd and this figure must be used in the TMDL calculations.

The design conditions and critical conditions analysis used in the TMDL calculations are standard EPA practice. The use of the 7Q10 flow condition has been previously discussed above. The maximum permitted flow figures are appropriate when used in steady-state conditions as employed in the Christina River Basin TMDL calculations The combination of these factors is designed to produce a 'worst-case' but possible scenario to ensure that WQS will be met and helps provide a reasonable Margin of Safety as noted above

C. <u>EPA's Approach is More Restrictive Than Necessary to Achieve Standards</u>

The comments in this section suggest that the revised TMDLs should only be used to set permit limitations during the month of August when critical flow and temperature conditions are expected to occur simultaneously.

EPA Response:

Both TMDL calculation procedures and NPDES permitting processes employed a critical conditions analysis to determine appropriate limitations. While low flow information and model calibrations may be limited to a period as short as one month (e.g, August) or less, comparable low flow conditions can occur at other times during the year. PADEP procedures for seasonal applications of NPDES permit limits employ a May 1 to October 31 period. The revised Christina River Basin low-flow TMDL and the specific TMDL reductions have been clarified in the revised TMDL document to indicate that the TMDL Waste load allocations are applicable during the May 1 to October 31 period used in PADEP permitting decisions. EPA believes this is an appropriate seasonal approach to ensure adequate protection of WQS and provide a reasonable Margin of Safety.

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MEMORANDUM

DATE: June 28, 2002
TO: Tom Henry and Larry Merrill, U.S. EPA Region III
FROM: Mike Morton, Tetra Tech, Inc.
SUBJECT: *Response to DARA Comments on Revised Christina River TMDL*

Attached are my responses to the issues raised by Hall & Associates (March 28, 2002 letter to EPA Region III) regarding the Revised Christina River Basin TMDL and the impacts on the Downingtown Area Regional Authority (DARA) wastewater treatment plant.

Response to DARA comments on Revised Christina River TMDL

U.S. Environmental Protection Agency
Region III

June 7, 2002

It appears the primary point of contention revolves around the water quality model's ability to simulate periphyton biomass and the associated daily range of dissolved oxygen (DO) due to photosynthesis and respiration. More specifically, the comments from Gallagher and Knorr focused primarily on the phosphorus half-saturation constant (KHPm) used in the model. It appears that neither Gallagher or Knorr was aware of the 1997 field study (Davis 1998) in which a laboratory algal assay determined a value for KHPm of 0.132 mg/L. This site-specific phosphorus half-saturation constant was used as the basis for formulating the periphyton kinetics in the water quality model. A literature search indicates that the algal phosphorus half-saturation constant can range from 0.001 to 1.520 mg/L (see Table 1 below).

Table 1. Literature values for phosphorus half-saturation constant.

Algal Species	Half-saturation Constant (mg/L)	Reference
Asterionella formosa	0.002	Holm & Armstrong, 1981
Asterionella japonica	0.014	Thomas & Dodson, 1968
Biddulphia sinensis	0.016	Quasim et al., 1973
Ceratualina bergonii	0.003	Finenko & Krupatkina, 1974
Chaetoceros curvisetus	0.074 - 0.105	Finenko & Krupatkina, 1974
Chaetoceros socialis	0.001	Finenko & Krupatkina, 1974
Chlorella pyrenoidosa	0.380 - 0.475	Jeanjean, 1969
Cyclotella nana	0.055	Fuhs et al., 1972
Cyclotella nana	0.001	Fogg, 1973
Dinobryon cylindricum	0.076	Lehman (unpublished)
Dinobryon sociale	0.047	Lehman (unpublished)
Euglena gracilis	1.520	Dlum, 1966
Microcystis aeruginosa	0.006	Holm & Armstrong, 1981
Nitzschia actinastreoides	0.095	Von Muller, 1972
Pediastrum duplex	0.105	Lehman (unpublished)
Pithophora oedogonia	0.980	Spenser & Lembi, 1981
Scenedesmus obliquus	0.002	Fogg, 1973
Scenedesmus sp.	0.002 - 0.050	Rhee, 1973
Thalossiosira fluviatilis	0.163	Fogg, 1973

As a part of his review, Knorr performed a statistical analysis of the model periphyton biomass data presented in Table 9-5 of the model report and concluded that the biomass projected by the model was significantly different from the biomass measured in 1985. Unfortunately, the model periphyton biomass values reported in Table 9-5 were from an early draft calibration report, not the final calibration. The ranges of model periphyton biomass from the final model calibration (during the period 8/1/1997 - 8/31/1997) are presented in the corrected table below:

Table 9-5. Comparison of model periphyton with 1985 measurements (Knorr and Fairchild 1987).

Site ID	River Mile	1985 Periphyton Biomass (ug chlorophyll-*a* / cm^2)	EFDC Grid Cell	Model Periphyton (ug chlorophyll-*a* / L)	Water Depth (m)	Model Periphyton Biomass (ug chlorophyll-*a* / cm^2)
1	109.3	6.2 - 10.2	54,69	74 - 97	0.30	1.6 - 2.0
2	NA	8.0 - 16.5	NA	NA	NA	NA
3	106.2	8.5 - 13.0	54,64	59 - 72	0.33	1.3 - 1.7
4	102.4	9.0 - 17.0	54,58	351 - 601	0.36	8.2 - 14.0
5	101.2	11.5 - 21.0	54,56	396 - 662	0.37	9.1 - 15.2
6	96.1	8.0 - 14.3	54,50	93 - 169	0.35	3.6 - 6.5

The purpose of citing the Knorr and Fairchild periphyton biomass was to demonstrate that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985. It is also important to understand a statement from the Knorr and Fairchild (1987) paper:

> *"High current velocities, however, may have caused erosion of accumulated algal cells, reducing standing crop below levels otherwise sustainable by ambient light and nutrient supply. Storm events on 16 and 27 July, and on 1 August during the 23 day incubation period, monitored by fluctuating discharge at USGS gaging station 01480870 located at site 5, provide additional evidence of probable scouring of the pots during the study."*

This statement implies that the periphyton biomass measured in 1985 may have been substantially lowered by three storm events. This confounds attempts to directly compare the 1997 model periphyton predictions with the 1985 observations. The time to establish maximum periphyton biomass following a scouring storm event typically ranges from 20 to 120 days (Biggs 2000). Knorr's use of the Crystal Ball Monte Carlo analysis was interesting, however, the exercise was moot due to the different hydraulic and nutrient loading conditions in 1985 and 1997.

Our responses to individual comments are presented below.

<u>Comments</u>

A. Periphyton Model Fundamentally Flawed

The model developed by EPA to evaluate compliance with dissolved oxygen standards in the Christina River Basin predicts periphyton growth as the primary factor affecting minimum DO levels in the receiving water. This projection of minimum DO was used to mandate more restrictive TP, CBOD, and ammonia limits. DARA has already notified the Agency that periphyton projections made to compare the TMDL loading with other allocation scenarios are fundamentally flawed for the following reasons:

- *No periphyton measurements were made to calibrate the model or to verify calibration of the periphyton growth subroutine, thus the model results are sheer guesswork.*

Response: Direct instream measurements of periphyton biomass were not made during the recent (1995-1997) field studies in the Christina River Basin. However, as part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass productivity at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 ug/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA. In addition, diel DO measurements from August 1997 show the diel DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. The water quality model projects these diel DO swings very well (see Figure 9-17 in the model report). This is clear evidence based on field observations that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are scientifically credible.

- *Site-specific periphyton data for the East Branch of Brandywine Creek from Knorr and Fairchild (1987), cited in the model documentation as the basis for periphyton biomass projections, demonstrate that the model does not accurately represent periphyton growth in the East Branch of Brandywine Creek. The model greatly under-predicts periphyton biomass upstream of the DARA outfall and over-predicts periphyton biomass downstream of the outfall.*

Response: The model documentation does not claim that the Knorr and Fairchild (1987) study was used as the basis for periphyton biomass projections. The Knorr and Fairchild periphyton biomass, measured in 1985, represented the only in-situ measurements available for comparison to the model periphyton biomass predictions. The Knorr and Fairchild data were not used to develop any coefficients in the model. The purpose of citing the Knorr and Fairchild periphyton biomass was to show that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985.

- *Available data do not indicate that periphyton data will change significantly due to higher loadings from DARA. In fact, the projected TP levels under permitted loadings are lower than the conditions observed by Knorr and Fairchild, which confirmed periphyton levels did not increase significantly below DARA.*

Response: The field study conducted by Davis (1998) indicates that periphyton growth in the East Branch Brandywine Creek in the vicinity of DARA is phosphorus limited. The model kinetics were developed based on the Davis (1998) study which confirmed that periphyton levels do, indeed, increase downstream of DARA. As part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 mg/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA.

- *Knorr and Fairchild, the only periphyton data cited in the final report, concluded that phosphorus did not limit growth of periphyton in the East Branch of Brandywine Creek at ambient concentrations significantly less than the TMDL level. Consequently, increases in phosphorus concentration above the TMDL level would have little, if any, effect on periphyton biomass, contrary to the model's prediction.*

Response: As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the Davis study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and periphyton biomass. The water quality model was formulated based on the Davis (1998) study and supports the conclusions of that study.

1. Findings of Thomas W. Gallagher

(a) *Literature and field studies indicate that limiting nutrient levels for periphyton growth due to phosphorus range from 5 to 50 ug/L, far lower than ambient TP levels found during various studies used to develop the TMDL.*

Response: No reference was provided for this statement. Site-specific field studies in the Christina River Basin (Davis 1998) indicate that limiting phosphorus levels for periphyton growth are greater than 0.100 mg/L.

(b) *The periphyton predictions in the model are not credible. Given the level of phosphorus in the TMDL and alternative scenarios, there should be no significant effect on periphyton biomass under low flows or increased loadings.*

Response: Given the fact that the site-specific phosphorus half-saturation constant was estimated as 0.132 mg/L, the increased phosphorus loadings from DARA cause a predictable increase in periphyton biomass and diel DO range downstream of DARA.

(c) *The predicted changes in DO associated with phosphorus loading for the TMDL and alternative scenarios are unrealistic, inconsistent with the literature, and inconsistent with site-specific analysis of the East Branch Brandywine Creek.*

Response: Site-specific diel DO measurements were made during the 1997 field study (Davis 1998). These DO measurements are shown in Figure 9-17 in the model report. The measured DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. As one can see from Figure 9-17, the water quality model provides a reasonable projection of these diel DO swings. The site-specific data collected in 1997 provides evidence that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are realistic.

(d) *The model used a phosphorus Michaelis constant for periphyton of 132 ug/L, over 100 times greater than that for suspended algae (without any scientifically defensible justification), and compensated for this by modifying the carbon:chlorophyll ratio to match the diurnal variation during the calibration period. The same data fit could have been obtained using more realistic model coefficients and would not have had unrealistic periphyton growth projections.*

Response: The Michaelis constant (i.e., phosphorus half-saturation constant) of 0.132 ug/L was derived from a field study conducted during August 1997 (Davis 1998). The commentor may not understand the use of the carbon-to-chlorophyll ratio in the water quality model. Algal biomass is computed in the model in units of carbon. The carbon-to-chlorophyll ratio has absolutely no bearing on any internal computations of algal growth or dissolved oxygen levels. The purpose of the carbon-to-chlorophyll ratio is to convert the algal biomass in carbon units to chlorophyll units for model output.

(e) *The model was developed without sufficient data to link nutrients, periphyton, and dissolved oxygen.*

Response: The model was developed based on a field data collected primarily from 1995 to 1998. In addition, a special field study conducted in 1997 (Davis 1998) to measure community photosynthetic and respiration rates in selected reaches of East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and White Clay Creek. As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and photosynthesis rates. The study recommended that pollution control strategies directed toward maintaining dissolved oxygen concentrations in these stream reaches should address the impact of phosphorus loads from wastewater discharges on the photosynthesis and respiration processes of instream periphyton.

2. Findings of Don Knorr

(a) *EPA's use of the information contained in Knorr and Fairchild (1987) is biased and incorrect.*

Response: The algal biomass from the 1985 field study by Knorr and Fairchild (1987) was included in Table 9-5 of the Christina Model Report to show that the predicted model periphyton was in the ball park of historical measurements.

(b) *The TMDL model predictions in the calibration report are significantly different than the data contained in Knorr and Fairchild (1987) and demonstrate that the model is inadequate for predicting periphyton biomass.*

Response: The information contained in Knorr and Fairchild (1987) was not used for calibrating the model. The information was presented as a simple side-by-side comparison of the predicted model periphyton biomass and biomass measured in the field to demonstrate that the model was computing biomass in a ballpark range consistent with historical field observations . In fact, the conditions during the 1985 field survey and the 1997 calibration periods were significantly different, so one would not expect the model biomass to exactly replicate the measurements made in 1985.

(c) *Knorr and Fairchild determined that phosphorus was not limiting to periphyton growth. This finding contradicts the TMDL model, which assumed that phosphorus was limiting periphyton at all sites.*

Response: The more recent field study conducted in August 1997 (Davis 1998) concluded that phosphorus was the limiting nutrient. Information from the 1997 field survey was used as the basis for developing periphyton kinetics in the water quality model.

(d) *The calculation error is likely due to the use of an invalid phosphorus half-saturation constant for periphyton growth. The study results suggest a half-saturation constant of 1.5 ug/L. The value used in the model is 132 ug/L, nearly 100 times higher.*

Response: The phosphorus half-saturation constant of 0.132 mg/L was derived from a site-specific laboratory algal assay study conducted in August 1997 (Davis 1998).

References

Biggs, B.J.F. 2000. New Zealand Periphyton Guideline: Detecting, Monitoring, and Managing Enrichment of Streams. Prepared for the Ministry for the Environment. 122 p. June 2000.

Davis, J.F. 1998. Measurement of Community Photosynthetic and Respiration Rates for Selected Reaches of the Christina Watershed. Prepared for Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control. March 1998.

Knorr, D.F. and G.W. Fairchild. 1987. Periphyton, benthic invertebrates and fishes as biological indicators of water quality in the East Branch Brandywine Creek. *Proceedings of the Pennsylvania Academy of Science*, 61(1):61-66.