MassDEP Appendix 1

Non-Point Source Best Management Practices and Efficiencies currently used in Scenario Builder

Values in parentheses are in progress of official approval

Agriculture BMPs		***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Nutrient Management		Landuse Change	N/A	N/A	N/A
Forest Buffers (varies by region; see Appendix 2)		Efficiency, Landuse Change	19-65%	30-45%	40-60%
Wetland Restoration (varies by region; see Appendix 2)		Efficiency	7-25%	12-50%	4-15%
Land Retirement		Landuse Change	N//A	N/A	N/A
Grass Buffers (varies by region; see Appendix 2)		Efficiency, Landuse Change	13-46%	30-45%	40-60%
Non-Urban Stream Restoration		Mass reduction/length	0.02 lb/ft	0.003 lb/ft	2 lb/ft
Tree Planting		Landuse Change	N/A	N/A	N/A
Carbon Sequestration/Alternative Crops		Landuse Change	N/A	N/A	N/A
Conservation Tillage		Landuse Change	N/A	N/A	N/A
Continuous No-Till (varies by region; see Appendix 2)		Efficiency	(10-15%)	(20-40%)	(70%)
Enhanced Nutrient Management		Efficiency	(7%)	(N/A)	(N/A)
Decision Agriculture		Efficiency	(4%)	(N/A)	(N/A)
Conservation Plans	High-till	Efficiency	8%	15%	25%
	Low-till	Efficiency	3%	5%	8%
	All hay	Efficiency	3%	5%	8%
	Pasture	Efficiency	5%	10%	14%
Cover Crops (see Appendix 1)		Efficiency	Varies	Varies	Varies
Commodity Cover Crops (see Appendix 2)		Efficiency	Varies	Varies	Varies
Stream Access Control with Fencing		Landuse Change	N/A	N/A	N/A
Alternative Watering Facility		Efficiency	5%	8%	10%
Prescribed Grazing/PIRG		Efficiency	9%	24%	30%
Horse Pasture Management		Efficiency	N/A	20%	40%
Animal Waste Management Livestock		Efficiency	75%	75%	N/A
Animal Waste Management Poultry		Efficiency	75%	75%	N/A
Barnyard Runoff Control		Efficiency	20%	20%	40%
Loafing Lot Management		Efficiency	20%	20%	40%
Mortality Composters		Efficiency	40%	10%	N/A
Water Control Structures		Efficiency	33%	N/A	N/A
Poultry Phytase		Application Reduction	N/A	N/A	N/A
Swine Phytase		Application Reduction	N/A	N/A	N/A

Dairy Precision Feeding and Forage Management	Application Reduction	N/A	N/A	N/A
Poultry Litter Transport	Application Reduction	N/A	N/A	N/A
Ammonia Emissions Reduction (interim)	Application Reduction	15-60%	N/A	N/A
Poultry Litter Injection (interim)	Efficiency	25%	0%	0%
Liquid Manure Injection (interim)	Efficiency	25%	0%	0%
Phosphorus Sorbing Materials in Ditches (interim)	Efficiency	40%	0%	0%
Resource BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Harvesting Practices	Efficiency	50%	60%	60%
Dirt & Gravel Road Erosion & Sediment Control – Driving Surface Aggregate + Raising the Roadbed	Mass reduction/length	0	0	2.96lb/ft
Dirt & Gravel Road Erosion & Sediment Control – with outlets	Mass reduction/length	0	0	3.6lb/ft
Dirt & Gravel Road Erosion & Sediment Control – outlets only	Mass reduction/length	0	0	1.76lb/ft
Urban BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Conservation	Landuse Change	N/A	N/A	N/A
Urban Growth Reduction	Landuse Change	N/A	N/A	N/A
Impervious Urban Surface Reduction	Landuse Change	N/A	N/A	N/A
Forest Buffers	Efficiency, Landuse Change	25%	50%	50%
Tree Planting	Landuse Change	N/A	N/A	N/A
Abandoned Mine Reclamation	Landuse Change	N/A	N/A	N/A
Wet Ponds and Wetlands	Efficiency	20%	45%	60%
Dry Detention Ponds and Hydrodynamic Structures	Efficiency	5%	10%	10%
Dry Extended Detention Ponds	Efficiency	20%	20%	60%
Infiltration Practices w/o Sand, Veg.	Efficiency	80%	85%	95%
Infiltration Practices w/ Sand, Veg.	Efficiency	85%	85%	95%
Filtering Practices	Efficiency	40%	60%	80%
Erosion and Sediment Control	Efficiency	25%	40%	40%
Nutrient Management	Efficiency	17%	22%	N/A
Street Sweeping	Efficiency	3%	3%	9%
Urban Stream Restoration	Load reduction/length	0.02lb/ft	0.003lb/ft	2lb/ft
Septic Connections	Systems Change	N/A	N/A	N/A

Septic Denitrification		Efficiency	50%	N/A	N/A
Septic Pumping		Efficiency	5%	N/A	N/A
Bioretention	C/D soils, underdrain	Efficiency	25%	45%	55%
	A/B soils, underdrain	Efficiency	70%	75%	80%
	A/B soils, no underdrain	Efficiency	80%	85%	90%
Vegetated Open Channels	C/D soils, no underdrain	Efficiency	10%	10%	50%
	A/B soils, no underdrain	Efficiency	45%	45%	70%
Bioswale		Efficiency	70%	75%	80%
Permeable Pavement w/o Sand, Veg.	C/D soils, underdrain	Efficiency	10%	20%	55%
	A/B soils, underdrain	Efficiency	45%	50%	70%
	A/B soils, no underdrain	Efficiency	75%	80%	85%
Permeable Pavement w/ Sand, Veg.	C/D soils, underdrain	Efficiency	20%	20%	55%
	A/B soils, underdrain	Efficiency	50%	50%	70%
	A/B soils, no underdrain	Efficiency	80%	80%	85%

Appendix 2 **BMPs**	**Hydrogeomorphic Region(s)**	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Buffers	Appalachian Plateau Siliciclastic Non-Tidal	54%	42%	56%
	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal	34%	30%	40%
	Coastal Plain Dissected Uplands Non-Tidal	65%	42%	56%
	Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Piedmont Crystalline Tidal	19%	45%	60%
	Coastal Plain Lowlands Non-Tidal	56%	39%	52%
	Piedmont Crystalline Non-Tidal	56%	42%	56%
	Coastal Plain Uplands Non-Tidal	31%	45%	60%
	Piedmont Carbonate Non-Tidal	46%	36%	48%
	Valley and Ridge Siliciclastic Non-Tidal	46%	39%	52%
Grass Buffers	Appalachian Plateau Siliciclastic Non-Tidal	38%	42%	56%
	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal	24%	30%	40%
	Coastal Plain Dissected Uplands Non-Tidal	46%	42%	56%
	Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Piedmont Crystalline Tidal	13%	45%	60%

	Coastal Plain Lowlands Non-Tidal	39%	39%	52%
	Piedmont Crystalline Non-Tidal	39%	42%	56%
	Coastal Plain Uplands Non-Tidal	21%	45%	60%
	Piedmont Carbonate Non-Tidal	32%	36%	48%
	Valley and Ridge Siliciclastic Non-Tidal	32%	39%	52%
Wetland Restoration (Ag & Urban)	Appalachian Plateau Siliciclastic Non-Tidal	7%	12%	4%
	Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal	25%	50%	15%
	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Piedmont Carbonate Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal	14%	26%	8%
Continuous No-till	Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal	10%	20%	70%
	Appalachian Plateau Siliciclastic Non-Tidal; Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Piedmont Carbonate Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal	15%	40%	70%
Cover Crop Early Drilled Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	45%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	34%	15%	20%
Cover Crop Early Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	38%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	29%	15%	20%
Cover Crop Early Aerial Soy Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	31%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	24%	15%	20%
Cover Crop Early Aerial Corn Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	18%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	14%	15%	20%
Cover Crop	Coastal Plain/Piedmont Crystalline/Karst Settings*	41%	7%	10%

Standard Drilled Rye (Low-till gets only TN efficiency)	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	31%	7%	10%
Cover Crop Standard Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	35%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	27%	7%	10%
Cover Crop Late Drilled Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	19%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	15%	N/A	N/A
Cover Crop Late Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	16%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	N/A	N/A
Cover Crop Early Drilled Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	31%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	24%	15%	20%
Cover Crop Early Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	27%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	20%	15%	20%
Cover Crop Early Aerial Soy Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	22%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	17%	15%	20%
Cover Crop Early Aerial Corn Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	15%	20%
Cover Crop Standard Drilled Wheat (Low-till gets only TN	Coastal Plain/Piedmont Crystalline/Karst Settings*	29%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	22%	7%	10%

efficiency)				
Cover Crop Standard Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	24%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	18%	7%	10%
Cover Crop Late Drilled Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	N/A	N/A
Cover Crop Late Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	11%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	9%	N/A	N/A
Cover Crop Early Drilled Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	38%	20%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	29%	20%	20%
Cover Crop Early Other Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	32%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	25%	15%	20%
Cover Crop Early Aerial Soy Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	27%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	20%	15%	20%
Cover Crop Early Aerial Corn Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	15%	20%
Cover Crop Standard Drilled Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	29%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	22%	7%	10%

Cover Crop Standard Other Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	24%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	19%	7%	10%
Commodity Cover Crop Early Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	17%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	15%	(N/A)	(N/A)
Commodity Cover Crop Early Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	7%	(N/A)	(N/A)
Commodity Cover Crop Early Aerial Soy Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	(N/A)	(N/A)
Commodity Cover Crop Early Aerial Corn Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	7%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)
Commodity Cover Crop Standard Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	7%	(N/A)	(N/A)
Commodity Cover Crop Late Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	7%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)
Commodity Cover Crop Late Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Early Drill Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	9%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)

Commodity Cover Crop Early Aerial Soy Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	6%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	5%	(N/A)	(N/A)
Commodity Cover Crop Early Aerial Corn Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Drill Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Rye	Coastal Plain/Piedmont Crystalline/Karst Settings*	18%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	14%	(N/A)	(N/A)
Commodity Cover Crop Early Other Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)

*Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Carbonate Non-Tidal

** Appalachian Plateau Siliciclastic Non-Tidal; Mesozoic Lowlands Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal; Blue Ridge Non-Tidal

MassDEP Appendix 2

Average Nutrient Concentrations of Sediment Related to Common O & M Activities

Practice	TP (ppm)	Range TP	TN (ppm)	Range TN	Location	Reference	Notes
Street Sweeping	1,000		2,500		ChesBay	CBP, 2011	
	513		1,012		FL	UF, 2011	
	1,034	381 – 1,437	2,163*	648 – 5,145	MD	DiBlasi, 2008	
Catch Basins	552		1,729		FL	UF, 2011	
	585	28 – 2,576	781*	56 – 5,831	MD	Law et al, 2008	Leaves only
	637		2,769		MD	MWCOG, 1993	Oil Grit
	980	114 – 1,932	3,480*	115 – 12,539	MD	Law et al, 2008	Sediment only
BMP Sediments	583	100 – 3,863	2,931*	219 – 11,200	Varies	Schueler, 1994	
	647		2,648		FL	UF, 2011	
Outfall Net Filters	448	321 - 815	6,832	4,178 – 12,422	MD	Law et al, 2012	
	557		8,050*		FL	Rushton, 2006	Leaves only
	593	404 - 985	3,907*	1,293 – 5,500	FL	Rushton, 2006	Sediment only
Stream Bank Sediments	220		1,460		MD	Stack, 2012	Proposed
	266	160 - 451			MD	Stack, 2006	
	355		850		MD	MD SHA	
	550		1,650		PA	Walters, 2012	Rural/Ag
	714	464 - 937	2,200	1,400 - 3,400	PA	Land Studies, 2004	Rural/Ag
	890	144 – 8,850	2705	3 – 8,250	MD	Stewart, 2008	
AVERAGE	**619**		**2914**				

*TKN Values

MassDEP Appendix 3

Dear Community Administrator:

This correspondence is intended to make you aware of some water quality activities taking place in Long Island Sound which could have potential future implications on your municipality. It is also serves as a request for information relative to your local storm water control and improvement activities which could have a benefit for each municipality by documenting pollutant reductions already being achieved through existing storm water programs. This information, if available, could potentially serve to reduce future regulatory burdens each municipality may be faced with to meet water quality goals in Long Island Sound.

First, I would like to put this request in some context. In 2001 the states of Connecticut and New York developed what is called a Total Maximum Daily Load (TMDL), which is essentially a pollution budget for nitrogen. Nitrogen has been identified as the pollutant that is causing a reduction in oxygen levels throughout the Sound. The TMDL is a regulatory requirement of the Clean Water Act and outlines the actions necessary, including pollution reduction, to achieve water quality standards.

To briefly summarize, the TMDL calls for significant improvements and nitrogen reductions from many sources including sewage treatment plants, storm water, and agriculture to name a few. The nitrogen budget also calls for a 25% reduction of nitrogen from point sources (sewage treatment plants) and a 10% reduction in nonpoint sources (agriculture and storm water runoff) in the northern states of Massachusetts, Vermont, and New Hampshire that also ultimately drain to Long Island Sound. A fact sheet has been attached that provides some additional detail of the TMDL and its regulatory requirements as it relates to Long Island Sound. Revisions to the 2001 TMDL are currently being discussed but will likely still require similar reductions from the three northern states.

Since the water quality studies that supported the conclusions of the TMDL were conducted in the late 1990's, Massachusetts is trying to obtain additional information and data from both our treatment facilities and from local municipal storm water coordinators to potentially get credit for municipalities who have already implemented new technologies and/or applied best management practices (BMPs) that may reduce the amount of nitrogen being discharged from their systems.

To accomplish this we are requesting any information you may have readily available regarding storm water BMP practices that have been put into place over the last several years. MassDEP is not requesting any additional work to be done by your staff, only an accounting of information that may already be readily available. Again the goal is to try to document and get credit for the storm water activities you are already implementing, or have implemented over the last several years.

To assist with this effort the Department has developed a list of potential BMPs below that may be required or implemented at the local level. We are requesting a few minutes of your

time to identify which BMPs have been or are currently being implemented in your community and any additional detail you may have. Providing the information on the survey below will allow MassDEP to more effectively advocate for your community and similarly situated communities. More importantly for you, it may also assist in documenting work already accomplished and to give credit for actions already taken.

Please mark an "x" in the center column if the particular BMP has been actually put in place in your community, and provide any statistics you have readily available in the far right hand column as to acreage coverage, or numbers, or weight (lbs. removed per yr)

Urban BMPs	***Checkmark yes (x)***	***DETAILS*** ***Approx. acres, or #'s, or Lbs removed;***
Catch Basin Cleaning		
Catch Basin Retrofits- Deep Sump/ Hood Installation		
Street Sweeping		
Lawn Fertilization Education Programs		
Leaf and Yard Waste Removal, with Proper Composting or Disposal		
Swales (Constructed)		
Bioswales, Bioretention, Rain Gardens (to control drainage)..No Underdrain Structure Constructed		
Bioswales, Bioretention, Rain Gardens (to control drainage)..With Underdrain Structure Constructed		
Nutrient Management Programs,(e.g., Lake/ Pond, or Town DPW Yards, or other Town Properties)		
Impervious Surfaces Reduction		
Tree Planting/ Reforestation/ Forest Buffers		
Urban Stream Restoration		
Wet Detention Ponds and/or Wetlands Installation		
Dry Detention Ponds		
Infiltration Practices without Sand, Vegetation		
Infiltration Practices with Sand, Vegetation		
Filtering Practices		
Erosion and Sediment Controls, as a result of Construction Control By-Laws in Place		
Groundwater Overlay District related BMPs		
Cluster Zoning; Min. Lot Size; LID Related BMPs		
Vegetated Open Channel(within, or at the edge of channel)		
Permeable Pavement with Sand, Vegetation		

(indicate underdrain, or no underdrain)		
Permeable Pavement without Sand, Vegetation (indicate underdrain, or no underdrain)		
Illicit Connections Correction		
Septic Connections to Sewer		
Septic Denitrification		
Septic Pumping		
IA Title 5 Advanced Wastewater Systems		
Groundwater Discharge Plants to Replace Title 5 Systems		
Other bmp not listed:		

____

Thank you in advance for your assistance. If you have any questions, please contact William Dunn at 508-767-2790.

Please return this survey form via email to: william.dunn@state.ma.us
or by mail to: William Dunn, MassDEP, DWM, Central Regional Office, 627 Main Street ,2nd Floor, Worcester MA 01608.

____

Long Island Sound TMDL

FACT SHEET

- **The revised TMDL, similar to the original TMDL, will allocate Nitrogen reductions in all upstream areas (including NY, CT, MA, NH, VT) from Long Island Sound, in order to improve the Hypoxia (low dissolved oxygen) induced water quality problems in the Sound.**

- **Watersheds within MA included in both TMDLs include: the Connecticut, Farmington, Westfield, Chicopee, Deerfield, Millers, Housatonic, French, and Quinebaug.**

- **The original TMDL in 2000 allocated the following Nitrogen reduction targets for MA, NH, and VT: (1) 25% reduction from NPDES permitted point sources; (2) 10% reduction from non point source runoff sources, including both urban, (including MS4 covered), and agricultural; (3) 18% reduction from atmospheric deposition sources.**

- **It is anticipated that the revised TMDL will have similar nitrogen reduction targets for MA, NH, and VT.**

- **Of all five Long Island Sound Watershed States, MA contributes 21% of the total contributions to Nonpoint Source Nitrogen Loading.**

- **Of the 21% Nonpoint Source Nitrogen Loading contributed by MA, 62% is estimated to come from urban/town sources, and 38% is from agricultural sources.**

- **As part of the proposed 10% Nitrogen reduction target in the original TMDL for urban non point source runoff, MassDEP is conducting this BMP survey to develop a database of Nitrogen removing BMPs that have recently been put in place in cities and towns within the watersheds listed above.**

- **These Nitrogen removing BMPs can include, but are not limited to : (1) BMPs put in place to satisfy MS4 Phase II Stormwater requirements; (2) BMPs that have been placed within groundwater overlay districts to address appropriate State and local wetlands requirements; (3) BMPs put in place as a result of actual By-Laws that have been adopted to control erosion at construction sites.**

MassDEP Appendix 4

CSN TECHNICAL BULLETIN No. 9

Nutrient Accounting Methods to Document Local Stormwater Load Reductions in the Chesapeake Bay Watershed

Version 1.0
REVIEW DRAFT

August 15, 2011

Important Note: This Technical Bulletin outlines the best current science on urban stormwater nutrient management, and is intended to help states and local governments define their baseline loads and choose the most cost effective combination of practices to meet their local load allocations under the Chesapeake Bay TMDL. This draft is being circulated to a wide group of Bay scientists and stormwater managers for peer review, and is open for comment until October 15, 2011. This review draft was written by Tom Schueler of the Chesapeake Stormwater Network, and comments can be e-mailed to him at watershedguy@hotmail.com

Table of Contents **Page**

Introduction **4**

Section 1: Nutrients and the Chesapeake Bay **6**

1.1 Impacts of Eutrophication 6
1.2 Stormwater Runoff as a Nutrient Source to the Bay 7

Section 2: Why We Need to Become Nutrient Accountants **10**

2.1 The Chesapeake Bay TMDL and Phase II WIPs 10
2.2 Implementation Plans for Local TMDLs 11
2.3 Enhanced MS4 Stormwater Permits 12

Section 3 What We Know About Nutrients in Stormwater **13**

3.1 Sources of Nitrogen in the Urban Landscape 13
3.2 Sources of Phosphorus in the Urban Landscape 15
3,3 Do Nutrient Hotspots Exist? 16
3.4 Event Mean Concentrations for Stormwater Runoff 18

Section 4 Tools to Estimate Local Loads **21**

4.1 The Simple Method 21
4.2 The Watershed Treatment Model 23
4.3 Other WIP Planning Tools 23
4.4 A Note about the Chesapeake Bay Watershed Model 24

Section 5 Pollutant Removal by Stormwater Practices **26**

5.1 Evolution in the Science of Defining BMP Removal Rates 26
5.2 Approved Removal Rates for Urban Stormwater BMPs 31
5.3 Proposed Interim Rates for Other Urban BMPs 33

Stormwater Retrofits 33
Composite Rate for New State Stormwater Standards 38
BMP by Design Era Approach 42
Maintenance Upgrades 43
Stream Restoration 45
Redevelopment Credits 47
Urban Reforestation 49
Street Sweeping 52
Urban Fertilizer Management 54
Septic System Hookups and Upgrades 56
Illicit Discharge Elimination 57
Others Nutrient Credits 58

		Page
Section 6: Progressive Strategy for Achieving Local Load Reductions		**59**
6.1	Form a Local Watershed Team	59
6.2	Decide on a Local Nutrient Load Model	60
6.3	Take Credit for Fertilizer Reduction on Turf	61
6.4	Take Credit for Stringent Redevelopment Standards	63
6.5	Become an Early Adopter of New State Stormwater Regulations	64
6.6	Take Credit for Community Reforestation	65
6.7	Take Credit for Stream Restoration Projects	66
6.8	Evaluate the Performance of Existing BMPs	66
6.9	Take Credits for Enhanced Street Sweeping	68
6.10	Investigate Septic Hookups and Upgrades	69
6.11	Evaluate Potential for Illicit Discharge Elimination	69
6.12	Investigate Stormwater Retrofits	70
References Cited		**72**
Appendix A: Detailed Technical Documentation		**79**

Acknowledgements

CSN would like to acknowledge several organizations that contributed to this effort (Biohabitats, the Center for Watershed Protection and Montgomery County DEP), although any omissions or mistakes are my own.

Introduction

This purpose of this Technical Bulletin is to help local and state stormwater managers in the Chesapeake Bay meet the following objectives:

- Understand the impact of nutrient over-enrichment on streams, rivers, estuaries and the main trench of the Chesapeake Bay.
- Define the best current science with respect to nutrient loads in urban stormwater and the effect of various management practices in reducing them.
- Provide technical methods to craft cost-effective watershed implementation plans to meet nutrient load allocations under the Chesapeake Bay TMDL.
- Propose interim removal rates for a wide range of urban stormwater practices for which official CBP approved rates have not yet been developed.
- Present methods for reporting, tracking and verification of local nutrient reductions over time.
- Assemble all the technical information on urban loads and BMP removal rates into a single document so it can be peer reviewed and accessed by stormwater managers.
- Provide practical low cost strategies for finding the best combination of urban BMPs to utilize in local watershed implementation plans.

Caveats: This Technical Bulletin should be considered a work in progress, subject to the review and comments of the Urban Stormwater Work Group of the Chesapeake Bay Program (CBP) and state partners. While CSN serves as the CBP's Stormwater Technical Coordinator, and has prepared this draft to support a common approach to stormwater nutrient accounting across the watershed, *this version should not be considered official guidance until it has received full peer review and been approved by the CBP and/ or the appropriate state water quality agency*.

Readers should always consult with their state water quality agency to learn about the process to be used in developing local watershed implementation plans and tracking, reporting and verifying urban BMP implementation. The Technical Bulletin contains numerous web links to find the appropriate state of EPA guidance on these topics. In addition, this version does not address pollutant loads generated by agricultural or wastewater sector, which will always be a key component of local nutrient reduction. This version focuses primarily on nitrogen and phosphorus, and only lightly touches on sediment. Other key pollutants which may require management and accounting in local TMDLs, such as bacteria, trash, and metals, are also not addressed in this version.

Organization of the Technical Bulletin: This bulletin has been written for a broad range of users, including local stormwater managers, engineering consultants, state and federal regulators, researchers, Bay modelers, and watershed managers. Since the bulleting consolidates a lot of technical information in a single volume, it has been organized into seven individual sections so that different users can find the information they need:

Section 1, Nutrients in the Chesapeake Bay. is targeted to a general audience, and presents the scientific case for why we need to manage nutrients to protect streams, rivers and the Bay.

Section 2, Why We Need to Become Nutrient Accountants, describes the key regulatory drivers behind the shift toward a more quantitative approach to nutrient management, d is intended for local stormwater managers.

Section 3, *What We Know About Nutrients in Stormwater*, presents a synthesis of more than three decades of research on how nutrients get into stormwater, and the typical nutrient concentrations found in stormwater runoff in the Bay.

Section 4, Tools to Estimate Local Nutrient Loads, briefly recounts a series of spreadsheet tools that have been recently developed to help local stormwater managers determine their best strategies for local nutrient reduction.

Section 5, Pollutant Removal by Stormwater Practices, is the longest section of bulletin, and contains the core data on the performance of stormwater practices, and the methods that can be used to calculate nutrient credits for a dozen different urban BMPs. The section is targeted for local stormwater managers, and their consultants, but will also be of interest to members of future urban BMP expert panels.

Section 6, A Progressive Strategy to Achieve Local Nutrient Reductions, is expressly targeted to local governments who want a simple road map to quickly evaluate which BMP credits will have the greatest impact reducing nutrient loads from their community. It also describes a suggested local process to develop a watershed implementation plan.

Appendix A, Detailed Technical Documentation, provides a home for the detailed assumptions and methods that are referenced in the main body of the bulletin

A series of *"bottom line" boxes* are also interspersed throughout the text to highlight the most important conclusions for local watershed managers.

Note to Reviewers: The final version will include examples on how to compute the various nutrient credits. While all comments are welcome, CSN is particularly interested in getting any performance monitoring data for urban BMPs that we missed in this compilation. We also welcome any alternative methods to compute nutrient reduction credits, and your thoughts on efficient ways to report, track and verify credits.

Section 1: Impacts of Stormwater Nutrients in the Chesapeake Bay

1.1 Impacts of Eutrophication

Nitrogen and phosphorus are invisible pollutants, but their impact on water quality is not. In modest amounts, nutrients are a vital element for plant growth, as any gardener or farmer can attest. In estuaries, small amounts of nutrients are needed to grow healthy sea grass, algae and other forms of aquatic life. If too many nutrients are added, however, plant growth is over-stimulated, with a dramatic impact to the health of the Bay. The first symptom is green water. The small single-celled plants in the water column, known as algae, take up nutrients quickly and then "bloom" over wide areas. Bright green algal blooms can quickly cover the water surface, causing fish kills, harming benthic life, and shading out beneficial sea grasses. Under some conditions, the algae can produce toxins that affect fish and humans, known as harmful algal blooms (e.g., *Pfsteria*).

The problems don't end with the blooms. Algae lead a short life, and die off in a matter of weeks, after which they settle to the bottom of the Bay. As the dead cells decompose, they literally suck oxygen out of the bottom waters of the Bay in the summer, creating zones of little or no oxygen where few creatures can survive. The size of these "dead zones" in the Bay shifts from year to year, depending on the weather and nutrient loads. In an average year, however, about 30% of the bottom waters of the Chesapeake Bay suffer from little or no oxygen.

The extent of these dead zones is not surprising, considering the enormous nutrient load delivered to the Bay every year. The Chesapeake Bay Program estimates that current watershed nitrogen and phosphorus loads must be reduced by 25 and 24%, respectively, in order to meet water quality standards (EPA, 2011).

The problem of nutrient enrichment is not confined just to the Bay. Excess nutrients impact thousands of miles of non-tidal streams that drain to the Bay. Aquatic life in these streams tends to be limited by total phosphorus and, to a lesser extent, nitrate. When freshwater streams are enriched with nutrients, they produce higher biomass, grow more bottom algae and rock slime and have lower oxygen levels. These habitat changes harm both fish and aquatic insects, and lead to lower biological diversity.

Extensive surveys conducted on streams in Maryland and North Carolina has shown that urbanization produces nutrient enrichment in streams that causes systematic declines in indices of biotic integrity for both fish and macro-invertebrates. This transition appears to occur at around 0.9 to 1.1 mg/l for total N and about 0.05 to 0.10 mg/l for total P (Morgan et al 2007, Morgan and Kline, 2010 and McNett et al, 2010)

These nutrient "threshold" concentrations are routinely exceeded during both stormwater and base flow conditions in most urban streams, which suggests that any nutrient reductions achieved to meet the Bay TMDL will result in improvements in local stream water quality and biodiversity.

1.2 Stormwater as a Nutrient Source to the Bay

Extensive monitoring and modeling have been conducted over the past three decades to define the major sources of nutrients within the Chesapeake Bay watershed. These efforts have culminated in the nutrient load projections of the Chesapeake Bay Watershed Model (CBWM) which was used to set load allocations for the Chesapeake Bay TMDL (EPA, 2011). The CBWM computes loads for the watershed as a whole, the seven Bay states and 225 subwatershed segments. The six main load categories include:

- Forest Runoff
- Wastewater
- Atmospheric Deposition to Open Water
- Urban and Suburban Runoff
- Agricultural Runoff
- Septic Systems (N only)

Tables 1 and 2 show the current TN and TP loads for the six loading sectors in Maryland, the target loads to meet water quality standards in the Bay, and the nutrient load reductions that are needed. The basic pattern is similar in other Bay states, but the exact numbers differ slightly due to their development intensity and geographical proximity to the Chesapeake Bay.

The runoff and septic leaching from urban and suburban land comprise about 20% of the total nitrogen load in Maryland (Table 1). To achieve the target load, more than 2.5 million pounds of nitrogen need to be reduced from the urban sector. This equates to about a 37% reduction of nitrogen coming from existing development in the state (although it may be possible to trade with another sector, such as agriculture).

Table 1
Total Nitrogen Loads, By Sector in Maryland Portion of Bay Watershed

Loading Sector	**2009 Load**	**Target Load**	**% Reduction Needed to Meet Target**
	Million pounds per year		
Forest Runoff	7.13	7.13	0
Atmospheric Deposition	0.69	0.69	0
Wastewater [1]	14.15	10.46	26%
Urban and Suburban Runoff	5.65	4.62	35%
Agricultural Runoff [2]	17.8	13.8	23%
Septic Leaching	4.0	2.45	39%
TOTAL	**49.4**	**39.1**	**21%**

Source: MDE (2010)
1 includes combined sewer overflows
2 includes confined animal feedlots

Stormwater runoff from urban and suburban land also comprises about 20% of the total phosphorus load in Maryland (Table 2). To achieve the target load for phosphorus, more than a quarter million pounds will need to be reduced. This means that a 36% reduction in phosphorus load would need to be attained on existing development in the state (absent any trading with another sector, such as agriculture).

It is important to note that major nutrient load reductions are difficult to achieve from some loading sectors, such as forest runoff or atmospheric deposition over open water. In addition, the wastewater treatment sector is close to approaching the limits of nutrient removal technology.

Table 2
Total Phosphorus Loads, By Sector in Maryland Portion of Bay Watershed

Loading Sector	**2009 Load**	**Target Load**	**% Reduction Needed to Meet Target**
	Million pounds per year		
Forest Runoff	0.35	0.35	0
Atmospheric Deposition	0.04	0.04	0
Wastewater [1]	0.87	0.69	34%
Urban and Suburban Runoff	0.67	0.44	36%
Agricultural Runoff [2]	1.44	1.25	12%
Septic Leaching	-0-	-0-	0
TOTAL	**3.3**	**2.72**	**12%**

Source: MDE (2010)
1 includes combined sewer overflows
2 includes confined animal feedlots

Another important factor to keep in mind with the urban stormwater sector is that it continues to grow as more land is converted for new development. This trend is evident in Table 3 which shows how urban stormwater has increased over time as a share of the total nutrient load to the Chesapeake Bay.

Back in 1985, urban stormwater comprised a relatively minor share of the total nutrient loads to the Bay. However, over the next 25 years, the importance of the urban stormwater sector has grown sharply. The sharp increase in urban nutrient loads reflects both increased urban sprawl and recent nutrient reductions from wastewater treatment plants, and to a lesser extent, croplands. According to the OIG (2007), urban stormwater is the only Bay nutrient load sector where we are seeing reverse progress in load reductions

The urban stormwater sector has significant potential to grow even greater in the future (unless smart growth policies are implemented to reduce sprawl and more stringent nutrient neutral stormwater regulations are imposed on development). The most recent land use projections by CBP forecast an increase of approximately 562,000 acres of developed land between 2010 and 2025.

Table 3
Urban Stormwater Loads as Share of Total Load to Chesapeake Bay from all Sources

Year	Total Nitrogen[1]	Total Phosphorus
1985	2	5
2000	9	15
2009	19	20
2030	??[2]	??[2]

[1] includes leaching from septic systems
[2] likely to increase if smart growth and new stormwater performance standards are not implemented across the watershed
These nutrient load statistics were derived from **v**arious historical Chesapeake Bay Program documents. The 2000 nutrient loads were provided in OIG (2007).

Box 1 Bay Nutrient Loads: The Management Bottom Line

- ✓ Nutrient enrichment is a serious water quality problem not only in the Chesapeake Bay but is also harming the quality of local streams
- ✓ Urban and suburban stormwater has increased nutrient loads to the Bay over the last three decades, and will continue to grow in importance due to future growth and development
- ✓ Currently, urban stormwater produces about 20% of the total nutrient load to the Bay each year
- ✓ New development in the future will need to be nutrient neutral, using stringent stormwater and smart growth practices to reduce nutrient loads to acceptable levels
- ✓ Nutrient reductions ranging from 20 to 30% may be needed from existing development in order to meet water quality standards

Section 2: Why We Need to Become Nutrient Accountants

Three regulatory drivers are converging together to force many local governments, planning district commissions and other agencies to take a more quantitative approach to manage their stormwater nutrient loads. These include the:

- Chesapeake Bay TMDL
- Local TMDLs
- NPDES MS4 Permits.

2.1 The Chesapeake Bay TMDL

The Chesapeake TMDL established load allocations for nitrogen, phosphorus and sediment and was finalized in early 2011 (EPA, 2011). At the current time, each Bay state is working with its local partners to develop a Phase II Watershed Implementation Plan (WIP). These state plans will be used to show how they will implement BMPs and other measures to accomplish 60% of their nutrient load reductions by 2017 and all of them by 2025. EPA expects the states to submit a draft by December 2011 and produce a final WIP by March of 2012 (EPA, 2011).

Each state has taken a slightly different approach on how they will engage their local partners in preparing the Phase 11 WIPs. Table 4 provides links to EPA and state websites that describe their unique WIP planning process. Readers are advised to consult them regularly since they are being frequently updated.

Table 4 Key Web links for State and Federal Bay TMDL and WIP Guidance [1]	
EPA	http://www.epa.gov/chesapeakebaytmdl/
DC	http://ddoe.dc.gov/ddoe/cwp/view,a,1209,q,502029.asp
DE	http://www.dnrec.delaware.gov/wr/Information/Pages/Chesapeake_WIP.aspx
MD	http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/PhaseIIBayWIPDev.aspx
NY	http://www.dec.ny.gov/lands/33279.html
PA	http://www.depweb.state.pa.us/portal/server.pt/community/chesapeake_bay_program/10513
VA	http://www.dcr.virginia.gov/vabaytmdl/index.shtml
WV	http://www.dep.wv.gov/WWE/watershed/wqmonitoring/Pages/ChesapeakeBay.aspx

1 links current as of 7.15.2011s

A few generalities can be made on how the Phase II WIP process will impact local governments going forward.

- Each state has elected to take a customized approach on how they will engage with local governments to develop strategies for nutrient reduction. In some cases, the jurisdictional unit they will work with might be a MS4 permitee, a planning district commission, an individual county, or a conservation district.

- The states will divide the Bay TMDL allocations into local area targets as appropriate. These local area targets are not regulatory allocations but will help partners better understand their expected contribution to meet the TMDL allocations.

- In most cases, local governments will need to submit data on current land use and prior BMP installation. They will also want to develop a local strategy for nutrient reduction and report their implementation of new BMPs to the state on an ongoing basis. In doing so, local governments will need to follow state and/or CBP approved procedures for tracking, reporting and verifying the BMPs they install.

- As part of the phase II WIP and two-year milestone process, the Bay states are responsible for aggregating the local BMP implementation data and submitting it as an input deck to EPA to document progress in load reduction. EPA enters the data into the Chesapeake Bay Watershed Model to determine the progress made in overall state nutrient reduction.

- It is important to recognize that the implementation phase is a 15 year iterative process, with multiple opportunities for adaptive management, technology enhancements and collaboration (NRC, 2011).

2.2 Watershed Implementation Plans for Local TMDLs

Many Bay communities are also responsible to show how they will achieve pollutant reductions to meet local TMDLs. More than a thousand TMDLs are in some stage of development or implementation across the Bay watershed. Local TMDLs are developed to meet water quality standards in streams, lakes, rivers and estuaries that are impaired by pollution, which could include bacteria, trash, sediment, nutrients, trace metals and other pollutants.

Urban areas are especially prone to water quality impairment, It is not surprising that a majority of local TMDLs are located within urban watersheds, and much of the required pollutant load reductions will need to come from the urban stormwater sector. Once a local TMDL has been finalized by the state water quality agency, communities are expected to develop an implementation plan to show how they will achieve the pollutant reductions needed to attain water quality standards.

This is particularly true when the pollutants are discharged into a municipal stormwater system and the community is subject to a NPDES MS4 Phase 1 or Phase 2 stormwater permit. EPA is now requiring that new and re-issued NPDES stormwater permits specifically contain language that the permit holder must address TMDL implementation for any approved TMDL waste load allocation located within their system. This includes a schedule of compliance and provisions to offset new or increased stormwater discharges (EPA Region 2, 2010). In general, the compliance schedules for local TMDL are long range, although permit holders must document the progress they are making in BMP implementation in their permit reports to the state water quality agency.

2.3 Enhanced MS4 Stormwater Permits

Phase 1 MS4 stormwater permits are derived from the Clean Water Act and are issued to two dozen big cities and suburban counties in Maryland, Virginia and the District of Columbia. The permits were first issued in the early 1990s and are a primary regulatory tool to treat the discharges of untreated stormwater to the Chesapeake Bay. Nearly all of the Phase 1 stormwater permits in the Chesapeake Bay watershed are expected to be re-issued in 2011 or 2012 with more stringent permit conditions.

The permit conditions may include the need to implement any approved local and Bay TMDLs noted in the preceding sections, but may also contain specific numeric retrofit provisions to treat the quality and volume of runoff from untreated impervious cover (EPA Region 3, 2010).

Maryland had incorporated numeric retrofit provisions in prior permit cycles and intends to expand them in the next permit cycle. While the precise nature of the retrofit permit provisions is still under negotiation between EPA and other Bay states, it is likely that will contain more numeric targets for retrofit and BMP implementation, reporting and tracking.

Phase 2 stormwater permits apply to nearly 500 smaller communities in the Bay watershed with a population less than 100,000. The permits require localities to implement six minimum management measures, including developing programs for stormwater education, public involvement, erosion and sediment controls, stormwater management, illicit discharge control and pollution prevention from municipal operations. Over time, these permits are likely to become more stringent, although perhaps not to the level of Phase 1 permits.

Recent surveys of local stormwater managers that administer MS4 permits indicate they are challenged to meet their current permits. For example, 86% indicated that they lack the budget/staff to fully implement current permits, and 67% indicated that they did not understand how to document pollutant reductions in local watershed implementation plans (CSN, 2010c).

In summary, all three regulatory drivers collectively create an increasing need to understand nutrient accounting at the local level. Consequently, local stormwater managers will need to become better nutrient accountants, and learn how to calculate pollutant loads and BMP reduction credits. The next section outlines what research has informed us about the “math” of nutrients in urban stormwater.

Section 3 What We Know About Nutrients in Stormwater

This section reviews what is known about the primary sources of urban nutrients that can be potentially washed off impervious surfaces and delivered to receiving waters via stormwater. A good understanding of the different sources of nitrogen and phosphorus is essential to craft effective stormwater management strategies.

3.1 Sources of Nitrogen in the Urban Landscape

The primary sources of nitrogen in urban stormwater are:

- Atmospheric deposition
- Wash-off of fertilizers
- Nitrogen attached to eroded soils and stream banks
- Organic matter (such as pollen and leaves) and pet wastes that are deposited on impervious surfaces
- Leaching of nitrate from functioning septic system leachate

Nothing stays aloft forever, gravity must be reckoned with. Pollutants fall out of the sky in two ways. First, when the turbulence created by the winds of the atmosphere can no longer counteract gravity, particles descend to earth in a process referred to as dry fall. Think of it as the film you see accumulating on your car windshield when it hasn't rained in a few days. The other way airborne pollutants can drop to the earth is to hook up with a raindrop or snowflake and wash out of the sky as wet fall.

This steady rain of pollutants can exert a real impact on watersheds, particularly if they fall on open water or paved surfaces. If they land on open water, they stand a good chance directly reaching the Chesapeake Bay. If they land on paved surfaces, they are easily washed into streams through the storm drain systems during storms.

The list of compounds that drop out of the atmosphere is long, and includes minute amounts of ammonium, cadmium, calcium, chloride, chromium, copper, fluoride, lead, magnesium, manganese, mercury, nickel, nitrate, phosphorus, sodium, selenium, sulfur, zinc, as well as some hydrocarbons and herbicides.

Much of the nitrogen found in urban runoff is deposited from the atmosphere, either in the form of dry fall or wet fall. Monitoring in the Washington metropolitan area revealed that 13 to 17 pounds of nitrogen fall from the sky each year, with the highest rates recorded in downtown areas and lower rates in suburban areas. These atmospheric loading rates are roughly equivalent to the total nitrogen load in stormwater runoff (Table 5), although atmospheric deposition over pervious areas is seldom subject to direct wash off.

Source area monitoring also sheds insights into the importance of air deposition. For example, rooftop runoff samples typically average about 1.5 mg/l, which is about 75% of the typical nitrogen concentration measured in urban stormwater pipes (Table 6).

Table 5 Relationship of Atmospheric Deposition to Urban Runoff Quality		
Nutrient	Atmospheric Deposition [1]	Stormwater Runoff Load [2]
	Pounds per impervious acre per year	
Total Phosphorus	0.7	2.0
Total Nitrogen	13 to 17.0 [3]	15.4
[1] measured rates during Washington NURP Study (MWCOG, 1983) [2] Simple Method annual stormwater runoff loads for one acre of impervious cover (Schueler, 1987) [3] About 40% of nitrogen deposition occurs through wet fall, which would presumably be quickly converted into runoff. 60% of nitrogen deposition occurs via dry fall, which is available for wash off in future storms, or may be blown over to pervious areas		

Another important source area is urban lawns. Monitoring indicates that lawn runoff has nitrogen concentrations that are five times higher than the average stormwater concentration (Table 6). This suggests that nitrogen can wash-off from fertilized lawns, particularly if they have heavily compacted soils.

Sampling also suggests that deposited organic matter (i.e., urban detritus) is a moderate source of nitrogen (leaves, pollen, pet waste, organic debris, etc). This is evident when runoff is sampled from street gutters, where urban detritus often accumulates (See Table 6). About two thirds of the nitrogen measured in stormwater is in organic form, which provides indirect evidence for the importance of organic matter as a nitrogen source.

Table 6 Nitrogen and Phosphorus EMCs for different urban land covers		
Urban Land Cover	Total N (mg/l)	Total P (mg/l)
Lawns	**9.70**	**1.9**
Highway	2.95	0.6
Streets (Variable)	1.40	0.5
Parking Lots	1.94	0.16
Rooftops	**1.50**	**0.12**
Stormwater Runoff EMC	**2.0**	**0.3**
Source; CWP, 2003 EMC = Event Mean Concentration		

Stream bank erosion is thought to be a major source of nitrogen in urban watersheds, but it needs further study. Most runoff monitoring studies collect nitrogen samples from the end of a stormwater pipe and not from larger urban streams (and therefore miss the nitrogen load produced by eroding stream banks). The soils in floodplains and stream banks tend to be enriched with both nitrogen and phosphorus. Stream bank erosion is very pronounced in urban and urbanizing watersheds. Recent research indicates that it can account for nearly two thirds of the annual sediment yield in urban watersheds (see CWP, 2003).

Nitrogen leaching from septic systems can be an important source, particularly for low density residential development in close proximity the Bay. Indeed, the Chesapeake Bay Watershed Model (CBWM) estimates that each functioning septic system delivers 12 pounds of nitrogen each year to the Bay, which far exceeds the stormwater load discharged from most low density residential sites.

3.2 Sources of Phosphorus in the Urban Landscape

The sources of phosphorus in stormwater runoff are similar to those for nitrogen, but their relative contribution is very different. For example, atmospheric deposition is not as important as a source of total phosphorus. About 0.7 pounds of phosphorus drop out of the sky each year, split equally between wet fall and dry fall (see Table 4). Even if all of it washed into storm drains, it would only account for about a third of the phosphorus load from urban areas.

The preceding conclusion is reinforced by the low phosphorus concentrations in rooftop runoff samples (Table 6). Atmospheric deposition supplies most of the phosphorus in roof runoff (although trees and bird droppings also play a role). Once again, the concentration of phosphorus in roof runoff is only about a third of the concentration found in stormwater pipes, so some other source in the urban landscape is responsible for the bulk of the total phosphorus load.

Source area sampling suggests that runoff of eroded soils and fertilizer from lawns is an important source of phosphorus. As can be seen in Table 6, the total phosphorus concentration in lawn runoff is approximately six times greater than that measured in stormwater runoff. In addition, total phosphorus concentration are significantly higher in residential areas (where lawns are ubiquitous) than in commercial and industrial areas and freeways (See Table 7).

Another key phosphorus source is the deposition and subsequent wash off of organic matter, pet wastes and litter from impervious surfaces. In particular, adjacent trees may account for a large portion of the phosphorus load when they shed leaves, pollen, flowers or fruits onto paved surfaces that subsequently break down and decompose.

As was the case with nitrogen, stream bank erosion is strongly suspected to be an important source of phosphorus in urban watersheds, but more research is needed to define its actual importance.

Table 7 National Median Nutrient Concentrations for Various Urban Land Uses (N= 3500)		
Urban Land Use	Total P (mg/l)	Total N (mg/l)
Residential	**0.30**	2.0
Commercial	0.22	2.2
Industrial	0.26	2.1
Freeway	0.25	2.3
Overall	0.27	2.1
Source: Pitt et al 2004		

3.3 Do Nutrient Hotspots Exist?

A key management question is whether certain land uses or activities exist in the urban landscape that generates above-normal nutrient concentrations. If such nutrient "hotspots" exist, it is advisable to target them for increased nutrient management. Recent research suggests that there are four nutrient hotspots that urban stormwater managers should be concerned about.

Residential land use with high input turf. As shown in Table 7, residential land generates slightly higher nutrient concentrations compared to other land uses. Within the residential land category, there is increasing evidence that lawns that are fertilized or over-fertilized generate higher nutrient concentrations in runoff and groundwater leachate than un-fertilized lawns (Bierman et al, 2010, Vlach et al 2009, Kennan, 2008, Easton and Petrovic, 2004, Guillard and Kopp, 2004 and Law et al, 2004). According to surveys conducted by Swann (1999), 50% of homeowners in the Bay watershed report that they fertilize their yard, with an average of two applications per year.

More importantly, 50% indicate that they over-fertilized their yards (i.e., exceed the recommended maximum application rate), and fewer than 10% conduct a soil test to determine if fertilization is actually needed. This is interesting given that existing soils are generally capable of supplying enough nutrients, particularly so in the case of phosphorus (Sutton and Cox, 2010). Given these findings, it is recommended that turf cover be split into two categories – fertilized and non-fertilized - when it comes to modeling local nutrient loads (see Table 8).

Table 8: Suggested EMCs to Characterize Lawn Management in WTM Model		
Nutrient	TP (mg/L)	TN (mg/L)
Residential	0.3	2.0
Fertilized	0.4	2.5
Non-fertilized	0.2	1.5

See Appendix A.2 for technical assumptions of derivation
EMC = Event Mean Concentration

Low density residential development served by septic systems. Rural development often relies on on-site septic systems to dispose of wastewater. The CBP estimates that each functioning septic system unit leaches about 12 pounds of total nitrogen annually, mostly in the form of nitrate-nitrogen. The impact of septic systems is most pronounced for systems in the coastal plain in close proximity to the Bay. Although the nitrate load moves through groundwater to reach surface waters (and is technically not a stormwater load), its migration is driven by storms and extended periods of wet weather. Some indication of the possible effect of septic systems on total nitrogen concentrations in the coastal plain is evident in Table 9, which compares Virginia EMCs data for sampling stations located in residential and non-residential catchments.

Table 9 Total Nitrogen Event Mean Concentrations in Virginia Stormwater Runoff	
Catchment Land Use	Total Nitrogen
Coastal Plain Residential	2.96
Coastal Plain Non-Residential	1.08
Source: Technical Memo CWP (2008) (N=300 storm events)	

The annual phosphorus load from functioning septic systems appears to be negligible, although it can be significant for failing systems that experience surface breakout.

Urban areas with high "human detritus" levels. Certain highly urban land uses qualify as nutrient hotspots. These areas are exposed to high levels of trash, litter and illegal dumping, a significant fraction of which is organic and biodegradable (aka, human detritus). The detritus is transferred to street gutters and storm drain cleanouts, where it decomposes and releases nutrients. An example of the urban detritus effect is shown in Table 10 which compares nutrient levels in a small urban watershed in Baltimore with extremely high gross solids loading against the national median nutrient concentrations.

As can be seen, nutrient concentrations are higher when small watersheds are subject to high levels of urban detritus. Further evidence for the urban detritus effect can be inferred from a study of pool water in oil grit separators in Maryland (Schueler and Shepp, 1993). Nitrogen and phosphorus concentrations were twice as high at gas stations and convenience stores that produced high levels of biodegradable litter.

Table 10 Comparison of Stormwater Quality Event Mean Concentrations from Runoff

Stormwater Pollutant	Baltimore City	National Median
Total Nitrogen	2.8 mg/l	2.0 mg/l
Total Phosphorus	0.32 mg/l	0.27 mg/l
Source: Baltimore City Diblasi (2008) Suburban National Pitt et al (2004)		

Golf Courses Golf courses are heavily fertilized and have drainage and irrigation systems designed to quickly move water through the soils and away from the course. Although golf course management practices have improved greatly in the last decade, they still appear to qualify as a stormwater hotspot, at least for total phosphorus and often for nitrate. Recent research by limnologists (Winter and Dillon, 2005) and the turf grass industry (Baris et al 2010) indicates that phosphorus and nitrate concentrations are elevated in streams that run through golf courses. At the present time, there is insufficient data on the golf course effect in the Chesapeake Bay watershed to assign a higher EMC. Still, stormwater managers should consider targeting golf courses for retrofits and riparian reforestation.

3. 4 Event Mean Concentrations for Nutrients in Runoff

When sampling runoff, researchers collect flow-weighted samples of pollutant concentrations throughout the entire storm hydrograph and combine them together to produce an "event mean concentration" which characterizes the average nutrient concentration for the storm as a whole. Over the past thirty years, thousands of samples have been collected which enables us to characterize nutrient concentrations over a broad range of land uses.

One of the key findings is that while urban stormwater is notoriously variable, it is also fairly predictable in its variability. For example, the median nutrient concentration for urban stormwater averages 2.0 mg/l for total nitrogen across the nation and in the Chesapeake Bay (Table 11). The nitrogen concentration in urban stormwater is on the low end of the range for runoff from croplands, and is significantly higher than forest or pasture. The median concentration of total phosphorus in stormwater runoff is about

0.3 mg/l, which is the mid range for phosphorus concentrations in cropland runoff, and much higher than forest or pasture runoff (Table 11).

Table 11
Comparison of Median Nutrient Concentrations For Various Land Uses in the Watershed

Land Use	Total P	Soluble P	Total N
	(mg/l)		
Urban [1]	0.30	0.16	2.0
Cropland [2]	0.25-0.50	0.10 -0.20	2.0 to 8.0
Forest [3]	0.05	0.01	0.6

[1] from Pitt et al 2004
[2] from various sources, range reflects differences in crop type, management, slope and manure/fertilization regime
[3] from Cappiella et al 2006

Another perspective on the "nutrient strength" of urban stormwater is provided in Table 12 which compares the typical concentration of nutrients in common discharges to the Bay, including untreated sewage, combined sewer overflows (CSO's) and the current technological limits for wastewater treatment in the Bay watershed. As can be seen, nutrient concentrations in urban stormwater are relatively low "strength" when compared to untreated wastewater and CSOs (but are much higher than runoff from forested reference watersheds.

Indeed, urban stormwater is roughly on par with the effluent from sewage treatment plants that utilize advanced biological nutrient removal technology. The key issue is that while sewage treatment plants in the Bay watershed discharge about 2 billion gallons of treated effluent each day, a typical storm over developed portions of the watershed produces trillions of gallons of polluted stormwater runoff. The implications of flow and concentrations on urban nutrient loads are discussed in the next section.

Table 12 Comparative strength of nitrogen and phosphorus concentrations in various stormwater and wastewater discharges (expressed in mg/L)

Parameter	Natural Waters	Urban Stormwater	Untreated sewage	CSOs	Treated sewage**
Nitrogen	0.6	2 to 3	20	3-24	3
Phosphorus	0.05	0.2 – 0.5	10	1-11	0.1

**** current technology in Chesapeake Bay**

Box 2 Urban Nutrient Sources: The Management Bottom Line

- ✓ Nutrients come from many sources and pathways before they become entrained in stormwater runoff.
- ✓ Managing some of these nutrient sources prior to wash off can be a cost-effective and practical strategy to reduce nutrient loads at their source.
- ✓ For example, atmospheric deposition is an important source of nitrogen and a less important source for phosphorus. Improved air quality regulations could sharply reduce atmospheric deposition rates.
- ✓ Similarly, lawn fertilization appears to be a significant source of the nutrients seen in urban runoff. Regulations and education campaigns to reduce or eliminate the need for fertilization can play a major role in reducing urban nutrient loads
- ✓ Four areas of the urban landscape can be considered nutrient hotspots: Residential lawns, septic systems of low density residential development, golf courses and urban areas with a lot of human "detritus"

Section 4 Tools to Estimate Local Stormwater Loads

A series of models and equations can be used to estimate stormwater nutrient loads at the site, subwatershed and Bay watershed scale. This section shows how these tools are inter-related and can be properly applied to estimate baseline nutrient loads.

4.1 The Simple Method

The Simple Method is an empirical equation developed by Schueler (1987) to estimate annual nutrient loads in stormwater runoff using easily derived parameters. It computes loads for storm events only, and is best applied to individual drainage areas or catchments. The basic equation is:

$$L = [\ P * Pj * Rv / 12\ ]\ [\ C * A * 2.72]$$

Where:

L = Annual load (lbs)
P = Annual rainfall (in)
Pj = Fraction of storms producing runoff (0.9)
Rv = Site runoff coefficient, based on impervious cover equation
C = Median TN or TP event mean concentration (mg/l)
A = Site Area (acres)
2.72 = Unit conversion factor

A modified version of the Simple Method has been developed to account for the differential impact of turf and forest cover in generating runoff from a site (CWP and CSN, 2008). The modified equation has been incorporated into the Virginia DCR site compliance spreadsheet, and uses a composite runoff coefficient to reflect the forest, turf, and impervious cover present at the site, as shown in the equation below.

$$Rvc = (Rv_I * \%I + Rv_T * \%T + Rv_F * \%F)$$

Where

Rv_I = runoff coefficient for impervious cover
Rv_T = runoff coefficient for turf cover or disturbed soils
Rv_F = runoff coefficient for forest cover
% I = percent of site in impervious cover
%T = percent of site in turf cover
%F = percent of site in forest cover

The appropriate runoff coefficients for each hydrologic soil group are provided in Table 13

Table 13. Site Cover Runoff Coefficients				
Site Cover Condition	Hydrologic Soil Group			
	HSG A	HSG B	HSG C	HSG D
Forest Cover	0.02	0.03	0.04	0.05
Disturbed Soils	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95
See Appendix A-1 for derivation of these runoff coefficients				

Despite its simplicity, these equations provide reasonably accurate estimates of annual nutrient loads in urban areas when compared to more sophisticated continuous simulation models. For example, Ohrel (1996) found strong agreement between the Simple Method and the HSPF model in multiple comparisons of annual stormwater nutrient loads (HSPF remains the basic core of the CBWM).

Indeed, as shown in Table 14, the predicted annual loads for Version 5.3.0 of the CBWM are nearly identical for total phosphorus on a unit acre basis. The predictions for total nitrogen are more divergent, although this may reflect the fact that the CBWM load includes both stormwater and septic system leachate. This may explain the disparity in nitrogen loads between the two methods for low density sites.

Table 14 Comparison on Average Annual Loads for Simple Method vs. Watershed Model Unit Loads				
% of Impervious Cover in Drainage Area	Total Phosphorus (lbs/ac/yr)		Total Nitrogen (lbs/ac/yr)	
	Simple Method	Watershed Model	Simple Method	Watershed Model
10 %	0.3	0.48	2.3	4.24 *
50 %	1.06	0.97	8.2	9.60
100 %	2.00	2.04	13.5	14.1
** Note to reviewers: Checking with CBWM team to make sure this comparison is correct given new unit loading rates under Version 5.3.2*				

The Simple Method has been incorporated into site-based stormwater spreadsheets in Virginia and Maryland, which allows engineers to predict reduced phosphorus loads as a result of proposed BMPs or retrofits at the site level. These spreadsheets can be accessed in Table 15, and need to be modified to handle nitrogen and sediment loadings.

4.2 The Watershed Treatment Model

The Watershed Treatment Model (WTM) is a spreadsheet model first developed by Caraco (1999) and recently updated (CWP, 2010—See Table 15). The WTM incorporates the Simple Method for urban loads, but also computes non-urban loads and secondary loads for small watersheds. The WTM was expressly designed to enable users to evaluate the effect of a broad range of urban BMPs and retrofits in reducing nitrogen, phosphorus and sediment loads. This is a strong advantage since it can handle official CBP-approved BMP removal rates, as well as interim BMP rates for practices that have yet to be reviewed.

The WTM works well when localities possess good land use/land cover and has been successfully used in many watershed plans and TMDL assessments. The WTM is a particularly versatile tool to quickly screen many different management options to isolate the most cost-effective combination of BMPs.

As with the Simple Method, the WTM typically agrees closely with annual nutrient loads predicted by more sophisticated simulation models, such as the CBWM. While the predictions of the WTM are robust, they cannot precisely reproduce the CBWM load projections within each model segment. This limitation, however, is not as serious as it may appear, since local governments are using the WTM for general planning purposes. They will still be responsible for reporting their specific BMP reductions to the state in an approved unit and format. More guidance on how to make local WTM modeling consistent with the Bay TMDL will be provided in a future Technical Bulletin.

4.3 Chesapeake Bay WIP Planning Tools

EPA and the states have developed a set of useful nutrient load analysis tools for local government. The CBP recently released Scenario Builder which is an extremely useful tool for rapidly testing various pollutant reduction strategies and practices at the county level scale (U of MD, 2010 and Table 15). In its current form, Scenario Builder is particularly well suited to evaluate agricultural BMP options.

Scenario Builder also enables users to evaluate the 20 urban BMP options for which there are officially approved rates, and to analyze the effects of land use conversion and rural BMPs such as filter strips and stream buffers. The tool is fully consistent with both the CBWM loading rates and approved BMP removal rates, which makes it easier for states to report implementation data to EPA for inclusion into the CBWM progress runs.

The only significant drawback to Scenario Builder is that it is currently limited to a fairly narrow range of urban BMP options (see Section 5.3). The CBP will be refining Scenario Builder in the coming years to make it a more robust tool for localities to evaluate alternative nutrient reduction strategies in urban watersheds.

Several Bay states are customizing Scenario Builder or creating their own tools. As of this writing, Maryland is closest to releasing a tool for specifically designed for counties and cities known as the Maryland Assessment and Scenario Tool (MAST –see Table 15).

Maryland requires that localities report their BMP removal credits using MAST, although they may use other models to develop local WIP plans. When released later in 2011, MAST will be fully compatible with the CBWM model and approved removal credits. In addition, MAST will also provide a wider menu of urban BMP credits. Virginia also has a similar tool under development which will be known as VAST which should be released in time to help localities develop WIP plans. Other states are expected to develop similar tools to aggregate the nutrient reductions at the local level and scale them up to the state level for reporting to EPA and inclusions into future CBWM runs.

Table 15
Guide to Nutrient Load Models and Tools in the Chesapeake Bay

Name	Status	Weblink
Simple Method	Available	See Section 4.1
MD Site Spreadsheet	Available	www.chesapeakestormwater.net
VA Site Spreadsheet	Available	http://www.dcr.virginia.gov/lr2f.shtml
WTM	Available	http://www.cwp.org/documents/cat_view/83-watershed-treatment-model.html
MAST	Soon	http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/PhaseIIBayWIPDev.aspx
EPA Scenario Builder	Early 2011 Release	http://archive.chesapeakebay.net/pubs/SB_V22_Final_12_31_2010.pdf
VAST	Under Development	http://www.dcr.virginia.gov/vabaytmdl/index.shtml

4.4 A Note about the Chesapeake Bay Watershed Model

The Chesapeake Bay Watershed Model (CBWM) has been under continuous development for more than 25 years and is now in Version 5.2.3. The model runs from the most recent version were used to establish the nutrient and sediment load target allocations for the Chesapeake Bay TMDL. The CBP has a work plan in place to refine and improve the model in the coming years.

It will always be difficult to exactly reconcile the nutrient load predictions of the CBWM and the simpler models reviewed in this section. This is not surprising given the three order of magnitude difference in the scale of the Bay watershed and local subwatersheds. Local governments will frequently have more detailed and recent land use and land cover, and more precise data on their existing urban BMP inventory.

Box 3 Nutrient Models: The Management Bottom Line

- ✓ Local governments can use tools such as the Simple Method to define the pre-BMP nutrient load for many of the BMP credits.
- ✓ Other spreadsheet tools such as the Watershed Treatment Model can be used to compare the impact of different combinations of BMP credits, forecast the impact of future load use change on local loads, and analyze the potential for enhancing the nutrient removal provided by your existing inventory of BMPs
- ✓ EPA and several states have also developed useful spreadsheet tools to analyze different BMP scenarios. While these tools are somewhat limited in their potential to evaluate urban BMPs, they are recommended for reporting BMP output metrics to your state nutrient tracking agency
- ✓ The Chesapeake Bay Watershed Model is a more sophisticated and complex simulation model that is being continuously improved and refined. Its primary value in the local WIP process is to indicate the mass of nutrients that need to be reduced within subwatersheds of the Bay. Local governments don't need to replicate bay model results, and only need to report their BMP output metrics to the state.

Section 5 Pollutant Removal by Stormwater BMPs

Over the past three decades, considerable research has been undertaken to understand the nutrient removal dynamics of urban stormwater practices and translate these into generic removal rates that can be used by watershed managers. This section begins with a brief review of how our understanding about BMP performance has evolved in response to new monitoring data and shifts in stormwater technology. This background is needed to interpret the many different (and sometimes conflicting) removal rates that have been assigned to different BMPs over time.

Section 5.2 describes the current CBP-approved BMP removal rates and the scientific peer review process used to develop them. These rates are to be used to compute local nutrient reductions.

Section 5.3 outlines recommended interim rates for a series of urban BMPs that have not yet been assigned approved nutrient removal rates. States and localities may use these rates for WIP planning purposes until such time as they receive final peer review by the Urban Stormwater Workgroup and other CBP committees.

5.1 Evolution of the Science of Stormwater BMPs

Stormwater managers have been grappling to define nutrient removal rates for stormwater practices, with at least ten different sets of rates published in the last 25 years (MWCOG, 1987, Schueler, 1992, Brown and Schueler, 1997, Winer, 2000, Baldwin et al, 2003, CWP, 2007, CWP and CSN, 2008, Simpson and Weammert, 2009, ISBD, 2010, and CSN, 2011). It is no small wonder that managers are confused given that the nutrient removal rates change so frequently.

Each new installment of published removal rates reflects more research studies, newer treatment technologies, more stringent practice design criteria and more sophisticated meta-analysis procedures.

For example, the first review involved only 25 research studies and was exclusively confined to stormwater ponds and wetlands, most of which were under-sized by today's design standards. The monitoring design for this era of BMP assessment evaluated the change in nutrient concentration as storms passed through individual practices. Analysis of individual performance studies showed considerable variability in nutrient removal efficiency from storm to storm (negative to 100%), and among different practices in the same BMP category.

The variability in removal rates was damped by computing a median removal rate for each individual practices and then computing a group mean for all the practices within the same group. This enabled managers to develop a unique "percent removal rate" for each group of BMPs.

By the turn of the century, about 80 research studies were available to define BMP performance, which expanded to include new practices such as grass swales, sand filters and a few infiltration practices. The number of BMP research studies available for analysis had climbed to nearly 175 by 2007. Table 16 portrays the percent removal rates for nutrients for different groups of stormwater practices. The percent removal approach provides general insights into the comparative nutrient capability of different BMPs groups, both in terms of total and soluble nutrient removal. For example, wet ponds and filtering systems are clearly superior to dry ponds when it comes to TN and TP removal, but wet ponds do a much better job than filtering systems in removing soluble N and P.

Table 16
Typical Percent Removal Rates for Total and Dissolved Fractions of Phosphorus and Nitrogen (N=175)

Practice Group	TP (%)	Sol P (%)	TN (%)	Nitrate-N(%)
Dry Ponds	20	- 3	24	9
Wet Ponds	52	64	31	45
Wetlands	48	24	24	67
Infiltration	70	85	42	0
Filtering Systems	59	3	32	-14
Water Quality Swales	24	-38	56	39
Source: CWP, 2007				

At about the same time, researchers began to recognize the limits of the percent removal approach. First, percent removal is a black box approach that provides general performance data, but little or no insight into the practice design features that enhance or detract from nutrient removal rates (Jones et al, 2008). Second, new data analysis showed that there were clear limits on how much any BMP could change nutrient concentrations as they passed through a practice. Extensive analysis of the nutrient levels in BMP effluent indicated that there appeared to be a treatment threshold below which nutrient concentrations could not be lowered.

This threshold has been termed the “irreducible concentration”. The nutrient concentration limits for each group of practices is shown in Table 17, and are caused by pass-thru of fine particles, internal re-packaging of nutrients, biological activity and nutrient leaching and/or release from sediments.

The third critique of the percent removal approach was that the population of monitoring studies upon which it is based is biased towards newly installed and generally well- designed practices. Very few monitoring studies have been performed on older practices or practices that have been poorly installed or maintained. The clear implication is that the ideal percent removal rate may need to be discounted to reflect these real world concerns, and several BMP reviews (Baldwin et al, 2003 and Simpson and Weammert, 2009) have derived more conservative rates in order to account for them.

Table 17 "Irreducible" Nutrient Concentrations Discharged from Stormwater Practices				
Stormwater Practice Group	Total Phosphorus	Soluble Phosphorus	Total Nitrogen	Nitrate Nitrogen
	mg/l			
Dry Ponds	0.19	0.13	ND	ND
Wet Ponds	0.13	0.06	1.3	0.26
Wetlands	0.17	0.09	1,7	0,36
Filtering Practices	0.16	0.06	1.1	0.55
Water Quality Swales	0.21	0.09	1.1	0,35
Untreated Runoff	0.30	0.16	2.0	0.6
Source: Winer (2000)				

The most serious critique, however, of the percent removal approach is that it focuses exclusively on nutrient concentrations and not flow reductions. This was not much of an issue with the first generation of BMPs (ponds, wetlands, and sand filters) since they had little or no capability to reduce runoff as it passed through a practice (ISBD, 2010c). With the emergence of new research on LID practices, however, the importance of runoff reduction in increasing the mass nutrient removal rate became readily apparent (see Table 18).

Table 18 Composite Annual Runoff Reduction and Nutrient Mass Loadings for LID Practices [1]			
LID Practices	Annual Runoff Reduction (%)	TP Mass Reduction (%)	TN Mass Reduction (%)
Bioretention	60	72	77
Dry Swale	50	65	65
Infiltration	70	78	75
Permeable Pavers	60	70	70
Green Roofs	52.5	52.5	52.5
Rain Tanks	52.5	52.5	52.5
Average LID	**60**	**65**	**65**
[1] Source: CWP and CSN (2008) and reflects the average of Level 1 and Level 2 design levels			

For example, bioretention only has a modest ability to reduce nutrient concentrations, but can reduce the volume of stormwater runoff by 50% or more. The product of the two factors results in an impressive mass reduction of nutrients.

Nearly 50 new performance studies on the pollutant and runoff reduction capability of LID practices have been published in the last five years. Collectively, this new research has had a profound impact on how nutrient reduction rates are calculated, and in particular, isolating the critical practice design and site variables that can enhance rates. CWP and CSN (2008) synthesized the runoff reduction research and calculated new (and higher) mass nutrient removal rates for both traditional and LID stormwater practices.

A key element of the new runoff reduction approach is that it prescribes two design levels for each practice that have a different nutrient removal rate. An example of the two level design approach for bioretention is shown in Table 19. The table reflects recent research that indicates which design features, soil conditions and performance standards can boost TN and TP removal. Some of these include:

- Increased depth of filter media
- No more than 3-5% carbon source in media
- Create an anoxic bottom layer to promote denitrification
- Increased hydraulic residence time through media (1-2 in/hr)
- Test media to ensure soils have a low phosphorus leaching risk

Designers that meet or exceed the Level 2 design requirements are rewarded with a higher nutrient mass reduction rate.

Table 19 Example of Two Level Design Approach for Bioretention

LEVEL 1 DESIGN	LEVEL 2 DESIGN
RR = 40% TP = 55% TN = 64%	RR= 80% TP= 90% TN = 90%
Treats the 90% storm	Treats the 95% storm
HSG C and D soils and/or under drain	HSG A and B soils OR has 12 inch stone sump below under drain invert
Filter media at least 24" deep	Filter media at least 36" deep
One cell design	Two cell design
Both: Maximum organic material in media of 5% and hydraulic residence time of 1 inch per hour through media	

The basics of the runoff reduction method and/or design level approach are now being incorporated into stormwater design manuals and compliance tools in Virginia, West Virginia, District of Columbia, Delaware and the Maryland Critical Area. Table 20 summarizes the mass nutrient removal rates developed to implement the new Virginia stormwater regulations.

Table 20 Mass Nutrient Removal Rates for Stormwater Practices			
Practice	**Design Level**[1]	**TN Load Removal**[4]	**TP Load Removal**[4]
Rooftop Disconnect [5]	1	25 to 50	25 to 50
	2 [6]	50	50
Filter Strips [5]	1	25 to 50	25 to 50
	2 [6]	50 to 75	50 to 75
Green Roof	1	45	45
	2	60	60
Rain Tanks & Cisterns [7]	1	15 to 60	15 to 60
	2	45 to 90	45 to 90
Permeable Pavers	1	59	59
	2	81	81
Infiltration Practices	1	57	63
	2	92	93
Bioretention Practices	1	64	55
	2	90	90
Dry Swales	1	55	52
	2	74	76
Wet Swales	1	25	20
	2	35	40
Filtering Practices	1	30	60
	2	45	65
Constructed Wetlands	1	25	50
	2	55	75
Wet Ponds [8]	1	30 (20)	50 (45)
	2	40 (30)	75 (65)
ED Ponds	1	10	15
	2	24	31

Notes

[1] See specific level 1 and 2 design requirements within each practice specification
[2] Annual runoff reduction rate (%) as defined in CWP and CSN (2008)
[3] Change in nutrient event mean concentration in and out of practice, as defined in CWP and CSN (2008)
[4] Load removed is the product of annual runoff reduction rate and change in nutrient EMC
[5] Lower rate is for HSG soils C and D, Higher rate is for HSG soils A and B
[6] Level 2 design involves soil compost amendments, may be higher if combined with secondary runoff reduction practices
7 Range in RR depends on whether harvested rainwater is used for indoor, outdoor or discharged to secondary runoff reduction practice. Actual results will be based on spreadsheet
[8] lower nutrient removal parentheses apply to ponds in coastal plain terrain

The runoff reduction method enables designers to achieve high removal rates when a mix of site design credits, LID practices and conventional stormwater practices are combined together to meet a specific phosphorus performance standard. In many cases, the aggregate nutrient reduction achieved by a mix of LID practices at a site will exceed the CBP approved rate for the individual practices (which reflects the higher treatment volume, better soil conditions and more stringent design criteria). In summary, urban

BMP nutrient removal rates have constantly evolved over time in response to new performance research, changing stormwater practices and paradigms, and more stringent design criteria and regulations. They are likely to change in the future and hopefully increase.

5.2 Approved Removal Rates for Urban BMPs in the Chesapeake Bay

Given the proliferation of removal rates described in the preceding section, the Chesapeake Bay Program has established a peer-review process to derive standard and consistent removal rates for a wide range of urban BMPs. These rates are used for the purpose of defining the aggregate nutrient and sediment reduction associated with BMP implementation in the context of the Chesapeake Bay Watershed Model.

Table 21
Current Urban BMP Efficiency Rates Approved by Chesapeake Bay Program as of 2/9/2011 [1, 2, 3]

URBAN BMP		Total Nitrogen	Total Phosphorus	TSS
		MASS LOAD REDUCTION (%)		
Wet Ponds and Constructed Wetlands		20	45	60
Dry Detention Ponds		5	10	10
Dry Extended Detention Ponds		20	20	60
Infiltration		80 (85) [4]	85	95
Filtering Practices (sand Filters)		40	60	80
Bioretention	C & D w/UD	25	45	55
	A & B w/ UD	70	75	80
	A & B w/o UD	80	85	90
Permeable Pavement	C & D w/UD	10 (20)	20	55
	A & B w/ UD	45 (50)	50	70
	A & B w/o UD	75 (80)	80	85
Grass Channels	C & D w/o UD	10	10	50
	A & B w/o UD	45	45	70
Bioswale	aka dry swale	70	75	80
Nutrient Management		17	22	NA
Street Sweeping	Bimonthly	3	3	9
Forest Buffers		25	50	50

[1] In many cases, removal rates have been discounted from published rates to account for poor design, maintenance and age, and apply to generally practices built prior to 2008
[2] Current Practices are designed to more stringent design and volumetric criteria, and may achieve higher rates –see Table 20
[3] Some practices, such as forest conservation, impervious cover reduction, tree planting are modeled as a land use change. Urban stream restoration is modeled based on a reduction per linear foot of qualifying stream restoration project
[4] Numbers in parentheses reflect design variation with a stone sump to improve long term infiltration rates

A clear technical protocol has been established to develop rates that are consistent, transparent and scientifically defensible (WQGIT, 2010). The process begins with BMP expert panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup, and other CBP management committees, to ensure they are accurate and consistent with the CBWM framework.

Since 2003, about 20 urban BMP rates have been established, with the supporting documentation provided in Baldwin et al (2003) and Simpson and Weammert (2009). The most current CBP-approved efficiency rates are provided in Table 21. Several additional urban BMPs are not expressed in terms of an efficiency rate, but rather as a land use conversion, reduced application rate or a mass load reduction. These are described further in Section 5.3.

A quick glance reveals that the rates tend to be fairly conservative, which reflects the concern that ideal or initial removal rates should be discounted due to real world implementation issues such as poor design, installation and maintenance, or simply the age of the practice. Indeed, the CBP has approved an alternative "BMP Design Era" approach whereby BMPs that were designed and installed within a specific design era are provided a generic removal rate. See Section 5.3.3 and Appendix A.3 for an example of this approach.

It is important to note that the Table 21 rates only apply to BMPs built prior to new state runoff reduction or environmental site design performance standards. The effective date for the new standards ranges from 2009 to 2014, depending on the individual state. A BMP expert panel has been convened to develop removal rates associated with clusters of many LID practices used to comply with the new performance standards.

Box 4 Urban BMP Rates: The Management Bottom Line

- ✓ Nutrient removal rates for urban BMPs are constantly evolving in response to new research findings, more stringent state stormwater regulations and enhanced design criteria. Over time, urban BMP removal rates should improve.
- ✓ The current urban BMP removal rates that are approved by the Chesapeake Bay Program are developed through a scientific review panel and tend to be conservative.
- ✓ As many as a dozen new BMP review panels will be convened in the coming years to derive removal rates for new BMPs and update the rates for existing BMPs
- ✓ This Technical Bulletin proposes interim rates for a range of urban BMPs that can be used on an interim basis for local WIP planning. In addition, the technical documentation to justify the new interim rates will be provided to future BMP review panels for further comment and analysis.

5.3 Proposed Interim Rates for Other Urban BMPs

There are a large number of urban BMPs for which there are either no CBP-approved rates, or the current approved rate needs significant updating. This section recommends options for defining interim rates to be used in the local WIP planning process.

5.3.1 STORMWATER RETROFITS

Status: This is a new urban BMP rate and will be the subject of a BMP Expert Panel that is scheduled to conclude in 2012. It is recommended that the proposed method be accepted on an interim basis during the WIP planning process, until such time as the Expert Panel makes its final recommendation.

Definition: Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Stormwater retrofits can be classified into five broad project categories, as shown below:

1. New retrofit facilities
2. BMP conversions
3. BMP enhancements
4. Green street retrofits
5. On-site LID retrofits

Technical Issues: Retrofits can be problematic when it comes to defining a nutrient removal rate. For example:

- Every retrofit project is unique to some degree, depending on the drainage area it treats, the treatment mechanism(s) it employs, the runoff volume it captures, and the degree of prior stormwater treatment at the site, if any.

- Many retrofits are under-sized in comparison to new BMPs designed to new development standards, due to site constraints. Some adjustment in pollutant removal capability is needed to account for situations where they cannot capture and treat the water quality volume.

- There is virtually no research available specifically for stormwater retrofits, so removal rates needs to be inferred from other known BMP and runoff reduction performance data.

- Many retrofits employ innovative combinations of runoff treatment mechanisms and may not be easily classified according to the existing CBP- approved BMP removal rates.

- Localities often evaluate dozens or even hundreds of candidate projects during retrofit investigations to find the best ones. Therefore, localities will need fairly simple protocols to estimate pollutant reduction achieved by individual retrofits projects as part of their watershed assessment and retrofit investigation.

Recommended Overall Protocol to Define Retrofit Removal Rate

The general protocol to define retrofit removal rates is as follows:

Step 1: Compute the baseline load for the drainage area to the proposed retrofit using the Simple Method (Schueler, 1987), the Virginia spreadsheet (CWP, 2009) or the unit nutrient load method (MDE, 2011). All three methods closely track the Bay Model projections for baseline nutrient loads for urban and suburban lands.

Step 2: Select the appropriate method to define a project-specific retrofit removal rate, based on its appropriate retrofit classification.

Step 3: Adjust removal rates using the runoff capture method if retrofit is under-sized

Step 4: Multiply the adjusted retrofit removal rate by the pre-retrofit baseline load to obtain the pounds of nutrients reduced by the project.

<u>New retrofit facilities:</u> This category includes new retrofit projects that create storage to reduce nutrients from existing developed land that is not currently receiving any stormwater treatment. Common examples of new retrofits include creating new storage upstream of roadway crossings, near existing stormwater outfalls, within the existing stormwater conveyance system or adjacent to large parking lots. Desktop and field methods for discovering opportunities for new retrofits are described in Schueler (2009).

There are two options to define removal rates for this class of retrofit projects:

CBP Rate Option: If the new retrofit project can be classified into one of the existing CBP urban BMP categories and has enough treatment volume to treat the runoff from at least one inch of rainfall, then the appropriate CBP approved rates should be used (i.e., Table 21).

Stormwater Retrofit Removal Rate Adjustor. If the retrofit is over or under-sized, or utilizes treatment mechanisms or design enhancements that cannot be classified under current CBP urban BMP categories, then designers should determine the actual rainfall depth controlled and degree of runoff reduction achieved by their retrofit project, and select the appropriate mass removal rate from Table 22. Some additional guidance for using Table 22 includes:

- Designers may interpolate between the rainfall depths if their new retrofit project has a non-standard rainfall depth controlled.

- High removal rates (HI) are assigned to new retrofit projects that achieve at least 50% reduction of the annual runoff volume through canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration.

- The low removal rate (LO) should be used if the new retrofit employs a permanent pool, constructed wetlands or filtering as the primary runoff treatment mechanism.

Table 22
Stormwater Retrofit Removal Rate Adjustor

Volumetric Criteria		**Mass Removal Rate %**	
Rainfall depth controlled	Degree of runoff reduction	Total Phosphorus	Total Nitrogen
0.25	LO	20	20
	HI	30	30
0.50	LO	30	35
	HI	45	45
0.75	LO	40	40
	HI	55	60
1.0	LO	55	55
	HI	75	70
1.25	LO	65	65
	HI	85	75
1.50	LO	75	67
	HI	82	85
2.0	LO	80	77
	HI	90	92
2.5	LO	90	85
	HI	95	95

The technical derivation for the mass removal rates can be found in Appendix A.8

BMP conversions are a fairly common and cost-effective retrofit approach where an existing BMP is converted into a different BMP that employs more effective treatment mechanism(s) to enhance nutrient reduction. Most BMP conversions involve retrofits of existing stormwater ponds, such as converting a dry detention pond into a constructed wetland (although many other types of BMP conversions are possible). Guidance on pond retrofits can be found in Profile Sheet SR-1 in Schueler (2009).

There are three options to define removal rates for BMP conversion projects:

> *Incremental Improvement Method*. Most older stormwater ponds can be classified according to CBP-approved urban BMP rates, so it is relatively straightforward to compute an incremental rate based on the difference between the old and new CBP BMP removal rate. For example, if a dry ED pond is converted into a wet pond, the phosphorus removal rate would increase from 20% to 45%, which would result in a net 25% removal due to the conversion retrofit.
>
> *Incremental Improvement for Maryland Design by Era Method*. An incremental rate can also be derived based on the age of the BMP being converted. MDE (2011) assigns unique nutrient and sediment removal rates for each of the four design eras it has established (see Table 24 in Section 5.3.5). In this case, designers simply calculate the incremental difference in removal rates for the more recent design era compared to the earlier design era, and then multiply it by the baseline load delivered to the original BMP.
>
> *Incremental Rate Using Stormwater Retrofit Adjustor*. The last method for BMP conversions is to use Table 22 to define a project specific mass removal rate for the original BMP and the proposed conversion based on the net change in rainfall depth controlled and degree of runoff reduction achieved. This method is recommended when the proposed BMP conversion utilizes LID practices; increases total treatment volume and/or involves major design enhancements.

<u>Enhance Existing BMPs:</u> This retrofit category applies to projects whereby the basic treatment mechanism of the existing BMP is not changed, but its nutrient reduction capability is enhanced by increasing its treatment volume and/or increasing the hydraulic retention time within the practice. BMP enhancements are a good strategy on older and larger ponds and wetlands built under less stringent sizing and design standards. BMP enhancement may also be a good strategy for the first generation of bioretention and filtering practices, whose original design lacked the features now known to enhance nutrient removal.

An example of a retrofit enhancement for an older wet pond might be to increase its treatment volume, re-align inlets to prevent short circuiting, add internal cells and forebays to increase flow path, and add aquatic benches, wetland elements and possibly even floating islands to enhance overall nutrient reduction.

At first glance, it would seem to be difficult to assign removal rates for these BMP enhancements, although many Bay states now utilize a two level design system whereby nutrient removal rates are increased when certain treatment volume and design features are met or exceeded (Virginia DCR, 2011, CSN, 2011, and soon to be implemented in DC, DE, WV).

Therefore, the recommended option to estimate the nutrient reduction achieved by BMP enhancement retrofits is as follows:

Step 1: The base nutrient removal rate for the existing BMP (prior to enhancement) should be the conservative CBP-approved rate found in Table 20.

Step 2: The designer should then evaluate the range of BMP enhancements to see if they qualify for the higher Level 1 or Level 2 rates shown in Table 21.

Step 3: The nutrient removal rate for the retrofit is then computed as the difference from the Level 1 or 2 rates and the existing CBP-approved rate.

<u>Green Street Retrofits:</u> Green streets utilize a combination of LID practices within the public street right of way, and are gaining popularity as an attractive option to treat stormwater runoff in highly urban watersheds (CSN, 2011c). Green streets provide many urban design benefits and create a more attractive and functional urban streetscape. Green streets typically involve a combination of practices such as permeable pavers, street bioretention, expanded tree pits, individual street trees, impervious cover removal, curb extensions and filtering practices. The linear nature of green streets makes them a very efficient composite LID practice that can treat several acres of impervious cover in a single system.

Numerous green street demonstration projects have been installed in cities within the Bay watershed. At the current time, there is no standard design for green streets, since each project must deal with unique constraints present in each individual green street section (e.g. street width, right of way width, underground utilities, development intensity, parking needs, street lighting, and pedestrian/automotive safety).

Consequently, it is impossible to assign a generic nutrient and sediment removal rate for green streets at this time. As an alternative, the nutrient removal credit for green streets can be estimated in a simple two step process:

Step 1 *Impervious Cover Reduction Credit*. The Simple Method can be used to compute the change in nutrient load that can be attributed the reduction in impervious cover associated with a narrower street. This is easily done by adjusting the site runoff coefficients to reflect the lower impervious cover associated with the green street.

Step 2. The green street project can then be analyzed as a whole to determine the actual rainfall depth it controls and degree of runoff reduction it achieves. Based on these factors, designers can select the appropriate mass removal rate from Table 22, and then multiply it by the adjusted baseline load computed in Step 1. The nutrient reduction calculated in this step can then be added to the impervious cover reduction credit computed in Step 1.

<u>On-site LID Retrofits</u>: This category includes the installation of a large number of small on-site retrofits, such as rain gardens, compost amendments, rain barrels, rooftop disconnections and tree planting, over the scale of a residential neighborhood. These retrofits are typically delivered by local governments or watershed groups, who provide

incentives and subsidies to individual property owners to implement them. In many cases, dozens or even hundreds of these small retrofits might be installed in any given subwatershed.

To simplify analysis, it is recommended that localities record the cumulative area of impervious cover treated by on-site retrofits, and then enter the average rainfall depth controlled and runoff reduction achieved in Table 22 to find the appropriate mass removal rate for all of them.

Local Tracking, Reporting and Verification

Localities should maintain a project file for each retrofit project installed. The file should be maintained for the lifetime for which the retrofit nutrient removal credit will be claimed. The typical duration for the credit will be approximately 25 years, although the locality may be required to conduct a performance inspection at least once every five years to verify that the practice is being adequately maintained and operating as designed.

Localities should also submit some basic documentation to the state about each retrofit, including GPS coordinates for the project location, the 12 digit watershed in which it is located, the nutrient reduction credit claimed (and the method used to compute it), and a signed certification that the retrofit has inspected after construction and meets its performance criteria

Localities are encouraged to develop a GIS-based BMP tracking system in order to schedule routine inspections and maintenance activities over time.

5.3.2 COMPOSITE RATE FOR IMPLEMENTATION OF NEW LID/ESD/RR PERFORMANCE STANDARDS

Status: This is a new urban BMP and will be the subject of BMP Expert Panel that is scheduled to conclude in 2012. It is recommended that the proposed method outlined be accepted on an interim basis during the WIP planning process, and until the Panel makes a final recommendation.

Definition: Every Bay state has adopted or is in the process of adopting more stringent stormwater standards that prescribe high runoff reduction volumes and promote low impact development practices. These new standards typically involve installing many different environmental site design and LID practices across each development site, rather than past approach of building a just a few large downstream BMPs to serve the entire site.

Technical Issues:

Several key technical questions arise when evaluating new state stormwater performance standards:

- *What type of aggregate nutrient reduction rate should be offered for new development projects designed to more stringent stormwater standards?* As was noted in Section 5.1, this new stormwater approach has the potential to achieve higher nutrient removal rates than the current CBP-approved rates for individual BMPs.

- *Would full compliance with the new stormwater performance standards assure that new development sites achieve nutrient neutrality in the future?* In this context, neutrality means that nutrient loads from future new development would not count as a new load source in the context of the Bay TMDL.

- *How would the aggregate nutrient reduction rate for the new performance standards be adjusted in the case of partial compliance or delayed rollout of the new standards?* For a number of reasons, not every site will be able to fully comply with the new performance standards.

There are significant differences among the Bay states in the terminology, sizing criteria and expected rollout of their new stormwater performance standards. For example:

- The terminology used to describe the same basic stormwater approach differs among the states and includes terms such as environmental site design, low impact development, runoff reduction, on-site retention, and resource conservation volumes.

- Each Bay state has a unique hydrologic performance standard in terms of the rainfall depth that must be treated with runoff reduction practices. This means that an aggregate nutrient load reduction rate must be independently derived for each Bay state.

- Each state/locality is on a different schedule to implementing the new performance standards, as a result of local ordinance approval, grandfathering provisions and other factors. This means that localities in several states may end up with a mix of practices designed under the old and new standards from approximately 2009 to 2014, which complicates efforts to track the net change in nutrient loads from new development going forward.

Recommended Process

The recommended process for each state to define nutrient neutrality in the context of their new stormwater performance standards is as follows:

Step 1: Analyze the target load reduction in each state using the Version 5.3.2 of the Chesapeake Bay Watershed Model (EPA, 2011) and sum up all the runoff-derived land sources of nutrient loads. These include runoff from forest, agricultural (excluding CAFOs) and urban and suburban land uses. Wastewater and CSO loads should be excluded from the calculation, since they are not runoff-related. In addition, atmospheric deposition over open waters of the Bay should also be excluded.

Step 2: Divide the total runoff-derived nutrient load by the total acres of land within the Bay watershed for the state to obtain the acceptable annual nutrient load, in lbs/acre/year.

Step 3: Compare these annual nutrient loadings against the sizing and LID technology standards inherent in your state stormwater performance standards. This is done by finding the expected annual nutrient load associated with your past and current standard, using Table 23.

Table 23
Post Development Nutrient Load for Different Combinations of Stormwater Volume Criteria

Volumetric Criteria		**Post Development Load** Lbs/imperious acre/year	
Rainfall Depth Controlled	Degree of Runoff Reduction	Total Phosphorus	Total Nitrogen
0.25	LO	1.6	12.0
	HI	1.4	10.5
0.50	LO	1.4	9.9
	HI	1.1	8.2
0.75	LO	1.2	8.7
	HI	0.9	6.1
1.0	LO	0.9	6.6
	HI	0.5	4.5
1.25	LO	0.7	5.1
	HI	0.3	3.7
1.50	LO	0.5	4.9
	HI	0.25	2.3
2.0	LO	0.4	3.5
	HI	0.2	1.5
2.5	LO	0.2	2.2
	RR	0.1	1.1
Details on the technical derivation can be found in Appendix A-8			

Table 23 provides an estimate of the post development nutrient load under different combinations of the rainfall depth controlled and the degree of runoff reduction provided.

Step 4. Track the cumulative impervious acreage of new development that adheres to the new performance standard.

Step 5. Make adjustments for individual sites that do not fully comply with the new standards, because they cannot meet the required rainfall capture volume, do not provide a high degree of runoff reduction, or are grand-fathered under the old design standard. In these circumstances, localities have two options:

The first option is to use Table 23 (or related phosphorus compliance spreadsheet) to analyze each individual project, and then track the aggregate shortfall from the nutrient neutral threshold on an annual basis. The nutrient reduction shortfall would be reported to the state and effectively added to their existing nutrient load allocation.

The second option is to require developers to obtain a nutrient offset or pay a fee in lieu to ensure an equivalent amount of nutrients are reduced elsewhere in the locality to cover the shortfall at the site.

Since most Bay states are shifting to a higher degree of runoff reduction and LID practices in their new stormwater standards, there should be a considerable improvement in nutrient removal compared to the standards developed in the late 1990's and early 2000. An example of how this analysis was applied to evaluate Maryland's ESD to MEP stormwater standard can be found in Appendix A-8.

Caveats about the Composite Method

There are several important caveats that apply to the composite method presented in this section. First, the composite method is designed solely for the purpose of creating an aggregate, macro-level tracking for future new development that is fully treated under these standards. Other design tools provide more site-specific estimates of the phosphorus reduction achieved at individual development sites, such as the MD Critical Area phosphorus compliance spreadsheet (CSN, 2011) and the Virginia state-wide stormwater compliance spreadsheet (VA DCR, 2011).

Local Tracking, Reporting and Verification

- Local governments should keep track of the impervious acres each year that fully meet the new standard and are considered by the state to be nutrient neutral.

- Local governments should provide a post construction certification that practices were installed properly at the development site and working as designed before they are entered into a local and/or state tracking database.

- In addition, localities should maintain project files for each development site where the credit is claimed for the lifetime of the project (usually 20 to 25 years).

- The duration of the credit is five years, but can be renewed if field inspection indicates the system of practices is performing to the new stormwater standard.

- Local governments should also keep track of any future development projects that are designed under the old standard, or cannot fully comply with the new standards. They should then report the aggregate nutrient increase for these projects to the state as an addition to their local baseline load.

- Localities should also develop and maintain a local tracking database that includes a maintenance inspection feature, whereby the site nutrient reduction credit is reduced or eliminated if the owner does not perform the ongoing maintenance to ensure the system of practices continues to perform well over time.

5.3.3 BMP BY DESIGN ERA APPROACH

Status: This credit was approved by a CBP BMP Expert Panel in March of 2011, and primarily applies to Maryland communities, although the basic concept could be used by other Bay states, as long as they customize the time lines to reflect the unique evolution of their stormwater regulations and standards over time (USW, 2011).

Definition: MDE proposed the BMP by Design Era approach as an alternate way for Maryland communities to report their historical BMP implementation. It allows communities to simultaneously report detailed BMP tracking data required to meet the Bay TMDL and keep track of their local MS4 permit retrofit requirements. Maryland communities can analyze their BMP inventories by the date of installation to derive a generic removal rate for each BMP, as shown in Table 24.

Technical Issues: More specific information on application of the Design by Era approach in Maryland can be found in MDE (2011). From a practical standpoint, it is recommended that localities merge their existing BMP inventory into their watershed GIS system. Experience has shown that as many as a third of all BMPs are located within the same drainage area, and/or are pretreatment practices that can only achieve a low or negligible nutrient removal rate. Failure to account for these BMPs properly can lead to double counting that leads to over-estimation of nutrient reduction by existing urban BMPs. Some useful “work-arounds” that can avoid these problems are provided in Appendix A-4 and A-5.

Table 24 Summary of MD BMP Design Era Nutrient Removal Efficiencies

	Total Nitrogen	Total Phosphorus	Total Suspended Solids
BMP 1: Pre 1985	0	0	0
BMP 2: 1985-2001	17	30	40
BMP 3: 2002 -2010	30	40	80
BMP 4: Post 2010	50	60	90
Era 1 Retrofits	25	35	65

Source: Urban Stormwater Workgroup (2011)

Recommended Process. The primary purpose of the BMP by Design Era approach is to help communities quickly assess the nutrient reduction achieved by their existing inventory of urban BMPs. MDE indicates that it can also be used as a default method for estimating nutrient reduction associated with BMP conversion retrofits, using the incremental removal rate between each design era. MDE will also accept alternative methods to estimate retrofit rates, when properly documented.

Qualifying Conditions: The BMP review panel recommended that the mass removal rates for all design eras may need adjustment (up or down), if future research better defines the effect of BMP age, maturation, and maintenance (or lack thereof) on actual nutrient reduction performance.

Local Tracking, Reporting and Verification: MDE has developed a sophisticated system to track local BMP implementation over time which can be found in MDE (2010).

5.3.4 BMP MAINTENANCE UPGRADES

Status: This is a new urban BMP which will be the subject of a BMP Expert Panel that is scheduled to conclude in 2012. It is recommended that the proposed method be accepted on an interim basis during the WIP planning process, and until the Panel makes a final recommendation.

Definition: Many communities have a legacy of thousands of older BMPs that either never worked to begin with, have lost their treatment capacity over time, or otherwise perform poorly in removing nutrients. An example of a typical county BMP inventory is provided in Table 25.

Table 25
Thirty Years of BMP Inventory in a Maryland County (2006)

Potentially High Performers		*Known Low Performers*	
Bioretention/Dry Swales	49	Underground Detention	270
Sand Filters	279	Dry Ponds	528
Wet pond	212	Oil Grit Separators	805
Pond Wetland	98	Proprietary Practices	239
Infiltration Basin	58	Flow Splitter	321
Infiltration Trench	459	Other (plunge pools)	30
Grand Total			**3350**
Adapted from MC DEP (2006)			

This nutrient removal credit only applies to major maintenance upgrades that can measurably improve the nutrient removal performance of existing BMPs. This occurs when the existing BMP has failed or lost its original stormwater treatment capacity. The credit is given when an existing BMP is rehabilitated to restore its original performance or when major sediment cleanouts are conducted. The credit is similar in many respects to the BMP enhancement retrofit credit, with the main difference being that the nutrient removal rate for the existing BMP has been down-graded to zero (based on field inspection).

Technical Issues

To qualify for this credit, communities need to undertake a field inspection program to assess the performance of their existing BMP inventory. The field inspections are used to downgrade individual BMPs whose hydrologic performance has failed or declined due to poor design, installation or maintenance. Specific reasons for a performance downgrade might be:

- Infiltration failure
- Lack of wetland cover in wetlands
- Significant bypass of stormwater inflows around the BMP
- Major loss of treatment capacity due to sediment deposition

Based on the field inspection, the nutrient removal rates for individual BMPs can either be downgraded to zero (failure) or to half the approved CBP rate (loss of treatment capacity), using the methods outlined in Appendix A-4.

For initial WIP planning purposes, communities may want to estimate that about 20 to 25% of their existing stormwater inventory installed prior to 2000 should be downgraded. The reduced performance should be reflected in the local WIP baseline nutrient load.

Recommended Process: Two options are suggested to define the nutrient removal credit for major maintenance upgrades:

The first option is fairly simple, and increases the down-graded removal rate up to the current CBP approved rate for the existing BMP that undergoes a makeover. In rare cases, the removal rate can be increased further to the Level 1 or Level 2 rate (see Table 20), if the BMP upgrade meets the appropriate design criteria.

The second option involves major sediment cleanouts at older BMPs to restore lost capacity. In this case, the credit is taken for the mass nutrient reduction associated with the mass of dredged sediments physically removed from the BMP, using the same general mass loading approach used for street sweeping (Section 5.3. 7), but using dry weight conversion and sediment enrichment factors that are appropriate for pond sediments (Schueler, 1996).

Qualifying Conditions:

The most important qualifying condition is that a locality must reflect their assumptions for the prevalence of BMP performance downgrades in their original the local WIP baseline load (i.e., reduce the removal rate for a fraction of BMPs to half of the CBP approved rate or lower).

The nutrient removal credit is taken after the BMP maintenance upgrade has been completed.

Local Tracking, Reporting and Verification: Localities should utilize the same general procedures as required for stormwater retrofits (Section 5.3.1).

5.3.5 URBAN STREAM RESTORATION

Status: This is a new interim BMP rate to replace the existing CBP-approved rate first crafted in 2003. A research team is currently reviewing several dozen research projects on various aspects of the urban stream nutrient cycle, and will develop a conceptual model to predict nutrient removal rate. The literature review will be forwarded to a CBP Expert Panel scheduled to conclude in 2012. It is recommended that the new rate be accepted on an interim basis during the WIP planning process, and until the Panel makes a final recommendation.

Definition: Recent research has shown clear differences in nutrient and sediment delivery rates between healthy, degraded and restored urban streams. In particular, urban streams experience high rates of channel erosion that deliver high nutrient and sediment loads. For example, the current version of the CBWM utilizes a strong empirical relationship between impervious cover and sediment delivery in urban watersheds (Langland and Cronin, 2003). The CBWM predicts sediment loads of 100 lbs/acre occur in watersheds with the least development, but this climbs to nearly 700 lbs/acre for the most intensely developed watersheds.

The floodplain and channel soils tend to be highly enriched with respect to nutrients, so channel erosion is suspected of being an important nutrient source (see Section 3). Other research has demonstrated that degraded streams have less capacity for internal nutrient uptake and processing, particularly with respect to de-nitrification. Stream restoration projects that reduce bank erosion and create in-stream habitat features have the capability to reduce both sediment and nutrient export in urban watersheds.

Technical Issues: The original nutrient removal rate for stream restoration projects was approved by CBP in 2003, and was based on a single monitoring study conducted in Baltimore County, MD (Table 26). The sediment and nutrient removal rates are based on the length of the stream reach restored, and appear to be very conservative.

More recent field studies by BDPW (2006) have evaluated the degree of nutrient reduction achieved by comprehensive urban stream restoration when compared to the in-stream nutrient load generated from un-restored and degraded urban streams. BDPW concluded from data on three comprehensive stream restoration projects that TP and TN load reductions of 0.068 lbs/linear foot/yr and 0.20 lbs/linear foot/yr could be conservatively supported (see Table 26).

Since then, about two dozen papers have been published on the nutrient and sediment dynamics of restored urban streams. While many of these studies reinforce the general conclusion that a higher removal rate is warranted, they are being extensively reviewed to determine if a more predictive method can be used to derive sediment and nutrient removal rates, based on various watershed, reach, cross-section and restoration design metrics.

Table 26
Removal Rate per Linear foot (lf) of Qualifying Stream Restoration

Source	TN	TP	TSS
CBP (2005) N=1	0.02 lbs	0.0035	2.55 lbs
Baltimore (2009) N=6	0.20 lbs	0.068 lbs	310 lbs
U of MD is presently conducting a study of up to 25 research studies on the effect of stream restoration on nutrient removal rates which will be run through an Expert Panel in 2012			

Recommended Rate: The BDPW rates should be used on an interim basis, until the stream restoration research review is completed by the University of Maryland, and the BMP Expert Panel has an opportunity to review its findings (scheduled for mid 2012).

Qualifying Conditions for Stream Restoration. The key issue is to outline the qualifying conditions to receive the credit. Clearly, stream restoration projects that are primarily designed to protect public infrastructure by bank armoring or rip rap do not qualify or a credit. For now, the recommended qualifying conditions for the project include:

- An entire urban stream reach greater than 100 feet in length that is still actively enlarging or degrading in response to upstream development. Most projects will be located on first to third order streams.
- Comprehensive stream restoration design, involving the channel, banks and floodplain using state approved design methods.
- Special consideration is given to projects that are explicitly designed to reconnect the stream with its floodplain and/or create instream habitat features known to promote nutrient uptake and/or de-nitrification.
- Pre and post-project monitoring may be required to substantiate bank/channel erosion rates, using bank pins, cross-sectional surveys or other methods.

It is anticipated that the BMP Panel will further expand and refine the qualifying conditions, as part of its future deliberations.

Local Tracking, Reporting and Verification

- Local governments should keep track of the length of qualifying stream restoration projects installed each year.
- They will also need to provide a post construction certification that the stream restoration practices were installed properly in the project reach and are working as designed before they are entered into a local and/or state tracking database.
- In addition, localities should maintain stream restoration project files for each development site where the credit is claimed for the lifetime of the project (usually 20 to 25 years).
- The duration of the credit is five years, but can be renewed if field inspection indicates the stream restoration project is still meeting its design objectives.

5.3.6 REDEVELOPMENT CREDITS

Status: This is a new urban BMP and will be the subject of BMP Expert Panel on Composite BMPs that is scheduled to conclude in 2012. It is recommended that the proposed method be accepted on an interim basis during the WIP planning process, and until the Panel makes a final recommendation.

Definition: This credit is used to account for nutrient reduction associated with the implementation of more stringent redevelopment stormwater requirements on existing, untreated impervious cover. Larger communities with high redevelopment rates and stringent stormwater requirements could expect to see substantial nutrient reductions which they can deduct from their baseline nutrient load allocation.

Technical Issues: Most Bay states have increased stormwater performance standards that apply to redevelopment in urban watersheds (for a review, see CSN, 2011). While the stormwater standards for redevelopment tend to be lower than for new development, they have the potential to incrementally reduce nutrient loads from untreated impervious areas during the redevelopment process.

The proposed redevelopment credit applies to redevelopment projects that meet the new redevelopment standards from 2010 and going forward. A simple tracking approach is needed since most redevelopment projects are small with respect to drainage area, yet are often large in number.

In order to comply with the new redevelopment standards, designers will need to employ multiple LID practices that are feasible at high intensity redevelopment sites, such as green roofs, foundation planters, permeable pavers and expanded tree pits (CSN, 2011). This suggests that a composite approach is needed to define the nutrient removal rate for the system of LID practices employed (i.e., Section 5.3.2), rather than an individual BMP removal rate.

Recommended Process: The proposed redevelopment credit tracking system should be reasonably accurate and yet easy to administer.

Step 1: Track the cumulative number of impervious acres that are redeveloped each year *and* meet or exceed the local and/or state stormwater redevelopment requirements. This includes projects that treat stormwater on site and/or reduce pre-existing impervious cover through acceptable conversion techniques.

Step 2 Multiply the qualifying impervious acres by the nutrient reduction credits shown in Table 27. The nutrient credits reflect the different levels of stormwater treatment required at redevelopment sites, as well as the extent to which on-site runoff reduction is implemented across a locality.

Table 27
Nutrient Reduction Credit for Different Combinations of Redevelopment Volumetric Criteria

Volumetric Criteria		Redevelopment Credit Lbs/imperious acre/year	
Rainfall depth controlled	Degree of runoff reduction	Total Phosphorus	Total Nitrogen
0.25	LO	0.4	3.0
	HI	0.6	4.5
0.50	LO	0.6	5.1
	HI	0.9	6.8
0.75	LO	0.8	6.3
	HI	1.1	8.9
1.0	LO	1.1	8.4
	HI	1.5	10.5
1.25	LO	1.33	9.9
	HI	1.7	11.3
1.50	LO	1.5	10.1
	HI	1.75	12.7
2.0	LO	1.6	11.5
	HI	1.8	13.5
2.5	LO	1.8	12.8
	RR	1.9	13.9
For derivation, consult appendix A-7			

Local Tracking, Reporting and Verification: The treated area of each individual redevelopment project can only be added to the local database if it has received a post-construction certification that it is actually working as designed. In addition, a municipality can only receive the credit if it meets the minimum state or permit standards for on-site maintenance inspections and enforcement.

5.3.7 URBAN REFORESTATION

Status: There is an existing CBP-approved BMP nutrient rate for reforestation in urban stream buffers. In addition, tree planting in urban areas is modeled as a land use change (i.e., shift from unit nutrient loading rate for turf cover to forest cover). Neither of these rates accounts for situations where stormwater runoff is directed to reforestation areas and/or when soil infiltration conditions are improved through soil restoration. In addition, there is no credit for urban tree planting techniques to increase forest canopy and improve stormwater treatment in highly urban watersheds. Interim methods for addressing these situations are proposed, and it is anticipated an Expert Panel and the Forestry Working Group will revisit the urban reforestation credits in late 2012 or early 2013.

Definition: Urban reforestation involves restoring compacted soils and planting trees explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapo-transpiration rates, and enhance soil infiltration rates. As a result, at least five kinds of reforestation are possible:

1. Upland Reforestation
2. Forest Filter Strip
3. Urban Stream Buffer
4. Urban Tree Canopy
5. Urban Tree Canopy w/ BMPs

Upland Reforestation is defined as tree planting on a turf or open area that does not receive stormwater runoff.

Filter Strips are an engineered practice where trees are planted in a zone that is designed to accept runoff from adjacent impervious cover.

Urban Stream Buffers involve planting trees within 100 feet of a stream or wetland to create a forest buffer and then installing controls at the boundary so that it can treat sheet flow from adjacent pervious or impervious areas.

Urban Tree Canopy involves planting trees in the street right of way in very urban areas to create a mature forest canopy over impervious areas. The canopy intercepts rainfall and acts as a "vertical stormwater disconnection" during the growing season (Cappiella et al, 2006).

*Urban Tree Canopy w/ BM*Ps increase tree canopy but also employs expanded tree pits to filter runoff from adjacent impervious areas.

Technical Issues: Research is limited on the hydrologic function and potential nutrient removal associated with the five kinds of reforestation described above. In general, the CBP approved nutrient and sediment removal rates are higher for reforestation that occurs in agricultural watersheds than in urban applications. The primary reason is that agricultural buffers and forest filter strips treat nutrients in both groundwater and surface runoff, whereas their urban counterparts treat concentrated runoff that can often short-circuit the system.

Lastly, the benefit of reforestation largely depends on where it is located in the urban landscape, what are the soil infiltration rates at the site and whether it can treat runoff from adjacent impervious areas. As an example, upland reforestation gets a nutrient credit that is much smaller than reforestation on permeable soils near a stream or a parking lot that is engineered to treat stormwater.

Recommended Rates for Reforestation.

Table 28 outlines the removal rates and reporting units for the five types of urban reforestation.

Table 28
Proposed Interim Rates for Reforestation, Based on Type and Location

Type and Location	Unit	Soil Type	TN	TP	TSS
Upland	Acres reforested	NA	10 [1]	10 [1]	20 [1]
Forest Filter Strip	Strip acreage + IC Acres treated	A & B	50	75	75
		C & D	25 [2]	50 [2]	60 [2]
Stream Buffer	Buffer acreage + IC Acres treated	A & B	50	50	75
		C & D	25 [2]	50 [2]	50 [2]
Urban Tree Canopy	Aggregate acres of forest canopy	In-situ	10	10	20
		Restored	15	15	25
Urban Tree Canopy BMPs	IC acres treated	NA	25 [3]	45 [3]	55 [3]

Notes:
[1] These rates are derived based on converting the forest cover to an equivalent impervious acre and determining nutrient reduction using Simple Method approach (see Appendix A-6)
[2] Rates shown are current CBP approved rates for urban filter strips and stream buffers, respectively
[3] Rates are assumed to be comparable to current CBP- approved rate for bioretention on C/D soils with under drains

Qualifying Conditions

The qualifying conditions for upland reforestation are as follows:

- The minimum contiguous area of reforestation must be greater than 5,000 square feet.
- If soils are compacted, they will need to be deep tilled, graded and amended with compost to increase the porosity and water holding capacity of the pervious area, using the methods outlined in the Bay-wide soil restoration specification.
- The proposed reforestation must be for the purpose of reducing runoff. Compensatory reforestation required under local or state forest conservation laws is not eligible for the credit

- A long term vegetation management plan must be prepared and filed with the local review authority in order to maintain the reforestation area in a forest condition.

- The planting plan does not need to replicate a forest ecosystem or exclusively rely on native plant species, but it should be capable of achieving 75% forest canopy within ten years.

- The construction contract should contain a care and replacement warranty extending at least two growing seasons, to ensure adequate growth and survival of the plant community. Control of invasive tree species should be a major part of the initial maintenance plan.

- The reforestation area shall be shown on all construction drawings and erosion and sediment control plans during construction.

- The reforestation area should be protected by a stormwater easement, deed restriction or other legal instrument which stipulates that no future development or disturbance may occur within the reforested area, for a minimum of at least ten years. Any clearing or land disturbance after that point will negate the value of the nutrient credit.

The qualifying conditions for forested filter strips and urban stream buffers can be found in state design guidance such as MDE (2009), VADCR (2009) and CSN (2011). Qualifying conditions for urban tree canopy w/ or w/o BMPs have yet to be developed.

Local Tracking, Reporting and Verification

Tracking of reforestation projects is critical given that there is such a lag time between when the trees are planted and when the full runoff and nutrient reduction benefits of a forest are realized. In most cases, it takes at least 10 to 15 years for a tree planting to acquire the characteristics of a forest. During this time, there are a number of threats to successful forest establishment (deer browsing, drought, invasive species, etc).

Therefore, the credit should not be reported until two growing seasons after the initial planting to ensure adequate growth and survival, followed by inspections and forest management activities every two years thereafter.

5.3.8 STREET SWEEPING

Status: This credit was approved by a CBP BMP Expert Panel in March of 2011

Definition: Frequent street sweeping of the dirtiest roads and parking lots within a community can be an effective strategy to pick up nutrients and sediments from street surfaces before they can be washed off in stormwater runoff.

Technical Issues: The basic data for defining the credit were initially developed by Law et al (2008) based on a Baltimore monitoring study and a nationwide literature review of prior street sweeping studies.

Recommended Process: The first and most preferred option is the **mass loading approach**, whereby the mass of street dirt collected during street sweeping operations is measured (in tons) at the landfill or ultimate point of disposal.

Step 1*:* Determine the hopper capacity of your current sweeper technology

Step 2*:* Weigh the street solids collected to develop a simple relationship between street solid mass (in tons) to hopper capacity

Step 3*:* Keep records on the annual mass of street solids collected from qualifying streets

Step 4*:* Convert tons into pounds of street solids (multiply by 2000), and converted to dry weight using a factor of 0.7

Step 5*:* Derive your nutrient reduction credit by multiplying the dry weight of the solids by the following factors:

- Lbs of TN = 0.0025 pounds of dry weight sweeping solids
- Lbs of TP = 0.001 pounds of dry weight sweeping solids

These factors are based on sediment enrichment data reported by Law et al (2008), adjusted from original mg/kg values of 1200 (TP) and 2500 (TN)

Step 6*:* Compute the TSS reduction credit by multiplying the annual mass of dry weight sweeping solids by a factor of 0.3. This correction eliminates street solids that are greater than 250 microns in size, and therefore cannot be classified as total suspended solids. This factor was developed by the BMP panel and reflects particle size data from two recent street sweeping studies. SPU (2009) estimated TSS removal from street sweeping that was approximately 20% of the total dry sweeping solids load recovered. The particle size distribution for recovered street sweeping solids by Law et al. (2008) showed approximately 30% of the recovered solids in this TSS size range (i.e. ≤ 250 μm) by mass.

The second accepted method is **the qualifying street lanes method**.

Step 1*:* Each locality reports the number of qualifying lane miles they have swept during the course of the year.

Step 2*:* Qualifying lane miles are then converted into total impervious acres swept by multiplying the miles (5280 feet) by the lane width (10 feet) and dividing by 43,560. If both sides of the street are swept, then use a lane width of 20.

Step 3*:* Multiply the impervious acres swept by the pre-sweeping annual nutrient load using the Simple Method unit loads (Schueler, 1987).

TP = 2.0 lbs/impervious acre/year
TN = 15.4 lbs/impervious acre/year

Step 4*:* Multiply the total pre-sweep baseline load by the pickup factors shown in Table 29 to determine the nutrient and sediment load credit for street sweeping.

Table 29 Multipliers to Reflect Effect of Street Sweeping on the Baseline Load [1]

Technology	TSS	TP	TN
Mechanical	.10	.04	.04
Regenerative/Vacuum	.25	.06	.05

[1] interpolated values from weekly and monthly street sweeping efficiencies as reported by Law et al (2008)

Qualifying Conditions for Street Sweeping Nutrient Reductions: The nutrient reductions only apply to an enhanced street sweeping program conducted by a community that has the following characteristics:

- An urban street with an high average daily traffic volume located in commercial, industrial, central business district, or high intensity residential setting.
- Streets are swept at a minimum frequency of 26 times per year (bi-weekly), although a municipality may want to bunch sweepings in the spring and fall to increase water quality impact.
- The reduction is based on the sweeping technology in use, with lower reductions for mechanical sweeping and higher reductions for vacuum assisted or regenerative air sweeping technologies.

Local Tracking, Reporting and Verification: Localities will need to maintain records on their street sweeping efforts using either method, and provide a certification each year as to either the annual dry solids mass collected or the number of qualifying street miles that were swept.

5.3.9 URBAN FERTILIZER MANAGEMENT

Status: There is an existing credit for urban nutrient management on pervious areas, although the qualifying conditions under which it can be claimed are not precise. In addition, several Bay states (MD, NY and VA) have enacted legislation to ban phosphorus in most commercial and retail fertilizer sales. No credits have yet been defined for communities that implement policies to restrict or eliminate fertilizer applications on publicly owned turf. An expert BMP review panel will be established to further refine urban fertilizer management nutrient credits in 2012.

Definition: Turf covers nearly 4 million acres in the Chesapeake Bay, or just under ten percent of total watershed area (CSN, 2009). Surveys have indicated that perhaps as much 50% of the turf cover is regularly fertilized (CSN, 2009). While some fertilizer is incorporated into turf biomass, research has shown a significant potential for nutrient export from urban lawns via stormwater runoff or leaching into shallow groundwater (see Section 3).

Fertilization is not generally needed to promote healthy turf growth in most lawns in the Bay watershed, given current rates of atmospheric deposition and the use of composting lawn mowers. Existing soils are generally capable of supplying enough nutrients, particularly so in the case of phosphorus. Consequently, there are three different urban fertilizer management strategies for which removal rates can be defined:

1. Automatic Credit for State-wide P Ban on Fertilizer
2. Fertilizer Education on Privately Owned Turf (Urban Nutrient Management)
3. Fertilizer Restrictions on Publicly Owned Turf

Automatic Credit for State-wide P ban on Fertilizer: The impact of a fertilizer P ban on future nutrient load from the urban and suburban land sector was modeled as an application reduction in the CBWM, and unofficial model runs suggest that it is an extremely effective phosphorus reduction strategy. The model predicted that the total phosphorus load from pervious urban lands would decline from 12 to 19% due to a P-ban, with the greatest reductions in states closer to the Bay and with the greatest turf density (Brosch, 2011). As might be expected, the reduction in urban nitrogen load was marginal, projected to be less than 1%.

The early CBWM estimates are generally in line with other research and modeling studies that have investigated the impact of fertilizer P-bans on phosphorus loadings. These studies were conducted outside the Chesapeake Bay, and typically found overall phosphorus reductions in the 10 to 12% range (Bierman et al, 2010, Vlach et al, 2009 and EPA Region 1, 2010).

Urban Nutrient Management: The CBP-approved rate for urban nutrient management on pervious land is 17% for TN and 22% for TP (see Table 21). According to CBWM documentation, this reduction is credited for urban lawns where fertilizer impact is reduced by adhering to certain best practices (e.g., soil testing and fertilizing at recommend rates in the appropriate season using slow release formulations). It is unclear whether the urban nutrient management credit also includes property owners that elect to become non-fertilizers. The credit appears to be overly generous (at least for phosphorus) since the 22% reduction for using P fertilizers judiciously is greater than the 17% reduction for eliminating phosphorus from fertilizer altogether (12 to 19%- see above).

Fertilizer Restrictions on Publicly Owned Turf: Communities can enact policies to restrict or eliminate fertilizer applications on publicly owned turf, which can comprise 10 to 15% of the total turf cover in their community (CSN, 2009). In general, fertilizer application rates tend to be lower on publicly owned turf, with the exception of golf courses and athletic fields.

Fertilizer restriction policies can be implemented rapidly by public land management agencies by changing purchasing and contracting policies in order to significantly reduce or even eliminate fertilizer applications. In addition, these policy changes do not require the same investment in homeowner outreach, education, engagement and behavior change that is inherent in the urban nutrient management model.

Technical Issues: The key technical issue with the last two fertilizer credits is getting accurate estimates of the acreage of pervious land where urban nutrient management or public land fertilization restrictions are actually being applied (and defining the baseline year in which it occurs). For example, it is presumed that education campaigns can produce changes in fertilizer behaviors by homeowners, but it is extremely hard to measure the precise acreage that is affected without detailed before and after surveys of homeowners. In addition, changes in homeowner fertilization behavior may stall or even reverse unless outreach campaigns are repeated.

Recommended Process to Define Fertilizer Management Credits

> *Automatic Credit for State-wide P Fertilizer Ban*. The potential impact of state-wide P ban on reducing urban nutrient loads will be projected in future CBWM model runs. These model runs will then be used to reduce each state's nutrient load allocation for the urban and suburban sector as the P bans go into effect from 2012 to 2014. In effect, localities will be granted an automatic phosphorus reduction credit that can be deducted from their local baseline loads.
>
> *Urban Nutrient Management*. Local governments may obtain additional nitrogen reduction credits if they implement education programs that reduce fertilizer applications on privately owned turf. There are two methods they can use to track the changes in fertilizer behavior:
>
>> *Option 1 Use Existing Urban Nutrient Management Credit*. In this option, it is recommended to use the full 17% reduction for nitrogen for certified acres that shift from fertilized to non-fertilized, and use half that rate for certified acres where fertilizers shift to lower impact fertilization methods. Communities in states that have not enacted fertilizer P bans may use the

same approach to credit phosphorus reductions for certified acres (22% non-fertilized/11% low impact fertilization).

Option 2 Residential Nutrient EMC. Communities that use WTM models can derive a more accurate estimate by tracking the changes in certified acres that have shifted from a high fertilizer input EMC to a low fertilizer input EMC using the relationship shown in Table 8 (Section 3).

Fertilizer Restrictions on Publicly Owned Turf. This method requires a comprehensive analysis of existing fertilization practices on the many different types of municipally owned land to identify specific acreage where future applications could be reduced or eliminated (Novotney et al, 2009). Once the acreage is defined and the community fertilizer restriction policy is implemented, then the nutrient load reduction credit can be computed using either Option 1 or Option 2 above.

Qualifying Conditions: The key qualifying condition for this credit is the certified acres where fertilizer applications change going forward. Several options are available to certify acreages, such as before and after surveys of homeowner fertilizer behavior, individual pledges to change behaviors, and changes in retail fertilizer sales. More work is needed to define these options.

Local Tracking, Reporting and Verification: Maintain records of certified acres where fertilizer use has changed.

5.3.10 SEPTIC SYSTEM HOOKUPS AND UPGRADES

Status: This is an existing CBP approved removal credit for three different septic system management activities. The credit only applies to nitrogen; no credit is granted for phosphorus or sediment reduction.

Definition: Section 3 noted that each functioning septic system in close proximity to the Chesapeake Bay can deliver as much as 12 pounds of TN per year. Credit is given for three septic system management practices: septic tank pump-outs, retrofitting existing septic systems with enhanced de-nitrification technology and connecting existing septic systems to sanitary sewers which can provide a higher level of treatment.

Technical Issues: Most septic systems are associated with low density residential development, although relict systems may also be found within the existing water and sewer envelope.

Recommended Rates: The CBP approved rates for septic system management activities are provided in Table 30.

Table 30 Nutrient Removal Rates for Septic Systems			
Practice	TN Removal	TP Removal	Reporting Units
Septic Denitrification	55	0	Systems
Septic Pumping	5	0	Systems
Septic connections/hookups	55	0	Systems
Source: CBP, 2007			

5.3.11 ILLICIT DISCHARGE ELIMINATION

Status: This is a potentially new BMP credit that is currently under development and may be considered for expert panel review in coming years. The proposed method shown here for defining a nutrient credit for the elimination of illicit discharges requires further technical and legal analysis. Depending on approval by the CBP, the credit may be allowed on an interim basis for select urban communities as part of the WIP planning process.

Definition: The proposed credit applies to episodic or chronic discharges of diluted sewage into the municipal storm drain system that are detected based on nutrient screening of dry weather flow at stormwater outfalls, tracked back up through the storm drain system to their source using the methods of Brown et al (2004) and physically eliminated.

High nutrient levels have been detected in dry weather flows in a number of urban streams in Maryland (CWP, 2010, CWP, 2011). Subsequent outfall screening using nutrient based indicators suggest that the much of nutrients are derived from illicit discharges of sewage. Part of the reason is the interaction of flows and overflows from aging sanitary sewers and storm sewers which often run close together.

Mass balance studies indicate that these discharges may account for as much as 20 to 30% of the annual nutrient load of some urban streams (CWP, 2011). This suggests that an aggressive local IDDE program could achieve significant nutrient reductions. IDDE efforts are already required under municipal MS4 stormwater permits.

Technical Issues: There are several issues involved in defining the nature, duration and qualifying conditions for this nutrient credit. For example, more research is needed to determine if the nutrient discharges reported by CWP (2010) are a universal phenomenon in the Bay watershed or are confined to urban watersheds with aging sewer infrastructure. Also, although most Bay communities are required to conduct outfall screening as part of their MS4 permits, few utilize screening indicators that detect the presence of diluted sewage flows, or screen smaller outfalls (less than 36 inches in diameter which have proven to be a larger share of all illicit discharges (Brown et al, 2004).

Recommended Process:

Step 1: The dry weather flow rate and nutrient concentrations should be measured at suspect outfalls identified during routine outfall screening.

Step 2: The discharge should be tracked back up the storm drain system to its source, using the investigation methods provided by Brown et al (2004).

Step 3: The flow rate and nutrient concentration from the source discharge should be monitored before and after the discharge is physically eliminated

Step 4: Subsequent monitoring should be conducted at the original outfall to conform that dry weather nutrient concentrations have returned to background levels.

Step 5: The nutrient credit is computed by multiplying the daily flow rate and nutrient concentration of the source discharge to derive a daily nutrient load. The daily load can then be multiplied by the number of days from when the suspect outfall was discovered and when the source discharge was physically eliminated.

Qualifying Conditions: No credit is given for fixing sanitary sewer overflows that occur within the urban stream corridor, nor is any credit given for elimination of transitory illicit discharges such as car wash-water.

Local Tracking, Reporting and Verification: To receive the credit, a community must provide physical evidence of how the discharge was eliminated, and document the change in nutrient concentrations at both the outfall and the source discharge. The "fixed" outfall should be re-screened every year to verify that the discharge has been permanently eliminated.

5.3.12 OTHER URBAN BMP RATES

Certain wetland restoration and shoreline erosion control projects may also be eligible for nutrient reduction credit, as shown in Table 31.

Table 31
Nutrient Removal Rates for Other Urban BMPs

Practice	TN Removal	TP Removal	Reporting Units
Shoreline Erosion Control	75	75	Linear Feet
Emergent marsh restoration	42	55	Acres
Forest wetland restoration	43	58	Acres
Source: CBP, 2007			

Section 6: A Progressive Strategy for Achieving Local Nutrient Reductions

The preceding sections suggest that local nutrient accounting can be daunting and complex process. This section synthesizes the prior technical analysis and recommends a simplified series of strategies to identify the easiest and most cost-effective combination of BMP credits to achieve your local nutrient reduction allocation.

Every community will develop its own unique nutrient reduction action strategy that reflects its size, population, development intensity, forecasted growth, MS4 stormwater permit status, terrain and staff resources. The basic approach to develop the action strategy, however, is much the same in all communities -- to engage in a simplified watershed planning process that progressively investigates which BMP credits are most applicable to your community. The basic idea is to proceed through the available BMP credits, starting by analyzing the easiest and less expensive ones and moving through the more complex and costly ones until compliance is achieved.

This watershed planning process is designed for smaller towns and counties that have limited staff and technical resources, and are not planning on creating their own local nutrient loading model. Instead, these smaller communities will simply be reporting their BMP implementation metrics directly to the state.

By contrast, larger communities may wish to undertake more advanced planning, modeling and BMP tracking activities. These more sophisticated nutrient accounting methods are described in more detail in Section 7. Both large and small communities should organize their efforts around the 12 BMP implementation strategies outlined in this section.

6.1 Put Together Watershed Team to Evaluate Local BMP Implementation

The first step is to convene an interagency team to evaluate the current level of BMP implementation in the community. The team lead is usually the agency responsible for administering the municipal stormwater permit, but this role may be performed by a planning agency in smaller community. It is also useful to invite other stakeholders to join the team, such as a planning district commission, soil conservation district, cooperative extension service or local watershed group.

The first task for the team is to obtain the local nutrient reduction allocation from the state or regional agency administering the TMDL, and coordinate with the state TMDL agency to better understand their local expectations for the Phase II watershed implementation plan process.

Next, the team should analyze local land use and land ownership data to determine what part of their load allocation can be legitimately excluded (i.e., state or federal lands, agricultural conservation areas).

The next task for the team is to identify which local agencies or stakeholders have primary responsibility to implement the dozen available urban BMP credits shown in

Table 32. In many cases, these agencies may already be implementing a credit, or could do so through modest changes to existing programs. In these situations, the team should:

- Determine whether they meet the qualifying conditions for the credit
- Calculate the aggregate BMP removal credits
- Analyze the budgetary impact of expanding BMP implementation
- Determine how the credits should be documented and reported to the appropriate state or regional agency responsible for aggregating BMP implementation data.

The next task is to analyze the nutrient reduction potential associated with new BMP credits that are not yet being delivered in the community. It is recommended that the watershed team progressively evaluate these potential credits in the order in which they are presented in this section.

Table 32: Organizing Your Local Watershed Implementation Team		
BMP Credit	**Lead Agency**	**Other Stakeholders**
Watershed Mapping/Planning	Planning, GIS	Local watershed group
Stormwater Retrofits	DPW or stormwater review agency	Schools, parks, roads, and other public land
New Development	Stormwater review agency	Land use planning
Maintenance Upgrades	DPW Maintenance crew	CIP budgets
Stream Restoration	Environmental resources	Parks
Redevelopment Credits	Stormwater review staff	Planning agency
Reforestation	Community forestry and Site planning agencies	Parks, street trees, schools
Street Sweeping	DPW Maintenance Crew	Street maintenance
Urban Fertilizer Management	MS4 Permit holder	Cooperative Extension
Septic Hookups/Upgrade	Sanitarian	wastewater Utility
Illicit Discharge Elimination	MS4 Permit holder	Watershed groups
Wetland/shoreline Restoration	Local environmental agency	Land conservancy

6.2 Decide Whether to Develop your own Local Nutrient Load Model

The team should review their local planning resources and decide whether or not to develop a local model to handle their local nutrient accounting (see Section 4). This decision is often based on whether a locality has existing watershed planning resources, such as detailed land use data, good GIS coverage, and an up-to-date stormwater BMP inventory. Some practical advice on the steps for developing a local nutrient model will be the subject of a future Technical Bulletin.

The benefits of developing your own local nutrient load model are:

- A better understanding of how future land use change will impact your baseline nutrient load as new development and redevelopment occurs.

- A more precise characterization of the prevailing land use, land cover and land ownership in your community.

- A better representation of the actual nutrient reduction achieved by your existing stormwater infrastructure, BMP inventory and local maintenance programs

- The ability to forecast nutrient loads for multiple watersheds in your community, which can be very important if they are subject to additional pollutant reduction through local TMDLs.

- A common platform to compare the nutrient reduction potential of different BMP credits.

- A more consistent and compatible method to document, track, and verify the actual BMP credits that are implemented to the appropriate regional or state reporting agency.

The drawbacks of creating a local nutrient loading model are that it may:

- May not be fully compatible with the outputs of the CBWM or the inputs needed for BMP tracking and reporting to the state.

- Require major upgrades to local GIS mapping systems or acquisition of new land cover data that is expensive.

- Take three to six months of staff resources or consultant help to set up.

- Divert resources to extended planning rather than immediate implementation

- Not be needed if a community has a low nutrient allocation, has an existing delivery system to implement effective urban BMP credits, or plans to meet their nutrient allocations through wastewater upgrades or agricultural BMPs.

6.3 Take Credit for Fertilizer Reductions on Urban Turf

The most cost effective nutrient reduction strategy in any Bay community is to reduce or eliminate fertilization on urban turf. When less fertilizer is applied to lawns, it translates to lower nutrient loads washing off pervious areas in stormwater (and less need for downstream retrofits to capture and treat the polluted stormwater). As was noted in Section 5.3.9, the total nutrient reduction achieved through urban fertilizer management can be impressive. Communities can employ three basic strategies to reduce fertilizer applications:

1. Automatic Credit for State-wide P Ban on Fertilizer
2. Fertilizer Education on Privately Owned Turf (Urban Nutrient Management)
3. Fertilizer Restrictions on Publicly Owned Turf

Team Homework

- Check to see if your state has enacted a phosphorus ban for residential fertilizer.

- Check your current nutrient management practices on municipally owned land, including schools, parks, and golf courses and landscaping areas, and estimate the number of acres that are currently fertilized.

- Check to see which local agencies, stakeholder groups or adjacent communities are currently providing homeowner outreach and education on fertilizer use, or could perform this role in the future.

Team Actions:

- If your state has not yet enacted a P-ban on lawn fertilizer (DC, DE, PA, WV), then you may want to work with your state-wide stakeholders to propose legislation in the coming years to enact such a ban. If you are located in MD, VA or NY, you will get an automatic credit for phosphorus reduction in your baseline load allocation in the coming years.

- Further work is needed to achieve nitrogen reductions through improved nutrient management on public land. The first priority is to focus on reducing fertilizer use on publicly owned land, which can comprise as much as 10 to 15% of the total turf cover across a community (CSN et al, 2008). Once existing public fertilization practices are known, it is relatively easy to modify existing local procurement, contracting and landscape maintenance policies to eliminate fertilization or require specific urban nutrient management practices, depending on how the public land is used (e.g., it may not be possible to eliminate fertilizer use on golf courses and athletic ball-fields). This approach should actually yield savings in many communities, depending on how many acres of public land are currently fertilized.

- The third action is to decide whether to expand fertilizer reduction efforts on private land through increased homeowner education programs. The potential for significant nitrogen and phosphorus reductions from private turf, but it can be hard to verify the actual changes in homeowner fertilization behavior that can be attributed to the retail or wholesale education efforts over time. Developing effective nutrient education programs involves more than printing a few flyers or posting material on a website; considerable research and survey work is needed to define current fertilization behaviors and target neighborhoods or populations for intensive education. Guidance on designing and budgeting for an urban fertilization education program can be found in CWP (2004).

6.4 Take Credit for More Stringent Stormwater Redevelopment Requirements

This strategy seeks to accelerate the adoption of more stringent stormwater requirements at redevelopment sites so that previously un-treated parts of the urban landscape can be incrementally treated by new LID practices. The new redevelopment stormwater requirements will roll out from 2009 to 2014, depending on which Bay state you are in. The roll out may possibly occur even later if there are significant grandfathering provisions or delays in getting local ordinances adopted and review policies in place.

Team Homework:

- Check with the economic development or planning office to see how much redevelopment activity is expected in the community over the next five to ten years to see if this is a viable strategy.

- Check with the local stormwater review authority to find out the earliest date by which the new state redevelopment performance standards can be adopted locally.

- Consider conducting a design charette to calculate the nutrient reduction impact on a proposed redevelopment project in the community.

Actions:

- Work with staff get the local stormwater ordinance and local design supplements ready as soon as possible.

- Make sure to develop a local offset fee program so that redevelopment projects that cannot fully comply with the new performance standard can pay a fee to the locality to provide an equivalent amount of treatment elsewhere in the watershed. The offset fee option provides flexibility to promote redevelopment, at the same time it provides a revenue stream to support local retrofitting. More guidance on developing a local offset fee program can be found in CSN (2011).

- Based on the future redevelopment forecasts, calculate the expected acres of impervious cover that could be subject to the new standards, and estimate the aggregate redevelopment credit, based on the rainfall capture volume and degree of runoff reduction achieved at typical redevelopment sites.

- The transition to a new redevelopment standard can be rocky, so be sure to invest in training on redevelopment practices and design techniques for both the private sector and local plan reviewers. The Chesapeake Bay Stormwater Training Partnership has developed extensive training resources which can be accessed at www.cbstp.org

- Work with the stormwater review agency to develop a tracking system for the aggregate nutrient credit achieved by individual redevelopment projects over time.

6.5 Become an Early Adopter of New Stormwater Performance Standards

Most Bay states are also making the transition to more stringent stormwater performance standards for new development projects. Localities have a strong incentive to accelerate the implementation of the new standards, as they often have the potential to achieve "nutrient-neutrality", i.e., ensuring that the nutrient load from the site does not exceed the acceptable annual nutrient load for runoff. Sites that are designed under the old standards, on the other hand, will generally add to a localities baseline load, since they cannot achieve nutrient-neutrality (see Section 5.3.2).

Each locality is on a different schedule to adopt the new performance standards, which reflects the state regulatory process, the need to adopt a local ordinance approval, deal with grandfathered projects and upgrade their plan review process. Consequently, most localities will end up with a mix of sites that have practices approved under the old or new standards between now and 2015. This mix of sites will complicate efforts to track the net change in nutrient loads from new development in most communities until the new standards are fully phased in. A further complication is that some new development projects may not be able to fully meet the new standards, due to physical constraints.

Homework

- Check with the land use planning office to get a forecast of future new development activity over the next five to ten years to determine whether land use change will have a material effect on the local baseline load.

- Check with the local stormwater review authority to find out the earliest date by which the new state stormwater performance standards for new development can be adopted locally.

- Adoption of a local ordinance is just the beginning of the implementation process, so consult with the stormwater review authority to see whether they need further training, stakeholder review, design supplements or enhancements to the review process to make for an earlier transition.

Actions:

- Develop a spreadsheet to track the acreage of new development treated by stormwater practices under the old and new performance standards, beginning in the baseline year of 2009. It is a good idea to link the spreadsheet to a GIS system so that each individual BMP or composite BMP can be tracked, inspected and maintained over time, using the new BMP reporting and verification procedures outlined in Section 5.3.2.

6.6 Take Credit for Community Reforestation

Reforestation is a cost-effective nutrient reduction strategy, particularly when trees are planted in key locations in the watershed, such as stream buffers or forest filter strips. Most communities have experience with reforestation, and some have established forest canopy goals to green their community. Costs can be further reduced if the tree planting and maintenance is performed by volunteers.

Homework

- The watershed team should investigate which local agencies and partner groups are currently engaged in reforestation, including community forestry, parks, public works (street trees), local watershed groups, and soil conservation districts.

- The team should also investigate which partner agencies can provide technical assistance, trees, volunteers and financial support to improve the delivery of reforestation projects.

- The team should maintain records on the acreage of reforestation projects from 2009 onward to maximize the nutrient credit. It should be noted that reforestation projects that are done to mitigate prior forest clearing are not eligible.

- In more urban cities, the team should assess their current street tree program, and see whether shifting to greater use of expanded tree planters would result in a meaningful nutrient reduction credit (see section 5.3.7).

Action Items:

- The first priority for the team should be to focus on strategic reforestation projects on un-forested streams located on public land or within private stream buffer easements. The team may wish to take a stream walk and used the unified stream assessment method to identify candidate reforestation projects (CWP, 2003). Extra nutrient credit is given if the reforested buffers are designed to treat runoff from adjacent impervious cover.

- The second priority is to find areas suitable for forest filter strips on public land that can also treat runoff from buildings and parking lots. Minor grading may be needed to capture concentrated runoff before it reaches the forest filter strip. There are many good locations for reforestation on public land; please consult Cappiella et al (2005) for guidance on watershed forestry practices.

- The third priority is to provide subsidies or incentives to reforest upland areas located on private land, or expand the urban street tree program in more urban cities.

- Most communities will need to develop new procedures to inspect and maintain reforestation projects over time so they actually grow into forest (and receive a nutrient removal credit). The requirements for long-term forest management and reforestation tracking are outlined in Section 5.3.7.

6.7 Take Credit for Current and Future Stream Restoration Projects

Qualifying stream restoration projects can achieve high nutrient reduction rates, as was shown in Section 5.3.5. Stream restoration is generally popular as it provides a visible benefit for the public, as well as a nutrient reduction benefit for the Chesapeake Bay. Recent data also indicates that stream restoration is cost competitive with pond retrofits when it comes to nutrient removal (CSN, 2011).

Homework

- Check with the local DPW and/or watershed restoration agency to determine whether any stream restoration projects have been installed in the past or are scheduled to be constructed in future capital budgets. Review the project designs to see if they meet the qualifying conditions for the stream restoration credit, as outlined in Section 5.3.5.

- Many communities will find that many of their stream restoration projects may not qualify, particularly if they only involve bank armoring to protect public infrastructure from severe bank erosion. The team should scrutinize these projects to see if they can be redesigned in the future to provide more comprehensive stream restoration benefits, and thus qualify for the credit.

Actions:

- Communities may seek to take a watershed approach to find suitable locations for urban stream restoration. Schueler (2004) provides guidance on the methods used to find and design good stream restoration projects.

6.8 Evaluate the Performance of Existing BMPs

Many communities have been treating stormwater runoff quality for several decades and may have hundreds, if not thousands, of older stormwater BMPs. Most of them were designed to less stringent standards and design criteria, and their nutrient removal performance has declined due to poor installation, maintenance and age. These older BMPs are often unsightly, overgrown and a source of nuisance problems and citizen complaints.

As noted in Section 5.3.4, these older elements of local stormwater infrastructure are excellent opportunities for maintenance makeovers to upgrade their nutrient removal capability. By retooling existing maintenance budget, communities can simultaneously eliminate eyesores and help clean up the Bay.

Homework

- The watershed team should consult with DPW or the local stormwater review authority to learn the history of stormwater management in their community, understand the performance of the existing stormwater BMP inventory, and get to a better sense of the quality of past BMP and maintenance records.

- The team should also investigate who owns and/or maintains the BMPs in the inventory. BMPs that are publicly owned or maintained are usually the best candidates for maintenance upgrades, although larger private facilities may also be suitable.

- The team should also check to see if any of the older BMPs have been previously been reported to the state for purposes of tracking stormwater treatment in the context of the Bay model. This will seldom be the case in smaller communities, but some larger MS4 communities have been reported their BMP implementation in the last five or ten years.

- BMPs that have not been reported yet to the state from any stormwater design era can be credited against the local baseline load. This is done by providing the drainage area served and the appropriate CBP-approved BMP removal rate provided in Section 5.2.

- The team will need to make an early judgment call as to whether the nutrient removal performance of these un-reported BMPs should be discounted or eliminated altogether. This decision should be based on an objective assessment of the condition and maintenance of existing BMPs. A common assumption is to assume 30% of all BMPs installed prior to 1995 have failed or no longer perform as designed. The adjustment for these initial downgrades should be reflected in a modestly higher local WIP baseline load.

- Lastly, the team should analyze the current operating or capital budget for stormwater maintenance to understand what is being expended and for what purpose. The current staffing levels for maintenance inspection and enforcement should be reviewed, as well. The team may choose to re-deploy budgets and staffing to perform the actions below:

Actions:

- The first priority is to consolidate all existing information on the existing BMP inventory for your community. This is primarily a desktop exercise to ensure paper and digital as-built files and maintenance records for all BMPs constructed prior to 2009 are entered into a common tracking database. Some field work may be needed to confirm the type, location and presumed nutrient removal rate for older BMPs. Some guidance on analyzing your BMP inventory is provided in Appendix A-9.

- The next priority is to shift from routine maintenance inspections to assessments that look at the actual hydrologic and nutrient removal performance observed in the field. Based on these observations, the performance of older BMPs can be downgraded due to poor design, installation and maintenance, or loss of treatment capacity. These performance downgrades are then accounted for using the BMP coding methods described in Appendix A-4.

- The final product is a list of older, down-graded BMPs that serve large drainage areas that are most suitable for maintenance makeovers, as described in Section 5.3.4.

6.9 Take the Credit for Enhanced Street Sweeping

Surveys have shown that most large communities in the Bay routinely sweep a portion of their street system, but most do so only for safety or aesthetic reasons, rather than to improve water quality (Law, et al, 2008). Substantial nutrient reduction credits can be achieved simply by re-deploying some existing street sweeping assets to intensively sweep the dirtiest streets.

Homework:

- The watershed team should find out the current street sweeping effort from the DPW, including street routes, sweeping frequency, and existing sweeper technology, as well as the cost per street mile swept.

- The team should identify the dirtiest urban streets in their community that are the best candidates for enhanced sweeping. Generally, these streets have a high average daily traffic volume and are located in commercial, industrial, central business district, or high intensity residential settings. Large municipal parking lots may also be good candidates. Most low density residential streets are not considered good candidates for enhanced street sweeping.

- The team may also want to get some actual hopper measurements to determine key variables for the “mass pick-up method” for nutrient removal (see section 5.3.8).

- The team can then calculate the likely nutrient removal associated with enhanced street sweeping for different combinations of streets, and see if the budget consequences are worth the increased effort.

Actions:

- The mass pickup method is generally recommended since it serves as a powerful incentive for sweeping crews and stormwater managers to maximize the mass of street solids and attached nutrients removed from the street.

- Over time, the community may want to upgrade their street sweeping technology, since newer regenerative vacuum sweeping models can nearly double the sweeper pick-up rate.

- DPW will need to maintain better sweeping records, regardless of which method is used to define the mass nutrient removal rate. The reporting requirements needed to verify the sweeping credit are provided in Section 5.3.8.

6.10 Investigate Septic Hookups and Upgrades

A community can obtain nutrient removal credit for three septic system management practices: septic tank pump-outs, retrofitting existing septic systems with enhanced technology and hookups to the sanitary sewer system. This credit primarily applies to rural communities with low density residential development, although relict systems may still be found within the existing water and sewer envelope in more urban communities.

Homework

- The watershed team should consult with the local sanitarian or public health authority that reviews septic system applications and keeps records of septic system maintenance to better understand how many septic systems exist in the community, and what condition they are in.

- The team may also want to consult with the local wastewater utility to see if there are clusters of septic systems that could be connected to the sanitary sewer system and thereby receive a higher level of wastewater treatment.

- Some Bay states may offer financial support to retrofit septic systems and/or connect them to the sewer system. If these are available, the watershed team should try to maximize their use. The methods for determining and verifying the nutrient removal credit can be found in Section 5.3.

6.11 Illicit Discharge Elimination

This potential credit applies to cities with aging sewer and storm drain systems that are required to investigate illicit discharges as part of their MS4 permit, and measure nutrient indicators as part of their routine outfall screening effort.

Homework

- Check with the local agency responsible for your MS4 stormwater permit to understand past efforts to detect illicit discharges in your community

- If dry weather water quality data is available for your streams, check to see if you have elevated dry weather concentrations of nitrogen (especially ammonia).

which is usually a sign that diluted sewage is being discharged from your storm drain system.

- The methods for determining this potential credit can be found in Section 5.3.11.

6.12 Investigate Stormwater Retrofits

Stormwater retrofits will undoubtedly play a role in meeting nutrient reduction goals as part of the local WIP planning process. They have not been considered until now, however, because it can take several years to go through the process of finding, designing, permitting and construct major storage retrofit projects (Schueler, 2007), and many communities may not yet possess the experience to deliver the most cost effective ones.

CSN will be releasing a Technical Bulletin in early 2012 on maximizing nutrient reduction through stormwater retrofits, so this section provides some general advice to the watershed team on some early decisions to consider when thinking about retrofits, as well as the usual homework and action items.

Advice:

- Widespread stormwater retrofitting involves a major long-term local investment in planning, assessment and implementation. Methods to estimate budgets for finding, designing and building retrofits can be found in Schueler (2007).

- Experience has shown that as much as 15 to 25% of untreated IC in suburban subwatershed can be treated by stormwater retrofits located on public land and/or privately owned BMPs. The feasibility of retrofitting, however, diminishes in more urban watersheds with a lot of impervious cover.

- From a cost standpoint, it is advisable to look first for retrofits opportunities that serve a large drainage area and treat many acres of impervious cover. As a rule of thumb, large storage retrofits, such as BMP conversions or enhancements, are usually the most cost effective solution for reducing nutrients, followed closely by new BMP retrofits located in strategic places in the urban landscape.

- Green street retrofits and on-site LID retrofits tend to be more expensive when it comes to removing nutrients, and they are usually only considered in highly urban watersheds with few other retrofit options.

Homework:

- The watershed team should check to see how much nutrient load remains after the previous nine urban BMP credits are assessed, to get a sense of how much retrofitting effort will be needed in the community.

- If there is still a significant load remaining, the community will need to undertake a *systematic retrofit investigation* to comprehensively evaluate all the potential retrofit opportunities in a community.

- Communities that are close to meeting their nutrient allocation may only need to perform a more *limited retrofit assessment* that is confined to analysis of the existing BMP inventory to find enough BMP conversions or enhancements to meet their remaining load.

- The team should investigate possibilities for long term retrofit financing and delivery, through a variety of mechanisms, including capital improvement budgets, revenues from stormwater offset fees and/or a stormwater utility, state and or federal demonstration grants, and stormwater maintenance budgets.

- The team is also encouraged to explore innovative approaches to get retrofits implemented such as maintenance enforcement at privately-owned BMPs, street reconstruction projects, and piggy-back retrofits through other municipal construction projects.

- The team should consult with their stormwater review agency to see if they possess the staff capability to do the retrofit analysis in house, or whether they will need to retain a consultant to perform the work.

- The team may also want to check whether any existing local agencies and stormwater stakeholders is currently delivering on-site LID practices, or has the capacity to do so in the future. The delivery may be through subsidies, technical assistance, stormwater utility credits and other incentives to build LID retrofits on private land.

Actions:

Limited Retrofit Assessment: This approach utilizes the existing local stormwater maintenance inspection, tracking and enforcement authority to identify potential retrofits and/or major maintenance upgrades, and gradually construct them over time.

The key element of this approach is to “mine” your BMP inventory to find old detention and extended detention ponds or other BMPs that could be good candidates for cost effective retrofits or maintenance upgrades (see section 6.8). A typical practice is to screen for public and private stormwater BMPs that are more than ten years old and serve at least 10 acres of drainage area.

DPW staff or consultants then conduct a field retrofit investigation of these priority BMPs as part of their routine stormwater maintenance inspection program. The team then computes the expected nutrient removal for the most promising retrofit candidates using the methods outlined in section 5.3.1.

Systematic Retrofit Investigation

The desktop and field methods for conducting a more systematic retrofit investigation in a subwatershed are detailed in Schueler (2007).

References Cited

Baldwin, A., T. Simpson and S. Weammert. 2003. Reports of urban BMP efficiencies. Prepared for EPA Chesapeake Bay Program. Urban Stormwater Workgroup. University of Maryland, College Park

Barten, J. and J. Johnson. 2007. Minnesota phosphorus fertilizer law. *Lakeline* 12(3): 23-28.

Baris, R., S. Cohen, W. Bainer and Q. Ma. 2010. Quantitative analysis of over 20 years of golf course monitoring studies. *Environmental Toxicity and Chemistry*. 29(6): 1224-1236

Bierman, P., B. Horann, C. Rosen and A. Hollman. 2010. Effects of phosphorus fertilization and turfgrass clipping management on phosphorus runoff. Final Report to Minnesota Pollution Control Agency. University of Minnesota. St Paul, MN

Biohabitats, Inc. 2010. Implementing environmental site design in Montgomery County, Maryland. Montgomery County Department of Environmental Protection. Rockville, MD.

Brosch, C. 2011. Personal communication. July 22, 2011. Estimated benefits of proposed lawn care legislation for MD, VA and PA. US EPA Chesapeake Bay Program. Annapolis, MD.

Brown, W. and T. Schueler. 1997. National Pollutant Removal Database for Stormwater BMPs. First Edition. Center for Watershed Protection. Ellicott City, MD.

Brown, E., D. Caraco and R. Pitt. 2004. Illicit discharge detection and elimination: a guidance manual for program development and technical assessments. U.S. Environmental Protection Agency. Office of Wastewater Management. Center for Watershed Protection. Ellicott City, MD

Cappiella, K., T. Wright and T. Schueler. 2005. *Urban Watershed Forestry Manual*. Part 1. Methods for increasing forest cover in a watershed. USDA Forest Service. Newton Square, PA.

Caraco, D. 2010. The watershed treatment model: Version 3.0. U.S. Environmental Protection Agency, Region V. Center for Watershed Protection. Ellicott City, MD

Center for Watershed Protection (CWP). 2003. Impacts of impervious cover on aquatic ecosystems. Ellicott City, MD.

CWP, 2003. The Unified Stream Assessment (USA): a user's guide. *Manual 10 in the Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection, Ellicott City, MD

CWP. 2004. Pollution source control practices. *Manual 8 in the Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection, Ellicott City, MD

CWP. 2005. *Maryland Watershed Planning Users Guide*. Maryland Department of Natural Resources. Annapolis, MD

CWP. 2007. *National Pollutant Removal Performance Database Version 3.0*. Center for Watershed Protection, Ellicott City, MD.

CWP and Chesapeake Stormwater Network (CSN). 2008. *Technical Support for the Baywide Runoff Reduction Method*. Baltimore, MD www.chesapeakestormwater.net

CWP, 2010. Technical memorandum: IDDE monitoring in Baltimore watersheds. Ellicott City, MD.

CWP, 2011. Field findings: pollution detection and elimination in Sligo Creek, Montgomery County, MD. Ellicott City, MD.

Chesapeake Bay Stormwater Training Partnership (CBSTP). 2010. Survey results of training needs and preferences of stormwater professionals in the Chesapeake Bay watershed. Chesapeake Stormwater Network, Baltimore, MD.

Chesapeake Stormwater Network (CSN). 2010. The Clipping Point: Estimates of Turf Coverage in the Chesapeake Bay Watershed. Technical Bulletin No. 8. Baltimore, MD. www.chesapeakestormwater.net

CSN, 2010c. Unpublished survey of stormwater permit managers in the Chesapeake Bay. Baltimore, MD.

CSN, 2011. *Stormwater design for high intensity redevelopment projects in the Chesapeake Bay watershed*. Technical Bulletin No. 5. Baltimore, MD.

CSN, 2011b. Environmental Site Design Criteria for the Maryland Critical Area. Draft. Maryland Critical Area Commission. Chesapeake Stormwater Network. Baltimore, MD.

CSN, 2012. Stormwater retrofitting to maximize nutrient reduction. Under development. Technical Bulletin No. 11. Baltimore, MD

CSN, 2010. Technical Bulletin No. 6. Version 2.0. Users guide for the ESD to MEP compliance spreadsheet in Maryland. Center for Watershed Protection. Baltimore, MD.

City of Baltimore (COB), 2006. 2005 NPDES MS4 stormwater permit annual report. Baltimore Department of Public Works. Submitted to Maryland Department of Environment. Water Management Administration. Baltimore, MD.

Metropolitan Washington Council of Governments (MWCOG). 1987. Guidance for complying with the 10% stormwater rule in the IDA of the Maryland Critical Area Zone. Maryland Department of Natural Resources. Annapolis, MD.

Easton, Z.M., and A.M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. *Journal of Environmental Quality*, 33:645–655.

Guillard, K. and K.L. Kopp. 2004. Nitrogen fertilizer form and associated nitrate leaching from cool-season lawn turf. *Journal of Environmental Quality,* 33:1822-1827.

International Stormwater BMP Database (ISBD). 2010a. International stormwater best management practice database pollutant category summary: nutrients. Prepared by Geosyntec Consultants and Wright Water Engineers.

IBSD. 2010b. International stormwater best management practice database pollutant category summary: bacteria. Prepared by Geosyntec Consultants and Wright Water Engineers.

IBSD. 2011. International stormwater best management practice database: technical summary of volume reduction. Prepared by Geosyntec Consultants and Wright Water Engineers.

Jantz et al (2005). Urbanization and the loss of resource lands in the Chesapeake Bay watershed. *Environmental Management*. 36(6): 808-825;

Jones, J., Clary, J., Strecker, E., Quigley, M. 2008. 15 Reasons you should think twice before using percent removal to assess STP performance. *Stormwater Magazine*. Jan/Feb 2008.

Kenna, M.P. 2008. Turfgrass and the Environment. In: J.B. Beard and M.P. Kenna (eds.), *Water Quality and Quantity Issues for Turf grasses in Urban Landscapes*. CAST Special Publication 27. Ames, Iowa; p. 65-90.

Langland, M. and S. Cronin, 2003. A summary report of sediment processes in Chesapeake Bay and watershed. USGS Water Resources Investigation Report 03-4123
Lehman, J., D. Bell and K. MacDonald. 2009. Reduced river phosphorus following implementation of fertilizer ordinance. *Lake and Reservoir Management*. 23: 307-312

Law, N., Band, L., and J. Grove. 2004. Nitrogen input from residential lawn care practices in suburban watersheds in Baltimore County, MD. *Journal of Environmental Planning and Management*, 47(5):737-755.

Law, N., K. Diblasi, and U. Ghosh.2008. Deriving reliable pollutant removal rates for municipal street sweeping and storm drain cleanout programs in the Chesapeake Bay Basin. Center for Watershed Protection. Ellicott City. MD.

Local Government Advisory Committee (LGAC). 2011. Our waters, our towns: local government's role in the watershed implementation plans. Alliance for the Chesapeake Bay. Annapolis, MD.

McNett, J., W. Hunt, and J. Osborne. 2010. Establishing Stormwater BMP Evaluation Metrics Based upon Ambient Water Quality Associated with Benthic Macro-invertebrate populations. *Journal of Environmental Engineering*, 136(5): 535-541.

Maryland Department of Environment (MDE). 2000. Maryland stormwater design manual. Volumes 1 and 2. Baltimore, MD.

MDE. 2009. Stormwater Regulations and Supplement to the 2000 Stormwater Design Manual. Baltimore, MD

MDE 2010. Maryland's Final Chesapeake Bay Watershed implementation Plan. Submitted to U.S. EPA Region 3 in response to Bay-wide TMDL. Baltimore, MD

MDE, 2011. Accounting for stormwater wasteload allocations and impervious acres treated: guidance for NPDES stormwater permits. June 2011 Draft. Baltimore, MD.

Mid-Atlantic RESAC (2006). Modeling future growth in the Washington, DC-Baltimore Region 1986-2030. Mid-Atlantic Regional Earth Sciences Applications Center. University of Maryland, College Park.

Metropolitan Washington Council of Governments. 1983. The Washington DC Nationwide Urban Runoff Project: Final Report. Department of Environmental Program. Prepared for US EPA. Washington, DC.

Montgomery County Department of Environmental Protection (MCDEP). 2006. Annual Report NPDES Municipal Separate Storm Sewer System Permit 00-DP-3320 MD 0068349. Watershed Protection Division. Rockville, MD.

Montgomery County Department of Environmental Protection (MCDEP). 2011. Implementation Plan Guidance Document. February 2011 Technical Memo Prepared by CSN and Biohabitats, Inc. Rockville, MD.
http://www.montgomerycountymd.gov/content/dep/downloads/implementationguidance02232011.pdf

Morgan R. and K. Kline. 2010. Nutrient concentrations in Maryland non-tidal streams. *Environmental Monitoring and Assessment*. Springer Science.

Morgan, R. K. Kline and S. Cushman. 2007. Relationships among nutrients, chloride and biological indices in urban Maryland streams. *Urban Ecosystems*. Springer

National Research Council (NRC). 2008. *Stormwater Management in the United States*. National Academy of Science Press www.nap.edu Washington, DC.

NRC. 2011. *Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: an evaluation of program strategies and implementation*. National Academy of Science Press www.nap.edu Washington, DC.

Ohrel, R. 1996. Simple and complex pollutant load models compared. *Watershed Protection Techniques*. 2(2): 364-368.

Pitt, R., T. Brown and R. Morchque. 2004. *National Stormwater Quality Database. Version 2.0*. University of Alabama and Center for Watershed Protection. Final Report to U.S. Environmental Protection Agency.

Pitt, R., Chen, S., Clark, S., Lantrip, J. 2005. Soil Structure Effect Associated with Urbanization and the Benefits of Soil Amendments.

Schueler, T. 1987. Controlling urban runoff: a manual for planning and designing urban stormwater best management practices. Metropolitan Washington Council of Governments. Washington, DC.

Schueler, T., P. Kumble and M. Heraty. 1992. A current assessment of urban best management practices: techniques for reducing nonpoint source pollution in the coastal zone. EPA Office of Wetlands, Oceans and Watersheds. Metropolitan Washington Council of Governments. Washington, DC.

Schueler, T and D. Shepp. 1993. The quality of trapped sediments and pool water within oil grit separators in suburban, Maryland. Final Report. Maryland Department of Environment. Metropolitan Washington Council of Governments. Washington, D.C .

Schueler, T. 2004. Urban stream rehabilitation. Manual 4. Small Watershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T, et al. 2005. Chapter 9. Scoping and budgeting a restoration plan. In *Methods to Develop Restoration Plans for Small Watersheds*. Manual 2, Small Watershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T, et al. 2007. Appendix E: Derivation of unit costs for stormwater retrofits and construction of new stormwater practices. In *Stormwater Retrofit Practices*. Manual 3, Small Watershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. 2005. Methods to develop restoration plans for small urban watersheds. Manual 2.*Small Watershed Restoration Manual Series*. U.S. EPA. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. 2007. Urban stormwater retrofit practices. Manual 3.*Small Watershed Restoration Manual Series*. U.S. EPA. Center for Watershed Protection. Ellicott City, MD

Schueler, T., L. Fraley-McNeal, and K. Cappiella. 2009. Is Impervious Cover Still Important? A Review of Recent Research. *Journal of Hydrologic Engineering*. April, 2009

Seattle Public Utilities (2009) Seattle Street Sweeping Pilot Study. Prepared by SPU and Herrera Environmental Consultants. April 22, 2009. Accessed online 30July 2010 http://www.seattle.gov/util/stellent/groups/public/@spu/@ssw/documents/webcontent/spu01_005046.pd

Simpson, T. and S. Weammert. 2009. Developing nitrogen, phosphorus, and sediment efficiencies for tributary strategy practices. BMP Assessment Final Report. University of Maryland Mid-Atlantic Water Program. College Park, MD.

Sutton, R. and C. Cox. 2010. Bay out of balance: broken system allows phosphorus pollution to worsen. Environmental Working Group. Washington, D.C.

Swann, C. 1999. A survey of residential nutrient behaviors in the Chesapeake Bay. Chesapeake Research Consortium. Center for Watershed Protection. Ellicott City, MD.

U.S. DOD. 2009. Stormwater management at federal facilities and federal lands in the Chesapeake Bay watershed. Draft report fulfilling section 202(c) of Executive Order 13508. Coordinated by Department of Defense. Washington, D.C.

U.S. EPA. 2009. Technical guidance for implementing the stormwater runoff requirements for federal projects under Section 438 of the Energy Independence and Security Act of 2008. EPA-841-8-09-001. Office of Water. Washington, DC.

U.S. EPA. 2010a. The next generation of tools and actions to restore water quality in the Chesapeake Bay. Final report fulfilling section 202(a) of Executive Order 13508. United States Environmental Protection Agency. Chesapeake Bay Program. Washington, DC.

U.S. EPA. 2011. *Final Chesapeake Bay Watershed Implementation Plan in response to Bay-wide TMDL*. United States Environmental Protection Agency, Region 3. Philadelphia, PA.

U.S. EPA 2011b. Guide for Chesapeake Bay jurisdictions for the development of Phase 11 watershed implementation plans. EPA Chesapeake Bay Program, Annapolis, MD.

U.S. EPA Region 1. 2010. Fact Sheet for the General Permit for Residual Discharges in the Charles River Watershed in Milford, Bellingham and Franklin, Massachusetts

U.S. EPA Region 3. Urban stormwater approach for the mid-Atlantic region and the Chesapeake Bay watershed. July 2010. Philadelphia, PA

University of Maryland. 2010. Estimates of county level nitrogen and phosphorus data for use in modeling pollutant reduction: documentation of Scenario-Builder 2.2. Prepared for U.S. EPA.

Urban Stormwater Workgroup. 2011. Technical Memo on street sweeping and BMP era recommendations of expert panel. 3.1.2011. Chesapeake Bay Program. Annapolis, MD.

Virginia DCR. 2011. Questions and answers about the Bay TMDL and the Phase 11 watershed Implementation Plan Development. Fact Sheet released June 27, 2011. Richmond, VA

Vlach, B. J. Barten, J. Johnson and M. Zachay. 2009. Assessment of source reduction due to phosphorus-free fertilizers. Final Report. Three Rivers Park District. Minneapolis, MN

Water Quality Goal Implementation Team (WQGIT). 2010. Protocol for the development, review and approval of loading and effectiveness estimates for nutrient and sediment controls in the Chesapeake Bay Watershed Model. US EPA Chesapeake Bay Program. Annapolis, MD.

Winer, R. 2000. National pollutant removal database for stormwater treatment practices. 2nd edition. EPA Office of Science and Technology. Center for Watershed Protection. Ellicott City, MD

Winter J. and P. Dillon. 2005. Effect of golf course construction and operation on water chemistry of headwater streams of the Pre-Cambrian shield. *Environmental Pollution*.

Appendix A
Detailed Notes on Technical Documentation
Note: *this section may be reorganized and expanded in the next version*

A-1 Derivation of Runoff Coefficients for Disturbed Soils

The three runoff coefficients provided in Table 13 were derived from research by Pitt et al (2005), Gregory et al (2004), Lichter and Lindsey (1994), Schueler (2001a), Schueler, (2001b), Legg et al (1996), Pitt et al (1999), Schueler (1987) and Cappiella et al (2006). Numerous researchers have documented the impact of construction earthworks on the compaction of soils, as measured by an increase in bulk density, a decline in soil permeability, and an increase in the runoff coefficient. These areas of compacted pervious cover (lawn or turf) have a much greater hydrologic response to rainfall than forest or pasture. The effect of earthworks and soil compaction nearly doubles the runoff coefficient from un-forested areas, as shown in Table 13).

A.2 Derivation of Residential Lawn EMCs

The EMC for residential land uses was split into two categories based on lawn care: high input and low input turf (HI and LO). The EMCs represent the 25^{th} and 75^{th} percentile values in the National Stormwater Quality Database (Pitt et al, 2004), because the distribution of data from residential runoff is approximately a normal distribution. Two estimates of fertilization are available for the area that range between 50% and 65% (Swann, 1999, Law et al, 2004). Making assumptions about past lawn care education and stewardship efforts, it is recommended that the lower 50% rate be used (half of all residential turf cover is high input and the other half is low input). Consequently, the composite EMC for residential land in a watershed would still equate to the ALL value.

A.3 Local Example of a BMP Design Era Approach

The following summarizes the basic BMP design era approach as applied in Montgomery County, MD (MCDEP, 2011). The initial classification of BMPs was performed based on an evaluation of the practice type, using a coding system shown in A-4. The relative performance of each practice type was based on national comparative reviews of pollutant removal and runoff reduction performance of practices (CWP, 2007; and CWP and CSN, 2008) or performance studies on individual practices (Schueler, 1998).

The second screen was based on the approval date for the BMP, which reflects the design era under which it designed and installed. Four broad design eras were defined, as follows:

- **Era 1: Pre-1986.** BMPs installed prior to full implementation of the Maryland Stormwater law of 1984, which typically focused on detention and peak shaving.

- **Era 2: 1986 to 2002**. These practices reflect a design era where water quality was an important part of design, although water quality sizing and design standards were not as great.
- **Era 3**: **2002 to 2009.** These practices were built to the more stringent water quality and channel protection sizing requirements and BMP design standards contained in the 2000 edition of the Maryland Stormwater Manual
- **Era 4**: 2010 and beyond. This era reflects implementation of ESD to the MEP in the County.

A.4 The BMP Coding Approach

A desktop coding system was used in MCDEP (2011) to assign a performance rate for individual BMPs, based on their design era and the BMP technology employed (Table A-1).

Code 0. Pretreatment Practices: This class of BMPs includes pretreatment BMPs that were never intended to provide full pollutant removal or runoff reduction, but were used to protect the function of a downstream practice. Typically, these pretreatment BMPs were installed in commercial areas and have a small contributing drainage area. They are often designed based on rate of flow and not the full water quality volume. The most numerous practices in this class are oil grit separators that have been shown to have little or no pollutant removal (e.g., see Schueler, 1998). This class also includes flow structures that split, redirect or dissipate flows, such as flow splitters, underground control structures, and plunge pools.

Pretreatment practices and flow structures that are located upstream of primary stormwater practices are not assumed to provide any additional runoff reduction, channel protection or flood control volume or produce any additional pollutant removal, which is be consistent with published studies of their performance. This class of BMPs is also considered to have low or no retrofit potential since most practices are undersized (relative to WQv), underground and located in densely developed areas where little or no surface area is available for retrofits. Consequently, Code 0 practices that are clearly pretreatment practices to another BMP are excluded from further desktop BMP analysis.

Code 1: Non-performing: This class of BMPs primarily comprises structures built in Design Era 1 (Pre 1986) that intended to provide detention and peak discharge control, such as dry detention ponds, dry extended detention pond and underground detention structures. In some cases, these structures were also built in other design eras, although there often was a water quality practice upstream. Research has shown that detention or extended detention alone provides low or marginal pollutant or runoff volume reduction. These detention BMPs typically serve larger drainage areas, and are ideal candidates for retrofits.

Code 2: Under-performing: This class of BMPs includes various structures built primarily in Design Era 2 such infiltration basins that have no runoff reduction capacity (either by design or by clogging after construction), and low to moderate pollutant removal capability, based on the National Pollutant Removal Database (2007 and earlier versions). Generally speaking most of these practices have moderate to large drainage areas. Their current hydrologic performance may be diminished due to the limited design requirements of that era, their age and maintenance condition This class of BMPs has the significant potential for ESD upgrades, traditional retrofits or maintenance upgrades. The composite runoff reduction and pollutant removal rates are consistent with reported performance values in the NPRD (CWP, 2007) and the most recent runoff reduction values in CWP and CSN (2008).

Code 3: Effective: This class includes a series of ponds with various combinations (or cells) of wet pools, extended detention, wetlands, sand filters and infiltration practices. The BMPs tend to have larger drainage area, Based on past performance research, this group is assumed to have limited runoff reduction capability, but moderate to high pollutant removal. In addition, most BMPs in this class also provide channel protection if they were built in Design Era 3.

Code 4: ESD/LID Practices: This class includes the new ESD/LID practices that will be used in Design Era 4. It is currently populated with bioretention, dry swales, working infiltration and vegetated swales and other ESD/LID practices. Most practices are applied to relatively small drainage areas. This is the most effective class of BMPs in that it maximizes both runoff reduction and pollutant mass reduction. To derive a composite estimate for runoff reduction and pollutant removal, we assumed the average reduction values for a group of six ESD/LID practices, as reported in CWP and CSN (2008) and Schueler (2009). The approach is presented in Table 18 and 19, and assumes an equal split between Level 1 and Level 2 design used by VA DCR. This is a reasonable split since the effectiveness of ESD practices differs based on soil type and design features.

Table A-1: Example of Performance Coding Based on BMP Technology

Performance Code	**Example[1]**
Code 0: Pretreatment BMPs[2] Not intended to provide runoff reduction or significant pollutant removal	Proprietary pretreatment practices, Oil/grit separator, Plunge pool, vegetated pool
Code 1: Non-performing BMPs Detention or other practices with no runoff reduction and no long term pollutant removal	Underground detention vaults Pond-dry quantity control , dry ED ponds
Code 2: Under-performing BMPs No runoff reduction and low pollutant removal	Infiltration basin with extended detention, infiltration basin,
Code 3: Effective BMPs No runoff reduction but moderate to high pollutant removal	Wet ponds, Wet ED ponds Sand filter, Pond-wetland
Code 4: ESD/LID BMPs High runoff reduction and moderate to high pollutant removal	Dry swale, Bioretention Infiltration trench, Green Roof, permeable paving
Loosely adapted from MCDEP (2011)	

Based on its code, each BMP was assigned a removal rate, runoff reduction rate and impervious acres effectively treated, by multiplying its baseline nutrient and sediment load for the drainage are it served by the rates shown in Table A-2

Table A-2 Composite Runoff Reduction, Impervious Treated and Pollutant Removal by BMP Code (MCDEP, 2011)						
Code	Description	RR[1] (%)	IAET[2] (%)	TSS (%)	TN (%)	TP (%)
1	Non-performing	0	0.05	5	0	0
2	Under-performing	5	0.15	20	5	5
3	Effective	10	0.75	80	40	50
4	ESD Practices	60	1.0	90	65	65
RR: percent annual reduction in post development runoff volume for storms [2] IAET: Fraction of contributing impervious acres effectively treated to the Water Quality Volume, and is multiplied by contributing impervious area to track IC acres treated in the watershed						

A-5 Dealing with Multiple BMPs within the Same Drainage Area

In early testing, it was evident that two or more BMPs were often present within the same drainage area. These situations are created for a number of reasons, including pretreatment practices prior to a stormwater treatment practice, the existence of a treatment train of multiple stormwater practices within a site, or a water quality practice located above a downstream channel protection or quantity control pond. Multiple BMPs within the same drainage area are quite common, occurring in as many as 50% of all drainage areas within some watersheds. This situation complicates the BMP coding process, so MCDEP (2011) employed the following decision sequence was made.

1. Where stand-alone Code 0 BMPs can be isolated in the GIS layer, they will be assigned a Code 2 pollutant removal rate for their contributing impervious drainage area.
2. If multiple BMPs still exist in the DA, the BMP type with the higher code will be considered the primary BMP.
3. The consultant team will perform an individual coding analysis for multiple BMPs found in DA exceeding 25 acres in size, using professional judgment, GIS and/or aerial photography to confirm the sequence of the treatment train, and determine the subset of drainage area that is treated by the highest coded BMP. In general, this will be done on an area-weighted basis.

A.6 Equivalence of Reforestation and Impervious Area Treated

Some projects like reforestation and compost amendments cannot be quantified in terms of impervious acres treated. The proposed solution for these projects is to consider them as equivalent impervious area, from a hydrologic standpoint using the compacted soil runoff coefficients presented in CWP (2009). Under this approach, ten acres of these practices installed on pervious land would be hydrologically equivalent to one impervious acre treated, using the Runoff Coefficient Approach, shown below:

The Rv for a one acre of impervious cover is 0.95 [Rv = 0.05 + 0.009 (100)]

Average Runoff Coefficient for Forest Cover, BCD soil types is 0.04

Average Runoff Coefficient for Disturbed Soils, BCD soil types is 0.223

Differential Runoff Coefficient of 0.183.

Assume ESD measures (reforestation, compost amendments, etc) are capable of reducing the differential by half (0.091). This is due to the fact that it takes many years for planted trees to achieve enough overhead canopy to function hydrologically as forest. Similarly, there is not enough data yet to show that compost amendments can shift disturbed soils fully to a forest cover runoff coefficient.

Then, it would take ten acres of these ESD measures to be equivalent to one acre of impervious cover of runoff reduction: (10 acres)*(0.091) + 0.04 = 0.95

Note: The effect of these ESD practices is different if they are used to boost runoff reduction by treating runoff from adjacent impervious areas (e.g., filter strip, grass channel, enhanced rooftop connection, etc).

A-7 Derivation of Redevelopment Credits

The following methods and technical assumptions were made to derive the nutrient credits for variable levels of stormwater treatment at redevelopment sites.

Step 1: Compute Baseline Nutrient Load for Unit Acre of Impervious Cover.

The Simple Method (Schueler, 1987) was used to compute annual nutrient loads, using standard assumptions for annual rainfall in the Bay watershed, and regional event mean concentration for nutrients. The resulting annual stormwater load was computed to be 2 and 15 lbs/acre/year for TP and TN, respectively.

Step 2: Define the "Anchor" Reduction Rate for a Composite of Redevelopment Practice.

An annual mass removal rate was computed using a composite of eight different preferred or acceptable redevelopment stormwater practices using the runoff reduction data provided in CWP and CSN (2008). The practices included rain tanks, green roofs, permeable pavements, urban bioretention, bioretention, dry swales, sand filters, and impervious cover removal with soil amendments. The mass removal rates are specific to the treatment of one inch of rainfall in Virginia, and the Level 1 and 2 approach was used to distinguish between the amount of runoff reduction an individual design achieved (Lo or Hi, as defined in CWP and CSN, 2008).

Step 3: Adjust the Anchor rate for Other Rainfall Depths Treated

The anchor rate was then adjusted for the 0.25, 0.50 and 0.75 inch rainfall depths, by estimating the untreated bypass volume from regional rainfall frequency curves, relative to the anchor rate (see Table A-3). For example, if the runoff from 0.25 inches of rainfall is treated, only 40% of the annual runoff volume would be treated (compared to 90% for the one inch event). The annual treatment volume was then used to define a lower nutrient reduction rate, based on the lower capture volume. The same basic approach was used to define maximum mass nutrient reduction rates for the 1.25 and 1.5 inch storm events.

Table A-3
Mass Removal Rates Based on Rainfall Treated and Runoff Reduction achieved

Volumetric Criteria		**Mass Removal Rate** %	
Rainfall depth controlled	Degree of runoff reduction	Total Phosphorus	Total Nitrogen
0.25	LO	20	20
	HI	30	30
0.50	LO	30	35
	HI	45	45
0.75	LO	40	40
	HI	55	60
1.0	LO	55	55
	HI	75	70
1.25	LO	65	65
	HI	85	75
1.50	LO	75	67
	HI	82	85
2.0	LO	80	77
	HI	90	92
2.5	LO	90	85
	HI	95	95

Step 4: Determine the Final Redevelopment Credit.

The baseline nutrient loads computed in Step 1 were than multiplied by the corresponding removal rate for each combination of runoff treatment and runoff reduction, as shown in Table A-3 to arrive at the recommended credits, as shown in Table A-4

Table A-4 Nutrient Reduction Credit for Different Combinations of Redevelopment Volumetric Criteria			
Volumetric Criteria		**Redevelopment Credit** Lbs/imperious acre/year	
Rainfall depth controlled	Degree of runoff reduction	Total Phosphorus	Total Nitrogen
0.25	LO	0.4	3.0
	HI	0.6	4.5
0.50	LO	0.6	5.1
	HI	0.9	6.8
0.75	LO	0.8	6.3
	HI	1.1	8.9
1.0	LO	1.1	8.4
	HI	1.5	10.5
1.25	LO	1.33	9.9
	HI	1.7	11.3
1.50	LO	1.5	10.1
	HI	1.75	12.7
2.0	LO	1.6	11.5
	HI	1.8	13.5
2.5	LO	1.8	12.8
	RR	1.9	13.9

A-8 Derivation of "Nutrient Neutrality" for New Development Stormwater Standards for each Bay State and Maryland Example

The recommended process for each state to define nutrient neutrality in the context of their new stormwater performance standards is as follows:

Step 1: Analyze the target load reduction for your state using the Version 5.3.2 of the Chesapeake Bay Watershed Model (EPA, 2011) and sum up all the runoff-derived land sources of nutrient loading. These include runoff from forest, agricultural (excluding CAFOs) and urban and suburban land uses. Wastewater and CSO loads should be excluded from the calculation, since they are not runoff-related, as was atmospheric deposition over open waters of the Bay.

Step 2: Divide the total runoff-derived nutrient load and divide by the total acres of land within the Bay watershed for the state to obtain the acceptable annual nutrient load, in lbs/acre/year.

Step 3: Compare these annual nutrient loadings against the sizing and LID technology standards inherent in your state stormwater performance standards. This is done by finding the expected annual nutrient load associated with your standard, using Table A-5. The Table provides an estimate of the post development nutrient load under different combinations of the rainfall depth controlled and the degree of runoff reduction provided. Most Bay states are requiring a high degree of runoff reduction or LID practices in their new stormwater standards.

Table A-5
Post Development Nutrient Load for Different Combinations of Stormwater Volume Criteria

Volumetric Criteria		**Post Development Load** Lbs/imperious acre/year	
Rainfall Depth Controlled	Degree of Runoff Reduction	Total Phosphorus	Total Nitrogen
0.25	LO	1.6	12.0
	HI	1.4	10.5
0.50	LO	1.4	9.9
	HI	1.1	8.2
0.75	LO	1.2	8.7
	HI	0.9	6.1
1.0	LO	0.9	6.6
	HI	0.5	4.5
1.25	LO	0.7	5.1
	HI	0.3	3.7
1.50	LO	0.5	4.9
	HI	0.25	2.3
2.0	LO	0.4	3.5
	HI	0.2	1.5
2.5	LO	0.2	2.2
	RR	0.1	1.1

The proposed process is best illustrated by analyzing data for the State of Maryland. The primary source for the Maryland nutrient loadings from the Chesapeake Bay Watershed Model, as reported in MDE (2010), and reprised in Table A-6

Table A-6 TP Loads, By Land Based Sector in Maryland Bay TMDL		
Loading Sector	**2009 Load**	**Target Load**
	Million pounds per year	
Forest Runoff	0.35	0.35
Urban and Suburban Runoff	0.67	0.44
Agricultural Runoff	1.44	1.25
ALL RUNOFF SOURCES	2.46	1.99 [3]
Acceptable Load (lbs/acre)	**0.56**	**0.34**
excludes CAFO portion of agricultural runoff Acreage: 5.866 million Wastewater sources excluded		

The acceptable P TP target load from the Bay TMDL from all land-based sources of phosphorus pollution is 1.99 million/lbs/yr. Land sources of phosphorus pollution included runoff from forest, agricultural (excluding CAFOs) and urban and suburban land uses. Wastewater and CSO loads were excluded from the calculation, since they are not runoff-related, as was atmospheric deposition over open waters of the Bay.

The land-based TP target load was then divided by the total land area in Maryland's portion of the Chesapeake Bay watershed (5.866 million acres) to arrive at an average per acre phosphorus load of 0.34 pounds per acre per year. The same analysis for nitrogen indicated that an average annual TN load of 4.44 lbs/acre/year.

The next step is to compare these baseline loads to the expected load reductions as a result of full implementation of the ESD to MEP standards at a typical development site. These standards call for more than 2 inches of rainfall depth controlled and a high level of runoff reduction. Based on this analysis, it is evident that post development loads under these standards would be 0.2 lbs/ac/yr and 1.5 lbs/ac/year for TP and TN, respectively. Both of these loads are under the acceptable nutrient load calculated earlier, which suggests, in general, that standards would achieve nutrient neutrality, with respect to future stormwater discharges.

There are several important provisos to this conclusion. First, the composite method is designed solely for the purpose of creating an aggregate, macro-level tracking for future new development that is fully treated under these standards. Other design tools provide more site-specific estimates of the phosphorus reduction achieved at individual development sites, such as the MD Critical Area phosphorus compliance spreadsheet (CSN, 2011) and the Virginia state-wide stormwater compliance spreadsheet (VA DCR, 2011).

Second, it is likely that a significant fraction of individual development projects may be unable to fully comply with higher state standards, either because they cannot meet the required rainfall capture volume and/or do not provide a high degree of runoff reduction. In these circumstances, localities have two options. The first is to use Table 21 or related phosphorus compliance spreadsheet to analyze each individual project, and then track the aggregate departure from the nutrient neutral threshold on an annual basis. The second option is to require the developer to get a nutrient offset or pay a fee in lieu to ensure an equivalent amount of nutrients are reduced elsewhere in the locality to cover the shortfall at the site.

A-9 Desktop Methods to Analyze the Performance of your BMP Inventory

Step 1: Check the individual BMP data in your inventory to make sure there is accurate information on their geographic location, drainage area, impervious cover treated, the year they were installed and BMP type.

Step 2: Merge the inventory into your watershed GIS system so that you can spatially analyze the BMPs and confirm BMP drainage areas.

Step 3: Exclude all code 0 BMPs from the analysis (see Appendix A-4)

Step 4: Analyze the remaining BMPs and code their performance based on their installation date using the design era approach (Appendix A-3) and/or the performance coding approach outlined in Appendix A-4).

Step 5: Use the GIS to determine if you have multiple BMPs in the same drainage area, and assign an overall performance code for the drainage area, using the methods outlined in Appendix A-5.

Step 6: Identify all of the BMPs installed since the 2009 baseline year, and exclude them from the baseline analysis (make sure to take credit for these new BMPs in your reporting to your state BMP tracking agency.

Step 7: Adjust the remaining baseline load by deducting the cumulative nutrient removal achieved by the BMP installed prior to 2009, using a spreadsheet or modeling tool such as WTM.

Step 8: If your locality does not have a strong maintenance inspection and enforcement program, you may want to discount the cumulative load reduction by 20 or 30% so that you can take advantage of maintenance upgrade and BMP retrofit enhancement credits in the future.

A.10 Land Use/Land Cover Splits

It is often important to convert land use data into its land cover components. Table A-7 presents the recommended splits for defining the three types of land cover within a land use. The impervious cover values were directly measured from GIS data and aerial photography from jurisdictions across the Chesapeake Bay in MD, PA, and VA (Cappiella and Brown, 2001). An adjustment was made for the institutional category, where it was split into two categories, intensive and extensive. The intensive category includes churches, schools and municipal facilities, as reported in Cappiella and Brown (2001). The extensive category includes greener institutional areas, such as park, cemeteries and golf courses.

Average forest cover was derived for each land use based on the estimated forest cover coefficients in Cappiella, et. al.(2005). These estimates are not directly measured, but are consistent with forest cover (not canopy) measurements from urban forestry models. Turf cover was obtained by subtraction from the total acreage after impervious cover and forest cover were added together, but represents a mix of pervious surfaces including turf, meadow, and fields.

Table A-7 Recommended Splits for Land Cover within Land Use Categories

LAND USE [1]	Impervious Cover	Forest Cover	Turf Cover
Low Density Residential	12.5	8.5	79.0
Medium Density Residential	24.5	15.0	60.5
High Density Residential	36.8	15.2	48.0
Multifamily Residential	44.4	14.6	41.0
Commercial	72.2	14.8	13.0
Industrial	53.4	14.6	32.0
Roadway	90	7.0	3.0
Intensive Muni/Institutional	35.2	13.8	51.0
Extensive Muni/Instit	8.6	36.4	55.0

1 see Cappiella and Brown for land use definitions

MassDEP Appendix 5

APPENDIX 5- YARDWASTE N/TN LOADING CALCULATION IN MA

Yardwaste* pickup by towns —TN Loadings reduction calculation methodology for LISS NPS BMP Assesment Report

Yardwaste pickup by a vast majority of the towns surveyed in MA consists curbside pickup of leaves, grass clippings, and other yardwaste such as small branches, and brush. This survey includes a loading TN reduction based upon a combination of all of these (organic) wastes. A random sampling of Springfield and seven surrounding area towns found most all towns collecting all of these wastes, with the average volume proportion of 43% Leaves, 31% Grass and 24% Small Branches/Brush.

(1) As for Leaf Wastes, Prof Milt Ostrofsky's article "Relationship Between Chemical Characteristics of Autumn- Shed Leaves and Aquatic Processing Rates" is used for this determination. From Table 1, % nitrogen content from typical trees in New England are identified and averaged: (A) Maples, Acer Saccharum, Rubrum, Saccharinum,Platanoides; (B) Birch, Betela Lutea, Populifolia; (C) Beech Fagus Grandifolia, (D) Oaks: Quercus Palustris, Coccinea, Muehlenbergii, Alba, Prinus, Rubra; (E) Walnut Juglans Nigra; (F) Hickoy- Carya Ovata; (G) Ash- Faxinus Americana; (H) Aspen- Populus Tremuloides. The average TN content turned out to be 1.08% N content. Assume you have 1 ton of wet leaf wastes and the average moisture content is 53%, or 47% leaf dry content (from Prof Ostrofsky email note, 2012) = 940 lbs dry leaf wastes.

These 15 common species were averaged as to Nitrogen (N) content to be 1.08%

To find TN per Dry Ton Leaves (2,000 lbs wet pickup ton) X .47 X 1.08% Nitrogen content %age= .0108 X 2,000 X .47 (Dry Content) = 10.15 lbs TN per ton.

(2) As for Grass Clippings Waste, The Rutgers University Cooperative Extension Fact Sheet "Nutrient Management of Land Applied Grass Clippings" was used to determine average Nitrogen content. Professors Uta Krogmann and Joseph H. Heckman of the Extension Service were the principal authors. Table 1 of that Fact Sheet shows that the Nitrogen content from their research ranges between 2.34% and 3.80%, with an average of 3.04%. Prof. Uta Krogmann goes on to say: "The table also gives the moisture content. Assume you have 1 ton of wet grass clippings and the average moisture content is 53% (Prof. Uta Krogmann article, 2001; Prof Ostrofsky email note, 2012). Then, you have 2000 lb *(1-0.53) = 940 lb dry grass clippings. Assuming 3.04% N, then you have 0.0304 * 940 = 28.576 lb N for that original 1 ton of wet grass clippings. Please keep in mind these are only average values."

To find TN per Dry Ton Grass Clippings (2,000 lbs wet pickup ton) X .47 X 3.04% Nitrogen content %age= .0304 X 2,000 X .47 (Dry Content) = 28.58 lbs TN per ton.

(3) As for Small Branches and Brush Type Waste, Prof Milt Ostrofsky, in consultation with his colleagues who have done Nitrogen research in small wood branches and brush, suggests "My colleague estimates the deciduous wood typically has 0.08% nitrogen by weight. It is largely cellulose. Here is my take: leaves contain a lot of chlorophyll - a molecule rich in nitrogen - and of course protein, also rich in nitrogen, so deciduous tree leaves (dicots) and grasses (monocot leaves) would be higher in nitrogen that would wood which is largely dead xylem. When I say deciduous wood, I mean branches and stems of your maples and oak - just the woody tissue. Use the 1.08% and 3.01% as the N content of leaves and grass clippings, respectively, and use 0.08% (for dry weight) as the N content of branches/stems/trunks, etc."Assume a ton of branches/ brush (wet at pickup) would be .47% dry weight, so once again as with leaves and grasses, 1 ton (2000 lbs) wet branches/brush (at pickup) would = 940 lbs of dry weight

To find TN per Dry Ton Small Branches/Brush (2,000 lbs wet pickup ton) X .47 X 0.08% Nitrogen content %age= .0008 X 2,000 X .47 (Dry Content)= 0.75 lbs TN per ton.

A survey on percentages of pickup makeup between Leaves, Grass, and Small Branches/Brush was taken from town officials in Springfield and West Springfield and six surrounding communities. The averages of the eight communities were: 43% Leaves; 31% Grass Clippings; 26% Small Branches/Brush. The average,per ton, of (wet) generalized yardwaste pickup in area communities, the average for nitrogen loading (determined from dry weight) would be:

10.15 (Leaves) X .43 + 28.58 (Grass Clippings) X .31 + .75 (Branches/Brush) X .26 = 4.36 (proportion for Grass) + 8.86 (proportion for Leaves) + 0.20 (proportion for Branches/Brush) = 13.42 lbs N or TN per ton

***Addendum Note- regarding conversion of weight given in Cubic Yards to Tons (or Lbs); A few communities provided yardwaste collection statistics in Cubic Yards. The MassDEP Bureau of Municipal Facilities has produced a Table, 'Volume-to-Weight Conversions for Recyclable Materials for use with the Municipal Recycling Data Sheet', in which average weights (in lbs/cu ft) are given for various recyclable materials typically in municipal wastes. The Table lists weights for the following: (1) Leaves- 400 lbs/cu yd; (2) Grass- 667 lbs/cu yd; (3) Brush-Branches- 500 lbs/cu yd. Therefore, for the purposes of this report, the average weight (in lbs) per cubic yard for yardwaste collections has been determined to be 500 lbs/ cu yd, or .25 tons, (a ton = 2,000 lbs).**

MassDEP Appendix 6

COMMUNITY STORMWATER BMP SURVEY RESULTS FOR THE LISS STUDY- MS4 COMMUNITIES

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
Agawam	street sweeping detritus collected	175 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	613 lbs
	catch basin cleaning detritus collected	42 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	171 lbs
	yardwaste pickup by town	1,800 tons, plus 35,000 tons from 10-11 snow/ice storm	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	24,156 lbs (regular)
	swales, bioswales,wet/dry detention ponds,infiltration practices	1,105 Acres total	QUESTIONABLE STATISTICS PROVIDED BY COMMUNITY	
	Erosion and sediment controls		Many communities report this, but indicate no records on specifics, e.g., type of control, acreages covered, etc.	
	illicit connections found	4	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic system tie-ins to sewer	51	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	336 lbs
	Stormceptor stormwater BMPs put in	4		
Douglas	catch basin cleaning detritus collected	36,250 lbs	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	74 lbs
	street sweeping detritus collected	103 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	361 lbs
	leaf/yardwaste pickup by town		NO STATISTICS PROVIDED BY COMMUNITY	
	lawn fertilization education program		No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	dry detention ponds/underground infiltration basin	1.9 acres	dry det.ponds/undergrd infiltrat.basin .05(efficiency) +.8/2 X 11.9 lbs X 1.9 (4 pp31)	10 lbs
East Longmeadow	street sweeping/catch basin detritus collected	118 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	413 lbs
	dry detention basins, subdivisions/commercial	25 acres	.05(effic) X 25(acres) X 11.9(lbs/yr) (4, pp 31)	15 lbs
	leaf/yardwaste pickup by town	400 ton yearly ave; oct 2011 storm 5,700 tons alone	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	5,368 lbs (regular)
	septic-tie ins to sewer	3-4 per year	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	20 lbs/yr
	lawn fertilization education program, 6,700 homes	6,700 homes	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
Easthampton	street sweeping detritus collected	all swept 2X per yr	NO USEABLE STATISTICS PROVIDED BY COMMUNITY	
	catch basin cleaning detritus collected	500 catch basins cleaned/yr	NO USEABLE STATISTICS PROVIDED BY COMMUNITY	
	leaf/yardwaste pickup by town	waste area open 2X per month	NO USEABLE STATISTICS PROVIDED BY COMMUNITY	
	urban stream restoration	.2 mile	.2 mile = 1,056' (google). 1,056 X .02 lbs TN credit per linear ft(4 pp 46)	21 lbs
	wet/dry detention ponds	2 acres	.05(efficiency-dry) + .20(effic-wet)/2 X 11.9 X 2 (4 pp 31, and 1 pp2	3 lbs
	Erosion and sediment controls		Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	septic connections to sewer	50 per yr	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	330 lbs
	vortechnics stormwater systems/ stormceptor	3 in last yr/ numerous stormceptors installed		
	illicit connections corrected	3 per yr	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	cluster zoning		NO STATISTICS PROVIDED BY COMMUNITY	
	Groundwater overlay district		NO STATISTICS PROVIDED BY COMMUNITY	

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
Gardner	catch basin cleaning detritus collected	600 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,449 lbs
	street sweeping detritus collected	3,150 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	11,025 lbs
	leaf/yardwaste pickup by town	195.3 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	2,621 lbs
	subdivision cluster housing built	35 acres	No TN credit has been established in the literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	deep sump pumps in catch basin retrofits	50	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	illicit connections found-broken sewer	1	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
Granby	catch basin cleaning detritus collected	45 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	184 lbs
	street sweeping detritus collected	180 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	630 lbs
	leaf/yardwaste pickup by town	40 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	537 lbs
	retrofit catch basins	2 per year	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	grassy swales	.5 acre per year	(Grass channel) .10+.45/2 + bioswale (.7)/2 X 11.9 X.5 acre(4 pp 31)	4 lbs
	illicit connections found-fixed	2 per year	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic system pumpouts	100 per year	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	60 lbs/yr
Hadley	catch basin cleaning detritus collected	60 cubic yards	conv. 1.5 tons/cu yd X tons X .7 dry wt. factor X 5.83 (2) Tom Schueler suggests using 2,914 ppm TN content for catch basin detritus	367 lbs
	street sweeping detritus collected	357 cubic yards	conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	1,874 lbs
	lawn fertilization education programs, 2.100 homes	2,100 homes	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	zoning by-laws for protection of groundwater disrict		NO STATISTICS PROVIDED BY COMMUNITY	
	by-laws for sewer tie-ins and illicit connections		NO STATISTICS PROVIDED BY COMMUNITY	
Holyoke	2 projects-stabilization basins and drainage w. sump-pumps in catch bas	approx 6 acres	.20 (for wet ponds-constructed wetlands) X 6 X 11.9 (4 pp 31)	14 lbs
	catch basin cleaning detritus collected	700 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,857 lbs
	street sweeping detritus collected	1,300 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	4,550 lbs
	leaf/yardwaste pickup by town	2,300 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	30,866 lbs
	4 projects- rain gardens with underdrain infilt system	.85 acre	bioswale (.7) + filter strip (.5)/2 X 11.9 X .85 (4 pp 30-31)	6 lbs
	leaching trench combined with subsurf. infiltration	1.01 acre	infiltration(.8) X 11.9 X 1.01 (4 pp 31)	10 lbs

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	189 tree replants w. combined 822 bioretent.plants	2 acres	forest buffers- replants (.25) X 11.9 X 2 (4 pp 31 & pp 50)	6 lbs
	impervious surfaces reduction-parking lot	.16 acre	No credit has been established from the literature yet	
	erosion and sediment controls		Many communities report this, but indicate no records on spedciics, e.g., type of control, acreages covered, etc.	
	illicit connections;sewer tie-ins; septic pumpouts		NO STATISTICS PROVIDED BY COMMUNITY	
	IA Title V systems; Groundwater treatment systems to replace septic Title V		NO STATISTICS PROVIDED BY COMMUNITY	
Longmeadow	catch basin cleaning detritus collected	197.7 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	807 lbs
	street sweeping detritus collected	466 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	1,631 lbs
	leaf/yardwaste pickup by town	435 tons leaves; 282 tons grass; 765 tons brush= 1482 tons	Appendix (5): Leaves- tons X 10.15; Grass- tons X 28.58; Brush- tons X .75	12,530 lbs (4,415 leaves; 8,059 grass; 56 brush)
	tree planting/reforestation/forest buffers	2 acres	forest buffers- replants (.25) X 11.9 X 2 (4 pp 31 & pp 50)	6 lbs
	Erosion and sediment controls	5 acres	Many communities report this, but indicate no records on specifics, e.g., type of control, acreages covered, etc.	
	vegetated open channels at edge of channel	2 acres	Vegetated open channels (.45 + .10)/2 X 2 X 11.9 (1 pp 2)	7 lbs
	illicit sewer connections corrected	3	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
Monson	catch basin cleaning detritus collected	268 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	1,094 lbs
	street sweeping miles per year	70 miles	convert miles to imperv acres/ 43,560 X 15.4lbs/imp.acre X .05 (4 pp 53)	131 lbs
	leaf/yardwaste pickup by town	210 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	2,818 lbs
	zone II groundwater protection district	approx 200 acres	No credit has been established for this category yet from the literature yet	
Northampton	catch basin cleaning detritus collected	20 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	82 lbs
	street sweeping detritus collected	1,718 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	6,013 lbs
	bioswales, rain gardens with/without underdrains	9 wet detention ponds, approx total- 3 acres	Wet ponds and wetlands (.2 efficiency) X 3 X 11.9 (4 pp 31 & 1 pp 2)	7 lbs
	dry detention ponds	9 dry detention ponds, approx total- 3 acres	.05 (efficiency) X 11.9 X 3 (4 pp 31 and 1 pp 2)	2 lb
	wet detention ponds/wetlands installation	approx 3 acres	Wet ponds and wetlands (.2 efficiency) X 3 X 11.9 (4 pp 31 & 1 pp 2)	7 lbs
	infiltration practices with sand,vegetation	approx total- 1.60 acres	.80 (efficiency) X 11.9 X 1.6 (4 pp 31 and 1 pp 2)	15 lbs
	filtering practices	25 proprietary structures- total acres unknown	NO STATISTICS PROVIDED BY COMMUNITY	
	Groundwater overlay district	80,000 square feet, approx 1.8 acres	No credit has been established for this category yet from the literature yet	
	cluster zoning, min.size lots with LID principles	open space cluster zoning with wetlands protection-acreage unknown		
Otis Air Base	catch basin cleaning detritus collected	> 300 lbs	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2 lbs

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	street sweeping detritus collected	15,600 lbs collected/year	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	27 lbs
	leaf/yardwaste pickup by town	200 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	2,684 lbs
	tree planting/reforestation/forest buffers	20 acres	forest buffers- replants (.25) X 11.9 X 20 (4 pp 31 & pp 50)	60 lbs
	Erosion and sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	illicit connections corrected	1	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic tie-ins to sewer	1	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	7 lbs/yr
Pittsfield	catch basin cleaning detritus collected	no weight stats kept by town	NO STATISTICS PROVIDED BY COMMUNITY	
	street sweeping detritus collected	no weight stats kept by town	NO STATISTICS PROVIDED BY COMMUNITY	
	leaf/yardwaste pickup by town	no weight stats kept by town	NO STATISTICS PROVIDED BY COMMUNITY	
	lawn fertilization education programs	no stats indicated	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	swales; biosw; wet/dry detention; infiltration ponds	part of City development; re-development	NO STATISTICS PROVIDED BY COMMUNITY	
	septic connections to sewer	2	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	13 lbs/yr
	illicit connections corrected		NO STATISTICS PROVIDED BY COMMUNITY	
Belchertown	catch basin cleaning detritus collected	62 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	253 lbs
	street sweeping detritus collected	1,024 cubic yards	conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	5,376 lbs
	dry detention basins in town maintained and cleaned	17 for a total of approx. 25 acres	dry extended detention basins .05(efficiency) X 11.9 X 25(4 pp31 and 1 pp 2)	15 lbs
	construction site controls for runoff	in place	NO STATISTICS PROVIDED BY COMMUNITY	
	stormwater management plan	in place	NO STATISTICS PROVIDED BY COMMUNITY	
	wetlands education program- brochures and ed	workshops conducted; brochures published and mailed out	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
South Hadley	catch basin cleaning detritus collected	46 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	188 lbs
	street sweeping detritus collected	458.8 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	1,606 lbs
	leaf/yardwaste pickup by town	1,398 tons (annually); 2011 snow/ice event picup- 10,500 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	18,761 lbs (regular/annual)
	lawn fertilization ed program		No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	Erosion and sediment controls	in place	Many communities report this, but indicate no records on specifics, e.g., type of control, acreages covered, etc.	
Southwick	catch basin cleaning detritus collected	750 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	3,061 lbs
	street sweeping detritus collected	1,250 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	4,375 lbs
	Congamond Lakes detention basin-infilt.basins-grassy swales 319 projects-		Statistics and loadings reductions contained in Table 9, Sect. 8	
	Erosion and sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	illicit connections corrections by-law	in place	NO STATISTICS PROVIDED BY COMMUNITY	
Spencer	catch basin cleaning detritus collected	100 cubic yards	conv. 1.5 tons/cu yd X tons X .7 dry wt. factor X 5.83 (2) Tom Schueler suggests using 2,914 ppm TN content for catch basin detritus	612 lbs
	street sweeping detritus collected	300 cubic yards	conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	1,575 lbs
	leaf/yardwaste pickup by town	800 cubic yards	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	2,684 lbs
	swales	3.3 acres	average of dry & wet swale (.55 dry effic.+.25 wet/2) X 11.9 X 3.3 (4 pp 30)	16 lbs
	bioswales/raingardens w. underdrain structure	1 acre	.70 (efficiency) X 11.9 X 1 (4 pp 31)	8 lbs
	infiltration practices without sand/vegetation	1 acre	.80 (efficiency) X 11.9 X 1 (4 pp 31 and 1 pp 2)	10 lbs
	erosion and sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	illicit connections corrected	at least 2	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don’t have all this info.	
Springfield	catch basin cleaning detritus collected	180 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	735 lbs
	street sweeping detritus collected	3,500 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	12,250 lbs
	leaf/yardwaste pickup by town	9,000 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	120,780 lbs
	catch basin retrofits/ deep sump w. hoods installed	20	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	bioswales constructed	2.2 acres	.70 (efficiency) X 11.9 X 2.2 (4 pp 31)	18 lbs
	impervious surfaces reduction	2 acres	No credit has been established from the literature yet	
	forest buffers/ reforestation		NO STATISTICS PROVIDED BY COMMUNITY	
	infiltration practices with sand filters etc	12 in last year, at least 2.5 acres total	.85 (efficiency) X 11.9 X 2.5 (4 pp 31 and 1 pp 2)	25 lbs
	Erosion and sediment controls	in place	Many communities report this, but indicate no records on specifics, e.g., type of control, acreages covered, etc.	
	sewer tie-ins	most of the city is sewered	NO STATISTICS PROVIDED BY COMMUNITY	
West Springfield	catch basin cleaning detritus collected	285 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	1,163 lbs
	street sweeping detritus collected	1,100 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	3,850 lbs
	leaf/yardwaste pickup by town	3,500 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	46,970 lbs
	swales/bioswales constructed	0.04 acres	.70 (efficiency) X 11.9 X .04 (4 pp 31)	.3 lbs
	urban stream restoration	0.3 mile	.3 mile = 1,584' (google). 1,584 X .02 lbs TN credit per linear ft(4 pp 46)	32 lbs
	wet detention ponds/wetlands installation	0.45 acre	Wet ponds and wetlands (.2 efficiency) X .1 X 11.9 (4 pp 31 & 1 pp 2)	.2 lbs
	infiltration practices without sand/vegetation	0.1 acre	.80 (efficiency) X 11.9 X .1 (4 pp 31 and 1 pp 2)	1 lb
	filtering practices	2 stormceptors		
	illicit connection corrections	5	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don’t have all this info.	

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	septic connections to sewer	1	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	7 lbs/yr
	septic pumping	23	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	14 lbs/yr
Westfield	catch basin cleaning detritus collected	750 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	3,061 lbs
	street sweeping detritus collected	2,750 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	9,625 lbs
	leaf/yardwaste pickup by town	7,000 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	93,940 lbs
	bioswales/retention/rain gardens w/o underdrain	5 acres	.70 (efficiency) X 11.9 X 5 (4 pp 31)	42 lbs
	bioswales/retention/rain gardens with underdrain	5 acres	.70 (efficiency) X 11.9 X 5 (4 pp 31)	42 lbs
	tree planting/reforestation/forest buffers	200 trees, 5 acres	forest buffers- replants (.25) X 11.9 X 5 (4 pp 31 & pp 50)	15 lbs
	urban stream restoration	0.2 miles	.2 mile = 1,056' (google). 1,056 X .02 lbs TN credit per linear ft(4 pp 46)	21 lbs
	wet detention ponds/wetlands installation	7.5 acres	Wet ponds and wetlands (.2 efficiency) X 7.5 X 11.9 (4 pp 31 & 1 pp 2)	18 lbs
	dry detention ponds	7.5 acres	.05 (efficiency X 7.5 X 11.9 (4 pp 31)	4 lbs
	infiltration practices with sand filters etc	2 acres	.85 (efficiency) X 11.9 X 2 (4 pp 31 and 1 pp 2)	20 lbs
	erosion and sediment controls, by-laws in place	200 acres	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	cluster zoning, min.size lots with LID principles	300 acres	No TN credit has been established in the literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	permeable pavement w.sand/veget.,no underdrain	1.5 acres	.8 (efficiency) X 11.9 X 1.5 (1 pp 3, 4 pp 30)	15 lbs
	septic denitrification	?? Questionnable figures given, town recontacted	?? Questionnable figures given, town recontacted	
	septic pumping	approx. 4 million gallons	1,750 gal. ave. sized septic system. 4 million gal =2286 septic systems. (4) pp 56-57, .05 X 16 X # septic sys =TN loading reduction	1,371 lbs/yr
Ludlow	catch basin cleaning detritus collected	500 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,041 lbs
	street sweeping detritus collected	1,750 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	6,125 lbs
	leaf/yardwaste pickup by town	reg. leaf-544 tons;grass 227 tons;brush oct storm >9,000 tons	Appendix (5): Leaves- tons X 10.15; Grass- tons X 28.58; Brush- tons X .75	10,346 lbs (regular only)
	lawn fertilization education programs	1,500 households (mailers)	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	bioswales, wet and dry detention ponds	approx. 2 acres	.70 (efficiency) X 11.9 X 2 (4 pp 31)	17 lbs
	erosion and sedimant controls-from by-laws in place	2 sites, approx. 1 acre	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	septic system tie-ins to sewer	5	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	33 lbs
	septic pumping	350	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	210 lbs/yr
Templeton	catch basin cleaning detritus collected	540 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,204 lbs
	street sweeping detritus collected	2,600 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	9,100 lbs
	leaf/yardwaste pickup by town		NO STATISTICS PROVIDED BY COMMUNITY	

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	lawn fertilization education programs	700 brochures taken by citizens from town hall	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	swales/ bioswales	required for all new construction	NO STATISTICS PROVIDED BY COMMUNITY	
	nutrient management programs	partridgeville pond 1.5 acres	.17 (credit) X 1.5 X 11.9 (4 pp 31)	3 lbs
	wet-dry detention ponds/infiltration basins	required for all new construction	NO STATISTICS PROVIDED BY COMMUNITY	
	erosion & sediment controls	required for all new construction	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	strict nitrogen/nutrient controls w/I zone II district	NO STATISTICS PROVIDED BY COMMUNITY	
	septic pumping	597,650 gal. pumped/year	1,750 gal. ave. sized septic system. 597,650 gal =342 septic systems. (4) pp 56-57, .05 X 16 X # septic sys =TN loading reduction	205 lbs/yr
	IA Title V systems; Groundwater treatment systems to replace septic Title V		No TN credit has been established in literature.	
Palmer	catch basin cleaning detritus collected	500 tons per year	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,041 lbs
	catch basin retrofits w. deep sumps	6	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	street sweeping detritus collected	1,750 tons per year	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	6,125 lbs
	leaf/yardwaste pickup by town	1,300 cu yards regular + oct 29, 2011 storm brings it to 13,000 cu yds for 2011	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	4,362 lbs
	lawn fertilization education programs	700 brochures taken by citizens from town hall	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	nutrient management programs	farmers involved -960 total acres in town area	.17 (credit) X 950 X 11.9 (4 pp 31)	1,922 lbs
	tree planting/reforestation/forest buffers	less than 10 acres, say close to 5 acres	forest buffers- replants (.25) X 11.9 X 5 (4 pp 31 & pp 50)	15 lbs
	erosion/sediment controls	new construction	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	illicit connections corrections	15 found and corrected in 2011	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic pumping	375 pumpouts in 2011	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	225 lbs/yr
Wilbraham	catch basin cleaning detritus collected	100 cubic yards	conv. 1.5 tons/cu yd X tons X .7 dry wt. factor X 5.83 (2) Tom Schueler suggests using 2,914 ppm TN content for catch basin detritus	612 lbs
	street sweeping detritus collected	150 cubic yards	conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	788 lbs
	leaf/yardwaste pickup by town	1,000 cubic yards; oct sno event spec.pickup- 10,000 cu yards	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	3,355 lbs (regular pickup)
	lawn fertilization education programs	educational flyers produced/mailed out to residents	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	swales		NO STATISTICS PROVIDED BY COMMUNITY	
	tree planting/reforestation/forest buffers	20 acres following tornado damage	forest buffers- replants (.25) X 11.9 X 20 (4 pp 31 & pp 50)	60 lbs
	urban stream restoration	.5 miles (5 acres)	.5 mile = 2,640' (google) 2,460 X .02 lbs TN credit per linear ft(4 pp 46)	53 lbs

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	wet detention ponds/wetlands installation	12 acres	Wet ponds and wetlands (.2 efficiency) X 12 X 11.9 (4 pp 31 & 1 pp 2)	29 lbs
	dry detention ponds	3 acres	.05 (efficiency X 3 X 11.9 (4 pp 31)	2 lbs
	infiltration practices without sand/vegetation	30 acres	.80 (efficiency) X 11.9 X 30 (4 pp 31 and 1 pp 2)	286 lbs
	erosion and sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	22 square miles	No credit has been established for this category from the literature	
	cluster zoning/min. lot sizes/LID	selective by zone	NO STATISTICS PROVIDED BY COMMUNITY	
	septic connections to sewer	12	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	79 /lbs/yr
	septic pumping	250	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	150 lbs/yr
Dalton	catch basin cleaning detritus collected	100 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	408 lbs
	street sweeping detritus collected	200 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	700 lbs
	yardwaste pickup by town	200 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	2,684 lbs
	catch basin retrofits/ deep sump w. hoods installed	40	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	lawn fertilization education programs	Dalton outreach ed. Programs to public schools and the public	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	swales	South St. project	NO STATISTICS PROVIDED BY COMMUNITY	
	tree planting/reforestation/forest buffers		NO STATISTICS PROVIDED BY COMMUNITY	
	erosion/sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	septic connections to sewer	10	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	66 lbs/yr
	septic pumping	up to individual homeowners	NO STATISTICS PROVIDED BY COMMUNITY	
Leicester	catch basin cleaning detritus collected	180 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	735 lbs
	street sweeping detritus collected	200 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	700 lbs
	leaf/yardwaste pickup by town	65 tons	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	872 lbs
	septic connections to sewer	4	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	26 lbs
	bioswales, schools		NO STATISTICS PROVIDED BY COMMUNITY	
	tree planting/reforestation/forest buffers	town common area	NO STATISTICS PROVIDED BY COMMUNITY	
	erosion/sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	in place	NO STATISTICS PROVIDED BY COMMUNITY	
	cluster zoning/min. lot sizes/LID	in place	NO STATISTICS PROVIDED BY COMMUNITY	
	illicit connections correction policy	in place	NO STATISTICS PROVIDED BY COMMUNITY	
Oxford	catch basin cleaning detritus collected	900 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	3,673 lbs
	street sweeping detritus collected	1500 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	5,250 lbs

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	lawn fertilization education programs	20% reduction targets in education program	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
Sturbridge	catch basin cleaning detritus collected	600 tons (ave./yr.)	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,449 lbs
	street sweeping detritus collected	700 tons (ave./yr.)	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	2,450 lbs
	leaf/yardwaste pickup by town	125 tons (ave./yr.)	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	1,678 lbs
	lawn fertilization education program	in place	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	swales/bioswales constructed	11 acres	.70 (efficiency) X 11.9 X 11 (4 pp 31)	92 lbs
	nutrient management programs	lake testing shows improvements	NO STATISTICS PROVIDED BY COMMUNITY	
	impervious surfaces reduction	a few road areas	NO STATISTICS PROVIDED BY COMMUNITY	
	tree planting/reforestation/forest buffers	50-100 trees/yr, several acres (4)	forest buffers- replants (.25) X 11.9 X 4 (4 pp 31 & pp 50)	12 lbs/yr
	wet/dry detention ponds	57 acres	.05(efficiency-dry) + .20(effic-wet)/2 X 11.9 X 57 (4 pp 31, and 1 pp2)	85 lbs/yr
	erosion/sediment controls	in place	Many communities report this, but indicate no records on specifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	implemented 2002	NO STATISTICS PROVIDED BY COMMUNITY	
	illicit connections correction	2	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic connections to sewer	average of 10 the past 3 years	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	66 lbs/yr
	septic pumping	452 houses; 2,874,000 gals in 2011	1,750 gal. ave. sized septic system. 2,874,000 gal =1,642 septic systems. (4) pp 56-57, .05 X 16 X # septic sys =TN loading reduction	985 lbs/yr
	IA Title V systems; Groundwater treatment systems to replace septic Title V----4 systems in town as of 2012		No TN credit has been established in literature.	
Southbridge	catch basin cleaning detritus collected	734 tons	5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	2,995 lbs
	street sweeping detritus collected	1,272 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	4,452 lbs
	leaf/yardwaste pickup by town	4,300 cubic yards	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	14,427 lbs
	dry detention ponds	5 acres	.05 (efficiency X 5 X 11.9 (4 pp 31)	3 lbs
	infiltration basins without sand/vegetation	5 acres	.80 (efficiency) X 11.9 X 5 (4 pp 31 and 1 pp 2)	48 lbs
	cluster zoning/min. lot sizes/LID	1 subdivision lately	No TN credit has been established in the literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	illicit connections corrections	1	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic connections to sewer	2	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	13 lbs/yr
	septic pumping	186,350 gallons last year	1,750 gal. ave. sized septic system. 186,350 gal =107 septic systems. (4) pp 56-57, .05 X 16 X # septic sys =TN loading reduction	64 lbs/yr
Southampton	catch basin cleaning detritus collected	502 tons	502 tons X .7 dry wt. factor X 5.83 lbs/ton	2,049

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	catch basin retrofits-deep sumps installed	240	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	street sweeping detritus collected	503	503 tons- 5 lbs/ton X dry wt. factor .7	1,761 lbs
	leaf/yardwaste pickup by town		NO STATISTICS PROVIDED BY COMMUNITY	
	lawn fertiliztion education programs		No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	nutrient management programs	96 acres	.17 (credit) X 96 X 11.9 (4 pp 31)	194 lbs
	impervious surface reduction	1.5 acres	No credit has been established from the literature yet	
	tree planting/reforestation/forest buffers	1 acre	forest buffers- replants (.25) X 11.9 X 1 (4 pp 31 & pp 50)	3 lbs
	wet/dry detention ponds	4 acres	.05(efficiency-dry) + .20(effic-wet)/2 X 11.9 X 4 (4 pp 31, and 1 pp2)	6 lbs
	erosion and sedimant controls-from by-laws in place	greater than 1 acre	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	3 acres	No credit has been established for this category yet from the literature yet	
	vegetated open channels at edge of channel	2 acres	Vegetated open channels (.45 + .10)/2 X 2 X 11.9 (1 pp 2)	7 lbs
	illicit connections corrected	3	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
	septic connections to sewer	3	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	20 lbs/yr
	septic pumping	95	(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	57 lbs/yr
	IA Title V advanced wastewater systems	3	No TN credit has been established in literature.	
Dudley	street sweeping/catch basin cleaning detritus collected	375 cubic yards for catch basin/street sweep detritus	187 yds X 1.5 conv fact X dry wt. factor .7 X 5.83; 188 yds X 1.5 conv f. X 5 X .7 dry wt.	CB-1,145 lbs; SS 987 lbs
	leaf/yardwaste pickup by town	500 cubic yards	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	1,678 lbs
	street sweeping detritus collected	see just above with catch basin cleaning		
	bioswales, rain gardens with/without underdrains	3 sites, 4 acres total area	.70 (efficiency) X 11.9 X 4 (4 pp 31)	33 lbs/yr
	nutrient management programs	have attempted with all projects	NO STATISTICS PROVIDED BY COMMUNITY	
	impervious surfaces reduction		NO STATISTICS PROVIDED BY COMMUNITY	
	tree planting/reforestation/forest buffers		NO STATISTICS PROVIDED BY COMMUNITY	
	dry detention ponds	5 sites, 1 acre	.05 (efficiency X 11.9 X 1 (4 pp 31)	.6 lbs
	infiltration practices	as needed	NO STATISTICS PROVIDED BY COMMUNITY	
	erosion/sediment controls	as needed	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	Groundwater overlay district	as needed	NO STATISTICS PROVIDED BY COMMUNITY	
	cluster zoning	emphasized	NO STATISTICS PROVIDED BY COMMUNITY	
	vegetated open channels at edge of channel		NO STATISTICS PROVIDED BY COMMUNITY	
	septic tie-ins to sewer	as needed	NO STATISTICS PROVIDED BY COMMUNITY	
	septic pumping	private	NO STATISTICS PROVIDED BY COMMUNITY	
Chicopee	catch basin cleaning detritus collected	598 catch basins cleaned, 2011	UNUSEABLE STATISTIC PROVIDED BY TOWN	
	catch basin retrofits		NO STATISTICS PROVIDED BY COMMUNITY	
	street sweeping detritus collected	2,500 tons per year	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	8,750 lbs

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	lawn fertilization education programs	signs around town	No TN credit has been established in literature. Followup monitoring to establish TN reduction levels from parcels would be necessary to document actual TN lbs reductions	
	leaf/yardwaste pickup by town	4,926 tons per year	Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	66,107 lbs
	bioswales, bio-retention, rain gardens		NO STATISTICS PROVIDED BY COMMUNITY	
	wet detention ponds/wetlands installation		NO STATISTICS PROVIDED BY COMMUNITY	
	infiltration practices with sand filters etc		NO STATISTICS PROVIDED BY COMMUNITY	
	erosion and sediment controls	in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	illicit connection corrections	2-3 per year	(4) new potential BMP credit, but must have flow rate and pre & post illicit outfall monitoring for TN. Most MA communities don't have all this info.	
Rutland	catch basin cleaning detritus collected	17.5 tons	5.83 lbs TN/ton X dry wt. factor .7 X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	71 lbs
	catch basin retrofits w. deep sumps	5 per year	No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
	street sweeping detritus collected	18 tons	5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	63 lbs
	leaf/yardwaste pickup by town	100 cubic yards	conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	336 lbs
	swales	2 acres	.70 (efficiency) X 11.9 X 2 (4 pp 31)	17 lbs
	bioswales	1 acre	.70 (efficiency) X 11.9 X 1 (4 pp 31)	8 lbs
	tree planting/reforestation/forest buffers	33 acres	forest buffers- replants (.25) X 11.9 X 33 (4 pp 31 & pp 50)	98 lbs/yr
	dry detention ponds	4 acres	.05 (efficiency X 11.9 X 4 (4 pp 31)	2 lbs
	erosion and sediment controls	by-laws in place	Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
	septic connections to sewer	3	(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	20 lbs/yr
Hampden	catch basin cleaning detritus collected	30.49 tons collected in 2011	5.83 lbs TN/ton X dry wt. factor .7 X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	124 lbs

Totals Summary		**LBS/Yr**
TOTALS FOR CATCH BASIN CLEANING, SHEET #1		37,707
TOTALS FOR STREET SWEEPING, SHEET #1		113,176
TOTALS FOR LEAF/YARDWASTE, SHEET #1		470,560
TOTALS FOR SEPTIC SYSTEM TIE-INS TO SEWER -SHEET #1		1,016
TOTALS FOR SEPTIC SYSTEM PUMPING -SHEET #1		3,341
TOTALS FOR DRY DETENTION PONDS- SHEET 1		99
TOTALS FOR URBAN STREAM RESTORATION- SHEET 1		127
TOTALS FOR WET/DRY DETENTION PONDS- SHEET 1		45
TOTALS FOR TREE PLANTING/REFORESTATION, SHEET #1		276
TOTALS FOR VEGETATED OPEN CHANNELS- SHEET 1		14
TOTALS FOR WET DETENTION PONDS- SHEET 1		52
TOTALS FOR SWALES/BIOSWALES- SHEET 1		304
TOTALS FOR INFILTRATION PRACTICES SAND/NON SAND- SHEET 1		405

Community	Urban BMP Type Found in Place	Total Acreage, # of Units, System Size, Lbs Detritus Removed	Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for the BMP (LBS)
	TOTALS FOR PERMEABLE PAVEMENT- SHEET 1		15	
	TOTALS FOR NUTRIENT MANAGEMENT PROGRAMS- SHEET 1		2,119	
	GRAND TOTAL TN REDUCTIONS- SHEET 1			**629,256 LBS/YR**

COMMUNITY STORMWATER BMP SURVEY RESULTS FOR THE LISS STUDY- NON MS4 COMMUNITIES

Community	Urban BMP Type Found in Place	Tonnage/Cu Yds Detritus;Acres; # of Units;System Size
Brookfield	catch basin cleaning detritus collected	300 cubic yards
	street sweeping detritus collected	260 cubic yards
	yardwaste pickup by town	200 cubic yards
	swales, constructed	3 acres
	tree planting, etc	10 trees, 1 acre
	wet detention ponds &/or wetlands constructed	1 acre
	cluster zoning; min. lot size;LID related BMPs	1 subdivision
	septic pumping	250 units/year
Egremont	catch basin cleaning detritus collected	50 tons
	street sweeping detritus collected	100 tons
Great Barrington	catch basin cleaning detritus collected	
	street sweeping detritus collected	
	swales/bioswales constructed	
	nutrient management programs	
	wet detention ponds &/or wetlands constructed	
	infiltration basins constructed	
	erosion/sediment construction controls	in place
	septic tie-ins to sewer	
Greenfield	catch basin cleaning detritus collected	
	street sweeping detritus collected	120 miles per year
	yardwaste pickup by town	15,000 cubic yards/year
	swales/bioswales constructed	2 acres
	urban stream restoration	

Community	Urban BMP Type Found in Place	Tonnage/Cu Yds Detritus;Acres; # of Units;System Size
	wet detention ponds &/or wetlands constructed	
	illicit connection corrections	active program in place
Lenox	catch basin cleaning detritus collected	1 ton per year
	street sweeping detritus collected	5 tons per year
	yardwaste pickup by town	88 tons per year
	catch basin retrofits with deep sump pump	15 in last year
	tree planting, etc	12 in last year, 1 acre
	wet detention ponds &/or wetlands constructed	1/4 acre
	dry detention ponds	1/4 acre
	septic connection to sewer	1
	septic systems pumped	average of 65 tanks per year
	IA Title V Advanced wastewater systems	25 IA systems
Montague	catch basin cleaning detritus collected	5 tons per year
	street sweeping detritus collected	45 tons per year
North Brookfield	catch basin cleaning detritus collected	125 cubic yards per year
	street sweeping detritus collected	1,000 cubic yards per year
	yardwaste pickup by town	500 cubic yards per year
	wet detention ponds &/or wetlands constructed	.75 acre
Otis	street sweeping detritus collected	24 miles of road swept per year
	swales/bioswales constructed	maintained with ongoing housekeeping activities

Community	**Urban BMP Type Found in Place**	**Tonnage/Cu Yds Detritus;Acres; # of Units;System Size**
	septic systems pumped	
Petersham	catch basin cleaning detritus collected	17.5 tons per year
	street sweeping detritus collected	20 tons per year
	septic systems pumped	
Williamsburg	catch basin cleaning detritus collected	100 tons per year
	street sweeping detritus collected	150 tons per year
	swales/bioswales constructed	
	dry detention ponds	
	infiltration basins constructed	
Monson	catch basin cleaning detritus collected	192 cubic yards
	street sweeping detritus collected	80 miles of roads swept per year
Lanesboro	catch basin cleaning detritus collected	15 tons per year
	street sweeping detritus collected	100 tons per year
	catch basin retrofits with deep sump pump	20 per year
	tree planting, etc	tree dept. handles this
	wet detention ponds	1.5 acres (combined really with infiltration basins)
	infiltration basins constructed	1.5 acres (combined really with dry detention basins)
	erosion/sediment construction controls	in place
	cluster zoning; min. lot size;LID related BMPs	zoning board

Community	Urban BMP Type Found in Place	Tonnage/Cu Yds Detritus;Acres; # of Units;System Size
	illicit connection corrections	sewer dept
	septic pumping/tie-ins to sewer	sewer dept
Hubbardston	catch basin cleaning detritus collected	20 tons per year
	catch basin retrofits with deep sump pump	approx 20 structures per year
	street sweeping detritus collected	500 tons per year
	bioswales, raingardens	approx 2 acres
	septic pumping	approx 50 systems per year
West Brookfield	catch basin cleaning detritus collected	20 tons per year
	street sweeping detritus collected	540 cubic yards per year
	Swales, bioswales,wet&dry detention ponds,filt,etc	approx 10 acres totals for all these(maintained by town)
	spec. project-dredge 2 ponds, install veget.swales	3/4 acre
	infiltration basins constructed	1/2 acre
	nutrient management programs	
	erosion/sediment construction controls	
	septic pumping	
Hampden	catch basin cleaning detritus collected	30.49 tons per year
	street sweeping detritus collected	

Total Summary	
TOTALS FOR CATCH BASIN CLEANING, SHEET #2	
TOTALS FOR STREET SWEEPING, SHEET #2	
TOTALS FOR YARDWASTE PICKUP, SHEET #2	
TOTALS FOR SWALES/BIOSWALES- SHEET #2	

Community	Urban BMP Type Found in Place	Tonnage/Cu Yds Detritus;Acres; # of Units;System Size
	TOTALS FOR TREE PLANTING/REFORESTATION, SHEET #2	
	TOTALS FOR WET/DRY DETENTION PONDS- SHEET 2	
	TOTALS FOR SEPTIC SYSTEM PUMPING -SHEET #2	
	TOTALS FOR DRY DETENTION PONDS- SHEET 2	
	TOTALS FOR SEPTIC SYSTEM TIE-INS TO SEWER -SHEET #2	
	TOTALS FOR INFILTRATION PRACTICES SAND/NON SAND- SHEET 2	
	TOTALS FOR WET DETENTION PONDS	
	GRAND TOTAL TN REDUCTIONS- SHEET 2	

Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for BMP (LBS)
conv. 1.5 tons/cu yd X tons X 5.83 X .7 dry wt. factor (2) Tom Schueler suggests using 2,914 ppm TN content for catch basin detritus	1,836 lbs
conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	1,365 lbs
conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	671 lbs
.70 (efficiency) X 11.9 X 3 (4 pp 31)	25 lbs
forest buffers- replants (.25) X 11.9 X 1 (4 pp 31 & pp 50)	3 lbs/yr
Wet ponds and wetlands (.2 efficiency) X 1 X 11.9 (4 pp 31 & 1 pp 2)	2 lbs/yr
UNUSEABLE STATISTIC PROVIDED BY TOWN	
(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	150 lbs
5.83 lbs TN/ton X tonnage X .7 dry wt. factor (2). Tom Schueler suggests using 2,914 ppm for TN content as an ave. for catch basin detritus	204 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	350 lbs
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
convert miles to imperv acres/ 43,560 X 15.4lbs/imp.acre X .05 (4 pp 53)	224 lbs
conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	50,325 lbs
.70 (efficiency) X 11.9 X 2 (4 pp 31)	17 lbs
NO STATISTICS PROVIDED BY COMMUNITY	

Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	**Total TN Removed/Year for BMP (LBS)**
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	4 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	18 lbs
Appendix (5) Yardwaste TN Calculation (average 13.42 lbs TN per ton typical yardwaste pidckup by towns)	1,181 lbs
No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
forest buffers- replants (.25) X 11.9 X 1 (4 pp 31 & pp 50)	3 lbs/yr
Wet ponds and wetlands (.2 efficiency) X .25 X 11.9 (4 pp 31 & 1 pp 2)	1 lbs
.05 (efficiency X 11.9 X .25 (4 pp 31)	.15 lbs
(4) pp 56-57. 12 lbs/yr X .55 efficiency %age X # of tie-ins to sewer	6 lbs
(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	39 lbs/yr
No TN credit has been established in literature.	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	20 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	158 lbs
conv. 1.5 tons/cu yd X .7 dry wt. factor X tons X 5.83 lbs TN/ton (3)	765 lbs
conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	5,250 lbs
conv .25 tons per cu yd. Appendix 5 Yardwaste TN Calculation (ave. 13.42 lbs TN per ton of average yardwaste detritus pickup)	1,678 lbs
Wet ponds and wetlands (.2 efficiency) X .75 X 11.9 (4 pp 31 & 1 pp 2)	2 lbs
convert miles to imperv acres/ 43,560 X 15.4lbs/imp.acre X .05 (4 pp 53)	2 lbs/yr
NO STATISTICS PROVIDED BY COMMUNITY	

Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	**Total TN Removed/Year for BMP (LBS)**
NO STATISTICS PROVIDED BY COMMUNITY	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	71 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	100 lbs
NO STATISTICS PROVIDED BY COMMUNITY	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	408 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	525 lbs
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
conv. 1.5 tons/cu yd X .7 dry wt. factor X tons X 5.83 (2) Tom Schueler suggests using 2,914 ppm TN content for catch basin detritus	1,175 lbs
convert miles to imperv acres/ 43,560 X 15.4lbs/imp.acre X .05 (4 pp 53)	149 lbs
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	61 lbs
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	350 lbs
No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
NO STATISTICS PROVIDED BY COMMUNITY	
Wet ponds and wetlands (.2 efficiency) X 1.5 X 11.9 (4 pp 31 & 1 pp 2)	4 lbs
.80 (efficiency) X 11.9 X 1.5 (4 pp 31 and 1 pp 2)	14 lbs
Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
NO STATISTICS PROVIDED BY COMMUNITY	

Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for BMP (LBS)
NO STATISTICS PROVIDED BY COMMUNITY	
NO STATISTICS PROVIDED BY COMMUNITY	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	82 lbs
No TN credits found in literature reviewed. The BMP improves catch basin detritus removal volumes, which improves overall TN removals	
5.0 lbs TN/ton X tonnage X dry weight factor 0.7 (4 pp 52)	1,750 lbs
.70 (efficiency) X 11.9 X 2 (4 pp 31)	17 lbs
(4) pp 56-57. 12 lbs/yr X .05 X # septic pumpouts	30 lbs/yr
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	82 lbs
conv. 1.5 tons/cu yd X tons X 5 lbs TN/ton X 0.7 conv.fact(4pp52)	2,835 lbs
.70 (efficiency) X 11.9 X 10 (4 pp 31)	83 lbs
.70 (efficiency) X 11.9 X .75 (4 pp 31)	6 lbs
.80 (efficiency) X 11.9 X .5 (4 pp 31 and 1 pp 2)	5 lbs
NO STATISTICS PROVIDED BY COMMUNITY	
Many communities report this, but indicate no records on spedcifics, e.g., type of control, acreages covered, etc.	
NO STATISTICS PROVIDED BY COMMUNITY	
5.83 lbs TN/ton X .7 dry wt. factor X tonnage (2). Tom Schueler suggests using 2,914 ppm for TN content as an average for catch basin detritus	124 lbs
NO STATISTICS PROVIDED BY COMMUNITY	

	LBs/yr
	4,832
	13,076 LBS/YR
	53,855 LBS/YR
	142

Process in Figuring TN Reduction--(Reference Cited, Appendix # & pp)	Total TN Removed/Year for BMP (LBS)
	4
	4
	219
	0.3
	6
	19
	9
	72,166 LBS/YR

MassDEP Appendix 7

Nitrogen Loading Estimates to

Long Island Sound

Review Draft

July, 2000

Introduction

This report summarizes the origin, transport, and delivery of total nitrogen (N) in the Long Island Sound (LIS) drainage basin both within Connecticut and New York and from tributary river areas north of Connecticut. Nitrogen has been identified by the Long Island Sound Study (LISS) as a primary pollutant responsible for low dissolved oxygen (hypoxia) in the bottom waters of the western and central Sound each summer. While N was naturally delivered to LIS before extensive human habitation of the basin, and pre-Colonial loads may have been quite large, development in the basin, particularly in close proximity to the Sound's shores, has let to substantial N enrichment.

Nitrogen's effect on oxygen levels in the LIS estuary is complex. While mineralization of organic N and nitrification of ammonia consume some oxygen, its major effect is as a limiting nutrient that stimulates excessive phytoplankton growth. Whether the phytoplankton dies, or is consumed by filter feeders such as zooplankton, much of the phytoplankton-generated organic matter eventually sinks to the bottom of the Sound. There it decays, using up oxygen in the process. A portion of the N is recycled from decaying fecal material and dead organisms that have settled with the sediments. Primary forms of N include ammonia, nitrite, nitrate and organic N. The sum of these forms, total N, is emphasized in this report.

Nitrogen load estimates presented in this report represent an "average" river discharge year based on long-term discharge data measured at United States Geological Survey (USGS) stations in Connecticut. While N data from 1986-1989 water years (October 1 through September 30) were used to calculate N loads at USGS stations to coincide with baseline and modeling periods established by the LISS, those riverine loads were adjusted to produce an average annual N load estimate. The "average year" database presented herein lends stability to a "baseline" condition from which management targets and decisions can be made throughout the New York and Connecticut portions of the LIS drainage basin. First order estimates are also presented for tributary drainage areas north of Connecticut, henceforth referred to as the "tributary" basins.

Key sources of N for which estimates were derived were point sources (sewage treatment plants and industrial discharges) and nonpoint runoff from urban, agricultural and forested lands. Nonpoint runoff was further divided into terrestrial and atmospheric components. Other reported estimates include atmospheric deposition of N directly on the estuary and a "natural" or pre-Colonial estimate against which today's enriched conditions are measured.

These N load estimates were generated several years ago (Stacey, 1996) and it is acknowledged that they could be improved with the newer land cover data and watershed modeling tools now available. Nevertheless, they will continue to be used to define LISS management targets and plans as a matter of consistency, which is critical to public outreach and development of management strategies. These N estimates have formed the basis for the Total Maximum Daily Load (TMDL) analysis developed by Connecticut and New York to manage the load of N and hypoxia in LIS. While the N loading estimates are believed to be suitable for gross evaluations and development of the TMDL, since their creation in the early 1990's much has been learned about N sources and delivery to LIS. Several technical flaws and potential improvements to the estimates are discussed in this report.

Study Area

The domain of this N loading analysis includes nearly the entire terrestrial drainage basin of LIS plus the surface of LIS and a portion of Block Island Sound (**Figure 1**). The Connecticut and New York portions of the drainage basin are emphasized and are more spatially detailed. Contributions of N originating north of Connecticut, called "tributary" loads, were based on monitored loads at the point the major tributaries crossed the state line into Connecticut. Information on land cover and point source loadings from the tributary areas was not well documented. The surface of the Sound plus a portion of Block Island Sound (a geographic unit defined in the LIS 3.0 eutrophication model developed for LIS (HydroQual, Inc., 1996) and used here for consistency) create a single segment needed to account for direct atmospheric deposition of N onto the water's surface.

Geographic Segmentation

Connecticut and New York portions of the basin were segmented into 11 "management zones", primarily along natural basin boundary lines (**Figure 2**). Connecticut is composed of six management zones that follow natural basin boundary lines while New York has five management zones that generally follow political boundaries. All of the Connecticut zones extend over state lines to follow the basin boundaries into New York, Massachusetts and Rhode Island, except for Zone 3 (the South Central Coastal that includes the Quinnipiac River Basin), which does not border another state. Hence, because basins were not split exactly at state political boundaries, portions of the tributary basins north of Connecticut are included in some of the Connecticut management zones as can be seen in **Figure 2**. The surface of the Sound forms the twelfth segment. The

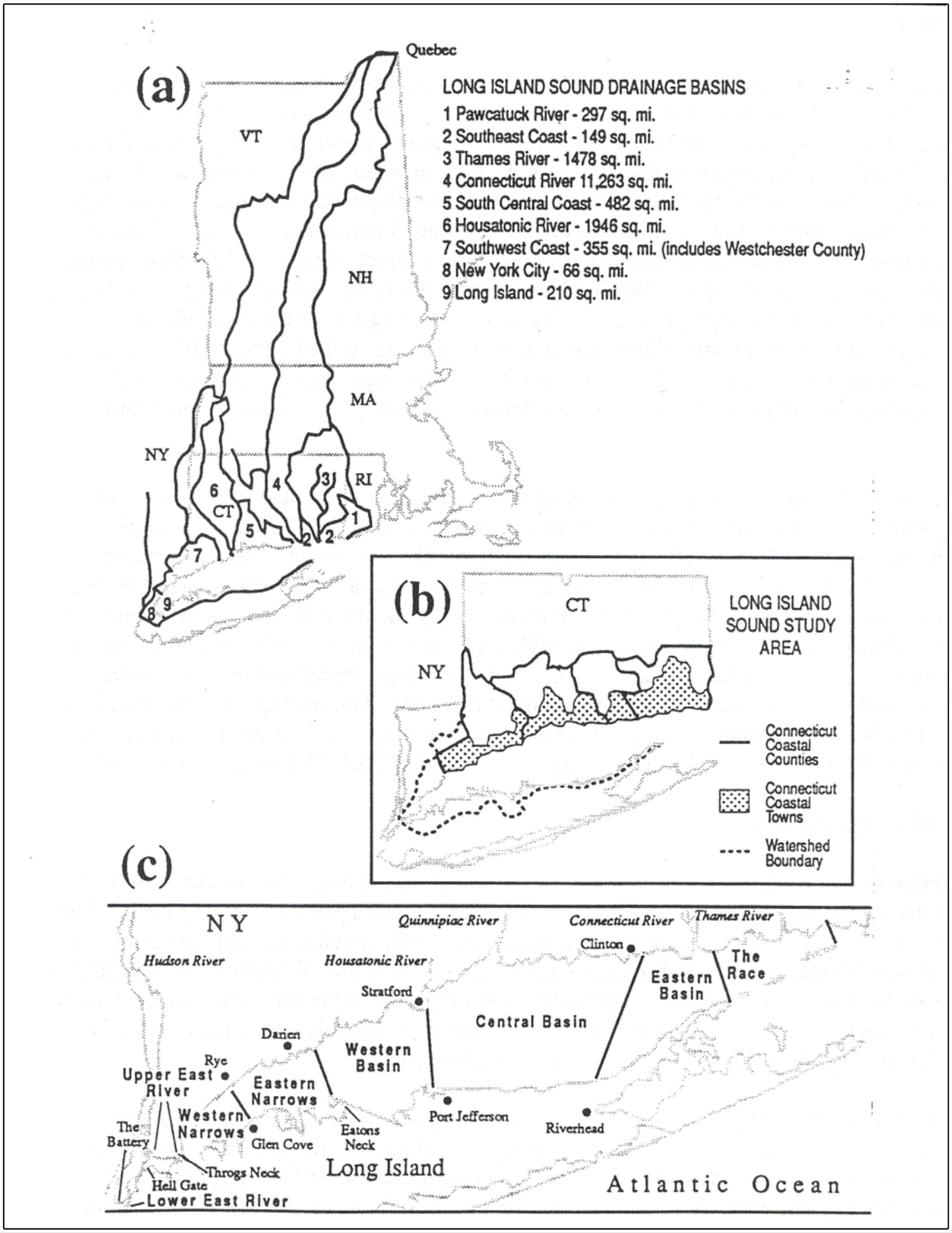

Figure 1. (a) Major basins of the LIS watershed; (b) Connecticut coastal towns and counties; and (c) features of LIS.

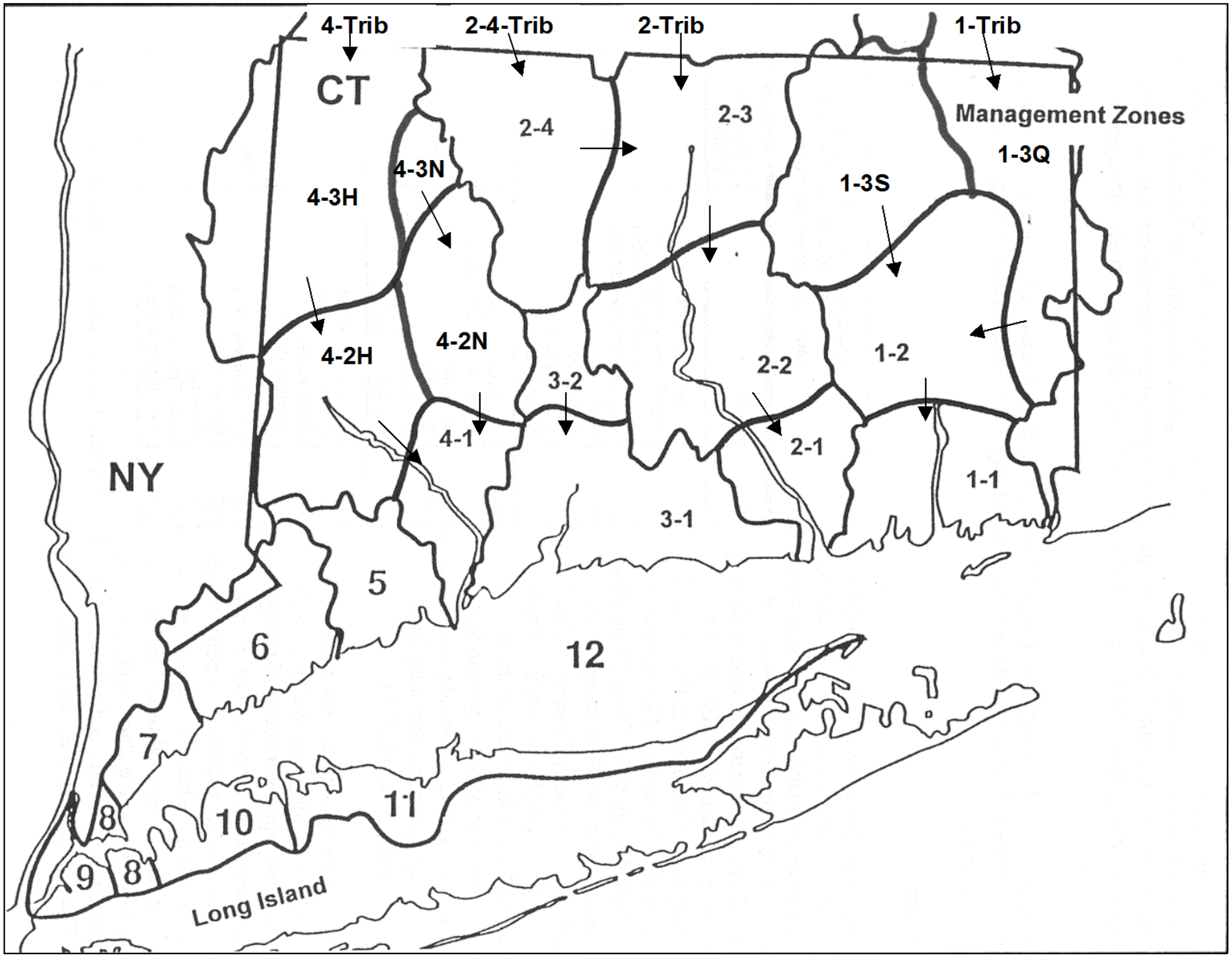

Figure 2. Management zones and segments used for LIS N load estimates.

easternmost basin bordering Connecticut and Rhode Island, the Pawcatuck River basin, was not included in the analysis.

Because of their large sizes, some of Connecticut's zones were further divided into smaller segments or "tiers". Tier 1 is closest to LIS and the higher numbered tiers are more distant from the Sound (**Figure 2**). The number of tiers created depended on basin size, but did not exceed the four tiers used in the Connecticut River basin. Tiers were needed not only to make the segment sizes more manageable, but also to account for N attenuation during transport through Connecticut. In the spreadsheet approach used to calculate N delivery to LIS, nutrients originating in more distant tiers were subjected to a loss or attenuation coefficient as they moved from one segment or tier through the next. The tributary areas north of Connecticut were lumped into one segment for each major basin--the Connecticut, Farmington, Housatonic, and Thames (Quinebaug). The Connecticut River tributary segment is disproportionately large, which makes relationships between sources and delivery to LIS less certain. Future efforts should be directed towards segmenting those tributary areas so attenuation can be better estimated and N load relationships between sources and delivery to LIS more accurately calculated.

The entire domain, including tributary drainage areas north of Connecticut and the surface of LIS, encompasses 4.7 million hectares (**Table 1**). Connecticut's 17 segments, which include the small portions of neighboring states dictated by sub-basin boundaries that cross state lines, cover about 1.4 million hectares (vs. 1.3 million hectares actually in Connecticut). New York's five segments cover about 114 thousand hectares. The surface of LIS, which includes portions of Block Island Sound, is about 482 thousand hectares. By far, the largest portion of the drainage area is in the north of Connecticut tributary areas, where some 2.69 million hectares are drained, most of it (2.5 million hectares) in the Connecticut River basin.

In sum, 27 land based segments were created, which counts each out-of-state "tributary" area as one segment (a total of four), each tier within a zone as a segment (a total of 22), and one water based segment for the surface of LIS (**Figures 1 and 2**).

Land Cover

A land cover database generated by Civco *et al.* (1992) was instrumental in estimating nonpoint source N loads within each segment in Connecticut. Civco used LANDSAT imagery interpretations to identify 22 land cover categories (**Table 2**). An additional layer of major roads (No. 7) was added from the Connecticut Department of Environmental Protection (CTDEP) geographic information system (GIS) to complete the database. The database is housed in CTDEP's GIS, providing a flexible means for analyzing and mapping nonpoint source loads of pollutants based on land cover export coefficients. New York land cover data were taken from a report prepared by the Long Island Regional Planning Board (1978). Land cover data for tributary drainage areas north of Connecticut were taken from an article by Jaworski *et al.* (1997), which

Table 1. Summary of land cover and areas (hectares) for the Long Island Sound drainage basin by geographic segment (**Figure 2**). Tributary areas refer to portions of the basin north of Connecticut.

Zone-tier	Hectares			
	Urban	Agriculture	Forest	Total
Connecticut and Tributary (north of CT)				
1-1	10563	4484	55528	70576
1-2	4703	8548	49414	62665
1-3Q	9644	12140	103891	125674
1-3S	7034	8119	91226	106379
1-Trib	5900	8259	44837	58996
1-Total	37844	41550	344896	424290
2-1	2988	2032	37874	42894
2-2	20571	13428	83694	117693
2-3	33206	19956	66992	120155
2-4	12618	9408	109395	131421
2-4-Trib	1730	1291	14997	18018
2-Trib	248558	298270	1938756	2485584
2-Total	319671	344386	2251708	2915765
3-1	27348	8922	68032	104301
3-2	9364	3151	15602	28118
3-Total	36712	12073	83634	132419
4-1	9075	3373	23490	35938
4-2N	8831	5200	34250	48281
4-2H	11745	11389	62782	85916
4-3N	2293	1615	16558	20467
4-3H	10883	33383	142767	187033
4-Trib	7617	25391	93946	126954
4-Total	50444	80351	373794	504589
5-1	19443	3861	32703	56006
6-1	23805	4267	33192	61265
Connecticut	224114	153277	1027391	1404782
Tributaries	263805	333211	2092536	2689552
CT + Tributary Total	487919	486488	3119927	4094334
New York				
7-1	12455	0	1152	13607
8-1	22501	0	0	22501
9-1	16997	0	0	16997
10-1	15277	0	10332	25609
11-1	25246	1619	8499	35364
NY Total	92476	1619	19983	114078
12-LIS	0	0	482080*	482080
TOTAL	580395	488107	3139910	4690492

Table 2. Aggregation of 23 land cover categories used in the Long Island Sound land cover database.		
No.	Name	Aggregate Category
1	Impervious surface	Urban
2	High density residential and commercial	
3	Medium density residential	
4	Roof	
5	Pavement	
6	Turf and grass	
7	Major roads	
8	Soil/grass and hay'	Agriculture
9	Grass, hay and pasture	
10	Soil/corn	
11	Grass/corn	
12	Soil/tobacco	
13	Grass/tobacco	
14	Deciduous forest	Forest
15	Coniferous forest	
16	Deep water	
17	Shallow water	
18	Non-forested wetland	
19	Forested wetland	
20	Barren land	
21	Bare soil	
22	Low coastal marsh	
23	High coastal marsh	

aggregated land cover into three categories, similar to the categories used for the Connecticut and New York land cover data.

Since export coefficients were not available for all 23 land cover categories provided in the Civco database, approximations of N yield were developed for three simpler, aggregated categories of urban, agricultural and forested (**Table 2**). Included in the forest category were land covers that were not expected to yield much N enrichment relative to urban and agricultural covers, such as wetlands and open water. Also, the analysis based on LANDSAT imagery did not distinguish low-density housing surrounded by trees from forest, which may have increased the forestland N budget estimates in some areas. The base unit used in this analysis was the hectare.

The distribution of land cover by management zone shows a trend toward more urbanized land cover, as a percentage, draining to the western part of the Sound (**Figure 3**). The dominant land cover category in Connecticut is forested (73%), followed by urban (16%) and agriculture (11%). As noted earlier, some of the forested land cover includes wetlands, surface waters, and low-density residential cover within forested grounds that the land cover analysis was unable to differentiate from forested cover. While the low-density housing, in particular, could affect N yield in the forest category, it was assumed that N export from that type of land use would not differ too greatly from forested cover. New York's land cover is dominated by urban (81%) followed by forest (17.5%) and a small agricultural component (1.5%) located primarily in Suffolk County on Long Island. Tributary areas (north of Connecticut) were dominated by forest cover as well (**Table 1**). For example, the tributary portion of the Connecticut River basin (north of Connecticut) is 78% forest, 12% agriculture, and 10% urban

Making the Nitrogen Loading Estimates

Gauging Station Nitrogen Loads

Monitored N concentrations and flow at USGS stream gauging stations located throughout Connecticut were used to quantify riverine flux against which the spreadsheet calculations were calibrated. While thirteen stations were eventually used as "checkpoints" for load estimation and calibration of the spreadsheet estimates (**Table 3**), land cover export coefficients were primarily developed through analyses of smaller basins without point sources like the Salmon River and Burlington Brook.

The USGS "water years" (October through September of each year) 1985 through 1988 (i.e., October 1984 through September 1988) were used to develop the monitored N load estimates (Cervione *et al.*, 1987; 1988; 1989a; 1989b). Each gauging station total N load was calculated by multiplying monthly discharge volume by the concentration of total N measured for that month. If a monthly total N concentration was unavailable, the average total N concentration for the preceding and following months was used. Generally, the

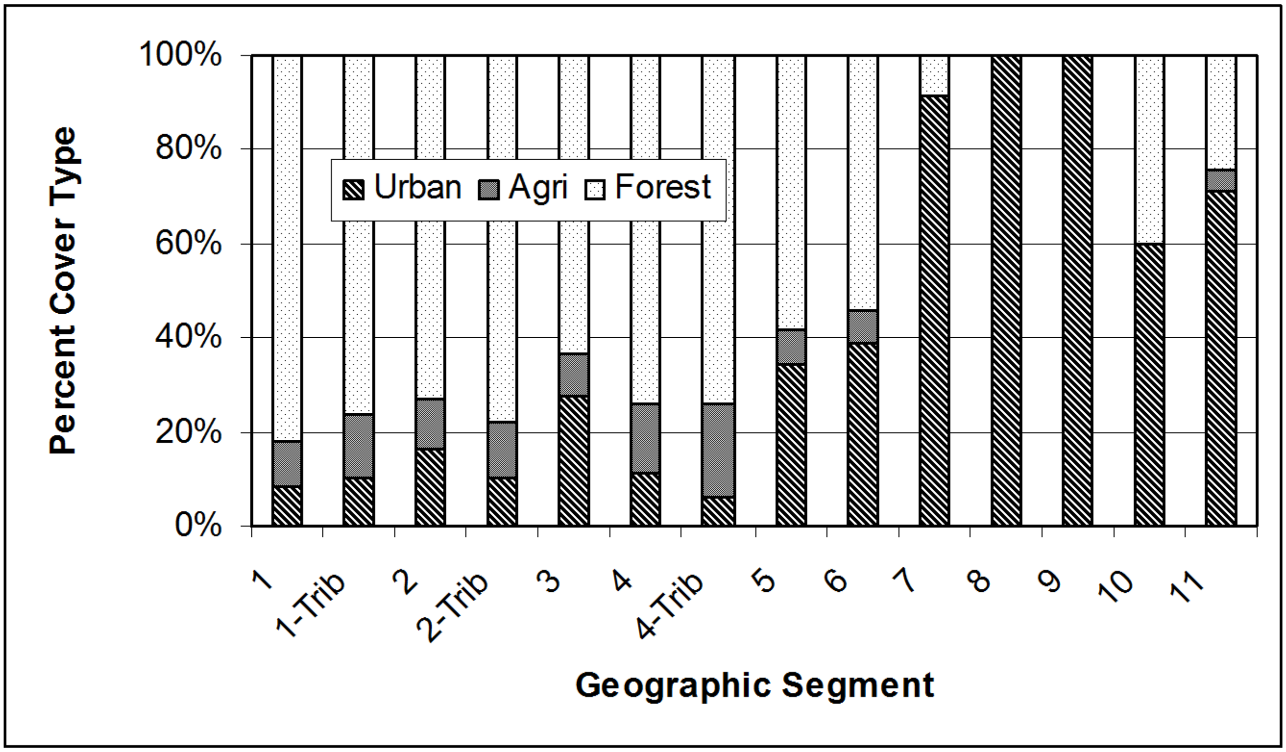

Figure 3. Percent distribution of land cover by management zone. Tributary portions are separated except for the Farmington River (zone 2-4-Trib), which is incorporated into the zone 2 statistic.

Table 3. USGS gauging stations used for N load comparison to calculated estimates and their general land cover characteristics. Total N loads were calculated for the 1985-1988 water years and adjusted by the ratio of the 1985-1988 average annual flow to the historical record average annual flow.

Gauging Station	USGS Station Number	No. of Samples	Land Cover Character	Unadjusted N Load (kg N/yr)	Adjustment Ratio	Adjusted N Load (kg N/yr)
Norwalk at Winnipauk	01209710	44	Urban	48181	1.29	62128
Saugatuck at Redding	01208990	44	Forest	22165	1.31	28990
Housatonic at Canaan	01196500	44	Tributary	917074	1.15	1057111
Housatonic at Stevenson	01205500	48	Mixed	2464872	1.20	2957846
Naugatuck at Beacon Falls	01208500	47	Urban	1636266	1.12	1831641
Quinnipiac at Wallingford	01196500	50	Urban	486603	1.22	594585
Burlington at Burlington	01188000	16	Forest	3070	1.19	3650
Farmington at Tariffville	01189995	44	Mixed	1146744	1.46*	1363383
Connecticut at Thompsonville	01184000	49	Tributary	12979691	1.07	13879184
Salmon at East Hampton	01193500	44	Forest	114242	1.17	133853
Quinebaug at Quinebaug	01124000	44	Tributary	210910	1.20	253345
Quinebaug at Jewett City	01127000	45	Agriculture	1274172	1.13	1440451
Shetucket at S. Windham	01122610	50	Agriculture	537093	1.16	623330

* The Farmington adjustment ratio was high because of the short period of record. The ratio 1.19, calculated for nearby Burlington Brook was used instead.

USGS stations were monitored for total N 11 times per year (February skipped) during water years 1985 through 1987 (WY1985-87). Beginning in April of 1988, supplementary monitoring was conducted at seven of the 13 checkpoint stations, increasing the monthly sampling to two times per month (**Table 3**). An annual N flux was computed by averaging the N loads for the four water years.

WY1985-88 were lower than average (drier) discharge years at all 13 gauging stations used in this analysis. In order to develop a N loading baseline that reflected a more average flow condition, the estimates of total N flux were increased proportionately to the ratio of the historical to the WY1985-88 discharge volumes at each station (**Table 3**). This may have resulted in high estimates of monitored N loads in point source-dominated streams where higher flows tended to have a dilution effect on N concentrations. Conversely, streams with small point source contributions may have yielded underestimates if higher flows flushed more N from the land. However, it was assumed that this source of error would not have major ramifications on management direction if estimation methods were kept consistent for all geographic areas. The monitored average year total N flux estimates were instrumental in developing multiple-source N loading estimates based on land use, atmospheric deposition and point source inputs and to estimating attenuation rates during riverine transport.

Source Categories

To be useful for targeting management efforts, total N flux estimates were divided into categories relative to the source of the N. Two standard, major groups, point sources and nonpoint sources, form the foundation of the N loading estimates. The point sources included all sewage treatment plants, combined sewer overflows (CSO) in New York City (NYC) zones 8 and 9, and industrial discharges. The nonpoint sources were subdivided into a terrestrial and atmospheric component. A separate atmospheric deposition component was used to account for direct deposition of N onto the surface of LIS (zone 12). Because the nonpoint source loads were derived from land cover export coefficients, nonpoint source loads of N, both of terrestrial and atmospheric origin, could also be categorized as urban, agricultural and forested. Finally, an estimate of pre-Colonial N loads was made to try to define how much N enrichment has been added to the LIS system by human activity. The pre-Colonial estimate was based on what N loads might have been when the entire drainage basin was mostly forested. The magnitude of the pre-Colonial load is uncertain but key to developing good estimates of the level of human enrichment. Setting the pre-Colonial N load too high or too low could cause under or overestimates of N enrichment, respectively.

Point sources, defined as discharges from sewage treatment plants, industries and CSOs in NYC (zones 8 and 9), were considered to be 100% enrichment. Nonpoint sources comprised diffuse nonpoint runoff from the land and through the groundwater, discharges from stormwater conveyance systems and the non-domestic sewage portion of CSOs in non-NYC zones, and atmospheric deposition on the land that contributed to the nonpoint source load of N. The final category of atmospheric deposition of N directly on the Sound's surface waters completed the input sources of N to LIS (**Figure 4**).

Not considered in this report were contributions of N transported by currents into LIS from northeastern estuaries and the Atlantic Ocean through The Race and from New York Harbor through the East River. These were designated the "boundary" loads in the LIS 3.0 eutrophication model developed from LIS (HydroQual, Inc. 1996).

Point Sources

Point source loads of total N were estimated by multiplying the concentrations of N in the effluent of sewage treatment plants and industries by the volume of the discharge. These sources were then summed for each of the 27 zones, tiers, and tributary segments defined earlier to create a point source contribution of N within each segment. For zones 8 and 9, the CSO contribution was included in the point source total. CSO loads were from a CSO planning study conducted for NYC (HydroQual, Inc., 1996). A base year condition approximating 1990 point source loads from sources greater than 20 lbs N/day was used for point source estimates to the extent practicable. While many plants were regularly monitored, particularly in the near coastal portions of the study area, data were not available for all plants. In cases where nutrient concentrations were not available (discharge volumes generally were) an estimate was based on average or estimated N concentrations in sewage effluent, usually at 15 mg N/l.

For many of the western LIS coastal point sources, N loads generated for the LIS 3.0 model were used here (HydroQual, Inc., 1996) reflecting best available data approximating 1990 loads. These loads have also been formalized as baseline loads for management purposes by the LISS (LISS, 1992). New York City treatment plant loads were adjusted upward to reflect the effect of the 1992 ban on offshore sludge dumping. Sludge dewatering at the NYC facilities in zones 8 and 9 increased the N load to the East River considerably. Estimates of N contributions from tributary plants north of Connecticut were made, but from a relatively weak database that relied on some mid-1980's flow data or design flow data and to which an estimated total N concentration was applied.

Nonpoint Sources

Nonpoint source N load estimation was more complex and relied on a spreadsheet model to calculate various nonpoint source components based on land cover yield that matched gauging station monitored flux estimates. The basic calculation was simple -- land cover within each of the three categories was multiplied by an appropriate export coefficient (**Table 4**) -- but determining acceptable export coefficients was a challenge because of limited site-specific studies. As a starting point, literature values for N export generated by Frink (1991) for Connecticut lakes were tried and turned out to work quite well for

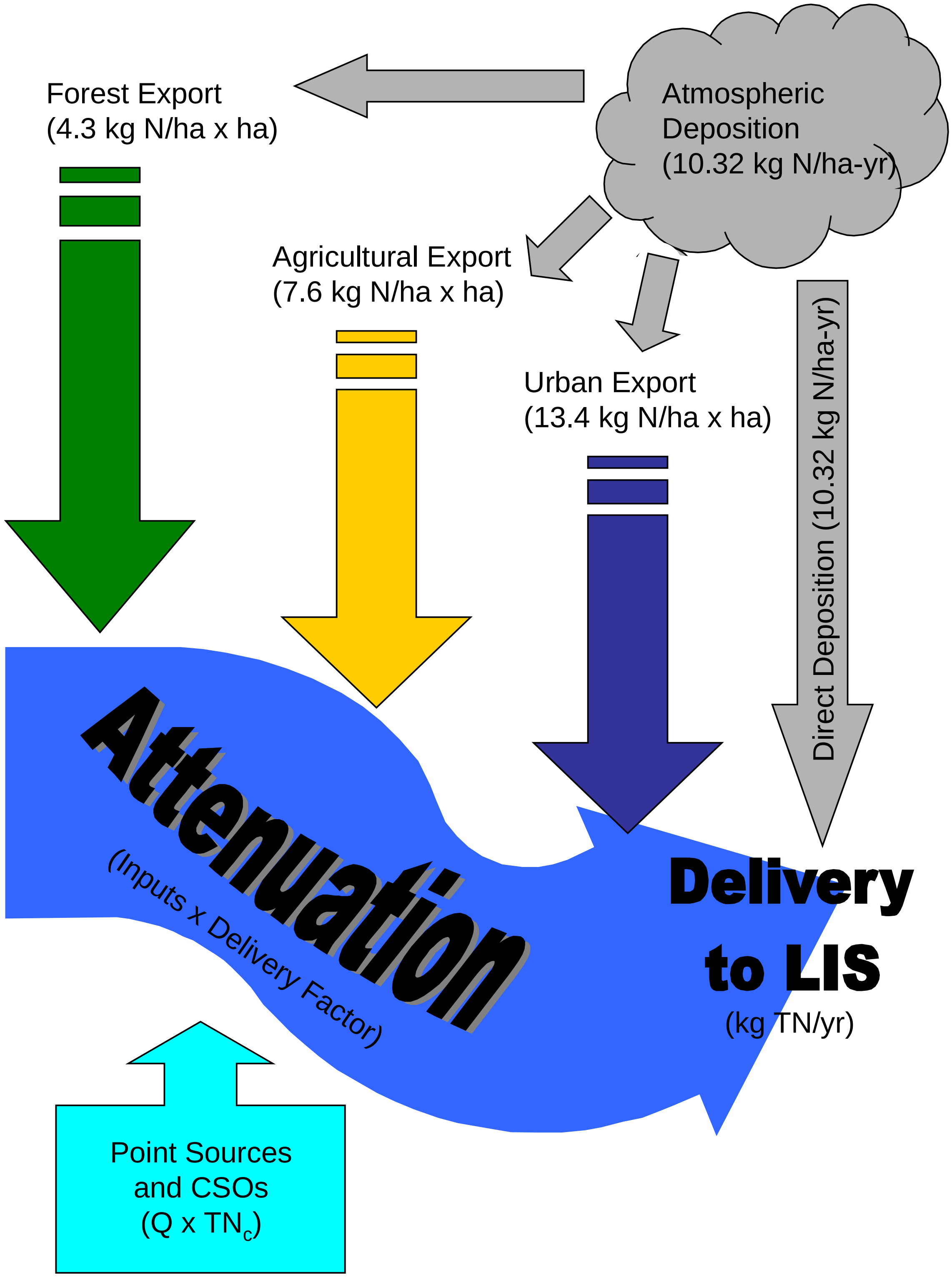

Figure 4. General scheme of N sources and budget development methodology for the LIS watershed. Q x TNc is flow times the total N concentration in the point source effluent.

Table 4. Export coefficients (kg total N/hectare-yr) for nonpoint source export at edge of field by land cover category and source and from reported values in the literature.

Land Cover	Export (kgTN/ha-yr)				
	LIS Estimates			Literature Estimates	
	Terrestrial Sources	Atmospheric Sources	Total	Frink (1991)	Alexander, Smith and Schwarz (2000)
Forest	0.9	3.4	4.3	0.1 – 10.8	1.8 – 11.2
Agriculture	4.2	3.4	7.6	0.8 – 79.6	2.2 – 42.5
Urban	6.5	6.9	13.4	1.6 – 38.5	3.6 - 175

urban and agricultural land covers when broadly applied.[1] Frink's forest coefficient (2.9 kg/ha-yr) appeared to underestimate N loading by more than 40% when tested against U.S. Geological Survey (USGS) monitoring data in selected test basins in Connecticut. This may have been a result of the type or maturity of the forest in Frink's study areas as compared to forests in the test basins, basin size, or any number of other land and soil features.

Nitrogen yield estimates based on land cover as reported in the literature vary widely. Frink (1991), in his review of published export coefficients, found a wide range of rates for broadly categorized land types (**Table 4**). More recently, Alexander *et al.* (2000) compared the USGS SPAtially-Referenced Regression On Watershed attributes (SPARROW) model land cover yields to the literature and reported a wide range of values both resulting from calibrated SPARROW outputs and the literature (**Table 4**). While the Frink estimates derived in Connecticut watersheds are clearly the most relevant to the N loading estimates developed for LIS, the literature seems to favor a higher yield from forested lands as well. SPARROW's median N export rate for forested lands was 4.5 kg/ha-yr and in applying EPA's Hydrologic Simulation Program – FORTRAN (HSPF) model to the Chesapeake Bay, Donigian *et al.* (1990) reported a range of yields from forested areas of 0.2 to 5.6 kg/ha-yr. The Chesapeake Bay model average forested yield was 4.3 kg/ha-yr (Linker *et al.*, 1993), which matches the export coefficient used for the LIS estimates.

Conversely, the literature suggests higher N export from agricultural and urban lands than used in the LIS estimates (**Table 4**). The agricultural difference is explained by the atypical character of agriculture in Connecticut compared to many other areas. Geographic areas reported in the literature often include a more intensive agricultural usage including double cropping each season and more animal units per acre. Many of the lands identified as agricultural in the Connecticut land cover database include fallow cropland and pasture and double cropping is rare in this climate. A lower agriculture land yield appears to be valid for Connecticut. Urban N export, on the other hand, may be underestimated in the LIS estimates, compared to the literature (**Table 4**). However, they are within the range of observed values and a more detailed examination of the literature studies would be required to determine the intensity of development in the reported studies compared to Connecticut. Of more concern might be the low-density housing that is prevalent in Connecticut but was not quantified in the land cover database used for this study.

Despite the uncertainty, the export coefficients for the three land cover classifications that were used provided a reasonably good fit for N loading data in Connecticut when compared to USGS monitoring data adjusted to represent an average flow condition. The

---

[1] Calibration of nonpoint source loads from the three land cover categories using export coefficients was an empirically driven iterative process. Using basins without point sources that reflected certain characteristics of urban, agricultural, and forest, Frink's coefficients were applied and the total N load so derived was compared to the gauging station monitored flux. It became apparent that the forest export coefficient was too low, based on comparisons in largely forested watersheds such as the Salmon. When it was eventually raised to the value reported here, the process produced estimates that matched monitored N loads quite well in smaller basins.

comparison between spreadsheet estimates and USGS data will be explored more fully below. However, there are many limitations with using a single export coefficient for three, broad land cover classifications throughout the entire LIS basin. These include variation in the land use within a category, basin size as it affects gross attenuation, and variations in topography, soil type, and other factors.

Management zones 8 and 9 (NYC), while treated as 100% urban land in this analysis, were not assigned a nonpoint source N load estimate. Instead, as described above, model estimates from a CSO study conducted for the city were used and added to the point source category. For remaining CSO areas in Connecticut[2], this report assigns the sewage component to the point source load and the storm water component to the nonpoint source load. Land cover generated estimates are based on the assumption that the sewage treatment plant loads provide a reasonable N loading estimate, as if the combined sewers were separated. So, for combined sewer areas in Connecticut, the sum of the point source estimate plus the nonpoint source estimate under non-combined conditions would equal the sum of the point source estimate plus the CSO estimate under combined conditions. All the N delivered to LIS is counted. The point source load is simply apportioned differently under the two scenarios.

Originally, the forest export coefficients were used to estimate natural or pre-Colonial conditions of N loading based on a faulty assumption that today's forests yield no more N than they did under natural (pre-Colonial) conditions. After additional monitoring of atmospheric deposition and review of more sophisticated approaches found in the literature that accounted for an atmospheric component of forest runoff (Jordan and Weller, 1996; Jaworski *et al.*, 1997; Valiela *et al.*, 1997; Vitousek *et al.*, 1997; The National Academies, 2000; Valigura *et al.*, 2000), a split between atmospheric and terrestrial sources of N was made (**Table 4**). A pre-Colonial export rate of 1.0 kg N/ha-yr was suggested in a recent article by Nixon (1997) for the neighboring Narragansett Bay drainage was used to estimate pre-Colonial N loading. A pre-Colonial total N export rate of about 1 kg/ha-yr seems to be supported in other recent articles by Howarth *et al.* (1996), Vitousek *et al.* (1997), and the The National Academies (2000).

Atmospheric Sources

The atmospheric deposition rate for N was based on a study conducted by Miller *et al.* (1993) who monitored weekly wet and dry deposition rates during 1991 and 1992 at two locations along Connecticut's coast. The total loading rate for the N components they measured (nitrite, nitrate and ammonia) was about 8.9 kg/ha-yr, which compared favorably with literature values (Valigura *et al.*, 2000). An organic N component of 1.4 kg/ha-yr was taken from Jaworski *et al.* (1992), which brought the total N deposition rate to 10.3 kg/ha-yr. This deposition rate was applied to the surface area of LIS to estimate direct loading to the Sound, and to all land areas in the terrestrial segments to estimate the N contribution from deposition on the land. It was assumed that about a third of the N

---

[2] In Connecticut, CSO areas of consequence include the cities of Hartford (zone 2-3), Bridgeport (zone 5) and New Haven (zone 3-1).

deposition to agricultural and forested lands was released to surface flow, based on work cited by Jaworski *et al.* (1992). Urban release was more complicated because of the impervious cover, but a rough estimate of two thirds was used based on literature values summarized by Valigura *et al.*, 1996.

The direct atmospheric loading rate of N was subdivided into a pre-Colonial and anthropogenic or enriched component as was done for general nonpoint source loading. As a first approximation, about 70% of the N deposition from the atmosphere (roughly equal to the nitrate component) was assumed to be enrichment. The total N deposition rate of 10.32 kg/ha-yr was used to calculate direct N loading to the Sound's surface.

Tributaries

Gross tributary import of total N into Connecticut was estimated for the Quinebaug (zone 1), Connecticut and Farmington (zone 2), and Housatonic (zone 4) Rivers where they crossed the border into Connecticut in the same manner as loading estimates were made for the segments within Connecticut and New York. USGS monitoring stations closest to the state border were used to compare the tributary or import loads with the combined point and nonpoint source estimates. All calculated tributary loads were higher than those measured at the gauging stations, and were reduced according to the observed difference to account for attenuation (**Table 5**).

Attenuation

When accounting for N loads originating within a segment and comparing it with USGS monitoring data at the lower terminus of a segment, it was assumed that N was not conservatively delivered downstream. It was expected that attenuation would occur because N is biologically, physically, and chemically mediated in aquatic environments. The primary sinks for various forms of N are uptake by plant matter and mineralization to nitrate, which can denitrify to N gas under certain conditions. Nitrogen is also stored in sediments, some more or less permanently. While these processes were too complex to accurately quantify in this spreadsheet approach, nutrient loss or attenuation was estimated and factored into the spreadsheet analysis. Riverine attenuation is widely reported in the literature and a critical component of N budget analyses (Hill and Sanmugadas, 1985; Correll *et al.*, 1992; Jordan and Weller, 1996; Alexander *et al.*, 2000; The National Academies, 2000).

It was difficult to derive workable attenuation factors for the LIS N loading estimates and their evolution cannot be reconstructed because of periodic adjustments based on empirical observations made over the years. There is no straightforward formula that provides consistent attenuation factors because of their presumed variability from basin to basin. A consistent approach was also constrained by the probable errors in both the N loading estimation process and the calculations used to estimate monitored flux from

Table 5. Comparison of calculated and measured total nitrogen loads for tributary stations with adjusted loads and applied attenuation rate.

Basin (zone)	Total N Load (kg/yr)			
	Calculated	At USGS Stn.	Adjusted	Attenuation (%)
Quinebaug (1)	389544	253338	253204	35
Connecticut (2)	17529711	13919270	14023769	20
Farmington (2)	97481	N/A	97481	0
Housatonic (4)	1244155	1057146	1057532	15

USGS data at the gauging stations. In many cases, spreadsheet estimates were lower than monitored flux estimates in test segments, probably because of inaccurate land export coefficients, small basin size, or incomplete accounting of sources, particularly point sources. In general, less than 20% of the N was believed to be lost during transport from throughout the state of Connecticut before delivery to LIS. This was largely based on N load comparisons for the tributary drainage areas north of Connecticut, which appeared to lose between 15 and 35% of the calculated load generated in that area before transport across Connecticut's border (**Table 5**). Specific attenuation rates for each geographic segment, which provide the base "balance" to the loading budget, are reported in a later section and compared to typical rates used in the USGS SPARROW model.

The Long Island Sound Calculated Nitrogen Load Estimates

Using the point and nonpoint estimation approaches described above, total N loads were first calculated for each segment using the formula:

$$TN_i = k_f A_{fi} + k_a A_{ai} + k_u A_{ui} + P_i$$

where:

TN_i = the total N load generated within segment *i*

and

k_f = the export coefficient for forested land cover, = 4.3 kg/ha-yr,
A_{fi} = hectares of forested land cover in segment *i*,
k_a = the export coefficient for agricultural land cover, = 7.6 kg/ha-yr,
A_{ai} = hectares of agricultural land cover in segment *i*,
k_u = the export coefficient for urban land cover, = 13.4 kg/ha-yr,
A_{ui} = hectares of urban land cover in segment *i*, and
P_i = the point source contribution of total N in kg/yr.

Attenuation of the generated loads for each segment through to delivery to LIS were calculated by:

$$TN_{id} = d * TN_i$$

where:

TN_{id} = the total N load delivered to LIS from segment *i*,

and

d = the delivery factor, which accounts for attenuation from that segment to LIS.

Export coefficients were calibrated first by comparison with monitored flux estimates in five small test basins (**Figure 5**). The sites tested ranged from largely forested basins such as the Saugatuck and Salmon to more urbanized basins such as the Quinnipiac and

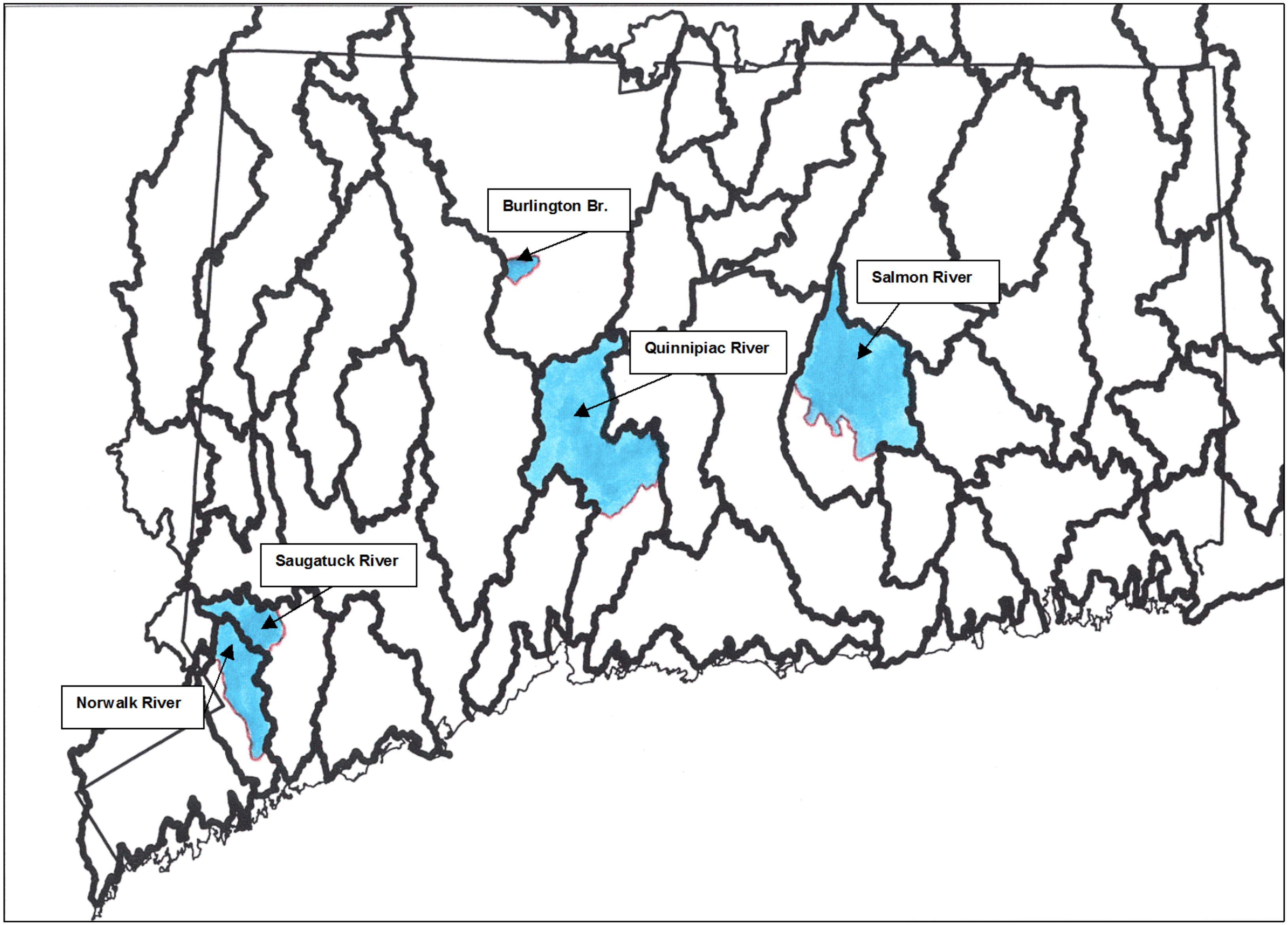

Figure 5. Five small watersheds in Connecticut used to develop land cover export coefficients and to test spreadsheet predictions against total N flux estimates from USGS monitoring data.

Norwalk. All were less than 30,000 ha in size. Initial efforts were in the Salmon River basin, where a good match between spreadsheet estimates and monitored flux estimates was obtained using the land export coefficients that became the standard for all basins (**Table 4**). The difference between the spreadsheet and monitored estimates was less than one percent (**Table 6**). When the approach was applied to other small basins, including two with point source contributions, the N loading estimates were all within six percent of each other except in the Burlington Brook basin (**Figure 6**). Burlington Brook may have provided a poor match because of its very small size.

The calculated, or predicted, N loads (**Table 6**) from the spreadsheet were correlated to the monitored flux estimates to test the strength of the relationship (**Figure 7**). The five data points correlated well, having an r^2 of 0.9999. The relationship $y = 0.9853x + 1687.1$ shows, however, that the spreadsheet N loads, while linear, were slightly less than the monitored loads. Because of the expectation that loads undergo attenuation during transport, and attenuation is not applied in this comparison, these results suggest that either the spreadsheet N load estimates are low or the monitored load estimates are high. The spreadsheet estimates may be low either because some point sources were missed or underestimated or because export coefficients were underestimates.[3] Basin size may also affect attenuation since most of the test basins were relatively small. If attenuation of nonpoint sources is occurring, the export coefficients account for that attenuation in these test basins. These shortcomings should not detract from the excellent overall agreement between the two load estimates at the five locations, as reflected in the high correlation coefficient. Use of land cover and export coefficients coupled with point source loading estimates for N appears to provide a very reasonable approximation of the actual delivery of N calculated at the gauging stations in small basins.

The spreadsheet approach was further tested against five larger basins within the LIS watershed (**Figure 8**) with more complex land cover and point source contributions (**Table 7**). The observed differences between spreadsheet N load estimates and those based on monitoring data, particularly when the monitoring estimates are higher, present difficulties for assigning attenuation rates. While the tributary data (**Table 5**) demonstrate a need to attenuate spreadsheet N loads to match monitored loads, the relationship was more scattered for five larger segments located mostly within the state of Connecticut (**Table 7 and Figures 9 and 10**). The smaller basin (**Table 6**) differences can be rationalized as being due to their small size and the incorporation of attenuation in the export coefficients. But in larger basins (**Table 7**) the expectation that longer transport times would lead to more attenuation does not seem to hold in every case.

Three of the five larger basins have lower N load estimates from the spreadsheet than the monitored load would suggest. Nevertheless, based on the tributary findings and based on reports in the literature (discussed below), attenuation should be part of the processes affecting N delivery to LIS. Hence, until more sophisticated analyses can be conducted, it is presumed that either the approach for calculating N flux from the monitoring data overestimates total N flux at the gauging stations or the spreadsheet predictions are

---

[3] Export coefficients, because they match monitored flux estimates at the end of a geographic segment, incorporate a certain amount of attenuation that would occur within a segment.

Table 6. Land cover (hectares) and total nitrogen loads from point and land cover based estimates compared to monitored nitrogen flux estimates at gauging stations in five small test basins.

River	USGS Station	Hectares			
		Urban	Agriculture	Forest	Total
Norwalk	Winnipauk	1868	457	5927	8252
Saugatuck	Redding	375	320	4570	5265
Quinnipiac	Wallingford	9364	3151	15602	28117
Burlington	Burlington	61	185	839	1085
Salmon	East Hampton	1239	2604	22494	26337

River	Total N Load (kg/yr)					
	Point	Urban	Agriculture	Forest	Total	
					Calculated	Monitored
Norwalk	6290	25031	3473	25486	60281	62128
Saugatuck	0	5025	2432	19651	27108	28990
Quinnipiac	354462	125478	23948	67089	570976	594585
Burlington	0	817	1406	3608	5831	3650
Salmon	0	16603	19790	96724	133117	133853

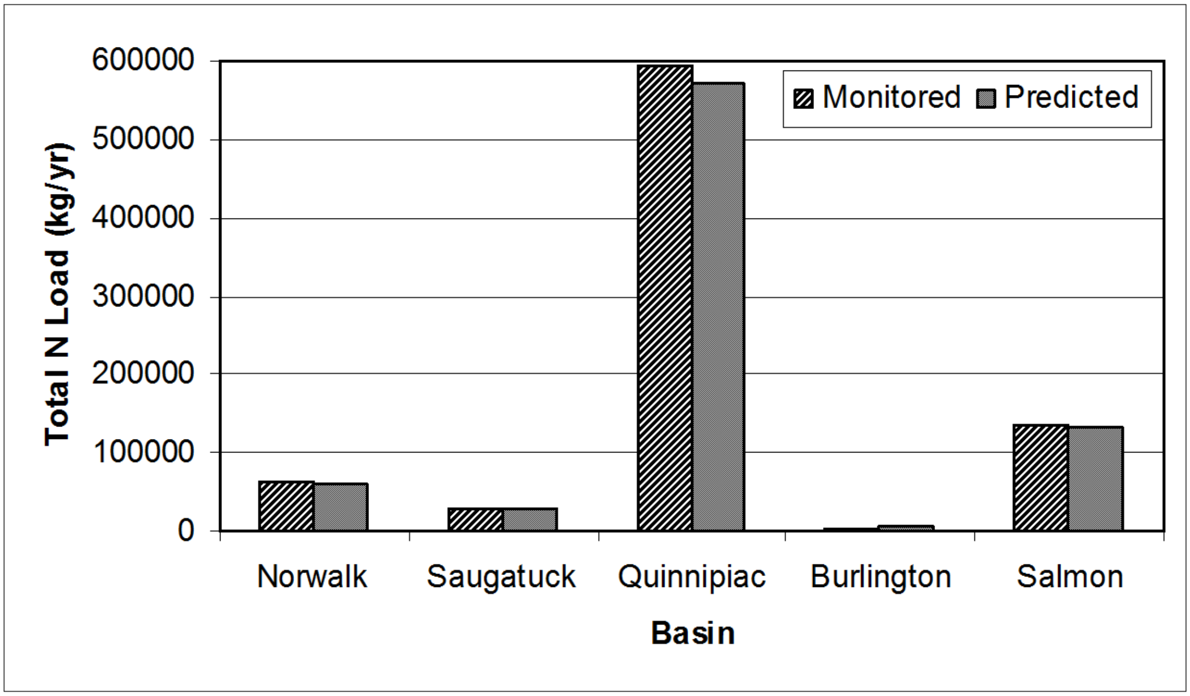

Figure 6. Comparison of total N load from spreadsheet predictions with monitored flux estimates from USGS data for five small watersheds in Connecticut.

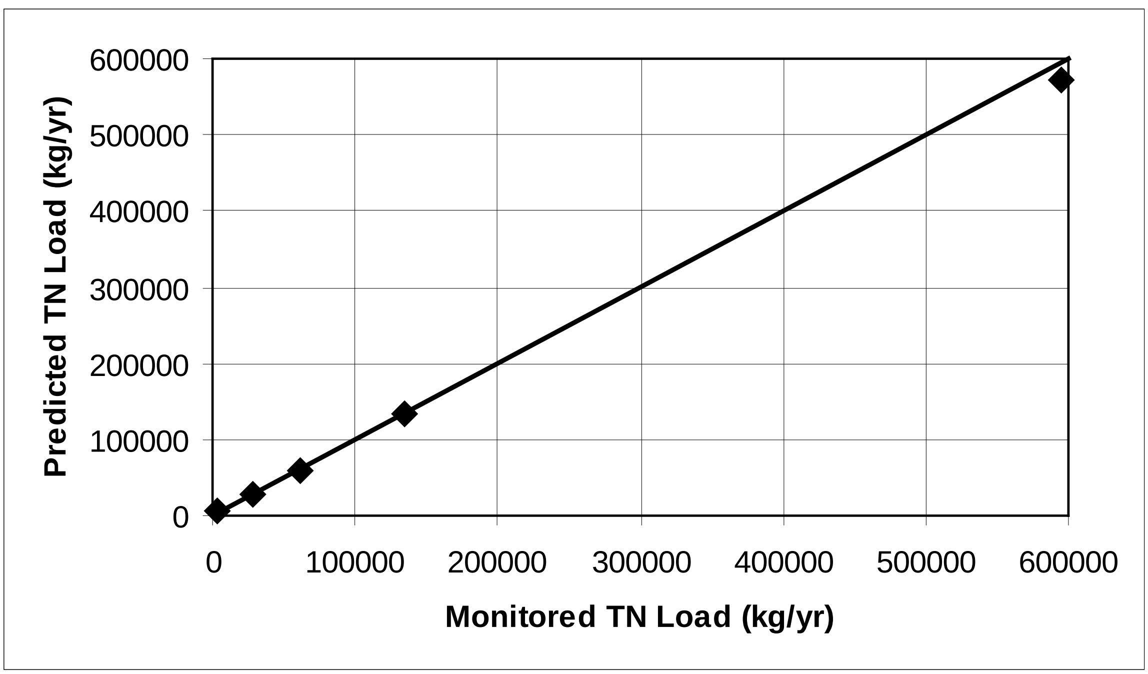

Figure 7. Relationship between monitored total N flux estimates and spreadsheet predictions for five small watersheds in Connecticut (Figure 5). The diagonal line

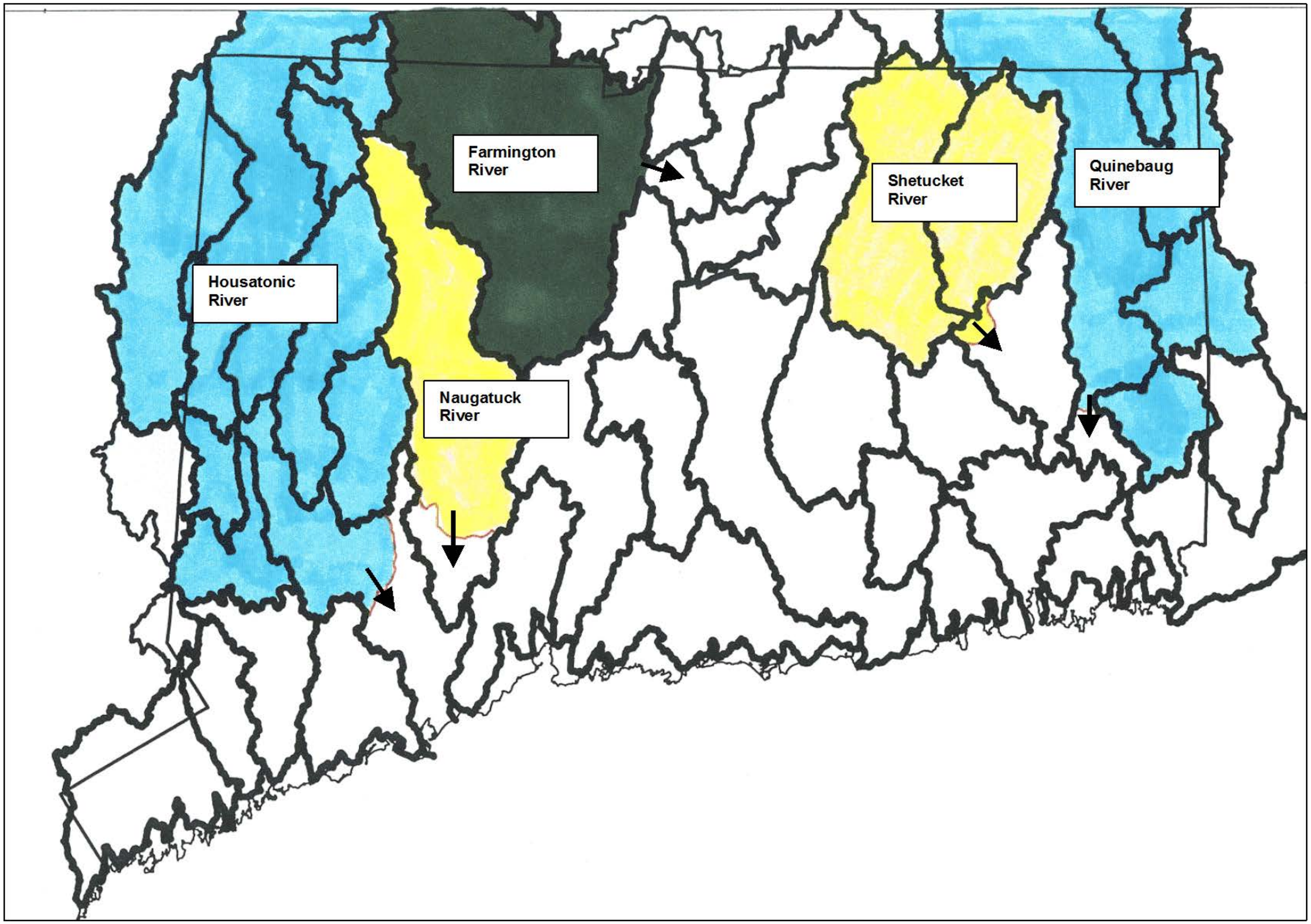

Figure 8. Five large basins in the LIS watershed used to test spreadsheet loading estimates with total N flux estimates calculated from USGS monitoring data.

Table 7. Land cover (hectares) and total nitrogen loads from point and land cover based estimates compared to monitored nitrogen flux estimates at gauging stations in five large test basins.

River	USGS Station	Hectares			
		Urban	Agriculture	Forest	Total
Housatonic	Stevenson	30245	70163	299495	399903
Naugatuck	Beacon Falls	11124	6815	50809	68748
Farmington	Tariffville	14348	10699	124392	149439
Quinebaug	Jewett City	15544	20399	148728	184671
Shetucket	South Windham	7034	8119	91226	106379

River	Total N Load (kg/yr)					
	Point	Urban	Agriculture	Forest	Total	
					Calculated	Monitored
Housatonic	928096	405283	533239	1287829	3154447	2957846
Naugatuck	995022	149062	51794	218479	1414357	1832618
Farmington	417041	192263	81312	534886	1225502	1363364
Quinebaug	307814	208290	155032	639530	1310666	1440451
Shetucket	112082	94256	61704	392272	660314	623350

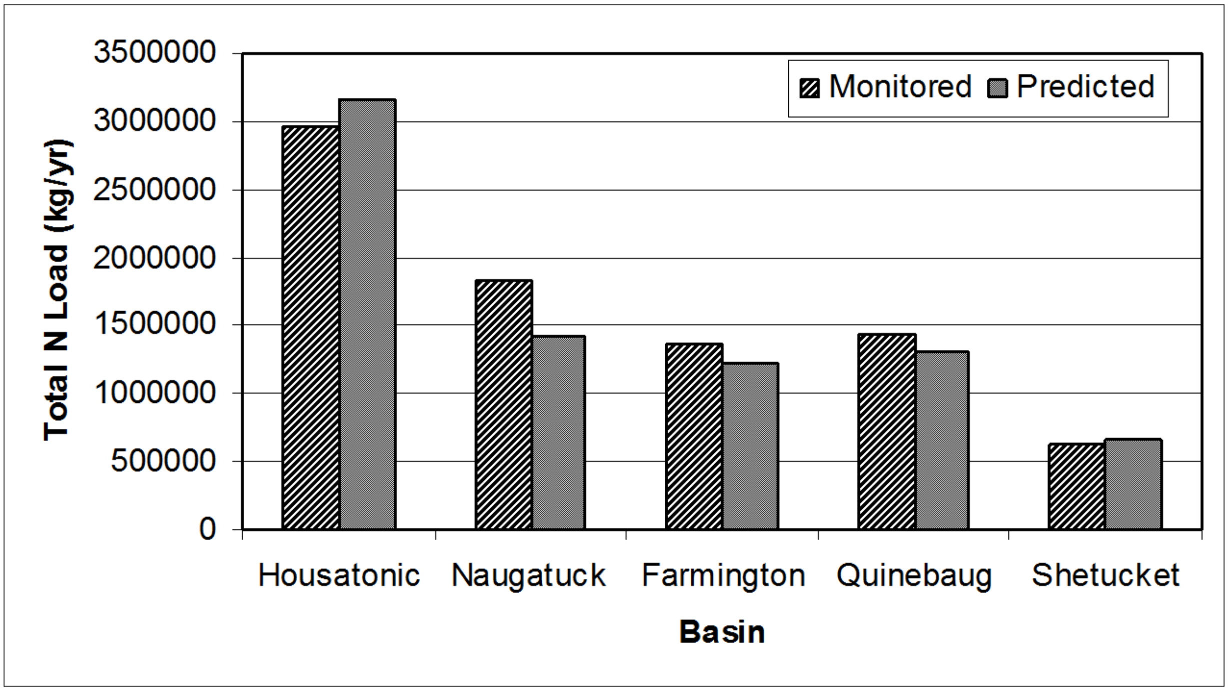

Figure 9. Comparison of total N load spreadsheet predictions with monitored flux estimates from USGS data for five larger basins in the LIS watershed. Riverine attenuation is not applied.

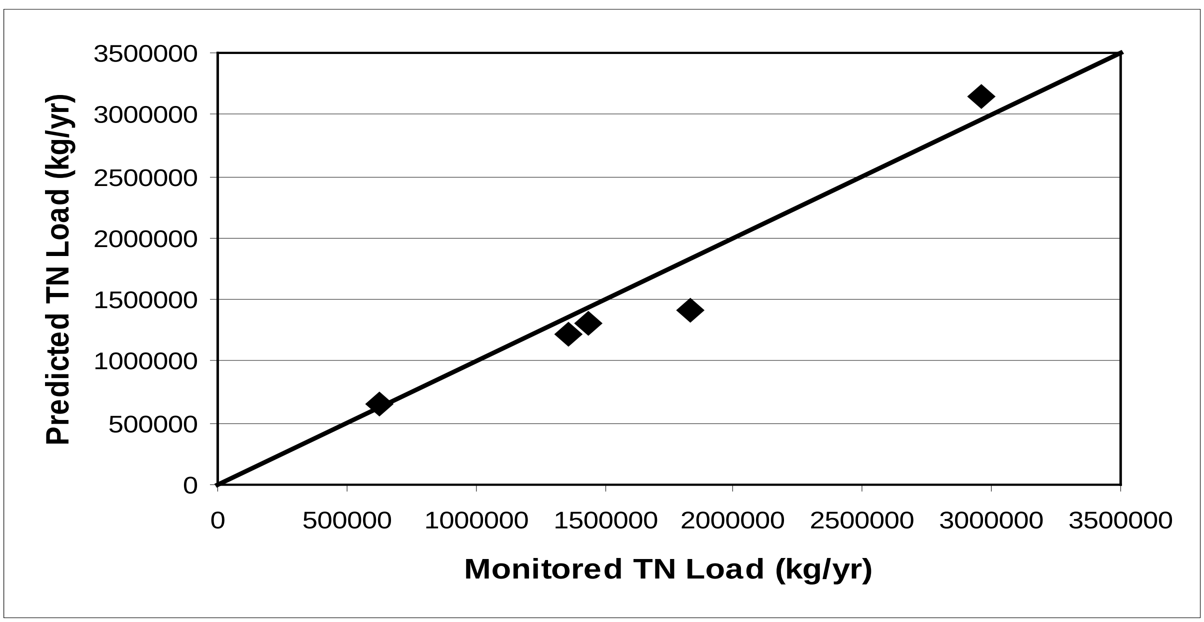

Figure 10. Relationship between monitored total N flux estimates and spreadsheet predictions for five larger basins in the LIS watershed (Figure 8). The diagonal line represents the 1:1 relationship.

underestimates. It is likely that the monitored total N fluxes are overestimates since the increase in N load under higher flows is not expected to be directly proportional to the increase in flow as was done to try to match average year loading conditions (**Table 3**).

Attenuation factors (fractional loss) for geographic segments in Connecticut were modest, ranging from 0 in the coastal tiers up to 0.48 in the uppermost tier of the Housatonic River where large river impoundments were expected to increase transport time and trap particulates. Most attenuation factors for the upper tiers did not exceed 0.2. No attenuation was applied to New York segments, which were all on the coast. Delivery factors (*d*), which equal 1 **–** the attenuation factor, are presented in **Table 8**.

As noted earlier, the need to include attenuation in an N budget analysis is well documented in the literature (Hill and Sanmugadas, 1985; Correll *et al.*, 1992; Jordan and Weller, 1996; Alexander *et al.*, 2000; The National Academies, 2000). The values used in the LIS analysis also appear reasonable when compared to those used in the SPARROW model (**Table 9**). Alexander *et al.* (2000) reported loss coefficients based on ranges of streamflow, having found fractional loss of N per day inversely correlated to streamflow. Applying the SPARROW coefficients to the average historical flows for nine sites and comparing them to attenuation factors incorporated into the LIS spreadsheet analysis shows the LIS factors to be conservative for the most part. Transforming the LIS attenuation factors into a time of travel in days using the SPARROW loss coefficients suggests that the levels of attenuation used in the spreadsheet could occur in relatively short periods, generally less than a day (**Table 9**). At the extremes, the Connecticut River at Thompsonville is probably the least conservative and the Quinebaug at Quinebaug the most conservative. Travel time through the nearly continuous impoundments in the Housatonic River is also likely to be greater than the 2.6 days estimated in the SPARROW application to the LIS attenuation factor for that river.

Total Nitrogen Generation and Delivery to Long Island Sound

According to the estimates developed here, more than 60 million kg of total N are delivered to LIS during an average year (**Table 8**). Based on a pre-Colonial N load estimate of 4.7 million kg N/yr (l kg/ha-yr x 4.7 million ha in the LIS watershed plus the surface of LIS), human activity has increased the N load more than 12 times. Point sources dominated the anthropogenic load of N to LIS, providing 63% of the total load of N reaching the Sound, attenuation considered (**Figure 11**). Atmospheric deposition, both on the watershed and directly to the Sound’s surface, contributes 27% of the total load of N reaching LIS (**Table 10**). Atmospheric deposition is about two thirds of the nonpoint source load of N, excluding direct deposition, according to these estimates.

Point Sources

Nitrogen loads from 105 point sources were calculated within the New York and Connecticut portions of the LIS drainage basin and another 114 from Massachusetts,

Table 8. Summary of land cover and total N loads generated and delivered to Long Island Sound by zone, tier and tributary segments from all sources.

Zone-tier	Hectares			Total N load (kg N/yr) generated in each segment					Delivery Factor	Total N delivered to LIS (kg N/yr)
	Urban	Agriculture	Forest	Urban	Agriculture	Forest	Point	Total		
1-1	10563	4484	55528	141549	34082	238771	977142	1391543	1.00	1391543
1-2	4703	8548	49414	63020	64961	212480	21527	361989	0.91	330858
1-3Q	9644	12140	103891	129228	92261	446730	252898	921117	0.75	689917
1-3S	7034	8119	91226	94250	61707	392273	112082	660312	0.83	546739
1-Trib	5900	8259	44837	79060	62768	192799	54916	389544	0.49	189708
1-Total	37844	41550	344896	507106	315780	1483053	1418565	3724504	0.85	3148763
2-1	2988	2032	37874	40043	15446	162857	0	218346	1.00	218346
2-2	20571	13428	83694	275652	102054	359883	1715867	2453456	0.93	2274354
2-3	33206	19956	66992	444966	151668	288067	918202	1802903	0.87	1559511
2-4	12618	9408	109395	169075	71500	470400	417041	1128017	0.81	913694
2-4-Trib	1730	1291	14997	23182	9812	64487	0	97481	0.81	78959
2-Trib	248558	298270	1938756	3330677	2266852	8336651	3595531	17529711	0.65	11376782
2-Total	319671	344386	2251708	4283595	2617332	9682345	6646642	23229913	0.71	16421646
3-1	27348	8922	68032	366458	67806	292536	1585742	2312542	1.00	2312542
3-2	9364	3151	15602	125481	23950	67089	354462	570983	0.83	473345
3-Total	36712	12073	83634	491939	91757	359625	1940204	2883525	0.97	2785887
4-1	9075	3373	23490	121609	25633	101009	636187	884437	1.00	884437
4-2N	8831	5200	34250	118333	39519	147275	995022	1300150	0.90	1166235
4-2H	11745	11389	62782	157378	86559	269962	353973	867872	0.69	594492
4-3N	2293	1615	16558	30732	12272	71201	0	114205	0.90	102442
4-3H	10883	33383	142767	145832	253711	613898	28975	1042416	0.52	536844
4-Trib	7617	25391	93946	102068	192972	403968	545148	1244155	0.44	543696
4-Total	50444	80351	373794	675952	610665	1607314	2559305	5453236	0.70	3828146
5-1	19443	3861	32703	260533	29345	140621	816879	1247378	1.00	1247378
6-1	23805	4267	33192	318992	32430	142727	824353	1318501	1.00	1318501
7-1	12455	0	1152	166897	0	4954	747755	919606	1.00	919606
8-1	22501	0	0	0	0	0	16431487	16431487	1.00	16431487
9-1	16997	0	0	0	0	0	8556684	8556684	1.00	8556684
10-1	15277	0	10332	204712	0	44428	480586	729725	1.00	729725
11-1	25246	1619	8499	338296	12304	36546	185306	572453	1.00	572453
12-LIS	0	0	482080*	0	0	0	0	4975066	1.00	4975066
TOTAL	580395	488107	3139910	7248021	3709613	13501611	40607766	70042077		60935342

* LIS surface area listed under forest but not included in the forest total.

Table 9. Comparison of spreadsheet attenuation rates used to calculate delivery of total nitrogen to Long Island Sound with loss coefficients used in the USGS SPARROW model.

River	USGS Station	Historical Average Annual Flow (m^3/sec)	SPARROW Loss Coefficients (per day)	Spreadsheet Attenuation (loss to LIS)	Time of Travel (days)[1]
Housatonic	Canaan	28.2	0.455	0.48	1.05
Housatonic	Stevenson	73.8	0.118	0.31	2.63
Naugatuck	Beacon Falls	14.1	0.455	0.10	0.22
Quinnipiac	Wallingford	6.0	0.455	0.17	0.37
Farmington	Tariffville	34.8	0.118	0.19	1.61
Connecticut	Thompsonville	466	0.051	0.13	2.55
Quinebaug	Quinebaug	7.7	0.455	0.25	0.55
Quinebaug	Jewett City	36.3	0.118	0.08	0.68
Shetucket	So. Windham	20.3	0.455	0.17	0.37

SPARROW Instream Loss Coefficients (Alexander, Smith and Schwarz, 2000)

Flow Range (m^3/sec)	Loss Rate Coefficient (per day)	Lower/Upper 90% CI
<28.3	0.455	0.344-0.579
28.3-283	0.118	0.063-0.176
283-850	0.051	0.007-0.092
>850	0.005	0.000-0.019

[1] Projected time of travel using SPARROW loss coefficients, i.e., spreadsheet attenuation estimates divided by SPARROW loss coefficients.

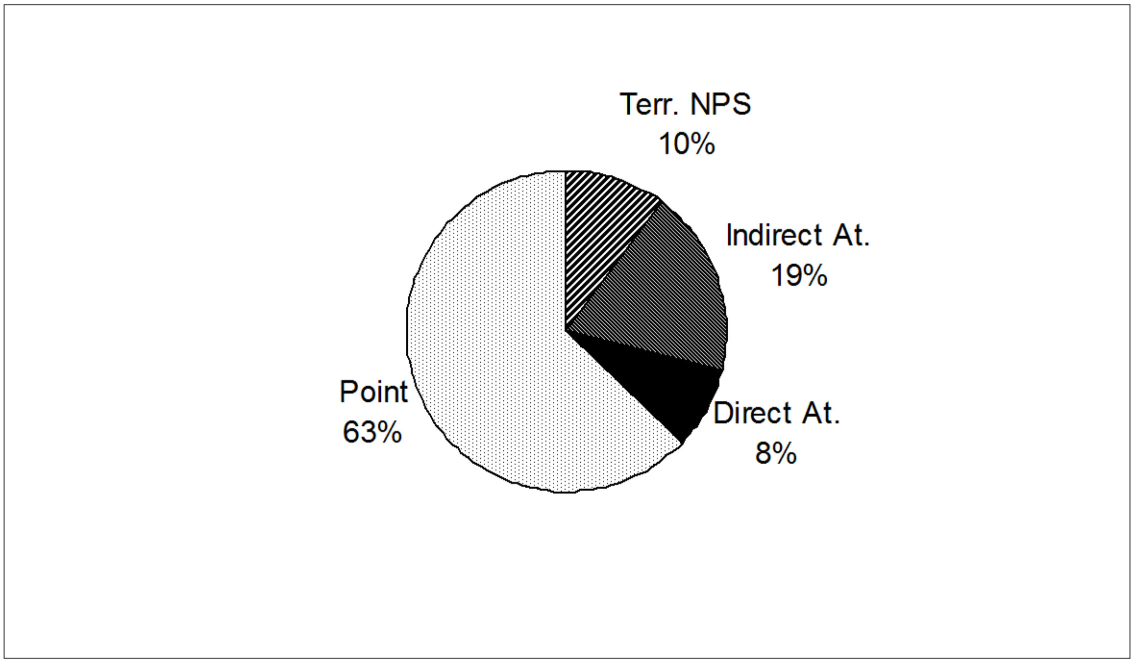

Figure 11. Distribution of total N delivery (percent) to LIS by major source category.

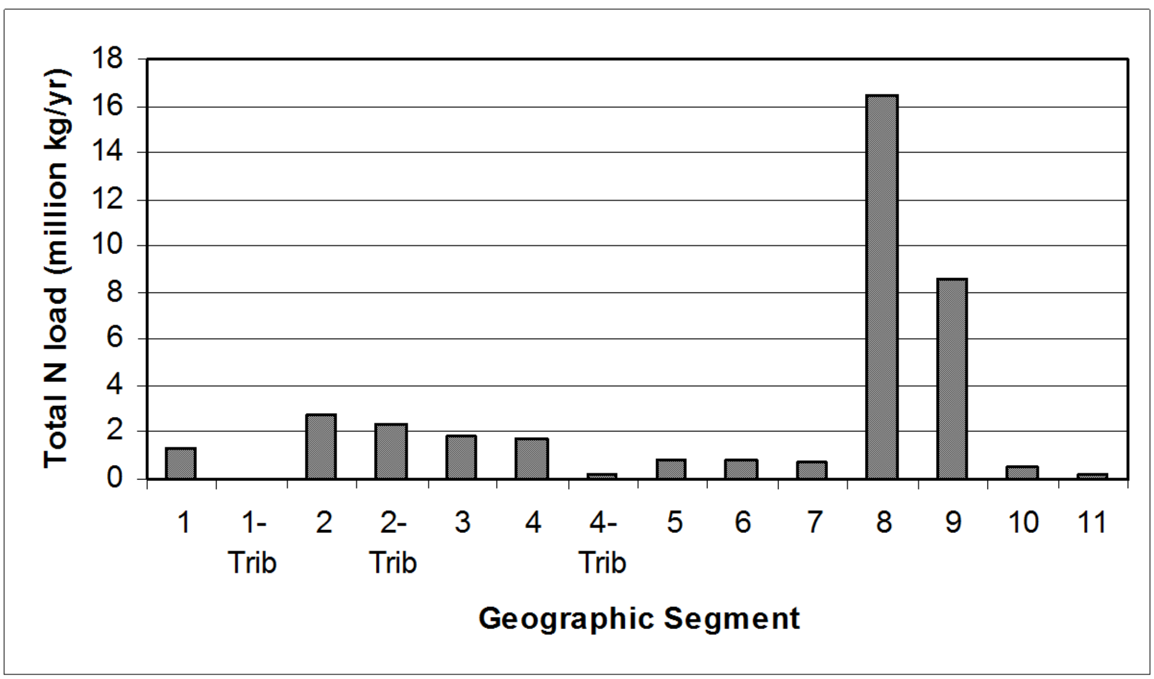

Figure 12. Geographic distribution of total N (million kg/yr) from point sources by geographic segment.

Table 10. Summary of nonpoint total N loads delivered to Long Island Sound by zone, tier and tributary segments from terrestrial and atmospheric sources.

Zone-tier	Total N load (kg n/yr) from terrestrial sources				Total N load (kg N/yr) from atmospheric sources				Total nonpoint N to LIS (kg N/yr)
	Urban	Agriculture	Forest	Total	Urban	Agricultural	Forest	Total	
1-1	68662	18835	49975	137472	72887	15247	188796	276930	414401
1-2	27940	32812	40648	101401	29660	26562	153559	209781	311182
1-3Q	46951	38189	70033	155173	49840	30915	264568	345323	500496
1-3S	37855	28236	67982	134073	40184	22858	256820	319862	453935
1-Trib	18676	16893	19652	55221	19826	13675	74241	107742	162964
1-Total	200084	134965	248290	583339	212397	109257	937984	1259638	1842977
2-1	19424	8536	34086	62046	20619	6910	128771	156300	218346
2-2	123951	52281	69826	246058	131578	42323	263786	437687	683745
2-3	186703	72501	52154	311358	198192	58691	197024	453908	765266
2-4	66431	32006	79749	178186	70520	25909	301275	397704	575890
2-4-Trib	9108	4392	10933	24433	9669	3555	41302	54526	78959
2-Trib	1048542	813024	1132427	2993994	1113068	658163	4278059	6049289	9043283
2-Total	1454159	982741	1379175	3816075	1543646	795552	5210216	7549414	11365489
3-1	177760	37472	61228	276460	188699	30334	231307	450340	726800
3-2	50459	10972	11641	73072	53564	8882	43976	106423	179495
3-Total	228219	48444	72869	349532	242263	39217	275284	556763	906296
4-1	58989	14165	21141	94296	62619	11467	79868	153954	248250
4-2N	51488	19590	27650	98728	54657	15859	104456	174971	273700
4-2H	52293	32767	38705	123765	55511	26526	146219	228256	352021
4-3N	13372	6083	13368	32823	14195	4925	50500	69619	102442
4-3H	36431	72207	66173	174811	38673	58454	249985	347111	521922
4-Trib	21636	46603	36949	105188	22968	37726	139585	200278	305466
4-Total	234209	191416	203986	629611	248622	154956	770613	1174190	1803801
5-1	126378	16217	29432	172027	134155	13128	111189	258472	430499
6-1	154735	17922	29873	202530	164257	14508	112854	291619	494148
7-1	80958	0	1037	81994	85940	0	3917	89856	171851
8-1	0	0	0	0	0	0	0	0	0
9-1	0	0	0	0	0	0	0	0	0
10-1	99301	0	9299	108599	105411	0	35129	140540	249139
11-1	164099	6800	7649	178548	174197	5505	28897	208599	387147
12	0	0	0	0	0	0	0	4975066	4975066
TOTAL	2742141	1398504	1981610	6122255	2910888	1132123	7486081	16504157	22626412

New Hampshire, Vermont and the New York portion of the Housatonic River basin. The majority of the point sources (77) were sewage treatment plants in Connecticut. Twenty sewage treatment plants were located in New York and eight industrial dischargers, only three of which had meaningful N loads, were all located in Connecticut. Many of the point sources discharging to the tributaries were small sewage or industrial plants.

By basin, the most point source N (65% of the point source load) *delivered* to the Sound came from NYC (zones 8 and 9). In Connecticut, the largest point source load delivered to the Sound was from Zone 2, the Connecticut River basin exclusive of the tributary portion, comprising 7% of the point source N load. Tributary point sources added about 6.8% to the point source N load, mostly from the Connecticut River (**Table 8 and Figure 12**).

Nonpoint Sources

Nonpoint N, including direct and indirect atmospheric deposition, contributed about 37% of the N reaching LIS (**Table 10**). The distribution of nonpoint enrichment was throughout the basin, but the more concentrated loads originated from coastal, urbanized areas. Tier 3 of zone 2 (Connecticut River basin) was the largest contributor of nonpoint source N from Connecticut and New York,[4] a function of size and level of development. However, the largest, single contributor of nonpoint source N (nearly 40%) is the tributary portion of the Connecticut River, by virtue of its size (**Figure 13**). Other centers of nonpoint source N enrichment included tier 1 of zone 3 (Quinnipiac), and tier 2 of zone 2, the Southwest Connecticut Coastal basin (zones 5 and 6), and Suffolk County (zone 11). About 11% of the nonpoint N was from agricultural land, urban land cover being the larger generator (about 25%). Atmospheric deposition directly on LIS accounted for 22% of the nonpoint source N and the balance, 42%, from forests.

Atmospheric sources contributed the second highest share of the N delivered to LIS (**Table 9**), accounting for about 27% of the total N load. More than a third of the atmospheric enrichment was deposited directly on the Sound's surface, the remainder delivered from the land with runoff. Atmospheric loads were dominated by the urban and forested land components. A large urban load was expected because of the efficient delivery to surface waters by the impervious cover. Although forests release only a small amount of N deposition per unit area with runoff, by virtue of their vast acreage in Connecticut and the northern tributaries, the load was large. At least two thirds of the atmospheric contribution is believed to be anthropogenically derived.

Tributaries

The Connecticut River dominated tributary loads (import from areas north of Connecticut) of N (**Table 8**). The Connecticut and Farmington River tributary portions

[4] As noted earlier, nonpoint source estimates do not include NYC zones 8 and 9, which are entirely categorized as point sources of N because of the prevalence of CSOs.

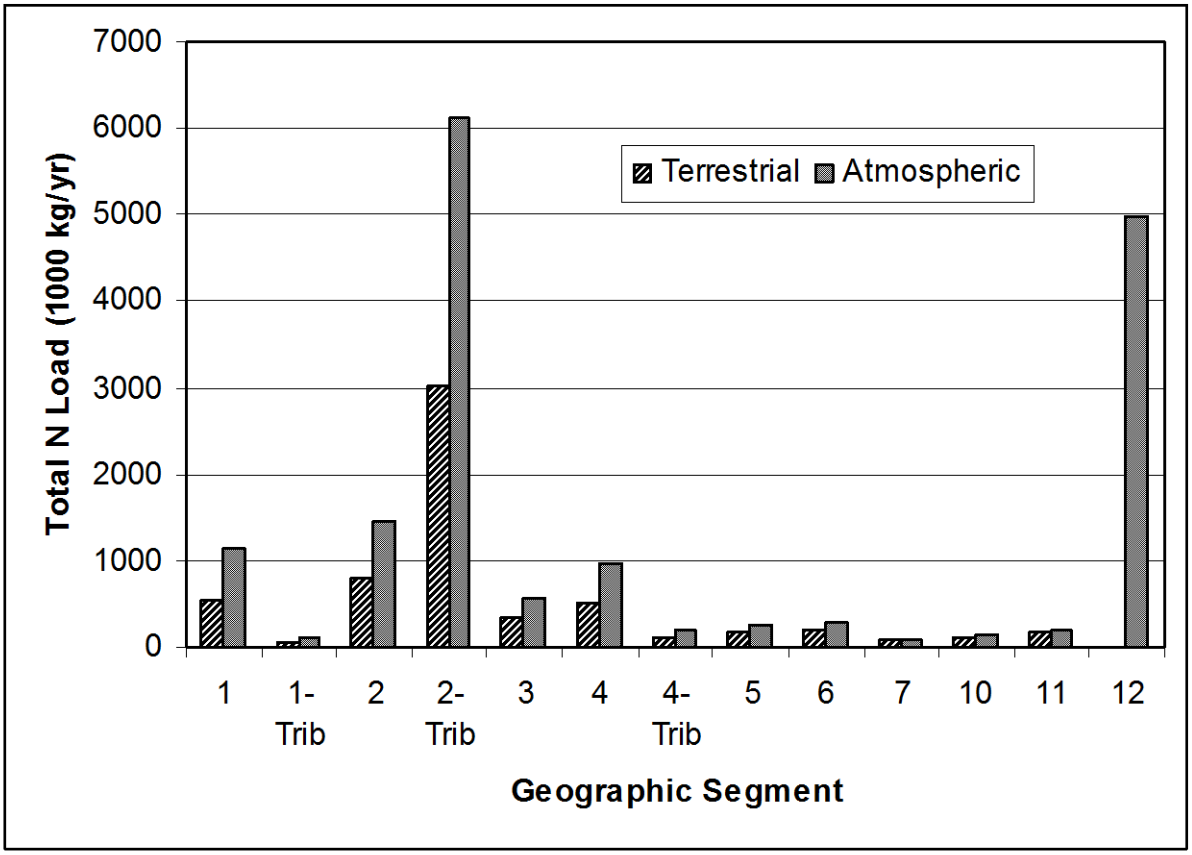

Figure 13. Geographic distribution of total N (1000 kg/yr) from nonpoint sources (terrestrial and atmospheric) by geographic segment.

combined contributed 70% of the N delivered to LIS from zone 2 and 94% of the N exported from tributary areas north of Connecticut. For the entire watershed, the Connecticut River tributary is important, contributing 18.7% of the total N delivered to LIS each year.

Pre-Colonial Load Estimate

Nonpoint runoff, atmospheric deposition, and tributary import from north of Connecticut were all sources of natural N delivered to LIS during pre-Colonial days. "Natural" N really represents an estimated of N loading that may have existed prior to extensive human habitation of the watershed. The estimates were calculated by applying a natural export coefficient to the entire basin, including the surface of LIS, of 1 kg/ha-yr. The pre-Colonial N load delivered to the Sound of 4.7 million kg/yr was about 7.7% of the total N delivered to LIS annually. Clearly, today's contribution of N to LIS is dominated by anthropogenic sources and highly enriched compared to the pre-Colonial N flux estimate.

Summary

Total N loads were estimated for 12 management zones established in Connecticut and New York portions of the LIS drainage basin. Additional estimates of N carried by major tributaries north of Connecticut were made to complete comprehensive load estimates. Because the LIS N load estimates have been used extensively to develop N-control plans, including the LIS TMDL, there is a reluctance to alter them at this time despite some apparent inaccuracies. In general, the LIS N loads are believed adequate to provide gross evaluations of N sources and to identify their relative importance for management purposes.

Source categories included point sources (sewage treatment plants, NYC CSOs, and industries) and nonpoint runoff, which was divided into terrestrial and atmospheric components. Atmospheric N estimates were made for, both direct (onto the Sound) and indirect (runoff from the land) categories and terrestrial N flux estimates were subcategorized into N originating from urban, agricultural and forested land categories. An estimate of natural sources, or the loads that were estimated to have occurred during pre-Colonial times, was also made.

Point source loads were based on discharge monitoring for most of the facilities in Connecticut and New York. The database for point sources in the tributary areas north of Connecticut was much weaker and estimates of N concentration applied to design flows were used in most cases. Nonpoint and atmospheric estimates were built on a combination of monitoring data (for atmospheric deposition rates and at stream gauging stations to serve as calibration and verification points) and estimates derived from export coefficients applied to land cover data. Literature values were used to supplement and help verify export coefficients and atmospheric runoff factors. Since N attenuates during transport, a loss coefficient was empirically derived and supported with reported rates used in the USGS SPARROW model.

The N load delivered to LIS was dominated by point source contributions, especially from the large NYC sewage treatment plants. Point sources contributed 63% of the total N flux to LIS. Direct and indirect atmospheric deposition was the second largest contributor of N (about 27%) and terrestrial nonpoint runoff contributed a relatively small 10% of the N enrichment. Tributary loads (north of Connecticut) were responsible for about 20% of the N delivered to LIS, dominated by atmospheric sources and, geographically by the Connecticut River tributary area (nearly 19%). An estimate of pre-Colonial total N loading to LIS suggests that the flux was only about 7.7% of current N delivery.

Improvements in the estimates, while not critical to management planning, would improve the overall accuracy of the N estimates. In particular, monitored flux estimates at the USGS station representative of an average year need to be verified. Presently, it appears that the LIS gauging station fluxes are overestimates and generally exceed the spreadsheet loads prior to accounting for riverine attenuation. Conversely, the land cover-based export coefficients may be low, or a combination of low export rates and high annual flux estimates at gauging stations may each be partially responsible for the mismatch of the data. There are also inadequate data to calibrate tributary N load estimates, particularly for point sources. Consideration should be given to more widespread point, nonpoint, river, and atmospheric deposition monitoring and studies to develop better estimates of N loading to LIS.

Literature Cited

Alexander, R.B., R.A. Smith, and G.E. Schwarz. 2000. Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. Nature. 403:758-761. (And Supplement).

Cervione, M.A., Jr., L.A. Weiss, J.R. Bohr, and J.W. Bingham. 1987. Water resources data Connecticut, Water Year 1985. U.S. Geol. Surv. Water-Data Rept. CT-85-1. USGS, Hartford, CT. 279 p.

Cervione, M.A., Jr., L.A. Weiss, J.R. Bohr, and J.W. Bingham. 1988. Water resources data Connecticut, Water Year 1986. U.S. Geol. Surv. Water-Data Rept. CT-86-1. USGS, Hartford, CT. 263 p.

Cervione, M.A., Jr., L.A. Weiss, J.R. Bohr, and J.W. Bingham. 1989a. Water resources data Connecticut, Water Year 1987. U.S. Geol. Surv. Water-Data Rept. CT-87-1. USGS, Hartford, CT. 295 p.

Cervione, M.A., Jr., B.S. Davies 3rd, J.R. Bohr, and J.W. Bingham. 1989b. Water resources data Connecticut, Water Year 1988. U.S. Geol. Surv. Water-Data Rept. CT-88-1. USGS, Hartford, CT. 346 p.

Civco, D.L., D.R. Miller, J.D. Hurd, and Y. Wang. 1992. Connecticut statewide land use and land cover mapping. Long Island Sound Research Project CWF 219-R, Technical Completion Report. Dept. Nat. Resour. Mgmt. Engr., Univ. Conn., Storrs, CT. 44 p.

Correll, D.L., T.E. Jordan, and D.E. Weller. 1992. Nutrient flux in a landscape: effects of coastal land use and terrestrial community mosaic on nutrient transport to coastal waters. Estuaries. 15(4):431-442.

Donigian, A.S., Jr., B.R. Bicknell, L.C. Linker, J. Hannawald, C.H. Chang, and R. Reynolds. 1990. Chesapeake Bay Program. Watershed model application to calculate Bay nutrient loadings. U.S. EPA, Environ. Res. Lab., Athens, GA.

Frink, C.R. 1991. Estimating nutrient exports to estuaries. J. Env. Qual. 20(4):717-724.

Hill, A.R. and K. Sanmugadas. 1985. Denitrification rates in relation to stream sediment characteristics. Water Res. 19(12)1579-1586.

Howarth, R.W., G. Billen, D. Swaney, A. Townsend, N. Jaworski, K. Lajtha, J.A. Downing, R. Elmgren, N. Caraco, T. Jordan, F. Berendse, J. Freney, V. Kudeyarov, P. Murdoch, and Z. Zhao-Liang. 1996. Regional nitrogen budgets and riverine nitrogen and phosphorus fluxes for the drainages to the North Atlantic Ocean: natural and human influences. Biogeochem. 35:75-79.

HydroQual, Inc. 1996. Water quality modeling analysis of hypoxia in Long Island Sound using LIS 3.0. Job No. NENG0035, HydroQual, Inc., Mahwah, NJ.

Jaworski, N.A., P.M. Groffman, A.A. Keller, and J.C. Prager. 1992. A watershed nitrogen and phosphorus balance: The upper Potomac River basin. Estuaries 15(1):83-95.

Jaworski, N.A., R.W. Howarth, and L.J. Hetling. 1997. Atmospheric deposition of nitrogen oxides onto the landscape contributes to coastal eutrophication in the northeast United States. Environ. Sci. Technol. 31:1995-2004.

Jordan, T.E. and D.E. Weller. 1996. Human contributions to terrestrial nitrogen flux. BioScience. 46(9):655-664.

Linker, L.C., G.E. Stigall, C.H. Chang, and A.S. Donigian. 1993. The Chesapeake Bay Watershed Model. U.S. EPA Chesapeake Bay Program, Annapolis, MD. 9 p.

Long Island Regional Planning Board. 1978. Long Island comprehensive waste treatment management plan. LIRPB.

LISS (Long Island Sound Study). 1992. Final Long Island Sound Study baseline load report. Prepared by NY State Dept. Environ. Conservation and CT Dept. Environ. Protection. 5 p.

Miller, D.R., N.P. Nikolaidis, L.H. Yang, M.A. Geigert, J. Heitert, and H.M. Chen. 1993. Technical report on the Long Island Sound atmospheric deposition project. Univ. Conn., Storrs, CT. 12 p.

Nixon, S.W. 1997. Prehistoric nutrient inputs and productivity in Narragansett Bay. Estuaries. 20(2):253-261.

Stacey, P.E. 1996. Report on nitrogen and organic carbon loads to Long Island Sound. Draft. CTDEP, Bureau of Water Management, Hartford, CT. 23 p.

The National Academies. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. National Academy Press, Washington, DC. Prepublication Copy. 377 p.

Valiela, I., G. Collins, J. Kremer, K. Lajtha, M. Geist, B. Seely, J. Brawley, and C.H. Sham. 1997. Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. Ecol. Appl. 7(2):358-380.

Valigura, R.A., W.T. Luke, R.S. Artz, and B.B. Hicks. 1996. Atmospheric nutrient input to coastal areas. Reducing the uncertainties. NOAA Coastal Ocean Program Decision Analysis Series No. 9., NOAA, Silver Spring, MD. 24 p.

Valigura, R.A., R.B. Alexander, D.A. Brock, M.S. Castro, T.P. Meyers, H.W. Paerl, P.E. Stacey, and D. Stanley (eds.). 2000. An assessment of nitrogen inputs to coastal areas with an atmospheric perspective. AGU Coastal Estuaries Series. In Press.

Vitousek, P.M., J. Aber, R.W. Howarth, G.E. Likens, P.A. Matson, D.W. Schindler, W. H. Schlesinger, and G.D. Tilman. 1997. Human alteration of the global nitrogen cycle: causes and consequences. Issues in Ecol. 1. 15 p.