Total Maximum Daily Loads with Stormwater Sources: A Summary of 17 TMDLs

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Introduction

Throughout the US there are thousands of waters listed for impairments from stormwater sources. The most common pollutants coming from stormwater sources include sediment, pathogens, nutrients, and metals. These listed impaired waters need a Total Maximum Daily Load (TMDL), which identifies the total pollutant loading that a waterbody can receive and still meet water quality standards. The TMDL also allocates a specific pollutant wasteload to specific point and nonpoint sources. When the TMDL is implemented, the stormwater wasteload allocation is implemented via the National Pollutant Discharge Elimination System (NPDES) stormwater permitting system. States and EPA Regions have used a variety of methods to develop stormwater source TMDLs during the past decade. With the expansion of NDPES Phase II stormwater to smaller municipalities and smaller construction activities, there has been increasing demand for more detailed quantification of stormwater allocations in TMDLs that are more useful for implementation in NDPES permits.

This report summarizes 17 TMDLs that have been developed for stormwater sources in 16 states throughout the country during the past eight years. They represent a range of pollutants, models used, and different allocation and implementation methods that will be helpful to TMDL practitioners and NPDES permitting agencies and permittees as they develop and implement new stormwater source TMDLs.

For information about the TMDLs in this summary, please contact Christine Ruf (ruf.christine@epa.gov) and Menchu Martinez at EPA Headquarters (martinez.menchu-c@epa.gov)

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Disclaimer

This document provides technical information to TMDL practitioners who are familiar with the relevant technical approaches and legal requirements pertaining to developing TMDLs and refers to statutory and regulatory provisions that contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on EPA or States, who retain the discretion to adopt approaches on a case-by-case basis that differ from this information. Interested parties are free to raise questions about the appropriateness of the application of this information to a particular situation, and EPA will consider whether or not the technical approaches are appropriate in that situation

Summary Table of 17 TMDLs with Stormwater Sources
USEPA, OWOW, Watershed Branch
April 2007
(TMDLs listed by model complexity)

Region	State	TMDL Name/Waterbody	TMDL pollutant(s)	Models	NPDES Permit, Allocation Method, Implementation Plans
Simple Models					
R1	VT	Potash Brook (2006)	Biological Impairment; flow as surrogate for SW pollutants	GWLF for flow volume w/ reference stream; GIS watershed delineation; P8-UCM; FGA	VT state watershed permit using adaptive management; permit to specify type, location, and implementation of BMPs to achieve flow reductions; comprehensive monitoring program.
R1	CT	Eagleville Brook (2007)	Biological Impairment; Impervious Cover as surrogate for SW pollutants	Percent impervious cover; GIS watershed delineation; ArcView© Impervious Surface Analysis Tool	Specific recommendations for voluntary actions to reduce impact of impervious cover using adaptive management (backup is potential state permit); DEP biomonitoring on rotating basin schedule.
R1	CT	Mill River, Rooster River, Sasco Brook (2005)	E. coli (geometric mean; Single Sample Maximum)	Criteria curve	WWTP; MS4 & SW minimum control measures in SWMPs, & guidance on septic systems & nuisance wildlife.
R2	NJ	Swartswood Lake (2005)	Phosphorus	Reckhow's Empirical Modal; Reference Condition (Watershed)	Potential implementation measures for nonpoint source categories (e.g., land use - specific SW runoff, septic tanks & internal loading).
R4	SC	Pee Dee River Basin (2005)	Fecal Coliform (geometric mean)	Load Duration Curve	WWTPs; MS4s; SSOs; MS4 WLAs expressed as % reduction goal; can use LDC to identify appropriate implementation.
R4	TN	Harpeth River (2002)	Sediment (narrative) Target: TSS or turbidity for WWTP; average annual sediment load for MS4/construction	Watershed Characterization System Sediment Tool	23 WWTPs; Phase I & II MS4s; 33 Construction GP; WLA for construction & MS4s average annual sediment load for given subwatershed. Implementation to be done within TN watershed approach, 5-yr cycle of planning, monitoring & assessment, etc.
R6	NM	Middle Rio Grande River (2002)	Fecal Coliform (geometric mean; Single Sample Maximum)	Hyrdotech© Computer Program Mass Balance	WWTPs, 4 "discrete SW conveyance"; Phase I MS4 Albuquerque; TMDL establishes separate numeric targets for each SW conveyance; SW permit lists requirements to address TMDL, including monitoring for BMP effectiveness.

Region	State	TMDL Name/Waterbody	TMDL pollutant(s)	Models	NPDES Permit, Allocation Method, Implementation Plans
R8	UT	Mantua Reservoir (2003)	Total Phosphorus, Dissolved Oxygen, and pH	TSI; Steady-state mass balance; chlorophyll a; Secchi depth response model	NPDES fish hatchery (limits for sediment); pump station for agricultural runoff; WLA for phosphorus reductions based on best professional judgment.
R9	CA	San Diego Creek and Newport Bay (1999)	Nutrients (phosphorus & nitrogen)	Mass Balance	Industrial permits; MS4 (Orange county); Individual Permits for nurseries and other NPDES permittees; level of nutrient management plans for agriculture operations; SW co-permittees submit analysis BMPS to meet targets; separate WLAs for TP for urban areas and construction sites; WLA for TN for urban runoff.
Mid-Range Models					
R3	PA	Wissahickon Creek (2003)	Sediment & Nutrients	Nutrients: EFDC; modified version of WASP; Sediments: GWLF (ArcView) module to simulate streambank erosion; BasinSim with output for a Streambank Erosion Simulation Module; Reference Condition (watershed)	NPDES Individual (industrial and municipal WWTPs); Phase I & Phase II; Sediment WLA for each MS4 based on land use specific loadings and streambank erosion. PA SW management policy cited; no allocations for construction general permit.
R5	IN	Lake Michigan shoreline (2004)	E. coli	EFDC	NPS only; upstream CSO inputs not addressed; TMDL mentions some implementation activities.
R10	OR	Tualatin River Subbasin (2001)	Temperature, Fecal Coliform, Total Phosphorus, Ammonia, Volatile Sollids	Event-based, unit load hydrology model; Steady State Water Quality Model; Streeter-P; Mass Balance analysis; “simple method”; Reference Condition (stream); WQC&F	WWTP, CAFOs, MS4; WQ Mgmt Plan describes specific mgmt measures and source categories; allocations estimated using a variety of methods based on pollutant.
Complex Models					
R2	NY	Oyster Bay and Mill Neck Creek (2003)	Pathogens (90 percentile criteria)	SWMM; WTM	WWTPs; requirements for MS4s to go beyond 6 min. measures; shellfish & beach monitoring.
R3	DE, MD, and PA	Christina River (2006)	Nutrients and Low Dissolved Oxygen Bacteria, Sediment	EFDC; HSPF; SWMM; Reference Condition (watershed)	WWTPs, CSO, MS4s; WLAs allocated by land use distribution in each municipality; PADEP has a proposed SW mgmt policy, but not required; SW WLA includes MS4 and nonpoint source loadings.

Region	State	TMDL Name/Waterbody	TMDL pollutant(s)	Models	NPDES Permit, Allocation Method, Implementation Plans
R5	OH	Lower Cuyahoga River (2003)	Phosphorus, Nutrients, Fecal Coliform	LDC; HYSEP; SWAT; Multi SMP; XP-SWMM; WASP	WWTP, MS4, CSOs; LDC used for MS4 allocations; Implementation actions include measures and timelines for monitoring, tracking & implementation.
R9	CA	Los Angeles River Watershed (2005)	Metals (copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), and selenium (Se)	EFDC; LDC; LSPC; WASP	WWTPs, + 1600 other NPDES permittees; MS4s; Indus & construction SW permittees; MS4s not given a specific WLA but share responsibility with others for total WLA per subwatershed. Detailed Implementation Plan has agreement between 18 municipalities to implement SW regulations jointly; monitoring components with identified responsible entities.
R10	AK	Chester Creek, University Lake, and Westchester Lagoon (2005)	Fecal Coliform (geometric mean or 10% not to exceed)	SWMM	MS4s; allocations based on modeling highest loads; 3 implementation scenarios modeled—(1) with public education, (2) with increased street sweeping frequency and efficiency, & (3) combination of first two. Provides info on BMPs and applicability in cold climates. Follow-up monitoring to track implementation & BMP effectiveness.

MODELS:

ArcView© Impervious Surface Analysis Tool
Basin Sim
Criteria Curve: Cumulative Relative Frequency Distribution
EFDC: Environmental Fluid Dynamics Code
Event Based Unit Load Hydrology Model
FGA: Future Growth Analysis
GIS Watershed Delineation
GWLF: Generalized Watershed Loading Function
HSPF: Hydrologic Simulation Program Fortran
Hydrotech© Computer Program
HYSEP: Streamflow Hydrograph Separation and Analysis
LDC: Load Duration Curve Approach
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P8 – UCM: P8-Urban Catchment Model
Reckhow's Empirical Model
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Streeter P: Streeter Phelps equation
Streambank Erosion Simulation Module
SWAT: Soil and Water Assessment Tool
SWMM: Stormwater Management Model
TSI: Carlson's Trophic State Index
WASP: Water Quality Analysis Simulation Program
WQC&F: Water Quality Criteria and Flow Approach
WCS: Watershed Characterization System Sediment Tool
WTM: Watershed Treatment Model

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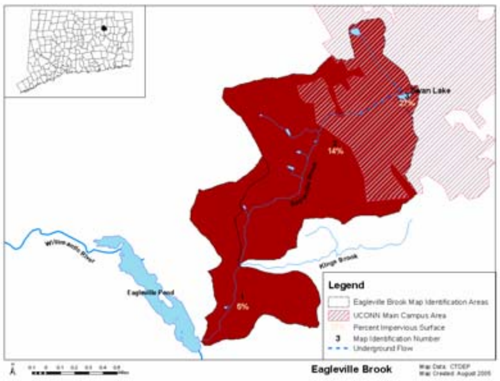
Eagleville Brook
Stormwater Source TMDL (2007)
Connecticut, USEPA Region 1

TMDL at a Glance



Subbasin:	Not listed
Watershed size:	2.4 square mile drainage area
Key beneficial uses:	Aquatic life
Impaired by:	Stormwater related stressors
Pollutant(s):	Combination of pollutants from developed areas, and other related stressors (stormwater runoff)
Sources considered:	Impervious cover (IC) used as a surrogate measure to represent stormwater flows
Model(s) used:	ArcView© Impervious Surface Analysis Tool
TMDL Web link:	TMDL Review available at http://www.epa.gov/NE/eco/tmdl/assets/pdfs/cteaglevillebrook.pdf

TMDL Highlights

Affected water uses:

- Aquatic life

Applicable WQS:

- Class A waterbody. Aquatic life criteria states that a variety of macroinvertebrate taxa and all functional feeding groups should normally be well represented. Aquatic species presence and productivity is only limited by natural conditions, permitted flow regulation, or irreversible cultural impacts. The water quality should sustain a diverse macroinvertebrate community of indigenous species.

Technical approach:

- *Key indicator* – Stormwater runoff from impervious surfaces.
- *Source assessment* – Biological monitoring determined that this waterbody did not meet aquatic life use goals. The state used the assessment methodology outlined in the *Connecticut Assessment and Listing Methodology*. The Inland Fisheries Division conducted fish population surveys and observed low fish densities and large amounts of habitat unoccupied by fish. The Bureau of Water Management also conducted an extensive benthic invertebrate assessment and found that the sites assessed had a Rapid Bioassessment Protocol III Benthic Community Score <54% of the reference site, meaning the waterbody is not meeting the aquatic life designated use.

- *Model* – ArcView© Impervious Surface Analysis Tool, developed by the Nonpoint Education for Municipal Officials (NEMO) at the University of Connecticut and the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center, was used to calculate the percent IC for each of the three Eagleville Brook sections.

Allocations:

- 12% IC target applied to the stormwater drainage area affecting both regulated and non-regulated sources in order to reduce pollutant loads and restore hydrologic and biological integrity.
- Eagleville Brook_01 require Anti-degradation, Eagleville Brook_02 requires a 21% reduction in % IC through stormwater management, and Eagleville Brook_03 requires a 59% reduction in % IC through stormwater management.

Implementation:

- Requires adaptive management strategy, which includes: 1) reducing IC where practical, 2) disconnecting IC from the surface waterbody, 3) minimizing additional disturbance to maintain existing natural buffering capacity, and 4) installing engineered BMPs to reduce the impact of IC on receiving water hydrology and water quality.
- Collect surface water chemistry and benthic macroinvertebrate data from the Eagleville Brook by the Connecticut Department of Environmental Protection (CTDEP) using the CTDEP Rotating Basin Ambient Monitoring Strategy.

Cost:

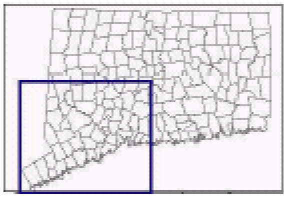
- Cost information is not available in the TMDL documentation.

References:

State of Connecticut Department of Environmental Protection. February 2007. *A Total Maximum Daily Load Analysis for Eagleville Brook, Mansfield, Connecticut.*

Mill River, Rooster River, and Sasco Brook Stormwater Source TMDL (2005) Connecticut, USEPA Region 1

TMDL at a Glance



Subbasin:	Southwest eastern
Watershed size:	Mill River and Rooster River – 25 and 15 square miles, respectively; Sasco Brook – 6 linear miles
Key beneficial uses:	Contact recreation
Impaired by:	Bacteria
Pollutant(s):	E. coli
Sources considered:	*Point sources* – Phase II MS4; regulated urban runoff/storm sewers, combined sewer overflow (CSO), dry weather overflows, and illegal connections to stormwater systems *Nonpoint sources* – collection system failure, urban runoff/storm sewers, on-site wastewater systems (septic tanks), domestic animals, and natural wildlife
Model(s) used:	Cumulative Distribution Function Method
TMDL Web link:	http://www.ct.gov/dep/lib/dep/water/tmdl/tmdl_final/swebasintmdlfinal.pdf

TMDL Highlights

Affected water uses:

- Contact recreation

Applicable WQS:

- Geometric mean less than 126/100 mL, single sample maximum 576/100 mL (numeric). The TMDLs are applicable during the recreation season from May 1 to September 30.

Technical approach:

- *Key indicator(s)* – E. coli
- *Source assessment* – Ambient monitoring data confirmed that bacteria densities are typically highest during the summer months.
- *Model* – A cumulative distribution function method was used to quantify the necessary bacteria density reduction. This procedure allows the contribution of each individual sampling result to be considered when estimating the percent reduction needed to meet a criterion that is expressed as a geometric mean.

Allocations:

- The analysis partitions the TMDL into wasteload and load allocations (WLA and LA) using ambient water quality data during periods of high and low stormwater influence; the wet weather data were used to calculate the WLA percent reductions, and the dry weather data were used to calculate the LA percent reductions.
- Using the cumulative distribution function method, each of the waterbody monitoring sites (5) received average percent reductions as WLAs and LAs to meet water quality standards.

- *Point source* – Regulated stormwater received a WLA. Dry weather flows from stormwater collection systems, illegal connections to stormwater systems, and CSOs required a 100 percent reduction because the management goal for these sources is elimination. Permitted discharges of treated and disinfected domestic wastewater received zero percent reductions.
- *Nonpoint source* – Onsite septic received a LA. Natural sources (e.g., from wildlife) received a zero percent reduction.

Implementation:

- Separate reduction goals are established for baseflow and stormwater dominated periods, which can assist local communities in selecting best management practices (BMPs) to improve water quality for each of these conditions.
- The technique used to allocate loads facilitates the use of ambient stream monitoring data to track progress toward water quality goals.
- It is expected that implementation of these TMDLs will be accomplished through implementing the provisions of the MS4 Permit.
- BMPs for the management of nonpoint sources include septic system testing and maintenance, nuisance wildlife control plans, and pet waste ordinances.
- To guide TMDL implementation, a water quality monitoring program is necessary. Typically, "event monitoring" is required of MS4 permits; however, due to the logistical difficulty for municipalities it is often times not the most efficient program to measure progress in achieving water quality standards. Therefore, the Connecticut Department of Environmental Protection encourages municipalities that are implementing TMDLs to request approval for an alternative monitoring program. The alternative program must be designed to accomplish two objectives: (1) source detection and (2) quantification of progress.

Cost:

- Cost information is not available in the TMDL documentation.

References

State of Connecticut Department of Environmental Protection. 3 March 2005. *A Total Maximum Daily Load Analysis for the Mill River, Rooster River, and Sasco Brook.* Hartford, CT. Available at http://www.ct.gov/dep/lib/dep/water/tmdl/tmdl_final/swebasintmdlfinal.pdf

Potash Brook
Stormwater Source TMDL (2006)
Vermont, USEPA Region 1

TMDL at a Glance

Subbasin:	Not listed
Watershed size:	7.13 square miles
Key beneficial uses:	Aquatic life
Impaired by:	Stormwater related stressors
Pollutant(s):	Sediment and combination of pollutants found in urban stormwater
Sources considered:	*Point sources* – NPDES regulated and unregulated urban and developed areas *Nonpoint sources* – limited agricultural and open space
Model(s) used:	Reference Watershed Approach, P8-Urban Catchment Model to develop Flow Duration Curve, Future Growth Analysis
TMDL Web link:	TMDL Review available at http://www.epa.gov/NE/eco/tmdl/assets/pdfs/vt/potashbrook.pdf

TMDL Highlights

Affected water uses:

- Aquatic life

Applicable WQS:

- The impairment is based on biological indices so there is no numeric pollutant criterion to use as the TMDL target. Instead, the in-stream target is expressed as a measure of hydrologic condition believed to be necessary to achieve the Vermont water quality criteria for aquatic life.

Technical approach:

- *Key indicator* – Sediment and mix of pollutants found in urban stormwater
- *Source assessment* – Biological monitoring of the fish and macroinvertebrate communities in reference sites to define the biological community goals for specific stream types. The Vermont Department of Conservation (VDEC) collected biological data from 1987 to 2004, and VDEC approved the use of biological data collected by South Burlington from 2001 to 2004.
- *Model* – Reference Watershed Approach whereby hydrologic targets are developed by using similar "attainment" watersheds as a guide. The "attainment" watersheds were selected using a careful statistical analysis of the watershed characteristics of 15 candidate "attainment" watersheds. Flow Duration Curves (FDC) were used to define hydrologic targets. This approach compares FDC between an impaired and appropriate attainment stream/watershed. The P8-Urban Catchment Model was used to develop the FDC model outputs.

Allocations:

Land use based allocation approach, which divided the Potash Brook watershed into three broad categories: Urban/Developed, Agriculture/Open, and Forest/Wetland. The overall percent reduction/increase in flows was distributed among these three categories as follows: 1) zero allocation for Forest/Wetland, 2) 91% reduction from Urban/Developed, wasteload allocation; and 3) 9% reduction from Agriculture/Open, load allocation.

Implementation:

- Implemented through iterative, adaptive management approach utilizing a watershed permit authorized by Vermont law.
- State watershed permit will specify the type and location of BMPs necessary to achieve the stormwater runoff reductions outlined in the TMDL; conditions for BMP implementation will be included in all applicable NPDES permits.
- A comprehensive monitoring program will be used to measure progress towards water quality standards and to amend the permits as needed.

Cost:

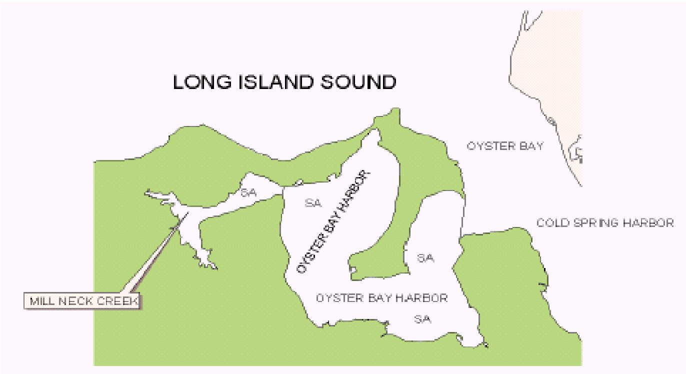
- Cost information is not available in the TMDL documentation.

References:

Vermont Department of Environmental Conservation. October 2006, *Total Maximum Daily Load to Address Biological Impairment Potash Brook (VT05-11) Chittenden County, Vermont.*

Oyster Bay and Mill Neck Creek
Stormwater Source TMDL (2003)
New York, USEPA Region 2

TMDL at a Glance



Subbasin:	Mill Neck Creek watershed and Oyster Bay Harbor's drainage area includes flows from Mill Neck Creek, Village of Bayville, Village of Centre Island, Beekman Beach, Hamlet of Oyster Bay, and Village of Cove Neck
Watershed size:	2,877 acres, including Oyster Harbor and Mill Neck Creek (Mill Neck Creek itself is about 297 acres); Oyster Harbor and Mill Neck Creek have about 17 miles shoreline
Key beneficial uses:	Shellfish harvesting
Impaired by:	Pathogens
Pollutant(s):	Total Coliform
Sources considered:	*Point source* – Three wastewater treatment plants (WWTPs) covered by NYSDEC SPDES (New York State Department of Environmental Conservation, State Pollution Discharge Elimination System) General Permits; stormwater discharges, drain pipes and culverts, from streets and parking areas and direct overland runoff flows from street ends and boat ramps (in 2003, fourteen municipalities submitted an application for inclusion in the SPDES General Permit for stormwater discharges from Municipal Separate Storm Sewer Systems (MS4s) and one industrial entity, Commander Oil Company, which has numerous large oil storage tanks and an off-loading dock. *Nonpoint source* – 39 residential and 4 other units dispose of domestic waste using cesspools; freshwater inputs from several creeks and ponds; boats, marinas, and mooring areas; wildlife and waterfowl; and agricultural and domestic animals.
Model(s) used:	Stormwater Management Model and Watershed Treatment Model
TMDL Web link:	http://www.dec.state.ny.us/website/dow/oystbay.pdf

TMDL Highlights

Affected water uses:

- Shellfish harvesting

Applicable WQS:

- A geometric mean of total coliform less than 70 most probable number (MPN)/100 mL and an estimated 90th percentile value of total coliform less than 330 MPN/100 mL (numeric). These standards are based on total coliform data derived from a minimum of the 30 most recent water samples. Based on analyses of historical data and the water quality data analysis conducted in this study, the 90th percentile criterion is more difficult to meet than the geometric mean criterion; therefore, this criterion is used as the goal for these TMDLs.

Technical approach:

- *Key indicator(s)* – Total coliform
- *Source assessment* – The sources were primarily identified from a shoreline survey conducted by NYSDEC in 1988. WWTPs contribute less than one percent of the load; stormwater from rainfall events accounts for about 88 percent; boats, marinas, and mooring areas contribute about 11 percent; and waterfowl and horses contribute less than 1 percent.
- *Stormwater Management Model (SWMM)* - simulates the quantity and quality of runoff produced by storms in urban watersheds and was used to estimate loads from Mill Neck Creek and its tidal tributaries. The water quality data used in the SWMM model was simulated by developing total coliform accumulation rates for each of the land uses.
- *Watershed Treatment Model (WTM)* - characterized point and nonpoint sources and quantified pathogen loadings for the four zones within Oyster Bay Harbor because of the lack of historical water quality data. The WTM spreadsheets calculated pathogen load annually using a series of runoff volume coefficients and pathogen loading estimates derived from scientific literature.

Allocations:

- The loading capacity was not exceeded for Mill Neck Creek and tributaries and two of the zones in Oyster Bay Harbor zones, so the wasteload and load allocations (WLA and LA) were established at current loads.
- *Point source* – In one of the Oyster Bay zones, the TMDL requires a 20 percent reduction in the stormwater load which included stormwater drainage, and in another zone, the TMDL requires a 90 percent reduction in stormwater which included urban runoff.
- *Nonpoint source* – In one of the zones in Oyster Bay, the TMDL requires a 95 percent reduction in boat and marina loadings.

Implementation:

- MS4s discharging to two of the zones within Oyster Bay Harbor will be required to provide controls beyond the six minimum measures.
- NYSDEC has proposed mitigation measures to reduce discharges from boats and marinas. For example, it is anticipated that discharges from boats and marinas will be reduced by designating the subject waters as "no discharge" zones.
- NYSDEC will continue its shellfish monitoring program at 39 stations to assess compliance. Data collected through the beach monitoring program at four beaches will also be used to assess the effectiveness of controls.

Cost:

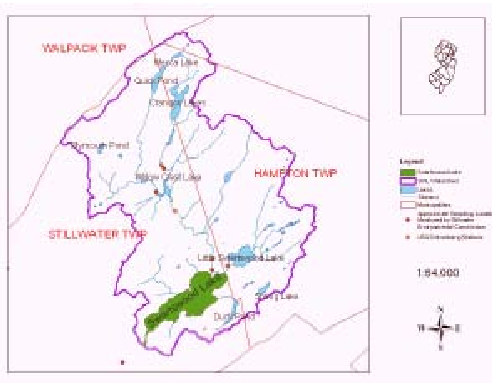
- Cost information is not available in the TMDL documentation.

References

New York State Department of Environmental Conservation (NYSDEC). September 2003. *Pathogen Total Maximum Daily Loads for Shellfish Waters in Oyster Bay Harbor and Mill Neck Creek, Nassau County, New York*. Available at http://www.dec.state.ny.us/website/dow/oystbay.pdf

Swartswood Lake
Stormwater Source TMDL (2005)
New Jersey, USEPA Region 2

TMDL at a Glance



Subbasin:	Northwest Water Region
Watershed size:	10,713 acres, excluding lake surface area (505 acres)
Key beneficial uses:	(1) maintenance, migration, and propagation of the natural and established aquatic biota, (2) primary and secondary contact recreation, (3) industrial and agricultural supply, (4) public potable water supply after conventional filtration treatment and disinfection, and (5) any other reasonable uses.
Impaired by:	Phosphorus
Pollutant(s):	Total phosphorus (TP)
Sources considered:	*Point source* – There are no point sources in the watershed. *Nonpoint source* – The TMDL identifies internal loading, septic tanks, and stormwater runoff as the primary contributors to total phosphorus to the lake. The land uses considered for stormwater runoff include medium/high density residential, low density/rural residential, commercial, mixed urban/other urban, and agricultural. Phosphorus from air deposition was also considered, but it was not determined to be a significant source.
Model(s) used:	Empirical model
TMDL Web link:	http://oaspub.epa.gov/tmdl/waters_list.tmdl_report?p_tmdl_id=12411

TMDL Highlights

Affected water uses:
- Recreational, water supply, and aquatic life

Applicable WQS:
- Numeric (0.05 mg TP/L) and narrative water quality standards apply. The state's nutrient narrative standard states, "except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the waters unsuitable for the designated uses."
- A target concentration, used to determine the loading capacity, was estimated based on a comparison of peak-to-mean TP concentrations.

Using annual average water quality data from 1994 and 2002-2004, peak-to-mean ratios of 1.42 and 1.62, respectively, were calculated. In previously established TMDLs by the New Jersey Department of Environmental Protection (NJDEP), a target concentration of 0.03 mg/L had been determined based on peak-to-mean ratios of 1.56 and 1.48 for two similar lakes—Strawbridge and Sylvan. Based on these data, NJDEP determined that 0.03 mg/L TP is an appropriate target phosphorus concentration for use in this TMDL and will assure that the 0.05 mg TP/L criterion will be met throughout the year.

Technical approach:

- *Key indicator(s)* – Total phosphorus
- *Source assessment* – Current loads for nonpoint sources were calculated by a unit areal load (UAL) methodology.
- *Model* – An empirical model developed by K.H. Reckhow (1979) was used to calculate the phosphorus loading capacity of the lake by relating the annual phosphorus load to a steady-state in-lake TP concentration. The model has previously been applied to north temperate lakes with hydrologic, morphologic, and loading characteristics similar to those of Swartswood Lake.

Allocations:

- *Point source* – The wasteload allocation is set to zero because there are no point sources in the watershed.
- *Nonpoint source* – The following nonpoint sources received a 57 percent reduction: (1) septic tank systems, (2) internal loading, (3) medium/high density residential, (4) low density/rural residential, (5) commercial, (6) mixed urban/other urban, and (7) agricultural

Implementation:

- The implementation plan includes: potential management strategies, responsible entities, and funding options to address the three major nonpoint sources of TP to the lake: stormwater runoff, septic tank leakage, and internal loading.
- The Swartswood Lake and Watershed Association have received Clean Water Act Section 319(h) funding to install a hypolimnetic aeration system, perform weed harvesting, and implement stormwater best management practices. A regional stormwater management plan is being developed for the Swartswood watershed through another 319(h) grant, which can serve as a foundation for future implementation strategies.
- The state's stormwater management rules establish a 300-foot special water resource protection area (SWRPA) surrounding "category one" (C1) waters and their intermittent and perennial tributaries, and both Swartswood Lake and Little Swartswood Lake are listed as C1 waters. In the SWRPA, new development is typically limited to existing disturbed areas to maintain the integrity of the C1 waterbody. For the Townships of Hampton and Stillwater, NJDEP has imposed a fertilizer ordinance that only allows the application of low phosphorus fertilizer (see www.njstormwater.org for the ordinance language).
- "Phosphorus contributions from future development are expected to be controlled through implementation of the Stormwater Management Rules, which establish quality standards for [total suspended solids] and nutrients."

Cost:

- Cost information is not available in the TMDL documentation.

References:

New Jersey Department of Environmental Protection, Division of Watershed Management. August 31, 2005. *Amendment to the Sussex County Water Quality Management Plan: Total Maximum Daily Load to Address Phosphorus and Fish Community Impairments in Swartswood Lake in the Northwest Region*. Watershed Management Area 1. Available at http://oaspub.epa.gov/tmdl/waters_list.tmdl_report?p_tmdl_id=12411

Reckhow, K.H. 1979. Uncertainty Analysis Applied to Vollenweider's Phosphorus Loading Criterion. *J. Water Pollution Control Federation*. 51(8):2123-2128.

Christina River Basin Watershed Stormwater Source TMDL (2006) Pennsylvania, Delaware, and Maryland, USEPA Region 3

(Nutrients and Low DO)
TMDL at a Glance

Subbasin:	Delaware River
Watershed size:	565 square miles
Key beneficial uses:	Primary contact recreation (swimming) and protection of aquatic life (fishing) (designated by Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control)
Impaired by:	Nutrients, organic enrichment, and low dissolved oxygen (DO) (Pennsylvania); nutrients and low DO (Delaware)
Pollutant(s):	Nutrients and low DO
Sources considered:	*Point sources* – Wastewater treatment plants (WWTPs), combined sewer overflows (CSOs) and municipal separate storm sewer systems (MS4s) *Nonpoint sources* – Septic systems, agricultural activities, and wildlife sources
Model(s) used:	Hydrologic Simulation Program–Fortran (HSPF), XP–Stormwater Management Model (XP-SWMM), and Hydrodynamic (and receiving water) Model
TMDL Web link:	http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/ChristinaMeetingTMDL/index.htm

TMDL Highlights

Affected water uses:
- Primary contact recreation and aquatic life

Applicable WQS:
- Numeric and narrative water quality standards (WQS) apply. There are four regulatory agencies with applicable WQS in the Christina River Basin—Pennsylvania Department of Environmental Protection (PADEP), Delaware Department of Natural Resources and Environmental Control (DNREC), the Maryland Department of the Environment (MED), and Delaware River Basin Commission (DRBC).
- Pennsylvania and Maryland allocation targets at PA-DE and MD-DE state lines, respectively: Total nitrogen – 3.0 mg/L and total phosphorus – 0.2 mg/L (Delaware WQS)

- Nitrate-nitrogen allocation targets: 10 mg/L (Pennsylvania and Delaware WQS)
- Nitrogen and phosphorus allocation targets were based on minimum and daily average DO WQS, which depend on the designated use (Pennsylvania WQS)
- DO allocation targets were based on DO WQS (Pennsylvania, Delaware, and Maryland WQS)

Technical approach:

Key indicator(s)
- Total nitrogen, total phosphorus, as well as DO, nitrate-nitrogen and ammonia-nitrogen

Source assessment
- *CSOs* – Nutrient loads from the 38 CSOs in the vicinity of the City of Wilmington that discharge to the Christina River Basin were determined using the flow rates calculated by the XP-SWMM model (see below) and event mean concentrations calculated from storm events monitored in 2003 and 2004.
- *MS4s* – Most of the townships and boroughs within the Christina River Basin in Chester County, PA, and all of New Castle County, DE, are covered by the Phase II MS4 program regulations. To assess the relative loads from different land uses within municipal boundaries, the HSPF model (see below) incorporated an inventory of municipal land use data as a proportion of the HSPF subbasins in which each municipality resides.

Models
- The modeling framework used consisted of three major components: (1) a watershed loading model, Hydrologic Simulation Program–Fortran (HSPF), developed for each of the four primary subwatersheds in the Christina River Basin by the U.S. Geological Survey (Senior and Koerkle 2003a, 2003b, 2003c, 2003d); (2) a CSO flow model, XP–Stormwater Management Model (XP-SWMM), developed by the City of Wilmington; and (3) a hydrodynamic (and receiving water) model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick 1992).

Allocations:

Point sources
- *MS4s* – Neither the PA nor the DE MS4 permits identify the boundaries of the stormwater collection system contributing areas within each municipality. Therefore, it is not possible to assign a wasteload allocation (WLA) specific to the storm sewer collection areas within each MS4 municipality. Because these systems have not yet been delineated, the TMDL includes nonpoint source loadings in the WLA portion of the TMDL. It is anticipated that the state's stormwater program will revise the WLA into the appropriate WLA and load allocation (LA) as part of the stormwater permit reissuance; however, the overall reductions in the TMDL will not change.
- *CSOs* – The annual average loads for CSO discharges (in kg per day of total phosphorus and total nitrogen) were established to meet the total phosphorus, total nitrogen, and DO WQS.
- *Non-MS4s* – The non-MS4 point source permittee's WLAs for five-day carbonaceous oxygen demand, ammonia, and total phosphorus are not reduced from their permitted levels.

Nonpoint sources
- After the municipalities delineate their MS4 areas, the nutrient loads associated with NPS may be separated from the WLA and moved to the LA. The LA is not divided into subcategories in this TMDL.

Implementation:
- There are state and local policies and regulations in place to help ensure implementation of best management practices (BMPs). At the

state level, PADEP has developed a Proposed Comprehensive Stormwater Management Policy (appendix A of the TMDL) that encourages implementation of BMPs for stormwater control to reduce pollutant loadings, recharge groundwater tables, enhance stream baseflow during drought periods, and reduce the threat of streambank erosion and flooding. This policy seeks to integrate watershed management plans with permitting programs.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Hamrick, J.M. 1992. *A Three-dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.* Special Report 317. The College of William and Mary, Virginia Institute of Marine Science.

Senior and Koerkle. 2003a. *Simulation of Streamflow and Water Quality in the Brandywine Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 02-4279.

Senior and Koerkle. 2003b. *Simulation of Streamflow and Water Quality in the White Clay Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4031.

Senior and Koerkle. 2003c. *Simulation of Streamflow and Water Quality in the Red Clay Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4138.

Senior and Koerkle. 2003d. *Simulation of Streamflow and Water Quality in the Christina River Subbasin and Overview of Simulations in Other Subbasins of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4193.

U.S. EPA Region III. 26 September 2006. *Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen under High-flow Conditions: Christina River Basin Watershed, Pennsylvania, Delaware, and Maryland.* Philadelphia, PA. Available at http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/ChristinaMeetingTMDL/index.htm

Christina River Basin Watershed Stormwater Source TMDL (2006) Pennsylvania, Delaware, and Maryland, USEPA Region 3

(Bacteria and Sediment)
TMDL at a Glance

Subbasin:	Delaware River
Watershed size:	565 square miles
Key beneficial uses:	Primary and secondary contact recreation, public water supply, and support of aquatic life
Impaired by:	Bacteria and sediment
Pollutant(s):	Bacteria and sediment
Sources considered:	*Point sources* – Wastewater treatment plants (WWTPs), combined sewer overflows (CSOs), and municipal separate storm sewer systems (MS4s) *Nonpoint sources* – Septic systems, agricultural activities, wildlife, and domestic pets
Model(s) used:	Hydrologic Simulation Program–Fortran (HSPF), XP–Stormwater Management Model (XP-SWMM), and Hydrodynamic (and receiving water) Model
TMDL Web link:	http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/ChristinaMeeting TMDL/index.htm

TMDL Highlights

Affected water uses:
- Primary and secondary contact recreation, public water supply, and support of aquatic life

Applicable WQS:
BACTERIA
- *Pennsylvania* – During the swimming season, from May 1 through September 30, the 30-day geometric mean fecal coliform bacteria levels must be less than the target value of 200 colony forming units (cfu)/100 mL and not more than 10 percent of fecal bacteria concentrations within a 30-day period can exceed 400 cfu/100 mL. During the non-swimming season (October 1 through April 30), the 30-day geometric mean target level is 2,000 cfu/100 mL.
- *Delaware* – The TMDL target endpoint for enterococcus bacteria is the geometric mean concentration of 100 cfu/100 mL.

- *Maryland* - For fresh waters, MD uses either enterococci or *E. coli* as the bacteria indicator. For waters not designated as beaches, only the steady state geometric mean indicator density for enterococci is 33 counts/100 mL and for *E. coli*, 126 counts/100 mL is the applicable criterion.

SEDIMENT

- The sediment TMDL endpoints are based on the reference watershed method. Pennsylvania's water quality standards (WQS) include a maximum 750 mg/L of total dissolved solids (TDS) and a monthly average of 500 mg TDS/L year round for potable water supplies.

Technical approach:

Key indicator(s)

BACTERIA

- Fecal coliform (PA), enterococcus (DE), and *E. coli* or enterococcus (MD)

SEDIMENT

- Total suspended solids (TSS) (PA)

Source assessment

- *CSOs* – Bacteria loads from the 38 CSOs within the vicinity of the City of Wilmington that discharge to the Christina River Basin were determined using the flow rates calculated by the XP-SWMM model (see below) and event mean concentrations during two storm events in 2003.
- *MS4s* – An inventory of municipal land use data as a portion of the HSPF (see below) subbasins in which the municipalities reside was used to assess the relative loads of bacteria and sediment from different land uses within municipal boundaries.
- *Septic systems* – The potential annual bacteria load from malfunctioning, as well as properly functioning, septic systems was estimated.
- *Wildlife* – Literature and empirical values were used to estimate wildlife population densities for different land use categories. Monthly adjustment factors were used to account for seasonal variations in wildlife populations.
- *Domestic pets* – The bacteria load from domestic pets was estimated in the HSPF watershed model runoff from urban and residential areas.

Models

BACTERIA

- *Enterococcus* - Three models were used to determine enterococcus bacteria TMDLs for waters listed in Delaware: (1) a watershed loading model, Hydrologic Simulation Program–Fortran (HSPF), developed for each of the four primary subwatersheds in the Christina River Basin by the U.S. Geological Survey (Senior and Koerkle 2003a, 2003b, 2003c, 2003d); (2) a CSO flow model, XP–Stormwater Management Model (XP-SWMM), developed by the City of Wilmington; and (3) a hydrodynamic (and receiving water) model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick 1992). Development of inputs for these models involved the analyses of historical water quality and stream flow data to estimate point and nonpoint sources of nutrients.
- *Fecal coliform* – The HSPF watershed models were used to calculate the baseline and allocation loads for fecal coliform bacteria for the TMDLs for the PA-listed waters. The models were calibrated over a four-year period (October 1994 to October 1998) to include low and high stream flow. Septic system loads and bacteria accumulation and storage on different land uses were estimated and incorporated into the models.

SEDIMENT

- A reference watershed approach was used to estimate the necessary sediment load reduction required.

Allocations:

Point sources

- The MS4 permits do not identify the boundaries of the stormwater collection system contributing areas within each municipality. Therefore, it is not possible to assign a bacteria or sediment wasteload allocation (WLA) specific to the storm sewer collection areas within each MS4 municipality. Because these systems have not yet been delineated, the TMDL includes nonpoint source (NPS) loadings in the WLA portion of the TMDL. It is anticipated that the state's stormwater program will revise the WLA into the appropriate WLA and load allocation (LA) as part of the stormwater permit reissuance; the overall reductions in the TMDL will not change.

BACTERIA

- The City of Wilmington's CSOs are NPDES-permitted discharges that currently have no permit limits; future permits will contain permit limits and require reductions in loads discharged to the Christina River, Little Mill Creek, and Brandywine Creek. The non-MS4 point source permittee's allocations for fecal coliform, enterococci, and TSS are not reduced from their permitted levels.

SEDIMENT

- MS4s received allocations based on drainage areas of each municipality. The area-weighted LAs were further allocated by the land use distribution of each municipality. None of the non-MS4 NPDES permitted dischargers were required to reduce their present TSS NPDES permit limits because available discharge monitoring reports indicated that the average discharge of sediment from such facilities was usually well below the permitted TSS concentrations.

Nonpoint sources

- The septic system loads of fecal coliform and enterococcus were reduced in the models by eliminating failed systems. After municipalities delineate their MS4 boundaries, the bacteria and sediment loads associated with NPS may be separated from the WLA and moved to the LA portion of the TMDL. The total allocations will remain unchanged.

Implementation:

- 1994 CSO Control Policy: Wilmington selected the presumptive approach to address its CSOs, which requires capture for treatment of 85 percent of the combined sewage flows and limiting CSO discharges to less than an average of four to six events per year. (Guidance defines the required capture as the elimination or the capture for treatment of no less than 85 percent by volume of the combined sewage collected in the combined sewer system (CSS) during precipitation events on a system-wide, annual average basis.)
- Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of bacteria and sediment reaching the streams can be made through the planning of riparian buffer zones, contour strips, cover crops, or stormwater retention techniques.
- For the Delaware portion of the Christina River Basin, the Christina Basin Clean Water Partnership has developed a Watershed Restoration Action Strategy (WRAS), which is intended to provide a guideline for future watershed protection and restoration actions (for example, by including goals and objectives for decreasing bacteria and sediment

loads). The WRAS, developed in June 2003, is also designed to interconnect with EPA's earlier low-flow TMDL for the Christina Basin and this high-flow TMDL.

- The TMDL also mentions other active watershed groups, as well as various local and government organizations, that provide watershed stewardship in the Christina River basin.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Hamrick, J.M. 1992. *A Three-dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.* Special Report 317. The College of William and Mary, Virginia Institute of Marine Science.

Senior and Koerkle. 2003a. *Simulation of Streamflow and Water Quality in the Brandywine Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 02-4279.

Senior and Koerkle. 2003b. *Simulation of Streamflow and Water Quality in the White Clay Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4031.

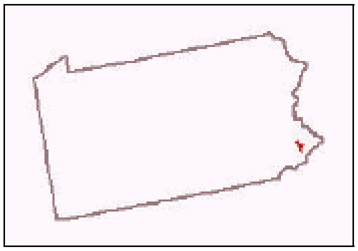
Senior and Koerkle. 2003c. *Simulation of Streamflow and Water Quality in the Red Clay Creek Subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4138.

Senior and Koerkle. 2003d. *Simulation of Streamflow and Water Quality in the Christina River Subbasin and Overview of Simulations in Other Subbasins of the Christina River Basin, Pennsylvania and Delaware, 1994-98.* U.S. Geological Survey Water-Resources Investigations Report 03-4193.

U.S. EPA Region III. 7 September 2006. *Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Basin Watershed, Pennsylvania, Delaware, and Maryland.* Philadelphia, PA. Available at http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/ChristinaMeetingTMDL/index.htm

Wissahickon Creek
Stormwater Source TMDL (2003)
Pennsylvania, USEPA Region 3

TMDL at a Glance



Subbasin:	Wissahickon Creek basin
Watershed size:	64 square miles
Key beneficial uses:	Trout stocking (maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna indigenous to warmwater habitat)
Impaired by:	Nutrients, low dissolved oxygen, siltation, chlorine, water/flow variability, oil and grease, and pathogens. The TMDL states that sources of impairments associated with water/flow variability and other habitat alterations are related to those sources contributing to the nutrient and siltation impairments. "Therefore, through implementation of [BMPs] to address [the] nutrient and siltation TMDLs, these related impairments will be addressed indirectly."
Pollutant(s):	nutrients and sediment
Sources considered:	
Point sources	
NUTRIENTS	▪ NPDES permitted discharges range from single family to large industrial and municipal wastewater treatment plants
SEDIMENT	▪ MS4s
Nonpoint sources	
NUTRIENTS	▪ Irrigated golf courses, areas with high concentrations of septic tanks and/or history of septic tank failure, unimpeded cattle access to streams, and low-level dams
SEDIMENT	▪ None; because the entire watershed is considered an urbanized area subject to MS4s, all sources of siltation (overland flow and streambank erosion) are considered point sources.
Model(s) used:	Low-flow, steady-state model, EPA's Environmental Fluid Dynamics Code; modified version of EPA's Water Quality Analysis Simulation Program; reference watershed approach, which consisted of a modified application of the Generalized Watershed Loading Function (GWLF) watershed model, including a module to simulate streambank erosion; ArcView version of GWLF, BasinSim with output for a Streambank Erosion Simulation Module.
TMDL Web link:	http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/wissahickon/index.htm

TMDL Highlights

Affected water uses: ▪ Trout stocking, aquatic life, water supply, and recreation

Applicable WQS:
- There are no numeric water quality standards for nutrients or sediment in Pennsylvania.

NUTRIENTS
- Based on analyses of 1998 and 2002 data, EPA determined that the link between nutrient concentrations, dissolved oxygen (DO) concentrations, and instream biological activity was a necessary component of TMDL endpoint determination. Only DO has applicable numeric criteria in Pennsylvania. The standards for DO are based on levels required to support fish populations, and the critical period is based on supporting the more stringent aquatic life use for trout stocking. This period requires a minimum DO level of 5.0 mg/L and a minimum daily average of 6.0 mg/L to support the aquatic life use for trout stocking from February 15 through July 31. For the remainder of the year, a minimum DO level of 4.0 mg/L and a minimum daily average of 5.0 mg/L are required to support warmwater fish.

SEDIMENT
- EPA used a reference watershed approach to develop the allowable sediment loading rates.

Technical approach:

Key indicator(s)

NUTRIENTS
- Given the scientific knowledge available and the model processes that describe the relationships of nutrients, carbonaceous oxygen demand (CBOD), sediment oxygen demand, and their impact on DO, EPA determined that the appropriate pollutants for the TMDL included ammonia nitrogen (NH_3-N), nitrate-nitrite nitrogen (NO_3+NO_2-N), ortho phosphate (ortho PO_4-P), and carbonaceous oxygen demand ($CBOD_5$).

SEDIMENT
- Total suspended solids (TSS), converted to lbs sediment/year

Source assessment

NUTRIENTS
- An analysis of 1998 and 2002 data indicated that during low-flow periods, nutrient concentrations are dominated by point sources. During the critical low-flow period, impacts from nonpoint sources (NPS) are limited because storm runoff is not a factor during such dry conditions.

SEDIMENT
- An analysis of 1998 and 2002 data indicated during wet weather conditions, the impact of point sources on the total siltation loads to the streams is negligible. To assess the relative loads of sediment from different land uses within municipal boundaries, EPA used land use specific, unit area loadings. Urban and residential land uses in the basin account for more than 50 percent of the total area and are considered to be major contributors of sediment loads. However, the largest contributors of sediment in the watershed are instream sources attributed to streambank erosion. The siltation modeling report estimated the load from streambank erosion and determined that the cause of the flow variability (periodic high flows) that results in streambank erosion is related to urban runoff and the sources of impairments are MS4s.

Models

NUTRIENTS
- A low-flow, steady-state model was used that included chemical and biological processes associated with nutrient enriched and eutrophic systems. Two models were used to simulate the hydrodynamics and water quality: EPA's Environmental Fluid Dynamics Code (EFDC) was used to simulate hydrodynamics, and a modified version of EPA's Water Quality Analysis Simulation Program (WASP5) used the results of the hydrodynamic model to simulate processes associated with nutrients, DO, and biological activity.

SEDIMENT

- A reference watershed approach was used to develop a TMDL for siltation, and the modeling framework consisted of a modified application of the Generalized Watershed Loading Function (GWLF) watershed model (Haith and Shoemaker 1987), including a module to simulate streambank erosion. The ArcView version of the GWLF (Evans et al 2001) was used to develop input and estimate sediment loadings from overland runoff. Using the hydrology input parameters from the AVGWLF model, BasinSim (Dai et al. 2000) was used to run GWLF with model output for a Streambank Erosion Simulation Module. This separate module estimated loadings from streambank erosion using daily flows predicted by GWLF, site-specific information, and process-based algorithms.

Allocations:

*Point source*s

NUTRIENTS

- EPA established the wasteload allocations (WLAs) by reducing CBOD, NH_3-N, NO_3+NO_2-N, and ortho PO_4-N loads from NPDES point sources until daily average and minimum daily DO criteria were satisfied. Nutrient WLAs for each point source were determined on a case-by-case basis, with most reductions determined by local improvements downstream from the point of discharge. Where dischargers were in close proximity, sensitivity analyses were performed to ensure that appropriate sources received reductions.

SEDIMENT

- Sediment allocations began at the top of the watershed and continued downstream to the mouth of the watershed. Total sediment loads were based on unit-area loadings for each land use, and the streambank erosion sediment load was distributed to each of the listed segments based on the drainage area of each listed segment within the appropriate subwatershed. Separate TMDL calculation approaches and margin of safety assumptions were used to determine WLAs associated with overland runoff and streambank erosion. Each MS4 permittee received a WLA based on the sediment loading from land uses and streambank erosion within their municipal boundaries. The MS4 WLAs for overland loads are allocated by landuse type, including low-intensity residential, high-intensity residential, hay/pasture, row crops, coniferous forest, mixed forest, deciduous forest, and transitional.

*Nonpoint source*s

NUTRIENTS

- NPS load reductions—through load allocations (LAs)—were considered unnecessary for background loads. However, to address the impairment in these stream segments, the TMDL recommends implementation measures to address non-source related factors that can result in biological improvements.

SEDIMENT

- The upstream load from the three of the five subwatersheds received LAs because these loads originated from sources outside the demarcated watersheds. However, the percent load reduction required in the LAs for NPS is 0.

Implementation:

- The TMDL provides "equally protective" nutrient and sediment TMDLs and WLAs based on several scenarios to provide implementation flexibility.
- Because instreambank erosion is the most significant contributor of sediment in the watershed, "… reductions in the sediment entrained in overland flow must be accompanied by substantial reductions in the volume of water delivered to the stream in order to achieve the water quality objectives of the TMDL. Efforts must also be taken to control

future potential sources of sediment and stormwater as new construction and redevelopment occurs."

MS4s

- In Pennsylvania, Philadelphia is one of two cities covered under the NPDES Phase I program, and 16 municipalities in the Wissahickon watershed are required to have NPDES Phase II permits. The State has developed a protocol that MS4s covered under the PA general permit can adopt to satisfy the permit requirements. MS4s can also choose to develop their own programs, but they must seek the Pennsylvania Department of Environmental Protection's (PADEP) approval.
- MS4 permits could be issued in the future on a watershed basis to improve stormwater management where multiple jurisdictions are responsible for a single watershed, as is the case in Wissahickon Creek, or where the approach can be specialized to focus on a pollutant of concern to all jurisdictions, such as sediment.

State-specific opportunities

- Pennsylvania adopted a "comprehensive stormwater management policy" on September 28, 2002, to more fully integrate post-construction stormwater planning requirements and emphasize the use of groundwater infiltration, as well as best management practices (BMPs) that control the volume and rate of stormwater (see appendix H of the TMDL for a copy of the policy).
- Under Pennsylvania's "Stormwater Management Act of 1978" (Act 167), counties are required to develop stormwater control plans for each watershed. A community must enact, administer, and enforce stormwater ordinances within six months of PADEP approval of an Act 167 plan. After a community has enacted its stormwater ordinances, the community may be eligible for state low interest loans to correct existing stormwater drainage problems. An Act 167 plan has not yet been prepared for the Wissahickon watershed.
- PADEP has finalized a model ordinance for municipalities that operate MS4s (available via the stormwater link at www.dep.state.pa.us).

Cost:

- Cost information is not available in the TMDL documentation.

References:

Dai, T., R.L. Wetzel, Tyler R.L. Christensen and E.A. Lewis. 2000. *BasinSim 1.0 A Windows-Based Watershed Modeling Package User's Guide SRAMSOE #362* (computer program manual). Virginia Institute of Marine Science, School of Marine Science, College of William & Mary, Gloucester Point, VA. http://www.vims.edu/bio/vimsida/basinsim.html

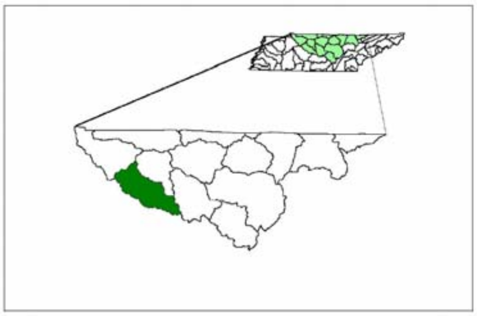
Evans, B.M., S.A. Sheeder, K.J. Corrandi, and W.S. Brown. November 2001. *AVGWLF Users Guide*. Environmental Resources Research Institute, Pennsylvania State University, University Park, PA. (3) The following reference is not included in the references section of the TMDL, but is referenced on p. 4-13:

Haith, D.A., and L.L. Shoemaker. 1987. *Generalized Watershed Loading Functions for Streamflow Nutrients*. Water Resources Bulletin 23(3):471-478.

U.S. EPA Region III. October 9, 2003. *Total Maximum Daily Load for Sediment and Nutrients: Wissahickon Creek Watershed.* Available at http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/wissahickon/index.htm

Harpeth River Watershed
Stormwater Source TMDL (2002)
Tennessee, EPA Region 4

TMDL at a Glance



Subbasin:	Harpeth River
Watershed size:	863 square miles
Key beneficial uses:	Fish and aquatic life
Impaired by:	Siltation and habitat alteration
Pollutant(s):	Sediment
Sources considered:	*Point source* – 23 wastewater treatment plants (WWTPs), 33 permitted construction sites, and municipal separate storm sewer systems (MS4s) (Phase I and II) *Nonpoint source* – agriculture, roadways, and urban sources
Model(s) used:	Watershed Characterization System Sediment Tool
TMDL Web link:	http://www.state.tn.us/environment/wpc/tmdl/approvedtmdl/HarpSed07.pdf

TMDL Highlights

Affected water uses:
- Fish and aquatic life

Applicable WQS:
- Sediment (narrative) – protection of fish and aquatic life, biological integrity

Technical approach:
- *Key indicator(s)* – Sediment and total suspended solids (TSS)
- *Source assessment* – The watershed characterization system (WCS) sediment tool (v.2.1), an ArcView GIS-based program developed by U.S. EPA Region IV, was used to determine the target average annual sediment loading values for reference watersheds in Level IV ecoregions, as well as the impaired watersheds. The sediment tool uses GIS data, the Universal Soil Loss Equation (USLE), and sediment delivery equations to estimate soil erosion and sediment delivery. The sediment tool also can be used to evaluate the effects of changing land uses and implementing various BMPs.

Allocations:
- *Point source* – The wasteload allocation (WLA) for each of the 23 NPDES regulated municipal and industrial WWTPs was set equal to their current NPDES permit limits for either TSS or turbidity. The WLA for NPDES regulated construction sites and MS4s is calculated as the average annual sediment load (lbs/acre/year) for a given

subwatershed, resulting in percent reductions ranging from about 33% to 90% depending on the subwatershed.

- *Nonpoint source* – The load allocation (LA) is calculated as the average annual sediment load for a given subwatershed, resulting in similar percent reductions. The LA includes NPDES Phase II MS4 discharges because Phase II permits had not yet been issued when the TMDL was developed.

Implementation:

- Implementation of the LAs for nonpoint sources will be accomplished within the framework of Tennessee's watershed approach. The watershed approach is based on a five-year cycle and encompasses planning, monitoring, and assessment and relies on participation at the federal, state, local, and nongovernmental levels. The approach is documented on the TDEC web site (see references).
- The Harpeth River Watershed Management Plan (TDEC 2002b) describes the partnerships among government agencies and stakeholder groups and the roles that each play in improving water quality and reducing pollutant loading. The TMDL states that these stakeholders "... should, at a minimum, be directed to: implement and maintain conservation farming, including conservation tillage, contour strips and no till farming; install grass buffer strips along streams; reduce activities within riparian areas; and minimize road and bridge construction impacts on streams."
- In Tennessee, aquatic resource alteration permits are required for any alteration of state waters not requiring a federal permit (TDEC 2000).
- Monitoring will be guided by the results of a Harpeth River watershed sediment study conducted by the Harpeth River Watershed Association and the Cumberland River Compact.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Tennessee Department of Environment and Conservation (TDEC), Division of Water Pollution Control; US EPA Region IV; and Tetra Tech, Inc. 10 May 2002a. *Total Maximum Daily Load (TMDL) for Siltation and Habitat Alteration in the Harpeth River Watershed (HUC 05130204), Cheatham, Davidson, Dickson, Hickman, Rutherford, and Williamson County, Tennessee*. Available at http://www.state.tn.us/environment/wpc/tmdl/approvedtmdl/HarpSed07.pdf

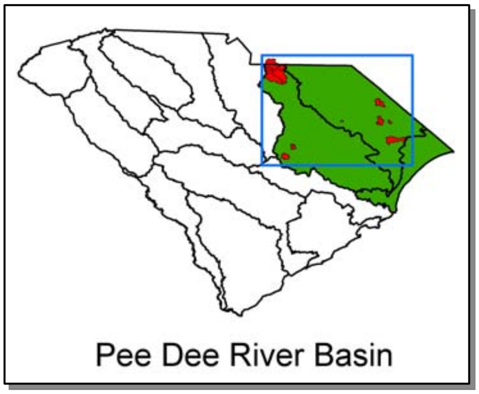
TDEC. 2002b. *Harpeth River Watershed Management Plan.* Available at http://state.tn.us/environment/wpc/watershed/wsmplans/harpeth/

TDEC. 2000. *Aquatic Resource Alteration*, Chapter 1220-4-7 (Revised).

TDEC. Watershed Management Approach web site. Available at http://www.state.tn.us/environment/wpc/watershed/

Pee Dee River Basin
Stormwater Source TMDL (2005)
South Carolina, USEPA Region 4

TMDL at a Glance



Subbasin: Pee Dee River Basin and Lynches River Basin
Watershed size: Pee Dee River Basin: 3,425 square miles, excluding the Lynches River and Black River Basins; Lynches River Basin: 1,387 square miles
Key beneficial uses: Primary contact recreation
Impaired by: Pathogens
Pollutant(s): Fecal coliform
Sources considered: *Point source* – Wastewater treatment plants, municipal separate storm sewer systems (MS4s), and separated sewer systems (SSOs). Fecal coliform sources associated with MS4s include leaking sewers, SSOs, pets, and wildlife.
Nonpoint source – Wildlife (the large population of deer in the watersheds may be a significant source of fecal coliform loading), agricultural activities (land application of manure from animal (poultry) feeding operations, uncovered animal waste stockpiles, cows allowed direct access to creeks), failing onsite wastewater disposal systems (septic systems, irrigation, and cesspools) and illicit discharges, and domesticated animals
Model(s) used: Load Duration Curve
TMDL Web link: Final TMDL document not available electronically

TMDL Highlights

Affected water uses:
- Primary contact recreation

Applicable WQS:
- Not to exceed a geometric mean of 200 colony forming units (cfu)/100 mL based on five consecutive samples during any 30-day period, nor shall more than 10 percent of the total samples during any 30-day period exceed 400 cfu/100 mL.

Technical approach:
- *Key indicator(s)* – Fecal coliform (numeric)
- *Source assessment* – Analyses were performed using fecal coliform data and precipitation data from 1994 to 2002 to estimate the relationship between rainfall and elevated fecal coliform bacteria loads at 16 water quality monitoring stations. The estimated load included loading from all sources including continuous point source discharges, leaking sewer lines, MS4s, SSOs, failing on-site waste disposal systems, land application fields, wildlife, pets, and livestock. The

analysis and load duration curves for each monitoring station demonstrate that exceedances at many of the stations are the result of nonpoint source loading.
- *Model* – The load duration curve (LDC) approach was used, which incorporates the assimilative capacity of a waterbody as a function of flow and allows for the maximum allowable loading to vary with flow conditions. LDC analysis involves using measured or estimated/modeled flow data, instream criteria, and concentration/load data to assess flow conditions in which water quality exceedances are occurring.

Allocations:
- *Point source* – To estimate the wasteload allocation (WLA) for each wastewater treatment plant (WWTP), the TMDL uses the permitted average flow rate for each point source discharge and the water quality criterion concentration. Because a WLA for each MS4 cannot be calculated as an individual value, WLAs for MS4s are expressed as a percent reduction goal derived from the LDC for nonpoint sources. Where multiple monitoring stations were located within the same MS4 jurisdiction, the station with the highest percent reduction goal was selected as the overall reduction requirement for the TMDL for each station within the MS4 jurisdiction. A WLA percent reduction was not calculated for NPDES permitted WWTPs because it was assumed that the continuous dischargers are adequately regulated under existing permits.
- *Nonpoint source* – The nonpoint load reductions were estimated for each monitoring station by calculating the difference between the existing loading and the load duration curve. The difference is the percent reduction, and the hydrologic condition class (moist, mid-range, and dry) with the largest percent reduction selected as the critical condition and the overall percent reduction goal for the LA.

Implementation:
- The LDC approach can be used to identify appropriate measures for implementation.

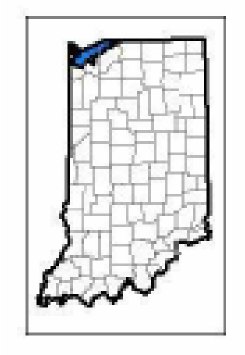
Cost:
- Cost information is not available in the TMDL documentation.

References:

U.S. EPA Region 4. September 2005. *Total Maximum Daily Loads for Fecal Coliform for Hills Creek, Lynches River, North and South Branch of Wildcat Creek, Flat Creek, Turkey Creek, Nasty Branch, Gulley Branch, Smith Swamp, Little Pee Dee River, Maple Swamp, White Oak Creek, and Chinners Swamp of the Pee Dee River Basin, South Carolina.* Atlanta, GA.

Lake Michigan Shoreline
Stormwater Source TMDL (2004)
Indiana, USEPA Region 5

TMDL at a Glance



Subbasin:	Lake Michigan shoreline in Lake, Porter, and La Porte Counties
Watershed size:	536 square miles
Key beneficial uses:	Swimming
Impaired by:	Pathogens
Pollutant(s):	Pathogens
Sources considered:	*Point source* – None; CSO's upstream, but not addressed in TMDL *Nonpoint source* – seven tributaries; residential septic systems from 11 locations; wildlife (deer, raccoons, and seagulls); swimmers, beach restroom facilities, beach sands, and algae at six major beach locations; and boaters at three marinas
Model(s) used:	Environmental Fluid Dynamics Code
TMDL Web link:	http://www.in.gov/idem/programs/water/tmdl/finalrpt/lkmichtmdl.doc

TMDL Highlights

Affected water uses:
- Swimming

Applicable WQS:
- E.coli (numeric)

Technical approach:
- *Key indicator(s)* - E.coli
- *Source assessment* – The existing load from the tributaries was calculated by estimating the *E. coli* load from each tributary during the 1999 beach season. The estimated load from swimmers at beaches was based on estimates of the number of people visiting the lakeshore beaches each day and 0.14 grams as the mean amount of fecal material shed per swimmer (Gerba 2000). Wildlife loads were calculated by estimating the wildlife population and the amount of *E. coli* contributed by each organism based on literature sources. Best professional judgment was used to calculate the load from boating activity by estimating the number of boaters and the percent of generated *E. coli* waste reaching the water (10 percent). Estimates of the loads from residential septic systems were based on U.S. census data and literature values for average daily discharge, septic effluent *E. coli* concentration, and septic failure rates.
- *Model* **–** Environmental Fluid Dynamics Code or EFDC (Hamrick 1992), a hydrodynamic fate and transport model, was used to establish baseline conditions and three allocation scenarios. The model has

three main components: (a) the *E. coli* loads, (b) water motion from physical transport, and (c) kinetic reactions that affect the fate of *E. coli*.

Allocations:

- *Nonpoint source only* – The seven tributaries were allocated percent reductions in *E. coli* load (counts/recreation season) ranging from 0 to 90.5%. However, the TMDL does not address the upstream sources transported through these tributaries. At the time the report was published, TMDLs were being developed for several tributaries. Two of the six beaches were allocated 80% reductions. The TMDL did not allocate reductions for any of the other nonpoint sources (the other four beaches, residential septic sources, boats, and wildlife).

Implementation:

- The TMDL documents several activities that should be implemented, including, including: (1) implementing tributary TMDLs to achieve water quality standards, including efforts to reduce *E. coli* loads associated with combined sewer overflows, septic systems, and livestock; (2) continuing efforts to reduce loads from septic systems through public education and maintenance and replacement programs; and (3) continuing efforts to reduce *E. coli* loads associated with boat pumpouts.

Cost:

- Cost information is not available in the TMDL documentation.

References:

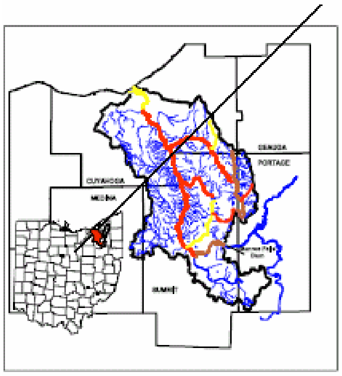
Gerba, C. 2000. *Assessment of Enteric Pathogen Shedding by Bathers during Recreational Activity and its Impact on Water Quality.* Quantitative Microbiology. 2:55-68.

Hamrick, J.M. 1992. *A Three-dimensional Environmental Fluid Dynamic Computer Code: Theoretical and Computational Aspects.* SRAMSOE #317, Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA.

Tetra Tech, Inc., for Indiana Department of Management (IDEM). August 2004. *Lake Michigan Shoreline TMDL for E. coli Bacteria.* Available at http://www.in.gov/idem/programs/water/tmdl/finalrpt/lkmichtmdl.doc

Lower Cuyahoga River
Stormwater Source TMDL (2003)
Ohio, USEPA Region 5

TMDL at a Glance



Subbasin: Lake Erie Basin

Watershed size: 813 square miles (Cuyahoga River Basin)

Key beneficial uses: Aquatic life, recreation activities, and public water supply; part of the Cuyahoga River is a designated state scenic river and several stream segments within the basin have been designated as state resource waters.

Impaired by: Organic and nutrient enrichment, bacteria, toxicity, low instream dissolved oxygen, flow alteration, degraded habitats, and sedimentation

Pollutant(s): Phosphorus, nutrients, fecal coliform

Sources considered: *Point sources* – Wastewater treatment plants, municipal separate storm sewer systems (MS4s), and combined sewer overflows (CSOs)
Nonpoint sources – unregulated runoff over land, septic systems, reservoir and diversions, groundwater

Model(s) used: Load Duration Curve, Streamflow Hydrograph Separation and Analysis, Soil and Water Assessment Tool, Multiple Discharge version of the Simplified Method Program, XP Stormwater Management Model, Water Quality Analysis Simulation Program

TMDL Web link: http://www.epa.state.oh.us/dsw/tmdl/Cuyahoga_lower_final_report.pdf

TMDL Highlights

Affected water uses:

- Cold water habitat, warmwater habitat (WWH), modified warmwater habitat, and limited resource water aquatic life uses; primary and secondary contact recreation; and public water supply.

Applicable WQS:

- *Narrative* – Free from suspended solids and other substances that enter the waters as a result of human activity and that will settle to form objectionable sludge deposits, or that will adversely affect aquatic life.
- *Numeric* – Dissolved oxygen (DO): Instantaneous minimum = 4.0 (WWH) mg/L (Cuyahoga River Ship Cannel DO instantaneous minimum = 1.5 mg/L); 24-hour average = 5.0 (WWH) mg/L. Fecal coliform bacteria: Geometric mean = 1,000 (most probable number or mpn); maximum = 2,000 mpn. Ecoregion biological criteria also apply.

Technical approach:

Key indicator(s)

- Total phosphorus, fecal coliform, dissolved oxygen, biological and habitat indices

Source assessment

- *Nonpoint sources* – The existing load from nonpoint source (NPS) runoff was not calculated—it was estimated as the difference between the total known instream load and the sum of the other input loads (including loss through the assimilative capacity of the river). The loads from septic systems were calculated based on a model developed by Mandel (1993) that uses system characterization by performance type and location and the number of systems. This method is also used in the Generalized Watershed Loading Functions model.
- *Point sources* – A daily load value per point source discharger was calculated by multiplying the daily flow and daily concentration with a conversion factor. To estimate the load from CSOs, the City of Akron used Stormwater Management Tool (XP-SWMM) and Water Quality Analysis Simulation Program (WASP) to determine the system loads and impacts to the stream water quality.
- *Groundwater* – The portion of the stream flow due to groundwater was calculated using the USGS Streamflow Hydrograph Separation and Analysis (HYSEP) model, a computer program that can be used to separate a streamflow hydrograph into baseflow and surface-runoff components (USGS 1996).
- *Future growth* – An area-weighted approach based on the average of each county's expected growth was used to factor future growth into the TMDL. This information was based on U.S. Census Bureau data and weighted by the land area of the county within the Cuyahoga watershed.
- *Instream loss* – The instream loss term due to assimilative capacity was estimated as the median for the daily total observed load in the stream minus the daily total known input load for days without runoff.
- *Model* – The load duration curve (LDC) approach was used, which identifies the allowable loads under the full range of flow conditions and provides a framework for comparing observed water quality data to the allowable load to evaluate when exceedances occur.

Allocations:

- *Point source*s – The CSO total phosphorus and fecal coliform allocations were determined based on the long-term control plans (LTCPs) for Akron and Cleveland. Specifically, each city's estimated overflow volume after LTCP strategy implementation was multiplied by an expected CSO-specific concentration based on the proposed control technologies for the various CSOs. A procedure was developed to relate the CSO overflow events to the LDC method.
- *Nonpoint source*s – Land cover was an important component for calculating both the total phosphorus and fecal coliform nonpoint source existing loads and allocations. The necessary runoff reductions were based on the additional load reductions needed on wet weather days after incorporating all other load reductions. The GIS-based Soil and Water Assessment Tool (SWAT) was used to support the allocation analysis. SWAT uses digital elevation information and other information to define watersheds so that land cover, soil data, and other information layers can be analyzed for each watershed.

Implementation:

- *Habitat goals* – Physical habitats within the Cuyahoga River were evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed for the Ohio EPA for streams and rivers in Ohio. The QHEI can be used as a guide to direct restoration efforts for habitat and sediment load reductions and provides a monitoring tool to measure progress towards habitat and sediment load goals.

- *Wetland protection* – The TMDL recommends that no new permits be issued that impact Category 2 and 3 wetlands in the Lower Cuyahoga River TMDL area. In addition, the TMDL states that all permits issued for impacts to Category 1 wetlands should ensure that mitigation is conducted on site if possible and at a minimum within the watershed area. Finally, if mitigation cannot be conducted on site or within the watershed area, then the TMDL states that a permit should not be issued for the proposed project.
- *Riparian protection* – Two mechanisms are proposed in the TMDL—(1) the passage of stream setback ordinances similar to the one passed in Summit County, and (2) the Cuyahoga Valley National Park's riverbank stabilization plan to address erosion threats to important park infrastructure (in development when the TMDL was written).
- *Stakeholders* – The TMDL states that one of the areas in which the Lower Cuyahoga River TMDL area excels "… is the formation of watershed groups promoting awareness, stewardship, and education." The TMDL mentions key partners, including the Cuyahoga Valley National Park, county park programs, and watershed-based groups located within the Lower Cuyahoga River basin.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Mandel, R. 1993. The Impact of Septic Systems on Surface Water Quality. Unpublished M.S. dissertation. School of Civil and Environmental Engineering, Cornell University. Ithaca, NY.

Ohio Environmental Protection Agency, Division of Surface Water. September 2003. *Total Maximum Daily Loads for the Lower Cuyahoga River.* Available at http://www.epa.state.oh.us/dsw/tmdl/Cuyahoga_lower_final_report.pdf

U.S. Geological Survey (USGS). 1996. *HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis.* Water Resource Investigations Report 96-4040. Lemoyne, PA.

Middle Rio Grande River Stormwater Source TMDL (2002) New Mexico, USEPA Region 6

TMDL at a Glance

Subbasin: Rio Grande River Basin
Watershed size: 3,204 square miles
Key beneficial uses: State uses affected: limited warmwater fishery, secondary contact recreation, and irrigation. The two segments for which this TMDL is written also have the designated uses of livestock watering and wildlife habitat. Tribal uses affected: primary contact ceremonial, primary contact recreation, secondary contact recreation, warmwater fishery, agricultural water supply.
Impaired by: Pathogens
Pollutant(s): Fecal coliform
Sources considered: *Point source* – Phase 1; City of Albuquerque municipal separate storm sewer system (MS4) and other individual National Pollutant Discharge Elimination System (NPDES) permittees, including four wastewater treatment plants (WWTPs) and four other discreet conveyances
Nonpoint source – Livestock rearing and operations, wildlife, migratory birds, domestic animals and pets
Model(s) used: Hydrotech© computer program and Mass Balance
TMDL Web link: http://www.nmenv.state.nm.us/swqb/Middle_Rio_Grande-Fecal_Coliform_TMDL-May2002.pdf

TMDL Highlights

Affected water uses:

- Warmwater fishery and limited warmwater fishery, primary and secondary contact recreation, primary contact ceremonial, and irrigation.

Applicable WQS:

- The Middle Rio Grande River is divided into two segments. The water quality criteria (WQC) for one of the segments states that the monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL, and no single sample shall exceed 2,000/100 mL. The WQC for the other segment states that the monthly geometric mean of fecal coliform bacteria shall not exceed 200/100 mL, and no single sample shall exceed 400/100 mL. The Pueblo of Sandia has tribal surface water quality standards and designated uses. For example, from April to September 30, the primary contact recreation standard is a geometric mean maximum of 100 colonies/100 mL based on a minimum of five samples taken over a maximum of 30 days and a single sample maximum of 200 colonies/100 mL. Other tribal standards apply for other uses.

Technical approach:

- *Key indicator(s)* – Fecal coliform (numeric)
- *Source assessment* – The main transport of fecal coliform and the focus of this document are stormwater conveyances. During the annual monsoon rain season (May through September), the four non-wastewater conveyance systems collect and transport fecal coliform from various sources in the watershed to the river. All exceedances based on the 1999 monitoring data were observed after summer rain

events. The following sources do not appear to be large contributors to the fecal coliform exceedances: failing or ill-sited septic systems, leaks in sanitary sewer systems, overflows from surcharged sanitary sewers, illicit connections of sanitary sewers to storm sewer collection systems, and unidentified broken sewer lines.
- *Model* – A Hydrotech© computer program was used to calculate the critical low flow value between May and September. The allocations were determined using a simple calculation based on the water quality criterion and applicable flows.

Allocations:

- *Point source* – Numeric targets for four stormwater conveyances were established in this TMDL and assigned a wasteload allocation (WLA).
- *Nonpoint source* – The load allocations (LAs) were calculated by determining the WLA for a particular arroyo or drain based on the mean annual maximum flow and the water quality criterion and then by subtracting that WLA from the corresponding loading capacity.

Implementation:

- The implementation approaches section describes several conventional best management practices (BMPs) and their estimated costs.
- There are other conveyances to the Middle Rio Grande in addition to the four addressed in this TMDL, and the state hopes that the Phase II Stormwater Management Program will address all of them.
- The TMDL mentions the New Mexico nonpoint source (NPS) task force, comprised of government, tribes and pueblos, soil and water conservation districts, industry, and environmental organizations. This task force was created to review Clean Water Act Section 319 proposals and to provide information to stakeholders and the public about NPS issues.

Cost:

- Cost information is not available in the TMDL documentation.

References:

New Mexico Environment Department, Surface Water Quality Bureau. May 2002. *Middle Rio Grande Total Maximum Daily Load (TMDL) for Fecal Coliform.* Available at http://www.nmenv.state.nm.us/swqb/Middle_Rio_Grande-Fecal_Coliform_TMDL-May2002.pdf

Mantua Reservoir
Stormwater Source TMDL (2003)
Utah, USEPA Region 8

TMDL at a Glance

Subbasin:	Mantua Reservoir watershed
Watershed size:	The watershed size is not included in the TMDL, and the surface area of the reservoir is 554 acres.
Key beneficial uses:	Secondary contact recreation; coldwater species of game fish and other coldwater aquatic life, including the necessary aquatic organisms in their food chain; and agricultural uses, including irrigation of crops and stock watering
Impaired by:	Nutrients
Pollutant(s):	Total phosphorus (TP), dissolved oxygen (DO), and pH
Sources considered:	*Point source* – Mantua fish hatchery (Utah Pollution Discharge Elimination System permit) and a pump station installed by Brigham City to pump agricultural runoff water *Nonpoint source* – Agriculture and background due to spring flow
Model(s) used:	Carlson's Trophic State Index, steady-state mass balance, chlorophyll a and Secchi depth response model
TMDL Web link:	http://www.waterquality.utah.gov/TMDL/Mantua_Reservoir_TMDL.pdf

TMDL Highlights

Affected water uses:

- Secondary contact recreation; and coldwater species of game fish and other coldwater aquatic life, including the necessary aquatic organisms in their food chain

Applicable WQS:

- The following numeric criteria apply to the coldwater fishery beneficial use: 6.5-9.0 pH; minimum 6.5 mg DO/L (30-day average), 9.5/5.0 mg DO/L (7-day average), and 8.0/4.0 mg DO/L (1-day average); and total phosphorus (indicator) 0.5 mg TP/L for rivers and streams and 0.025 mg/L for lakes and reservoirs. Note: For the DO criteria, the first number (e.g., 9.5 in 9.5/5.0 above) applies when early life stages are present; the second number (e.g., 5.0) applies when all other life stages are present.
- The TMDL targets are to achieve: (1) the applicable water quality criteria for DO in the upper 50% of the reservoir's water column, (2)

the pH standard of 6.5-9.0 for at least 90% of the in-lake measurements, and (3) 25 µg TP/L as the in-lake total phosphorus concentration as an annual average of surface values.

Technical approach:

- *Key indicator(s)* – Total phosphorus (numeric)
- *Source assessment* – The Mantua fish hatchery is the only permitted point source in the watershed, which contributes 29% of the TP load. However, because phosphorus is listed as a pollution "indicator" in the water quality standards, the hatchery permit did not include permit limits for phosphorus, only sediment. There is an additional point source—a pump station installed by Brigham City to pump agricultural runoff water that contributes 25% of the TP load. The other sources include other agriculture (15% of the TP load) and background due to spring flow (31%).
- *Models* – A steady-state mass balance (phosphorus reduction response) model—as described by Vollenweider (1976), Reckhow (1979), and EPA (1983)—was used to estimate the inflow TP load reduction required to meet the mean annual in-lake TP concentration of 0.025 mg/L. The Carlson Trophic State Index (TSI) (Carlson 1977) and a chlorophyll *a* and Secchi depth response model (Carlson 1977) were used to predict the expected trophic condition given a 0.025 mg/L TP target concentration.

Allocations:

- *Point source* – The TP loads were allocated to point sources based on conservative, best professional judgment that the individual reductions could be met. The two point sources—the pump station and Mantua fish hatchery—received 100 and 15 percent reductions, respectively.
- *Nonpoint source* – The two nonpoint sources—the Box Elder Creek diversion and Bunderson Spring/Dam Creek—each received 20 percent reductions.

Implementation:

- The reservoir will continue to be monitored on a biannual basis to track changes in trophic state.
- *Point sources* – The agricultural pump station is no longer a source of TP—the water was diverted to create a wetland to mitigate for a highway project. In addition, the fish hatchery has changed its feeding practices from a low-efficiency sinking feed to a high-efficiency, low-phosphorus, floating feed. However, the document states that the Mantua fish hatchery should clean the sedimentation basin at the lower end of the hatchery on an annual basis. A diagnostic and feasibility report or clean lakes study (Loveless 1998) provided several other suggestions for additional activities to restore the reservoir using agricultural and aquacultural best management practices (BMPs).
- *Nonpoint sources* – In addition to annually reconstructing and maintaining the existing sediment retention basin located upstream from the Box Elder Creek diversion, the TMDL lists several other BMPs that could reduce TP loads from nonpoint sources.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Carlson, R.E. 1977. A Trophic State Index for Lakes. *Limnol. Oceanogr*. 22(2):361-9.

Loveless, R.M. 1998. *Diagnostic and Feasibility Report on Mantua Reservoir.* Mountainlands Association of Governments, Provo, Utah.

Reckhow, K.H. 1979. *Quantitative Techniques for the Assessment of Lake Quality*. U.S. EPA Office of Water Planning and Standards, Washington DC. EPA 440/5-79-015.

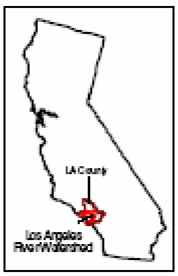
U.S. EPA. 1983. *Technical Guidance Manual for Performing Wasteload Allocations.* Book IV: Lakes and Impoundments. Washington, DC. EPA 44/4-84-019.

Utah Department of Environmental Quality, Division of Water Quality, TMDL Section. 23 May 2003. *Mantua Reservoir Total Maximum Daily Load (TMDL).* Available at http://www.waterquality.utah.gov/TMDL/Mantua_Reservoir_TMDL.pdf

Vollenweider, R.A. 1976. Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication. *Mem. Inst. Ital. Idrobiol*. 33:53-83.

Los Angeles River Watershed
Stormwater Source TMDL (2005)
California, USEPA Region 9

TMDL at a Glance



Subbasin:	Los Angeles River
Watershed size:	834 square miles
Key beneficial uses:	Aquatic life and water supply
Impaired by:	Metals
Pollutant(s):	Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), and selenium (Se)
Sources considered:	*Point sources* – Wastewater effluent from the Tillman, Los Angeles-Glendale, and Burbank treatment plants, as well as an estimated 1,600 other permittees in the Los Angeles River watershed, including: other wastewater treatment plants (WWTPs), municipal stormwater (3 facilities—two municipal separate storm sewer systems (MS4s) and Caltrans), industrial-related stormwater, construction-related stormwater, major individual facilities (3, including the Pacific Terminals LLC Tank Farm, Boeing Company Santa Susana Field Lab, and Metropolitan Transit Authority), minor individual facilities, and general discharges *Nonpoint sources* – Open space and direct atmospheric deposition
Model(s) used:	Environmental Fluid Dynamics Code 1-D, Water Quality Analysis Simulation Program, Loading Simulation Program in C++, Load Duration Curve
TMDL Web link:	http://www.swrcb.ca.gov/rwqcb4/html/meetings/tmdl/tmdl_ws_los_angeles.html

TMDL Highlights

Affected water uses:

- Aquatic life (i.e., wildlife habitat; warm freshwater habitat; rare, threatened, or endangered species; wetland habitat; and marine habitat) and water supply (i.e., groundwater recharge)

Applicable WQS:

- *Narrative* – Toxic substances shall not be present at levels that will bioaccumulate in aquatic life resources to levels harmful to aquatic life or human health
- *Numeric* – The numeric targets in this TMDL are based on the water quality objectives in the California Toxics Rule (CTR). The CTR establishes freshwater, acute and chronic, hardness-dependent aquatic life criteria for Cd, Cu, Pb, Zn, and Se. The CTR values for Cd, Cu, Pb, and Zn are based on the dissolved fraction and are hardness dependent, and the freshwater CTR standard for Se is based on the total recoverable metals concentration.
- Separate targets are developed for dry and wet weather because hardness values and flow conditions in the Los Angeles River and tributaries vary during dry and wet weather.

Technical approach:

- *Key indicator(s)* – Copper, lead, zinc, cadmium, and selenium (narrative and numeric)
- *Source assessment* – During dry weather, most of the flow in the Los Angeles River is comprised of wastewater effluent from the Tillman, Los Angeles-Glendale, and Burbank treatment plants. During the dry season, wastewater treatment plant (WWTP) mean monthly discharges range from 70 to 100 percent of the monthly average flow. In contrast, in months with rain events, WWTP monthly average discharges equaled less than 20 percent of the monthly average flow. The sources of Se are not understood, and additional study is required to determine whether the Se contributions are from natural or background sources.
- *Models* – Two different hydrodynamic and water quality models were used to calculate the existing load during dry and wet weather conditions. The Environmental Fluid Dynamics Code 1-D (EFDC1D) was used to model the hydrodynamic characteristics of the Los Angeles River and its tributaries during dry weather. EFDC1D was linked to the Water Quality Analysis Simulation Program (WASP5) to simulate water quality within the Los Angeles River. U.S. EPA's Loading Simulation Program in C++ (LSPC) was used to simulate the hydrologic processes and pollutant loading from the Los Angeles River watershed during wet weather over a 12-year period. In addition, load duration curves were used to establish the wet weather loading capacities for Cd, Cu, Pb, and Zn.

Allocations:

- TMDLs were developed for wet and dry conditions because of the variability in flows, water hardness, sources, and relative magnitude of loadings between these conditions. Wet-weather targets are developed for storm conditions based on acute criteria because it would be inappropriate to apply criteria based on long-term exposure to storms that are generally short-term and episodic in nature. Wet and/or dry weather allocations for each metal were determined based on available water quality data.
- *Point sources* – "Grouped" dry and wet weather wasteload allocations (WLAs) were established for the two MS4 permits and the Caltrans permit. The loadings associated with indirect air deposition are included in the wet weather stormwater WLAs. The watershed is divided into six subwatersheds with jurisdictional groups assigned to each subwatershed. Each municipality and permittee will be responsible for the WLAs shared by their jurisdictional group, and will not necessarily be given a specific allocation for the land uses under their jurisdiction.
- *Nonpoint sources* – Mass-based wet and dry weather LAs were calculated for open space and direct air deposition. "Open space" refers to open space that contributes metals directly to the river and not through the storm drain system (about 200 square miles).

Implementation:

- The wet and dry weather models should provide useful in evaluating management scenarios to help achieve load reductions in TMDL implementation. In addition, a watershed approach is implemented in this TMDL; that is, metals allocations are developed for upstream reaches and tributaries that drain to impaired reaches.
- This TMDL includes an implementation plan. In addition, the monitoring section includes several components (the entities responsible for implementing each component are in parentheses):

ambient monitoring (MS4s and Caltrans), compliance assessment monitoring (Tillman, LA-Glendale, and Burbank WWTPs), and special studies (no entities specified).

- Los Angeles has an agreement between 18 municipalities to implement the stormwater regulations jointly.

Cost:

- Cost information is not available in the TMDL documentation. However, this TMDL includes a cost analysis based on a potential phased implementation strategy that involves combining structural and non-structural BMPs. The cost analysis focuses on compliance with the grouped WLA for MS4 and Caltrans stormwater permittees in the urban areas of the watershed and includes a cost analysis of street sweeping (a non-structural BMP), infiltration trenches and sand filters (structural BMPs), as well as the results of a region-wide cost study.

References:

U.S. EPA Region 9 and California Regional Water Quality Control Board (CRWQCB) Los Angeles Region. June 2005. *Total Maximum Daily Loads for Metals: Los Angeles River and Tributaries*. Available at http://www.swrcb.ca.gov/rwqcb4/html/meetings/tmdl/tmdl_ws_los_angeles.html

San Diego Creek and Newport Bay Stormwater Source TMDL (1999) California, USEPA Region 9

TMDL at a Glance

Subbasin:	Central Orange County in the southwest corner of the Santa Ana River Basin
Watershed size:	154 square miles
Key beneficial uses:	Groundwater recharge; navigation; water contact and non-contact recreation; water non-contact recreation; commercial and sport fishing; warm freshwater habitat; preservation of biological habitats of special significance; wildlife habitat; rare, threatened, or endangered species; spawning, reproduction, and development; marine habitat; shellfishing harvesting; and estuarine habitat
Impaired by:	Nutrients
Pollutant(s):	Phosphorus and nitrogen
Sources considered:	*Point source* – Industrial permits; MS4 (Orange County); Individual Permits include permit requirements for nurseries and other NPDES permittees. There are three large nurseries and numerous, smaller nurseries. Other point sources include those with waste discharge requirements and specific effluent limits for nitrogen compounds; and stormwater sources without specific numeric effluent limits for nutrients. *Nonpoint source* – The nonpoint sources are mainly agricultural. Other nonpoint sources include open space, particularly during storm events; atmospheric deposition; unregulated nurseries; shallow groundwater that contributes to base flows in storm channels and may exchange with the saltwater in Newport Bay; and nutrients stored in plant biomass and bay sediments that may be resuspended into the water column.
Model(s) used:	Mass Balance
TMDL Web link:	http://www.epa.gov/owow/tmdl/examples/nutrients/ca sdnbay.pdf

TMDL Highlights

Affected water uses:

- The beneficial uses listed above are affected in one or more of the following waterbodies—upper and lower Newport Bay, San Diego Creek (divided into two reaches), or tributaries to San Diego Creek

Applicable WQS:

- *Narrative* – Separate narrative standards exist for algae and dissolved oxygen in enclosed bays and estuaries (Newport Bay) and inland surface waters (San Diego Creek and tributaries).
- *Numeric* – Reach 1 in San Diego Creek has a 13 mg/L total inorganic nitrogen (TIN) water quality objective, and reach 2 has a 5 mg/L TIN objective. There are no numeric water quality objectives for phosphorus on San Diego Creek.

Technical approach:

- *Key indicator(s)* – Total phosphorus (TP) and total nitrogen (TN)
- *Source assessment* – Several studies determined that about 80% of the nitrate-nitrogen loading to Newport Bay was from the Peters Canyon Wash, the main tributary to San Diego. San Diego Creek contributes the vast majority (80%) of the TP load to Newport Bay. Studies also indicated that increases in particulate levels (sediment)

and TP levels are closely related. Data were lacking regarding the nutrient load contribution of shallow groundwater to base flows in storm channels, which may exchange with the saltwater in Newport Bay. The amount of nutrients stored in plant biomass and bay sediments that can be resuspended into the water column was another unknown.

- *TMDL endpoints* – The total phosphorus TMDL is based on a 50% reduction in current phosphorus loading to Newport Bay, and the total nitrogen TMDL is based on a 50% reduction in the current low-flow loading of TN to Newport Bay. The California Regional Water Quality Control Board (Regional Board) also amended its Santa Ana Basin Plan to require a 50% reduction in sediment loading to Newport Bay.
- *Model* – Analyses based on flow rates and the applicable standards or targets were used to estimate loads and allocations.

Allocations:

- *Point source* – The point sources with TN wasteload allocations (WLAs) include urban runoff and other NPDES discharges, and the point sources with TP WLAs include urban areas and construction sites. EPA would normally establish individual WLAs for each NPDES discharger, but did not do so because the Regional Board was scheduled to adopt specific WLAs for individual NDPES dischargers in April 1998.
- *Nonpoint source* – The TN load allocations (LAs) include nurseries, agricultural discharges, and undefined sources. The TP LAs include agricultural land and open space.
- Because Total Inorganic Nitrogen (TIN) levels are elevated throughout the year, the TMDLs include allocations that apply during the wet and dry seasons. However, wet season allocations only apply during non-storm events, since exceedances of the standard are not observed when flow rates are above 50 cubic feet per second.

Implementation:

- The Regional Board's TMDL and associated Basin Plan provisions dated December 9, 1997, along with subsequent modifications dated January 23, 1998, and March 6, 1998, describe the following implementation activities:

  - issuing waste discharge requirements to currently unregulated nurseries greater than 5 acres and with discharges that contain greater than 1 mg TIN/L;
  - revising existing waste discharge requirements for currently regulated nursery operations;
  - revising existing NPDES permits for which discharges of nutrients exceed 1 mg TIN/L;
  - requiring the development of nutrient management plans for all agricultural operations not regulated by waste discharge requirements; and
  - requiring that the co-permittees of the stormwater permit submit an analysis of best management practices (BMPs) that will be implemented to achieve the urban runoff targets.

- In addition to nutrient reductions, the loading capacity of Newport Bay was expected to increase with implementation of proposed dredging of sedimentation basins in upper Newport Bay. This project would increase tidal flushing of upper Newport Bay, diluting the nutrient inputs from the San Diego Creek watershed and other tributaries.

Cost:

- Cost information is not available in the TMDL documentation.

References:

California Regional Water Quality Control Board, Santa Ana Region. 1997. Resolution No. 97-77. Amendment to the Santa Ana Region Basin Plan.

California Regional Water Quality Control Board, Santa Ana Region. 1997. *Staff Report on the Nutrient Total Maximum Daily Load for Newport Bay/San Diego Creek.*

U.S. EPA Region 9. *Total Maximum Daily Loads for Nutrients: San Diego Creek and Newport Bay, California*. Available at http://www.epa.gov/owow/tmdl/examples/nutrients/ca_sdnbay.pdf

Chester Creek, University Lake, and Westchester Lagoon Stormwater Source TMDL (2005) Alaska, USEPA Region 10

TMDL at a Glance

Subbasin:	Not listed
Watershed size:	30 square miles
Key beneficial uses:	Drinking, culinary, and food processing water supply
Impaired by:	Pathogens
Pollutant(s):	Fecal coliform
Sources considered:	*Point sources* – Municipal separate storm sewer systems (MS4s) and the sources associated with various types of land cover within the MS4 boundaries *Nonpoint sources* – Domestic pets, waterfowl, and wildlife, septic systems, indigent people living near creeks, leaking sewer lines, and natural background
Model(s) used:	Stormwater Management Model
TMDL Web link:	http://www.dec.state.ak.us/water/tmdl/pdfs/chestercrwatershedTMDLEPAFinal.pdf

TMDL Highlights

Affected water uses:

- Drinking, culinary, and food processing water supply; water recreation; and growth and propagation of fish, shellfish, and other aquatic life, and wildlife

Applicable WQS:

- The fecal coliform criteria for drinking, culinary, and food processing water supply states that in a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10 percent of the samples may exceed 40 FC/100 mL.

Technical approach:

- *Key indicator* – Fecal coliform
- *Source assessment* – The largest and most frequent exceedances of the criteria occur during summer months, likely due to increased stormwater runoff. Areas with the highest fecal coliform loading rates tended to be residential land uses with a high degree of imperviousness and located close to the stream. In a 2003 report on fecal coliform sources and transport processes, the Municipality of Anchorage stated that the likely sources with these land uses are warm-blooded animals, including domestic pets (particularly cats and dogs) and wild animals.
- *Model* – The Stormwater Management Model (SWMM, Huber and Dickinson 2001) was selected to estimate existing and potential future fecal coliform counts in the watershed. SWMM simulates the quantity

and quality of runoff produced by storms, as well as during baseflow conditions. TMDLs are developed on a monthly basis to isolate times of similar weather, runoff, and instream conditions. However, at the subwatershed level, SWMM provides daily fecal coliform count predictions, which allows for a direct comparison with the state's WQS. SWMM also was used to assess the effectiveness of various implementation options (see implementation section below).

Allocations:

- *Point source*s – The wasteload allocations and required reductions are based on whichever component of the water quality standard (WQS)—the 30-day geometric mean criteria or the 10 percent not-to exceed criteria—is most restrictive. The TMDL analysis using SWMM determined when (i.e., spring and summer) the highest loads occurred and allocated the greatest reductions during those months.
- *Nonpoint source*s – Loading from waterfowl and wildlife are not included in the allocations because these contributions do not result from human activities. A load allocation of zero was set for this TMDL.

Implementation:

- Implementation of the TMDL will occur through the Municipality of Anchorage's MS4 permit through BMPs.
- The SWMM model was used to assess the effectiveness of three implementation options. The three implementation scenarios were simulated with the calibrated SWMM model: (1) public education—informing the public about the benefits of "cleaning up" after their pets was assumed to result in a 30 percent decrease in the surface build up of fecal coliform on landscaped, street, directly connected, and indirectly connected impervious land cover types; (2) increased street sweeping frequency and efficiency—street sweeping frequency was increased from monthly to weekly intervals and the efficiency was assumed to increase to eighty percent; and (3) a combination of scenarios 1 and 2. Simulation results suggested that a combination of education and increased street sweeping frequency and efficiency (scenario 3) could have a significant impact on reducing FC loading. However, for University Lake, significant additional reductions beyond those in scenario 3 are required to comply with both components of the WQS (the 30-day geometric mean and 10 percent not-to-exceed criteria).
- Follow-up monitoring will be coordinated between the Department of Environmental Conservation and the Municipality of Anchorage to track the progress of implementation and water quality response, track BMP effectiveness, and track the water quality to evaluate future attainment of WQS.

Cost:

- Cost information is not available in the TMDL documentation.

References:

Alaska Department of Environmental Conservation. May 2005. *Total Maximum Daily Load for Fecal Coliform in Chester Creek, University Lake, and Westchester Lagoon, Anchorage, Alaska.* http://www.dec.state.ak.us/water/tmdl/pdfs/chestercrwatershedTMDLEPAFinal.pdf

Huber W.C. and R.E. Dickinson. 2001. *Stormwater Management Model User's Manual.* Version 4.4. Athens, GA.

Tualatin River Subbasin
Stormwater Source TMDL (2001)
Oregon, USEPA Region 10

TMDL at a Glance

Subbasin:	Wilamette River Basin
Watershed size:	712 square miles
Key beneficial uses:	Salmonid fish spawning, incubation, fry emergence, and rearing (temperature); water contact recreation (bacteria); salmonid spawning, rearing, and passage (dissolved oxygen); and salmonid fish spawning, salmonid fish rearing, resident fish and aquatic life, anadromous fish passage, water contact recreation, and aesthetic quality (pH/chlorophyll *a*)
Impaired by:	Heat from human caused increases in solar radiation loading to the stream network, heat from warmwater discharges to surface waters of human origin, pathogens, insufficient concentrations of dissolved oxygen, and human caused increases in instream phosphorus concentrations
Pollutant(s):	Temperature, bacteria, total phosphorus, ammonia, and volatile solids
Sources considered:	*Point sources* – Wastewater treatment plants (WWTPs) covered by municipal separate sewer system (MS4) NPDES permits, concentrated animal feeding operation (CAFO), septic systems *Nonpoint sources* – septic systems, forest land use, and non-regulated runoff (urban, rural, agricultural, and forest)
Model(s) used:	Event-based, unit load hydrology model, Steady state water quality model, Streeter-Phelps equation, Water quality model, Mass balance analysis, "simple method", Reference condition
TMDL Web link:	http://www.deq.state.or.us/wq/TMDLs/docs/willamettebasin/tualatin/tmdlwqmp.pdf

TMDL Highlights

Affected water uses:

- Salmonid fish spawning, incubation, fry emergence, and rearing; anadromous fish passage; resident fish and aquatic life; water contact recreation; fishing; and aesthetic quality.

Applicable WQS:

TEMPERATURE

- Numeric standards are based on temperature that protects various salmonid life stages. Narrative standards specify conditions that deserve special attention, such as the presence of threatened and endangered cold water species. Dissolved oxygen (DO) violations are also a trigger for the temperature standard. A surrogate measure used is percent effective shade (expressed as the percent reduction in potential solar radiation load delivered to the water surface) to help translate the nonpoint source (NPS) solar radiation heat loading allocations.

BACTERIA
- Numeric and narrative standards apply. The numeric standard states that organisms of the coliform group commonly associated with fecal sources shall not exceed: (1) a 30-day log mean of 126 *E. coli* organisms per 100 mL, based on a minimum of five samples, and (2) no single sample shall exceed 406 *E. coli* organisms per 100 mL.

DISSOLVED OXYGEN (DO)
- Numeric and narrative standards apply. The applicable criteria are determined by the presence of cool- or cold-water aquatic life and the life stages of any salmonids present (spawning, rearing, etc.) and based on fish survey information, habitat assessments, and professional judgment.

pH/CHL
- Numeric and narrative standards apply. There are three WQS impacted by elevated chlorophyll *a* concentrations—pH, DO, and aesthetics. The applicable average chlorophyll *a* value used to determine possible beneficial use impairment is 0.015 mg/L.

Technical approach:

Key indicator(s)

TEMPERATURE
- Heat per unit time or kcal per day, as well as percent effective shade, which is used as a surrogate measure for NPS pollutant loading

BACTERIA
- *E. coli*

DO
- Sediment oxygen demand (SOD), settleable volatile solids in runoff, and ammonia

pH/CHL
- Total phosphorus (TP)

Source assessment

TEMPERATURE
- Natural background sources were determined to contribute 44% of the heat loading. Anthropogenic NPS heat loading is the dominant pollutant source, contributing 49%, and the heat loading from NPDES point sources is relatively small (7%).

BACTERIA
- An initial subbasin source assessment was conducted to determine whether the sources were associated with runoff. The assessment was made by grouping the individual samples by whether there was likely to be runoff at the time of sampling. It was estimated that runoff would occur when the rainfall on the day of sampling was greater than 0.1 inches for urbanized watersheds and 0.2 for watersheds with mixed uses. Urban runoff is likely a significant source of bacteria (e.g., from pet and other animal waste, illegal dumping, failing septic systems, and sanitary sewer cross-connections and overflows).

DO
- A volatile solids source assessment identified runoff as probably the most important source of solids affecting SOD. Ammonia is the primary target for TMDL development to address the DO levels in the lower mainstem of the Tualatin River because the primary sources of ammonia and the technology to control these loadings are well understood. However, the control of ammonia by itself will not result in full attainment of the DO criteria; and therefore, reductions in SOD on the mainstem are necessary.

pH/CHL
- The sources of TP are divided into four broad categories: background sources, WWTPs, runoff, and other sources. Data on TP concentrations for agricultural and forested land runoff in the subbasin are lacking, but the available data indicate that the phosphorus concentrations from these sources exceed natural background concentrations. The source assessment for Oswego Lake was conducted separately, and five primary phosphorus sources were identified in a 1987 diagnostic and restoration analysis of the lake: precipitation, groundwater, releases from sediment, input from the

Tualatin River (via Oswego Canal), and input from the local watershed tributaries.

Models

TEMPERATURE
- Natural background loading was calculated by simulating the solar radiation heat loading that resulted with system potential near-stream vegetation. Percent effective shade surrogates were developed to help translate the NPS solar radiation heat loading allocations, which can be calculated directly from the loading capacity, quantified in the field, or through calculations. The system potential temperatures determined by computer modeling also were used to assign WLAs to the point sources.

BACTERIA
- An event-based, unit load hydrology model was used to evaluate precipitation-driven bacteria loadings from specific land uses. Allocations for non-runoff periods were based on a straightforward analysis of instream bacteria levels and the percent reductions necessary to achieve standards.

DO
- TRIBUTARIES: A steady state water quality model was developed for the various representative streams to evaluate the sensitivity of DO concentrations to the parameters that appear to impact DO the most on the various representative stream segments. In Scoggins Creek, an analysis of the discharges from a lumber mill (Forestex) was conducted using the Streeter-Phelps equation.
- MAINSTEM: USGS developed a water quality model based on ammonia data to estimate DO levels for the lower mainstem of the river (Rounds et al. 1999 and TBTAC 1997).

pH/CHL
- TRIBUTARIES: A mass balance spreadsheet analysis was used to estimate the concentrations that would result on the mainstem of the Tualatin River due to background conditions. The total loadings from runoff sources was estimated using the "simple method" in which the amount of runoff for a specific time period is multiplied by the estimated pollutant concentration to give a total loading for that time period.
- OSWEGO LAKE: A reference stream was used to determine the background wet weather storm concentration of phosphorus in the tributary streams in the natural Oswego Lake watershed.

Allocations:

Point sources

TEMPERATURE
- Point sources are allowed heat that produces a 0.25°F increase over background temperatures within the zone of dilution.

BACTERIA
- The allocations for runoff sources of bacteria were based on a computer model that estimates the bacteria loadings from specific land uses during rain events. Four WWTPs, sources covered by municipal separate storm sewer system (MS4) NPDES permits, and concentrated animal feeding operation (CAFO) direct discharges require bacteria WLAs. CAFO direct discharges and septic systems are allocated wasteload allocations (WLAs) of 0 during runoff events and all other times during summer and winter.

DO
- SOD: The SOD reductions (ranging from 20-50%) for the mainstem and tributaries are addressed through volatile solids WLAs in runoff.
- AMMONIA: This TMDL updates the 1988 ammonia TMDL because subsequent computer modeling estimated that the allocations were not stringent enough to meet DO criteria in the critical late summer and early fall months and may have been too stringent in the spring/early summer when the river's assimilative capacity was greater. The ammonia monthly mean WLAs were calculated based on the WLA

	design concentration multiplied by the monthly median flow, and the WWTP design concentrations are based on the loading capacity.
pH/CHL	▪ TRIBUTARIES: The runoff allocations associated with point sources include point sources other than WWTPs. The allocations have been provided in concentration- and load-based units. The TMDL states that this combination of measures is considered appropriate because it addresses the WQS and lends itself to the design of control measures. ▪ OSWEGO LAKE: The WLAs are set equal to the background loadings and are allocated to discharges from the City of Lake Oswego's MS4. The allocations (LAs and WLAs) are divided into two categories—summer (May 1 through October 31) and winter (November 1 through April 30).
Nonpoint sources	
TEMPERATURE	▪ The NPS heat load allocation (LA) is translated effective shade surrogate measures that linearly determine the NPS solar radiation allocation. Effective shade surrogate measures provide site-specific targets for land managers. Anthropogenic nonpoint sources of solar radiation received an allocation of zero.
BACTERIA	▪ Bacteria load allocations were derived for septic systems, forest land use, and runoff and other discharges and were calculated using event mean concentrations for storm events.
DO	▪ SOD: Similar to the point sources, the SOD reductions (ranging from 20-50%) for the mainstem and tributaries NPS are addressed through volatile solids LAs in runoff. ▪ AMMONIA: The LA design concentrations were set to result in allocations similar to the previous ammonia load allocations documented in the 1998 ammonia TMDL.
pH/CHL	▪ TRIBUTARIES: LAs are categorized as background (groundwater) sources and runoff. A narrative LA was given to riparian bank erosion: "No excessive riparian bank erosion may occur in the Tualatin River Subbasin during the TMDL season." ▪ LAKE OSWEGO: Like the point sources, the nonpoint source LAs are set equal to the background loadings. The LAs are for all other discharges and instream contributions (e.g., instream erosion).
Implementation:	
Water quality management plan	▪ A water quality management plan (WQMP) has been developed to address these TMDLs, and it focuses on protecting and planting trees along riparian areas; urban stormwater and agricultural/forestry runoff management; temperature control of other permitted discharges; and ammonia, phosphorus, and temperature control of discharges from WWTPs. ▪ The WQMP includes a table with management measures and source categories sorted by parameter. This table is designed to be used by the designated management agencies (DMAs) as guidance for selecting management measures to be included in their implementation plans. Each DMA will be responsible for examining the categories to determine if the source and/or management measure is applicable within their jurisdiction. The WQMP is in appendix I of the TMDL. As the WQMP is implemented, the Department of Environmental Quality expects that management agencies will develop benchmarks for attainment of TMDL surrogates that can be used to measure progress.

Habitat and flow impairments	▪	The habitat and flow modification "impairments" associated with the exceedance of biological criteria will be addressed in management plans to be developed by the DMAs.
Heat credits	▪	The TMDL discusses the use of "heat credits" by calculating the heat reductions associated with flow augmentation and relating those reductions to the heat increases caused by effluent discharge.
Cost:	▪	Cost information is not available in the TMDL documentation.

References:

Oregon Department of Environmental Quality. August 2001. *Tualatin Subbasin Total Maximum Daily Load*. Available at http://www.deq.state.or.us/wq/TMDLs/docs/willamettebasin/tualatin/tmdlwqmp.pdf

Rounds, S.A., Wood, T.M., and Lynch, D.D. 1999. *Modeling Discharge, Temperature, and Water Quality in the Tualatin River, Oregon* (Water-Supply Paper 2465-B) (p. 115).

Tualatin Basin Technical Advisory Committee (TBTAC), Water Quality Modeling Subcommittee. 1997. *Technical Review of Tualatin River Water Quality Monitoring.*