Nonpoint Source Workgroup #1 Report to P.A. 12-155 Coordinating Committee

July 28, 2016

Acknowledgements

Many individuals and partner organizations provided information and input to the work and reporting of the Nonpoint Source Workgroup. The Collaborative Activities of DEEP and Connecticut stakeholders throughout the PA 12-155 process are documented at: http://www.ct.gov/deep/phosphorus

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1 Executive Summary: Nonpoint Source Workgroup Report Pursuant to Public Act 12-155

Public Act 12-155 provided legislation enabling municipalities to receive additional funds from Connecticut's Clean Water Fund to remove phosphorus in sewage treatment plant discharges, regulates fertilizers use and the amount of phosphorus in fertilizers, and required DEEP to work with affected municipalities to develop a statewide response to address phosphorus in nonpoint source pollution. Nonpoint source (NPS) pollution is water pollution from sources such as stormwater, agricultural runoff, septic system leachate, and soil erosion. To develop this statewide response, an NPS Workgroup made up of municipal representatives, Federal and State environmental professionals, environmental consultants, and academicians was formed to evaluate the sources of phosphorus from NPS pollution. The NPS Workgroup reviewed existing programs that address NPS pollution, studied the status and trends of phosphorus in NPS pollution, and identified and assessed methods and strategies to reduce phosphorus in NPS runoff. The Nonpoint Source Workgroup was co-chaired by Virgil Lloyd, of Fuss and O'Neill and Christopher Malik from the Nonpoint Source and Watershed Section of DEEP's Bureau of Water Protection and Land Reuse.

The NPS Workgroup reviewed DEEP planning, outreach and education, technical assistance, financial assistance, and regulatory programs that address NPS pollution. Additionally the NPS Workgroup reviewed programs in other State, Federal, and municipal agencies that focus on NPS pollution including UConn, CT Agricultural Experiment Station, CT Department of Public Health, CT Department of Agriculture, USDA Natural Resource Conservation Service, EPA, municipal land use commissions, and local health departments. The NPS Workgroup then went on to identify and review the sources of phosphorus in NPS pollution impacting Connecticut waters. The sources identified by the NPS Work Group are: stormwater runoff, agricultural runoff, fertilizers, soil erosion, internal phosphorus loading from sediments, and septic systems. The NPS Workgroup assessed how each identified nonpoint source of phosphorus is being addressed and how programs could be implemented or augmented to further reduce phosphorus in NPS pollution.

Stormwater runoff is a known conveyer of phosphorus to waterways. The NPS Workgroup found that a number of DEEP stormwater permits were in place and that these permits were being enhanced at the time the Workgroup was gathering its information. The NPS Workgroup recommended continued development of watershed based planning by DEEP with towns and local groups, enhancing outreach to municipalities, continuing evaluation of practices and technologies to remove phosphorus, regional approaches to managing stormwater, and developing and promoting financing programs to assist municipalities with improving stormwater infrastructure and programs. The Workgroup also recommended enhancing DEEP's Stormwater Permitting program by targeting source of phosphorus.

Through information provided by UCONN, the NPS Workgroup found that Connecticut has excess phosphorus in the form of animal manure, feed, and fertilizer. Centrifugal separation of solids from manure can concentrate phosphorus in the solids, allowing liquid manure to be land applied with less impact to water quality. Anaerobic digestion, paired with solid separation, can further reduce the volume of waste and can produce energy and value added products like farm animal bedding, soil conditioners, and peat for potting. The Workgroup also discussed manure exchange/brokerage systems that coordinate manure transfers from areas of phosphorus excess to areas with phosphorus deficiencies.

To better manage phosphorus in agriculture wastes, the NPS Workgroup recommended providing funding to finance technologies, develop pilot projects, and create manure exchange programs. The goal of additional financing would be to make these technologies more available to more farmers. The NPS Workgroup also recommended expanding nutrient management plans for animal feed lot operations, and incentivizing and educating farmers to adopt soil health practices.

Public Act 12-155 restricts the amount and use of phosphorus in fertilizer for residential lawns and gives authority to the Connecticut Department of Agriculture to write regulations and enforce this provision of the act. The NPS Workgroup made recommendations for fertilizer use of lawns and gardens, croplands, container nurseries, and golf courses.

The NPS Workgroup reviewed existing state and municipal permitting programs to control soil erosion from land being developed. These programs are supported by DEEP published guidelines for erosion and sedimentation control and low impact development. The NPS Workgroup recognized that enforcement of local and state regulations for erosion and sedimentation control is an important component in controlling phosphorus from construction sites. The NPS Workgroup determined that comprehensive planning on a watershed-wide scale would be beneficial in reducing in-stream channel erosion.

The extent of water quality impacts from phosphorus releases in lake and pond sediments, known as internal loading, were considered by the Workgroup. The NPS Workgroup report includes a discussion on methods to control internal phosphorus loading including chemically binding the phosphorus by treating the water body with aluminum or calcium compounds or adding oxygen to water. Both techniques require active management and are not commonly used in Connecticut.

Onsite wastewater disposal systems, commonly called septic systems, can also be a sources of phosphorus. The NPS Workgroup worked with several experts to assess the extent of phosphorus from septic systems. While current regulatory requirements are quite effective, old systems; lack of maintenance, improper use, poor sitting, and uneven distribution of effluent in the leaching field can result in phosphorus loading to watercourses. The NPS Workgroup recommended encouraging town-wide wastewater planning, establishing a state grant or loan program to fund septic systems upgrades, and implementing a statewide septic system management program that tracks and manages data to identify areas with excessive phosphorus loading. The NPS Workgroup also recommended a point of sale inspection and repairs program for septic systems similar to other states.

The NPS workgroup found that many Federal, state, and local programs are in place that address phosphorus in NPS pollution. In some cases additional programs for agricultural waste and septic system upgrades are needed to reduce phosphorus loading to Connecticut waters. In other cases, existing programs could be expanded to further address phosphorus in NPS pollution. Some new or expanded programs will require additional funding and expansion or addition of regulatory programs will require individuals, communities, and businesses to accept a higher level of control than is currently required by existing statutes and regulations.

2 Introduction

2.1 Purpose of Workgroup Study

Public Act 12-155 required the Connecticut Department of Energy and Environmental Protection (DEEP) to collaborate with municipalities impacted by the statewide strategy to reduce phosphorus pollution affecting non-tidal surface water bodies. A provision of the act required an evaluation and recommendations for a state-wide response to address phosphorus nonpoint source pollution. A work group was formed with the following primary goals:

- Evaluate the relevant sources of phosphorus from nonpoint sources (NPS), and current status and trends.

- Identify and assess alternative methods and strategies to achieve realistic phosphorus reductions from NPS. Where possible, assess the relative associated costs.

- Make concluding recommendations to reduce phosphorus loading from NPS.

2.1.1 Nonpoint Source Pollution

Many activities associated with various land uses within Connecticut have the potential to contribute pollution to ground and surface water resources. Water pollution that is not concentrated within a drainage system, or discharged from a point, such as a pipe, is called nonpoint source pollution. Potential sources of Nonpoint Source Pollution can include agriculture, waste from domestic animals and wildlife, malfunctioning septic systems, runoff from impervious surfaces / developed areas and managed turfgrass, and soil erosion.

Pollutant levels, or loadings, from nonpoint sources can vary greatly depending on watershed conditions, land use, and weather conditions. For the purposes of this committee's report we have included regulated stormwater as an NPS source, so the terms nonpoint source runoff and stormwater are used interchangeably, and have focused on discharges to fresh waters.

2.2 Nonpoint Source Workgroup Structure

- The Nonpoint Source Workgroup is co-chaired by Virgil Lloyd, of Fuss and O'Neill and Christopher Malik from the Nonpoint Source and Watershed Section of DEEP's Bureau of Water Protection and Land Reuse.

- The Nonpoint Source Workgroup met 10 times and collaboratively discussed and shared information. The group's makeup was well balanced and represented expertise in all the potential source groups that are discussed below.

- Details of the Nonpoint Source Workgroups meetings have been recorded on the website www.ct.gov/deep/phosphorus

- The organization of the workgroup strived to assure continuity, transparency, and balance.

- The individuals who participated in the Nonpoint Source Workgroup are listed in the acknowledgements:

NPS Workgroup Meeting Schedule:

- November 20, 2014, from 10 to 11:30 a.m. Holcombe Room, 5th floor, DEEP HQ

- October 7, 2014, from 1 to 2:30 p.m. in Room 2B at DEEP Headquarters

- July 22, 2014, from 1 to 2:30 p.m. in Holcombe Room, 5th floor, DEEP HQ
- May 6, 2014, from 1 to 2:30 p.m. in Room 2B at DEEP Headquarters
- March 24, 2014, from 1 to 2:30 p.m. in Room 2B at DEEP Headquarters
- February 10, 2014, from 10 to 11:30 a.m. in Room 2B at DEEP Headquarters.
- January 6, 2014 from 1 to 2:30 p.m. in Room 2A, at DEEP Headquarters.
- November 25, 2013, from 1 to 2:30 p.m. in Room 2B, at DEEP Headquarters.
- October 25, 2013 from 1 to 2:30 p.m. in DEEP Holcombe Room.
- September 30, 2013 in DEEP Russell Room

There was one subcommittee for Onsite Wastewater Systems, the subcommittee meeting schedule was:

- June 24, 2014, at 10 a.m. in Room 2B at DEEP Headquarters
- March 10, 2014, at 1 p.m. in Room 2A at DEEP Headquarters
- January 17, 2014, at 1 p.m. in Room 2B at DEEP Headquarters

3 Connecticut Nonpoint Source Pollution Management

3.1 DEEP Nonpoint Source Pollution Program

DEEP is responsible for protecting water quality under a number of regulatory and non-regulatory programs, including the NPS Management Program. The U.S. Clean Water Act, Section 319 requires states to have NPS management plans. Connecticut's first NPS Management Plan was approved by the EPA in 1989 and since then has been updated several times to address changes to national NPS guidance and changing conditions. The most current plan was approved in 2014. Many of the existing plan elements target nonpoint sources of water quality impairments related to nutrients including phosphorus, and sediments which contribute phosphorus.

2014 CT NPS Program Plan
DEEP's 2014 Nonpoint Source Management Program Plan is posted at www.ct.gov/deep/nps Connecticut's approach to controlling NPS pollution includes

both statewide initiatives and focused watershed management planning and implementation projects. The 2014 Plan seeks to address the following Statewide:

- Protect the environment and public health from the impacts of polluted runoff
- Inform the public and partners about the causes and impacts of NPS pollution
- Set priorities for addressing pollution sources
- Identify long-term goals for protecting and restoring water resources in Connecticut that are threatened or impaired by polluted runoff.
- Establish specific short-term goals, objectives, and measurable milestones for the next 5-years that will contribute to achieving long-term NPS program goals of restoring and protecting water quality
- Evaluate NPS priority watersheds lists

DEEP Nonpoint Source Program Elements

Programatic goals include:

- Coordinate State actions and assist communities in forming partnerships
- Draft watershed based plans, and implementing environmental projects to restore and protect Connecticut's water quality on a watershed-wide scale.
- Facilitate development of a statewide NPS management tracking system or program to quantify NPS pollution reductions and credits (i.e., BMPs implemented, areas applied, pollutant load reductions achieved).
- Review pollution credit/trading programs developed by other states and their applicability.

Source specific strategies exist for major NPS categories:

Table 2-1. Connecticut NPS Pollution Categories

Major Sources	Other Sources
Runoff from Developed Areas	Land Disposal
Transportation	Brownfields and Contaminated Sites
Landscaping and Turf Management	Forestry
Subsurface Sewage Disposal Systems	Material Storage
Agriculture	Resource Extraction
Domestic and Wild Animals	Atmospheric Deposition
Boating and Marinas	
Hydrologic and Habitat Modification	

DEEP's Nonpoint Source Program

DEEP's Nonpoint Source Program consists of three Watershed Managers and a supervisor. The NPS program works with other DEEP programs and stakeholders including municipalities, Connecticut's five Conservation Districts, watershed, advocacy and other non-governmental organizations, and citizens. DEEP develops collaborative partnerships with stakeholders to develop and implement strategies to reduce pollutant loadings and restore water quality. More details of Connecticut's Nonpoint Source Program are available at www.ct.gov/deep/nps

DEEP uses a number of overall strategies to address NPS pollution, major ones include:

- Pollution Prevention
- Education and Outreach

- Enhanced Management and Regulation of Stormwater
- Agricultural Management and Assistance
- Municipal Technical Assistance
- Watershed Based Plans and Total Maximum Daily Load Analyses (TMDLs)
- Planning & Implementation Grants

Pollution Prevention is of Central Importance
Pollution prevention (P2), or source reduction, is a logical starting point to reduce nonpoint source phosphorus pollution. Pollution prevention emphasizes preventing or minimizing pollution, rather than controlling pollution after it is generated. Pollution prevention is the most effective NPS pollution control strategy and therefore plays a central role in the state's NPS Management Program and other DEEP regulatory and non-regulatory programs. Numerous pollution prevention practices are available for a variety of land uses and pollution source categories. P2 practices are emphasized in the recommendations in this report and DEEP's NPS Program Plan. DEEP has a Pollution Prevention Program that coordinates pollution prevention activities in cooperation with the NPS Program. Information can be found at www.ct.gov/deep/p2

Stormwater Runoff in Urban Areas is the Largest Single Source of Nonpoint Source Pollution in Connecticut
Urban storm runoff is the largest single source of nonpoint source phosphorus polluting Connecticut's surface waters. Much of the runoff from urban areas that is collected in storm drains, or discharges from construction, commercial, or industrial sites, is now regulated by stormwater general permits (regulated stormwater pollution). Regulated stormwater is considered nonpoint source pollution for the purposes of this report. More information on Stormwater Management and Permitting www.ct.gov/deep/stormwater

Best Management Practices (BMPs)
Adoption or application of practical and cost-effective measures known as Best Management Practices (BMPs) is a common strategy to control NPS pollution. Many necessary land use activities require BMPs to protect water quality. BMPs can be structural: infrastructure or devices, or non-structural: operational practices or behavioral modifications. Capital, operational, and maintenance funds must be provided to ensure that BMPs successfully control pollution.

3.2 DEEP's Program Partners

Regional and local partners are needed to implement effective strategies to reduce NPS pollution because NPS pollution is diffuse and comes from many different sources. DEEP cooperates with numerous partners for technical outreach in the agricultural sector including, but not limited to, the USDA Natural Resource

Conservation Service (NRCS), Connecticut Department of Agriculture, University of Connecticut Cooperative Extension System, Connecticut Agricultural Experiment Station, and Connecticut Conservation Districts. These agencies work with agricultural industry representatives and individual producers to improve operations, reduce the threat of pollution, and manage wastes in a safe and efficient manner. Similarly DEEP has many municipal program partners in urban areas addressing NPS phosphorus pollution. Connecticut's municipalities are without a doubt our most important partner in managing nonpoint source pollution.

Some of DEEP's primary NPS partners and activities are summarized in Appendix 4.

Table 2.2

NPS Program Partners in Connecticut

Federal:
- U.S. Environmental Protection Agency
- U.S. Department of Agriculture
  - Natural Resources Conservation Service
- U.S. Army Corps of Engineers
- U.S. Department of Commerce
  - National Oceanic and Atmospheric Administration Fisheries, Ocean and Coastal Resource Management, National Weather Service
- U.S. Department of Interior
  - U.S. Fish and Wildlife Service
  - U.S. Geological Survey
  - National Park Service

State:
- CT Department of Energy & Environmental Protection
- CT Department of Public Health
- CT Department of Transportation
- CT Department of Agriculture/Aquaculture
- CT Office of Policy and Management
- CT Department of Economic and Community Development
- CT Department of Emergency Services and Public Protection
- CT Department of Administrative Services
- University of Connecticut NEMO, CLEAR, Agriculture Extension Centers, CIRCA, Sea Grant
- CT Agricultural Experiment Station

Local/Regional:
- Municipalities
- Regional Councils of Government
- Conservation Districts
- Water Utilities
- Water Pollution Control Authorities
- Local Health Districts
- CT Conference of Municipalities (CCM)

CT Council of Small Towns (COST)
Neighboring State and County Governments

Other:
Private Colleges and Universities
Watershed Organizations
Advocacy Groups and other NGOs
Land Trusts
Industry Organizations
News Media Organizations

Native American Tribes

3.3 Major Pollutant Source Groups

The following primary source groups of NPS phosphorus have been categorized by the NPS Workgroup and are consistent with the 2014 CT DEEP NPS Program Plan. Each of these source groups is discussed in greater detail later in the report. There may be some overlap in these groupings: urban stormwater may contain animal waste from pets and wildlife, and soil erosion may contain animal wastes and fertilizers, etc.

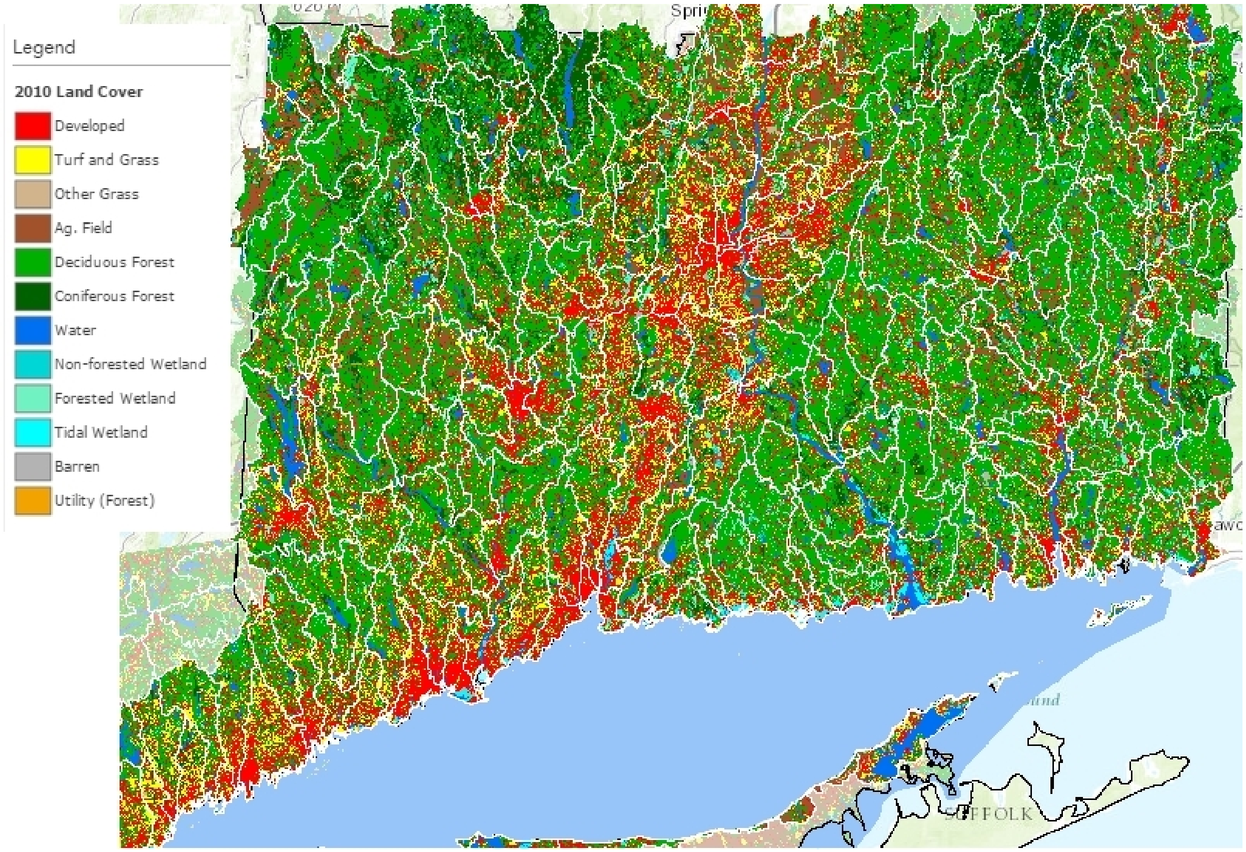
- **Urban Stormwater**
- **Agricultural Animal Waste and Manures**
- **Phosphorus Fertilizers**
- **Soil erosion**
- **Internal Loading**
- **Onsite Wastewater Disposal Systems**

3.4 Relative Assessment of NPS Loading

Differing land use/land cover types, patterns, and conditions are the most important factors to consider when estimating NPS pollutant loads. Connecticut's Land Use Land Cover types were analyzed by UConn Cooperative Extension Service Center for Land Use Education and Research (Clear) in 2010. The following values and trends were observed between 1985 and 2010 that affect efforts to reduce phosphorus input to surface waters:

Within streamside corridors, (within 300 feet of a watercourse) 39.5 square miles were converted to "turf" or "developed" from a total of 1323 square miles. That amounts to 1186 acres per year of valuable stream buffers lost to development or turf. Similarly, Connecticut lost 13.3 acres per day of its forested land, and added 10 acres per day of developed area and 4.4 acres per day of turf. All of these trends point to an increase in the rate of nonpoint source phosphorus pollution if they continue unabated.

DEEP conducted a statewide analysis of phosphorus loading from nonpoint sources as part of the Interim Phosphorus Strategy. Modeling analyzed outputs for three aggregated land cover types: Developed, Forested, and Agriculture and applied export coefficients to predict phosphorus loadings based on land cover areas. DEEP's analyses tell us that overall pollution loadings vary considerably by regional watershed, governed by land cover. Maps have been prepared of this analysis and can be found in Appendix 1. The methodology is discussed in detail in the reporting from the Scientific and Technical Workgroup #2. Additional modeling will utilize the USGS Sparrow model.



2010 Connecticut Land Use Land Cover Map (UConn Clear Changing Landscape Website)

More precise assessment and modeling of NPS pollution can be done to further quantify NPS loadings from more specific sources in regional and local watersheds. This is done in both Watershed Based Plans and TMDLs that have an NPS load. See http://www.ct.gov/deep/watershed Watershed Management Plans and Documents page and http://www.ct.gov/deep/tmdl . The modelling accomplished by DEEP indicates that conversion of agricultural land to developed land use has resulted in increased phosphorus loadings from nonpoint sources.

3.5 Review of Alternative Approaches

Each major NPS source grouping for NPS phosphorus was evaluated looking at current status, trends, and existing management efforts. Consideration was given to additional alternative methods and strategies to achieve realistic phosphorus reductions from the NPS source, looking at both regulatory and non-regulatory approaches. This involved looking at State and local authorities. Both statewide initiatives and focused watershed management approaches were considered. Where possible key responsible parties, partners and funding needs were identified. Pollution prevention and source control was emphasized as the most effective NPS pollution control strategy and therefore plays a central role in many recommendations. A common strategy to control NPS pollution is through the adoption or application of practical and cost-effective management practices known as Best Management Practices (BMPs) and is discussed below in more detail.

3.6 Best Management Practices

BMPs allow for many everyday activities to continue while preventing or reducing NPS pollution. BMPs can be:

- Structural: infrastructure or devices; or
- Non-structural: operational practices, programs, or behaviors

The use of BMPs can reduce pollution and protect water quality while allowing many necessary land use activities to continue. In many cases they require education and technical assistance, and capital, operational and maintenance costs must be allocated. Many times BMPs are implemented in a treatment train, with several types combined in sequence. (i.e., in combination or one after another)

3.6.1 BMP Efficiencies and Costs

Assigning pollutant removal efficiency values and cost effectiveness to BMPs is not a simple analysis. There have been numerous recent analyses, many with support from the US EPA, that have identified ranges of both BMP efficiencies and costs. BMP efficiencies are typically expressed by a percentage value, the percentage of a pollutant that is removed or prevented by a practice. Costs are generally expressed as a cost per pound of a pollutant removed. BMP pollutant removal values can be very important if reductions are to be formally credited in a regulatory program such as permits or TMDLs.

The types of structural BMPs that are most effective at removing phosphorus were reviewed and researched as part of this report, particularly those applicable to urban and agricultural runoff. Those most effective at removing phosphorus are essentially those which remove suspended solids efficiently, particularly those which remove the fine fraction: silt and clay particles. Structural BMPs that infiltrate or filter the first flush of runoff, including the use of natural soil and vegetation site features, have been shown to be quite effective at controlling phosphorus. This is because most well drained natural soils in Connecticut are very effective at removing and holding (adsorbing) phosphorus. Site conditions must be able to handle and infiltrate runoff volumes. Examples of structural BMPs include retention/infiltration basins, infiltration wells/trenches, bio-retention basins, vegetated swales and buffers, separation chambers, and media filters. Based on DEEP’s informal observations, filtration devices which are most effective are also those which require short maintenance intervals.

In addition to capital costs, maintenance of BMPs is critical and often affects both cost and removal efficiencies significantly. As expected, many of the removal efficiencies and costs varied greatly as many factors come into play such as soil conditions, land area, land and capital costs, and operation and maintenance requirements. Maintenance costs also vary by site, particularly if there are other contaminants in the material removed from the BMPs. Urban Runoff, (Section 4.1) and Urban BMP Performance Efficiency and Costs Analysis Appendix 2, (Section 5.2) contain more information on some of the estimated ranges of BMP efficiencies and costs.

4 Summary of Priority Recommendations

The Nonpoint Source Workgroup recommends the following actions be considered priority recommendations for implementation. Considerable analysis of the source group categories has been undertaken to produce these recommendations. Additional detail for each recommendation is presented in the appropriate source group section, along with other pertinent recommendations.

Predicting load reductions, if specific recommendations are implemented, is not a simple task, as all NPS water pollution loadings are subject to considerable variation, and can be increased or reduced by climate and behavioral practices. The recommendations are not ranked by cost effectiveness or load reductions expected, as the load reductions achieved may vary considerably by location, and over time. Some of the recommendations, if implemented, will provide additional benefits, above and beyond their role in reducing phosphorus inputs to surface waters.

4.1 Urban Runoff & Soil Erosion

Watershed Based Plans: DEEP and their partners should continue the development of watershed plans in urbanized areas as the best way to holistically look at water quality conditions related to stormwater sources and propose management measures. Watersheds with phosphorus related water quality impairments due to urban runoff and high impervious cover should be targeted for development of plans. These plans should include a modeled assessment of NPS phosphorus loading, sources, management measures, and estimated load reductions. These plans could also qualify towns for NPS funding for implementation projects.

Municipal Green Infrastructure Low Impact Development Outreach and Implementation: Enhance municipal outreach and implementation of Green Infrastructure (GI) and Low Impact Development (LID). Maintain a website and listserve to share information with municipalities on the use and effectiveness of GI and LID techniques in Connecticut and nationally. Hold workshops or training to share and exchange information on GI and LID approaches and techniques. Develop municipal regulation guidance related to GI and LID. DEEP and UConn CLEAR should be key partners in this effort.

BMP Research and Guidance: Continue to research and evaluate the latest information on new or modified BMPs to more effectively address water quality impacts from urban runoff, including consideration of pollutant removal and runoff reduction effectiveness, maintenance issues, and cost. This should target the most recently available research on the performance of existing and new structural and non-structural BMPs for reduction of nutrients. Regularly update statewide Stormwater BMP manuals and guidance, including the 2004 Connecticut Storm Water Quality Manual, the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control, and associated LID Appendices. Solicit regular input from the consulting community, UConn and the academic community, state agencies, and the regulated community through a State NPS Technical Committee.

Enhance the existing DEEP Stormwater Programs and General Permits: Target stormwater impaired waters and phosphorus related sources. This should include all four types of General Permits that DEEP issues, which require steps to control stormwater pollution from urban areas and land use types. The MS4 permit in particular should target measures to reduce urban phosphorus sources and transport including: illicit discharges; fertilizer use and turf management; minimizing the effect of impervious cover (IC); road and property management measures for sweeping paved areas, catch basin cleaning and leaf management; pet waste; first flush retention; LID practices; and public education programs to raise awareness about fertilizers, lawn and leaf management, detergents, sediment and effects of IC. To assist municipalities in these efforts DEEP and UConn CLEAR should be key partners to develop an outreach and technical assistance program.

Preserve or augment staff and resources to inspect and enforce **DEEP's Stormwater General Permit program.** The Construction General Permit was recently revised with tighter restrictions affecting activities that drain to impaired water bodies. Similar restrictions will be implemented in revisions of the other stormwater general permits, including MS4, as they are revised and adopted. DEEP oversees and enforces activities which affect over 5 acres of disturbed area. Municipalities oversee and enforce projects which disturb less than 5 acres.

4.2 Animal Waste & Fertilizer

Enhance Agriculture Animal Waste Management and Technologies that concentrate phosphorus in separated solids (centrifuge technologies): Allow for reduced phosphorus concentrations in land applied liquid manure and repurposing of phosphorus in compost or other value added products. Separated portions of the manure can be stored more easily and may allow more feasible transportation of manure to become an economically viable substrate for biomass to energy facilities. A solid separator coupled with a decanter centrifuge may remove up to 40% of the phosphorus in liquid dairy manure. Includes:

- **Manure solid/liquid separation technologies on individual farms** – promote and provide funding for the purchase and installation of manure separation facilities on targeted farm locations.
- **Centralized/regional composting centers -** promote regional animal waste composting facilities in combination with food waste/leaf compost facilities.

Centralized/regional anaerobic digestion for dairy and food waste: Assist with capital costs and organize cooperative agreements to pool resources for centralized digesters. Existing models of centralized digesters demonstrate a means of reducing waste volume while capturing gas and energy from the manures. Anaerobic digesters can convert waste that can pollute surface waters to value added products that can be more easily transported and applied as fertilizers and soil conditioners, reducing problems from excess phosphorus, odors, and pathogens. Benefits include:

- Electricity from digester complex can be used to power a separator, centrifuge, and farm operations.

- Heat for drying locally grown grains, reducing import of grains containing phosphorus.
- Phosphorus extracted from manure used as soil amendment or fertilizer.
- Value-added products (containing phosphorus) transported out of watersheds of concern.
- Liquid dairy manure applied at an agronomic rate for nitrogen without over applying phosphorus.
- Reducing phosphorus in runoff because land applied liquid is absorbed better than solid or semi-solid manures.

Manure exchange/brokerage system – Incentivize or capitalize private companies to coordinate manure transfer from areas of nutrient excess to areas of soil nutrient need. This will demonstrate value of the nutrients in manures and offset the costs of chemical fertilizers needed on farms.

Nutrient Management Plans for Animal Feeding Operations (AFOs), Identify and incentivize manure management strategies on fields to discourage manure applications greater than agronomic, or crop removal levels, where agronomic levels exist, based on soil test recommendations. Improve distribution of manure on cropped lands with incentives for optimal (or less) soil test values and nutrient management plans.

Provide capital funding for pilot projects to evaluate new technologies for managing manures and agricultural waste such as:

- Pelletizing
- Gasification
- Phosphorus recovery from poultry and liquid dairy manure.

Provide incentives for farms to adopt and apply soil health practices. Soil health refers to the goal of having a diverse and functional soil through the use of land management and plants in the soil as much as possible. Incentives to apply soil health practices would help to reduce soil loss, phosphorus transport from fields, and reduce water runoff from fields by maintaining or improving water infiltration to soils and potentially reduce nutrient application need. Some incentives related to soil health may include provision of assistance to maximize the use of diverse cover crops including inter-row seeding.

Support the formation of a NRCS State Technical Committee, Nutrient Management Subcommittee: Representatives from poultry and dairy operations, NRCS, UCONN Extension, DEEP, CT Farm Bureau, CT Dept. of Agriculture, and other stake holders should organize to determine how to best implement these recommendations.

Fund continuing farmer education related to soil nutrient management, manure management and soil health to bring awareness to the existing problems and provide opportunity to learn or develop new solutions on the subject of NPS Phosphorus (and nutrient) reduction.

4.3 Onsite Wastewater Treatment

Through outreach programs at the regional and state level, encourage development of **town-wide wastewater management plans** that evaluate the potential for water pollution in areas of concern based on the preceding criteria, as they relate to onsite wastewater treatment systems that do not function properly. Such a planning document should also evaluate the range of options available to mitigate or prevent pollution impacts, and recommend one or more strategies to cost-effectively prevent or address those impacts.

Implement a Statewide Comprehensive Onsite Wastewater Treatment System (OWTS) management program through regulation or statute, with ongoing maintenance and inspection requirements. As part of a comprehensive program, the means and resources to track and manage data is critical for the administration and success of any management undertaking. A Data Tracking and Management System will allow regulators of OWTS to: identify data trends, identify, and prioritize actions in areas of concern, implement site-specific measures, and reduce phosphorus discharge from systems, as identified.

Require **Point of Sale Inspections of all Onsite Wastewater Treatment Systems** and require upgrades to systems not meeting a minimum standard through regulation or statute.

4.4 Statewide NPS Management

Convene a **Nonpoint Source Technical Committee** with other State Agencies and meet regularly to develop and implement more effective policies and procedures to minimize nonpoint Source pollution.

5 Analysis of Nonpoint Source Phosphorus Pollution by Source Group with Recommendations

5.1 Urban Stormwater

5.1.1 Analysis of Problems and Issues

5.1.1.1 Urban Runoff

In developed areas, a large portion of the natural landscape has been replaced with impervious surfaces such as roads, driveways, parking lots, buildings and other highly altered landscape conditions. Rainfall and snowmelt that once percolated slowly into the soil now quickly runs off these hardened surfaces in higher volumes, picking up and transporting various accumulated pollutants. This is commonly referred to as “urban runoff”. Often, urban runoff is conveyed directly to storm sewers or drainage ways and discharged directly to water bodies, where the captured pollutants degrade surface water quality. Approximately 47% of the state’s land area is considered developed land use (CLEAR, 2010) and much of that area is pre-1980s development before modern stormwater management practices and regulation were in effect. New growth and development will continue to contribute urban runoff impacts unless management practices are changed.

5.1.1.2 Urban Phosphorus Sources

Phosphorus can be a significant pollutant in urban runoff and contributor to water quality related impairments in lakes, ponds, rivers, and streams in the urban areas of Connecticut. Phosphorus in urban runoff can be roughly characterized into three forms: dissolved, adsorbed, and organic / colloidal. The fine particles that accumulate on impervious surfaces contains both adsorbed and organic forms of phosphorus, and most of the phosphorus that accumulates on impervious surfaces is contained in that fine material. For this reason the majority of phosphorus contained in urban stormwater is contained in the first flush, or initial period of discharge of stormwater from impervious surfaces. Best Management Practices (BMPs) that infiltrate or treat that first flush can therefore be effective to control phosphorus in stormwater. Phosphate ions in the soluble form, such as those found in fertilizers and wastewater are the most plant available form of phosphorus. In most well drained soils, ferric, aluminum, and other cations are very effective at removing and holding (adsorbing) phosphorus. Infiltration practices are effective at preventing P from reaching surface water bodies, provided that soil particles are not eroded by runoff.

Sources of phosphorus in urban areas can vary by urban land use type (residential, commercial, industrial), location and specific activities, however primary urban sources of phosphorus generally include:

- Lawn and landscape fertilizer
- Leaf litter and yard waste
- Animal and pet waste
- Litter and trash
- Illicit wastewater discharges
- Soil erosion and sediment.

5.1.2 Pollution Abatement Strategies for Urban Areas

Nonpoint source pollution, because it is diffuse and variable in nature requires a combination of strategies including those listed here to achieve results:

- Build **capacity for further watershed planning,** restoration, and protection.
- Reduce and **disconnect impervious cover**.
- **Identify and utilize areas where stormwater infiltration is feasible** and prudent, and prioritize preservation and protection of important groundwater recharge areas. Analyze impervious cover and effects of build-out, including teardowns where appropriate.
- **Identify potential stormwater retrofit sites**: areas with high loading such as agricultural areas, disturbed soil, parking lots, road crossings, and areas of increased road sand and salt application / hills
- Implement **Streambank stabilization** practices to reduce instances of severe erosion
- Enhance **Riparian buffer management** to more effectively remove pollutants and sediments from sheet flow
- **Pollution Source Control and Discharge prevention**, characterize pollutants, primary pollutant of concern, others including pathogens, TSS, metals, nutrients, BOD, COD, pesticides, organic pollutants, hydrocarbons,

volatiles, and PAHs. Some sources that can be abated or reduced include: dumping, trash, litter and spills by residents and drivers, lawncare, pet waste, nuisance wildlife, and illicit discharges. Citizen awareness of risks associated with improper disposal is a necessary starting point.

- **Prioritize** which of these strategies can have the most benefit and are achievable. Estimate funding sources available, quantify needs, shortcomings, and benefits.

- **Maintain** Best Management Practices to ensure optimum function.

5.1.2.1 Best Management Practices (BMPs)

Phosphorus pollution from urban areas can be reduced through a variety of non-structural and structural methods. The overall tiered approach to addressing stormwater impacts is to start with non-structural source controls/pollution prevention measures, then apply practices to reduce runoff volumes, and then apply treatment practices. Applying multiple practices in sequences, known as treatment trains, is accepted as an effective strategy where feasible.

Non-structural BMPs are source controls, operational and maintenance practices, and education/outreach programs that prevent or reduce phosphorus pollution at the source. Examples include reduced fertilizer use, low phosphorus fertilizers and detergents, leaf pickup, pet waste pickup, and road and parking lot sweeping. Rainwater harvesting and water re-use options, collecting and storing runoff for later use to water lawns, golf courses and gardens are also good source control practices.

Structural BMPs are constructed practices and manufactured devices used to reduce runoff volume or capture and treat runoff. Examples of structural BMPs include retention/infiltration basins, infiltration wells/trenches, bio-retention basins, vegetated swales, separation chambers, and media filters. Structural BMPs that infiltrate the first flush of stormwater have shown to be quite effective to control phosphorus as most natural soils are very effective at removing and holding (adsorbing) phosphorus. Site conditions must however be able to handle and infiltrate runoff volumes. More recent research from USEPA has suggested that the very first flush of runoff (as little as the first ¼ inch) may contain the most significant portion of the phosphorus load. This may be important, as it suggests that perhaps smaller volume and less expensive treatment structures/devices may help address existing highly urbanized areas where land area and soil conditions are limited.

Many urban site retrofit techniques have concentrated on reducing the effect of impervious cover (IC), by disconnecting impervious areas and infiltrating or treating runoff in those areas. In 2014, DEEP developed a document, “Watershed Response Plan for Impervious Cover”, to help reduce the negative effects of IC and restore water quality. The plan is a useful tool and guidance for local communities, municipal officials, businesses and watershed groups. The plan provides information on the local watershed conditions, impervious cover, and implementation measures, and can be used to complement existing municipal stormwater programs and practices. The document can be found at: http://www.ct.gov/deep/cwp/view.asp?a=2719&Q=567354&deepNav_GID=1654

Low Impact Development (LID) or Green Infrastructure (GI) techniques provide cost effective pollution prevention in site planning and design, through management of both runoff volumes and stormwater quality. These techniques use natural site features (soil and vegetation) and small scale controls and practices designed to mimic the natural hydrology of a site. Many of these LID and GI techniques are effective at reducing phosphorus and can be effectively applied for new or re-development sites. Examples of LID include pervious pavement, natural drainage ways, vegetated buffers/filter strips, rain gardens, parking lot islands, and green roofs.

DEEP has produced both a Storm Water Quality Manual and Low Impact Development Appendix to provide planning, design concepts, various stormwater management techniques and practices, pollutant removal effectiveness and selection criteria. These documents are available at DEEP’s Municipal Outreach for Green Infrastructure and Low Impact Development web page: http://www.ct.gov/deep/cwp/view.asp?a=2719&q=464958&deepNav_GID=1654

5.1.2.2 Best Management Practices (BMPs) Pollutant Removal Efficiencies and Costs

DEEP’s Storm Water Quality Manual and Low Impact Development Appendix are a primary resource for Connecticut stakeholders seeking to implement stormwater mitigation plans. For this report, DEEP conducted a further literature search of the latest information on stormwater BMPs, pollutant removal efficiencies, and relative costs. BMPS with phosphorus removal information were analyzed. The University of New Hampshire Stormwater Center is one of the more notable sources of stormwater management BMP testing and information. Local New England sources provide relevant information due to similarities in precipitation and soil types. DEEP’s search for current BMP information also included meeting with USEPA Region 1 stormwater and water quality technical staff as well as collaboration with UConn CES/Clear and NEIWPCC. Appendix 2 (Section 5.2) includes a narrative summary of this information and a detailed table of pollutant removal efficiencies and relative costs researched. As expected, many of the removal efficiencies and costs varied greatly as many factors come into play such as soil conditions, land area, land and capital costs, and operation and maintenance requirements.

Most phosphorus in urban runoff is adsorbed onto fine sediment and also becomes suspended in the first flush of runoff from impervious surfaces. The easiest way to reduce nonpoint source phosphorus, once pollution prevention is already exhausted, is to divert that first flush of runoff to infiltrate it to the ground, or if that is not feasible, apply a treatment practice to remove that fine sediment.

It is often necessary to pretreat and remove the coarse grained solids (sand), so that the second level of stormwater treatment does not become overwhelmed with sediment. Effective phosphorus treatments must remove the fine grained sediments (silt and clay). This often requires devices that take up a significant area or volume so that those fine particles can have residence time needed to settle out, or come in contact with significant surface areas of plant material, or filtration media such as sand and gravel.

BMP removal efficiencies for phosphorus range greatly from 0-80%. However BMPs for certain infiltration systems and LID techniques have removal efficiencies as high as 60% and are generally cost effective. The values in the tables below are taken from Appendix 2 Table 5.2.1 and are estimates. All references are included there. “No treatment” values were changed to 1% to facilitate comparison.

The workgroup’s prioritized recommendations for non-structural practices to reduce NPS phosphorus pollution loading to surface water bodies include:

BMP Type	**Removal Efficiency**	**Cost per lb. P removed**
Street sweeping (enhanced)	1 – 15%	<$100/lb. (spring/fall) $600/lb. (summer)
Fertilizer use education program	3 – 10%	$311/lb.
Organic waste / leaf litter collection	5%	Not Determined

The workgroup’s prioritized recommendations for structural practices to reduce NPS phosphorus pollution loading to surface water bodies include:

BMP Type	**Removal Efficiency**	**Cost per lb. P removed**

Infiltration Practices	60 – 85%	$3252-$3399/lb.
Impervious Urban Surface Reduction	Not applicable	$7,354/lb.
Illicit Discharge Detection	100%	$35 - $75 / lb.
Permeable pavement (porous asphalt)	20 – 80%	$12,563 -$70,342/lb.
Bioretention Unit/ Rain Gardens	1- 85% 59% (retrofit)	$2,935-$5,544/lb. $12,501/lb. (retrofit) $2791-$4329/lb. (rain gardens)
Sub-surface gravel wetlands	58%	Not Determined
Vegetated filter strip	Not determined	Not determined
Vegetated swales	1 – 90%	$14,600/acre treated

Selection of BMPs is site dependent. Available area and accessibility for maintenance can be important concerns in urban areas. A qualified engineer or stormwater professional should be consulted, and pretreatment and maintenance schedules and costs are necessary considerations. There are many other types of practices and references included in Table 5.1.1 Appendix 2. Combining several implementation strategies is often recommended.

Low Impact Development strategies are included within the structural and non-structural recommendations. Retrofits in urban areas are often very costly compared to installing these types of features at time of construction.

Cost and benefits are evaluated relative to phosphorus removal. Many types of practices have secondary benefits that are not accounted for in this analysis. Tree filters are an example of devices that provide secondary benefits. All costs are approximate. LID approaches are most effective where water is infiltrated into the ground. Practices with underdrains are often not as effective at removing pollutants including phosphorus.

5.1.2.3 Current Stormwater Regulation

Knowledge of the impact of urban stormwater on water quality, led to the development of federal and state regulation of urban stormwater during the 1990s. There are now four types of General Permits that DEEP issues under the federal Clean Water Act, National Pollutant Discharge Elimination System (NPDES) which requires steps to control stormwater pollution from urban areas and land use types. Four Stormwater General Permit programs are administered by the DEEP:

“Industrial General Permit” regulates industrial facilities with point source stormwater discharges that are engaged in specific activities according to their Standard Industrial Classification (SIC) code.

"Construction General Permit" requires developers and builders to implement a Stormwater Pollution Control Plan to prevent the movement of sediments off construction sites into nearby water bodies and to address the impacts of stormwater discharges from a project after construction is complete.

"Commercial General Permit" found only in Connecticut, requires operators of large paved commercial sites such as malls, movie theaters, and supermarkets to undertake actions such as parking lot sweeping and catch basin cleaning to keep stormwater clean before it reaches water bodies.

"MS4 General Permit" requires each regulated municipality to take minimum measures to keep the stormwater entering its storm sewer systems clean before entering water bodies. One important element of this permit is the requirement that towns implement public education programs to make residents aware that stormwater pollutants emanate from many of their everyday living activities, and to inform them of steps they can take to reduce pollutants in stormwater runoff.

For more information on state stormwater permits, go to www.ct.gov/deep/stormwater

DEEP also recommends that municipalities use local land use authorities to implement similar stormwater control measures for activities not regulated by a state stormwater permit. DEEP has produced both a Storm Water Quality Manual and Low Impact Development Appendix to provide planning tools and technical guidance to develop local stormwater programs and regulations. These documents are available at:
http://www.ct.gov/deep/cwp/view.asp?a=2719&q=459488&deepNav_GID=1654

5.1.2.4 Recommendations: Urban Areas

The following recommendations have been developed to address the impacts from urban runoff, targeting phosphorus in particular. They are based partly on the above analysis of existing urban runoff conditions, current stormwater regulatory programs, and recommendations contained in the 2014 Connecticut NPS Program Plan.

- DEEP and their partners should continue the development of **Watershed Based Plans** in urban areas as the best way to holistically look at water quality conditions related to stormwater sources and propose management measures. Watersheds with phosphorus related water quality impairments due to urban runoff and high impervious cover should be targeted for development of plans. These plans should include a modeled assessment of NPS phosphorus loading, sources, estimate load reductions, and management measures. These plans could also qualify towns for NPS funding for implementation projects.

- **Impervious Cover (IC) Outreach and Assistance:** Develop an outreach effort for the 2014 DEEP Watershed Response Plan for Impervious Cover, targeting phosphorus related impairments and urban and suburban communities where impervious cover (IC) and stormwater runoff are responsible for water quality impairments. This should include building on the technical tools and outreach developed for the Eagleville Brook IC TMDL and responding to an Impervious Cover-Based TMDL, UConn NEMO/CLEAR Program, 2011.

- **Municipal GI/LID Outreach and Implementation**: Enhance municipal outreach and implementation of GI and LID. Maintain a Municipal Outreach for Green Infrastructure and Low Impact Development website to share information with municipalities on the use and effectiveness of GI and LID techniques in Connecticut and nationally. Hold workshops or training to share and exchange information on green infrastructure (GI) and Low Impact Development (LID) approaches and techniques. Develop municipal regulation guidance related to GI and LID. DEEP and UConn CLEAR should be key partners in this effort.

- **BMP Research and Guidance**: Continue to research and evaluate the latest information on new or modified BMPs to more effectively address water quality impacts from urban runoff, including consideration of pollutant removal and runoff reduction effectiveness, maintenance issues, and cost. This should target the most recently available research on the performance of existing and new structural and non-structural BMPs for reduction of nutrients. Regularly update statewide Stormwater BMP manuals and guidance, including the 2004 Connecticut Storm Water Quality Manual, the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control, and associated LID Appendices. Solicit regular input from the consulting community, UConn and the academic community, state agencies, and the regulated community through the State NPS Technical Committee.

- **Regional Approaches**: Promote regionalization, watershed management and municipal cooperation to address runoff-related water quality issues and implement more effective municipal stormwater programs. Support the development of regional partnerships (i.e., coalition, collaborative, etc.) to increase the capacity and cost-effectiveness of municipal compliance with the MS4 General Permit and non-regulatory NPS runoff issues, and provide capacity and tools for partners. Regional stormwater partnerships could build upon existing watershed management plans, regional planning, watershed organizations, conservation districts and others. This could be modeled after successful stormwater coalitions in other areas of New England such as the Central Massachusetts Regional Stormwater Coalition. Seek startup funding to establish a regional stormwater coalition in Connecticut. One possible source is the Regional Performance Incentive Program (RPIP) grants through the Connecticut Office of Policy and Management.

- **Stormwater Program Financing Mechanisms**: Promote the development of long-term, dedicated financing mechanisms for municipal stormwater programs, such as a stormwater utility. Funding derived from a stormwater utility can be used to address local stormwater management needs including drainage infrastructure, flooding, and polluted waterbodies, as well as support regulatory compliance such as municipal MS4 Permit responsibilities. Support the implementation of a stormwater utility in those Connecticut communities that have already performed stormwater utility feasibility studies and/or that have expressed an interest in pursuing a utility or similar funding mechanism.

- **Enhance the existing DEEP Stormwater Programs and General Permits** to target stormwater impaired waters and phosphorus related sources. This should include all four types of General Permits that DEEP issues which requires steps to control stormwater pollution from urban areas and land use types. The MS4 permit in particular should target measures to reduce urban phosphorus sources and transport including: illicit discharges; fertilizer use; minimizing the effect of IC; IC retrofit programs; road and property management measures for sweeping paved areas, catch basin cleaning and leaf management; pet waste; local requirements for new and redeveloped sites to minimize runoff volume and effect of IC, first flush retention, and LID practices; turf management for municipal properties to reduce turf area and fertilizer use; and public education programs to raise awareness about fertilizers, lawn and leaf management, detergents, sediment and effects of IC. To assist municipalities in these efforts DEEP and UConn CLEAR should be key partners to develop an outreach and technical assistance program. NPS and Stormwater Permit programs should target outreach and regulatory strategies that specifically address phosphorus pollution from the fine dust and organic matter that accumulates on impervious surfaces. Education of citizens and landscape contractors that disposing of anything onto paved streets is illegal and has adverse environmental effects. Disposal practices for yard and landscape waste onto impervious areas, streets, and wetlands have been commonplace, exacerbated by the widespread modern practice of using leaf blowers.

5.2 Animal Waste and Manures

5.2.1 Analysis of Problem and Issues

Connecticut's agricultural producers generate large tonnages of manure and animal waste that has high concentrations of phosphorus. Sources include chickens for egg production, dairy and beef cattle, horses, and other smaller farms. There can be significant costs involved with recycling and disposal of those wastes, while minimizing pollution. Some of the relevant issues include: high energy costs associated with transporting wet materials and/or processing them into marketable products, shortage of available land area for application, and seasonal climatic issues. Connecticut's soils, where well drained, typically have excellent capacity to adsorb phosphorus. Erosion of phosphorus enriched soils can result in significant phosphorus loading to surface waters. Manure management and storage practices play a role in controlling rates of phosphorus release to surface waters. Severity and impacts resulting from phosphorus pollution problems is influenced by local soils, topography, and receiving water characteristics, as well as variations in storms and seasonal attenuation.

A statewide analysis of manure nutrient production was prepared by the University of Connecticut Cooperative Extension Department (Meinert, unpublished data). The analysis by Richard Meinert showed that Connecticut's estimated animal population could produce approximately 9.1 million pounds (4,550 tons) per year of phosphorus (as P_20_5). Meinert concluded that if all available cropland received agronomic manure nutrient application that there would be a theoretical annual surplus of 3.9 million pounds (1,950 tons) of phosphorus. 43% of the phosphorus in Connecticut's manure is surplus, assuming that all cropland is "open" to manure spreading. The dairy and poultry industries together account for nearly 80% of these nutrient loads.

Up to 90% of the phosphorus transported from cropland is attached to sediment. Thus, erosion control is of prime importance in minimizing phosphorus loss from agricultural land. Because surface runoff is the main mechanism by which phosphorus and sediment are exported from most watersheds, it is clear that phosphorus export will be minimized if surface runoff does not occur. (http://pubs.cas.psu.edu/FreePubs/pdfs/uc162.pdf)

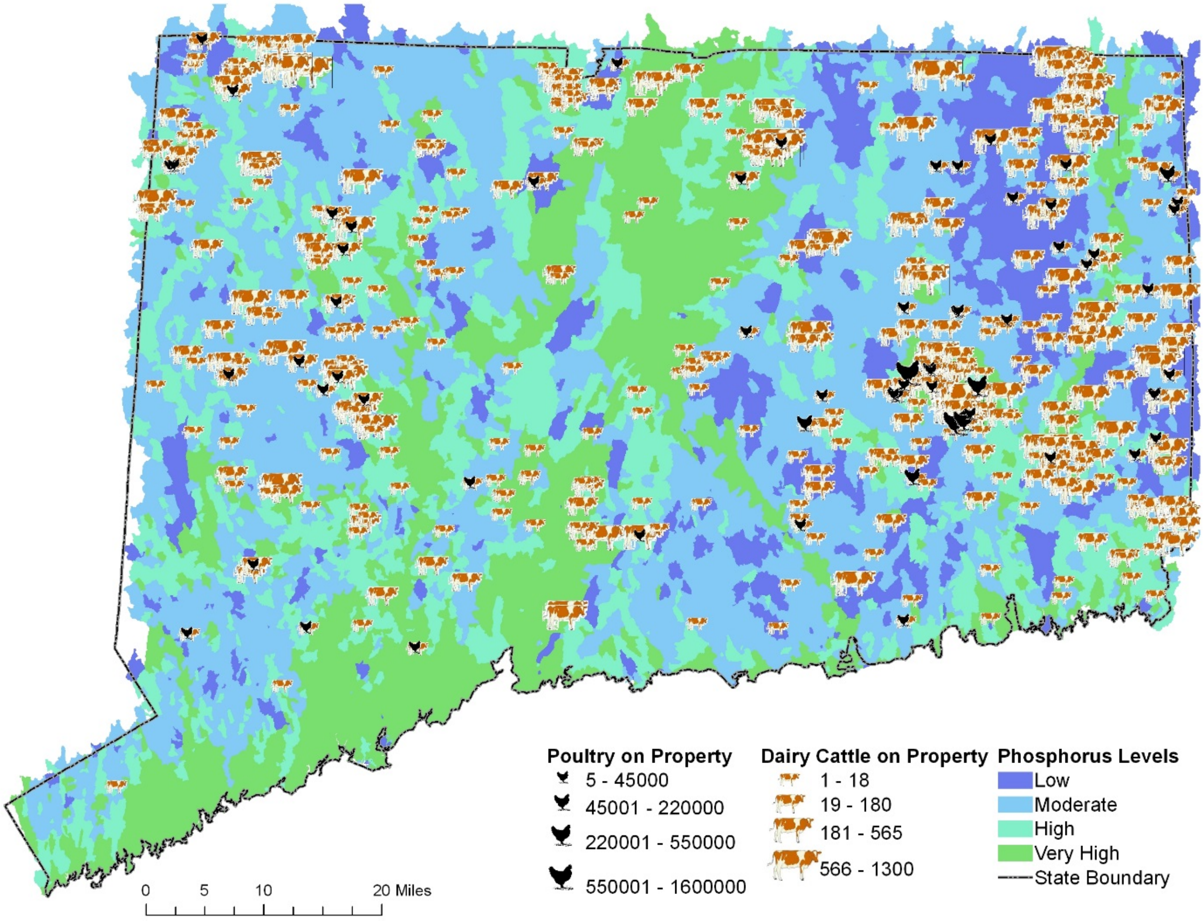


Figure 4.2.1 Poultry and Dairy Cattle Animal Feeding Operations Superimposed over Modeled Phosphorus Values in Non-tidal waters

Over application of manure sometimes occurs in farm fields that are most convenient and cost effective for farmers. Phosphorus export can increase dramatically where over-application of manure to fields occurs, resulting in concentrations of phosphorus in soils that are greater than what soils can adsorb. Leaching of soluble phosphorus can result in very high rates of export. Export of soluble phosphorus to surface waters can also occur when manure is applied to wetland soils as hydric soils do not have the capacity to adsorb much phosphorus.

Connecticut’s dairy and poultry producers produce more that 1.15 million tons of manure per year. This is more than can be land applied to cultivated fields at agronomic rates. In addition, social factors, like odors, increasingly limit land application of manure as residential properties are developed adjacent to farmland.

Development of feasible and efficient manure management systems will be essential when DEEP's proposed Concentrated Animal Feeding Operation (CAFO) general permit is implemented.
It is necessary to reduce excess water pollution that results when the animal waste generated is not managed and disposed in an optimal manner. Even with thorough implementation of best management practices, some pollution to the State's waters is inevitable, particularly during large storm events.

Value added products such as compost, container growing media, organic fertilizer, and energy can and should be produced from the waste products produced. There are startup and maintenance costs associated with these recommended practices. In some cases improvements are simply lacking a funding source and local backing to be implemented. In other cases, more collaborative planning is needed to flesh out details.

Most of the recommendations in this section apply to cattle and poultry operations. Additional planning and implementation should take place to better address pollution from sources such as horse farms and smaller sources where animals are raised. Connecticut DEEP's Nonpoint Source Program partners with UConn and NRCS to assist those that are willing.

5.2.2 Anaerobic Digesters

Anaerobic digesters with secondary treatment technologies are expensive. Regional digesters can increase the economic feasibility of processing a combination of livestock manure and food waste from a region. The result is reducing waste and pollutant volumes, generating energy in the form of both methane and heat, and creating of a product that can be used as a soil conditioner.

Public Act 11-80 authorized the Clean Energy Finance and Investment Authority (CEFIA) to establish a 3 year pilot program to support the use of on-site anaerobic digestion facilities to generate electricity and heat through loans, grants or power purchase agreements. The objective was to promote renewable energy, sustainable practices and economic prosperity of CT farms and other businesses by using organic waste. CEFIA published a request for proposals (RFP) in 2012 for on-site anaerobic digestion facilities but received no proposals, despite extending the deadline for submittal.

The CEFIA's 2012 RFP intended to solicit digester projects, but was unsuccessful. The following barriers were identified in 2012 by stakeholders and listed below:

- Electrical generation was limited to only offsetting on-site demand.
- Did not recognize the potential for anaerobic digesters to reduce greenhouse gases.
- Did not include anaerobic digesters as a priority of the State plan to meet the Renewable Portfolio Standard mandate.

- Required shovel ready projects.

The following benefits of regional renewable energy digesters with secondary treatment technologies can have significant local, regional and statewide environmental importance:

- Energy production reduces the demand for electricity.
- Reducing greenhouse gases by improved nutrient management and renewable energy production. Methane, a potent greenhouse gas, is captured for beneficial uses rather than released to the atmosphere.
- Enabling dairy farms to comply with the manure and wastewater handling and management requirements of federal regulations concerning Concentrated Animal Feeding Operations (CAFOs).
- Establishing manure and food waste processing capacity in CT to address surplus manure nutrients and the Solid Waste Management Plan.
- Reducing nutrient surplus and nutrient loading to CT's waterbodies and soils resulting in improved surface and ground water quality.
- Creating alternative technology models and long-term solutions to dairy manure and food waste management.
- Protecting local and regional public health, air quality, water quality and impacts to climate.
- Investing in viable farming operations for local food production thereby reducing transportation energy consumption and emissions
- Building sustainable agriculture to maintain a working landscape and preserve open space.

If we are going to encourage the efficient generation of methane from on-farm digesters, we need to incorporate an economically viable process for farm digester operators to evaluate and use various sources of carbon to increase methane yields. One Connecticut farmer with a digester discovered that the regulatory framework to bring ice cream waste (a food grade carbon source) to a farm digester is a bit onerous and potentially costly, with no certainty that additional, more costly permits would not be required in the future.

Legislative authorization to simplify utilization of available carbon materials would streamline the permitting processes for anaerobic digesters on farms. Legislation could be proposed that redefines certain types of dairy “waste” as not waste when used as a carbon supplement in digesters at amounts necessary to maximize the yield of methane. It would need to be made clear that anaerobic digestion is not a disposal operation for dairy waste, but a use of dairy waste. Material handling and storage should be reviewed and approved under the Comprehensive Nutrient Management Plan (CNMP) developed for the farm with assistance from NRCS. DEEP's Water Permitting and Enforcement Division reviews and approves CNMPs.

5.2.3 Recommendations: Animal

Waste

Centralized poultry waste combustion/incineration – Develop the means to provide assistance with capital costs and/or incentives to install a combustion system to concentrate nutrients for more effective transport, and capture energy from the manure.

- Available poultry manure would require a clean wood waste source for incineration and land application
- Revenue produced from energy production and ash by-product which can be used as a phosphate/potash fertilizer, approx. Residual ash would be 10% weight of the litter going in. (Dagnall et al. 2000)
- Conversion of poultry manure and wood biomass into a soil fertilizer that can be managed, transported, stored and applied at an agronomic rate for phosphorus.
- Heat used at poultry facilities for heating, hot water for egg washing, and drying locally grown grains. Using locally grown grains reduces importation of phosphorus in grains from out of state.

Manure solid/liquid separation technologies on individual farms tied in with manure transport/composting – Help with capital costs to purchase and install facilities on farms. Composting of separated solids is more feasible than slurry alone

- New centralized/regional composting centers combined with food waste/leaf compost facilities.
- On-farm compost systems.
- Incorporate technologies that concentrate phosphorus in separated solids (centrifuge or other technologies) allowing for reduced phosphorus concentrations in land applied liquid manure and re-purposing of phosphorus in compost or other value added product.

Separated portion of the manure can be stored at a high dry matter (DM) content. Allows more feasible transportation of manure to be economically viable for biomass to energy facilities, high DM waste (~70% DM) can be transported 4x further than low DM wastes (<10% DM) (Dagnall et al. 2000)

Manure transportation system – Develop the means to implement a manure transport system throughout the state of CT to help distribute manure nutrients from areas of high livestock and nutrient concentrations to areas in need of nutrients.

- Deferred cost payments: Accounting for appropriate costs per mile for method of transport utilized (rail, road, barge) must be associated with soil testing and nutrient management plans (NMPs) where nutrients are needed

- Incentive payment program for optimal (or lower) soil test values ($/ac) to encourage adaptive soil nutrient management and defer costs of transport when excess nutrients need to be exported from the farm.

Centralized/regional anaerobic digestion for dairy and food waste – Provide grant funding and organize cooperative agreements to pool monies and resources for centralized digesters.

Existing models of centralized digesters demonstrate a means of centralizing nutrients to gain economic feasibility and capture gas and energy from the manures. Digesters significantly reduce manure odors, allowing for greater use and diversity of manure applications, such as application to previously unavailable land bases near populous areas. Anaerobic digesters as a stand- alone technology do not reduce phosphorus concentration or improve water quality directly. However, pre-treatment technologies can reduce phosphorus concentrations in liquid manure and potentially improve water quality. A solid separator coupled with a decanter centrifuge may remove up to 40% of the phosphorus in liquid dairy manure. The synergy of technologies and the resulting value-added products make anaerobic digesters appealing for reducing phosphorus:

- Electricity from digester complex used to power separator, centrifuge, and operation of farm.
- Heat for drying locally grown grains reducing importation of grains with more phosphorus.
- Phosphorus extracted from manure used in compost or in organic fertilizer
- Value-added products (containing phosphorus) transported out of watersheds of concern.
- Liquid dairy manure applied at an agronomic rate for nitrogen without over applying phosphorus.
- Reducing runoff from liquid application because land applied liquid is infiltrated into the soil more readily than solid or semi-solid manure, reducing NPS phosphorus in storm runoff.

Existing grants and financial incentives should be modified and developed to support regional anaerobic digesters with secondary treatment technologies for phosphorus removal.

Incentives are needed to attract private entities to develop/invest in regional facilities. To identify the type and size of incentives needed, funds are needed to evaluate feasibility for development of regional manure management facilities.

Establish a manure exchange/brokerage system – Incentivize or capitalize private companies to effectively coordinate manure transfer from areas of nutrient excess to areas of soil nutrient need to demonstrate a value of the nutrients in manures and offset the costs of chemical fertilizers needed on farms with nutrient management plans or soil test recommendations.

Financial incentives, tax credits, grant and loan program - To implement NPS phosphorus reduction practices for on farm, off farm solutions, and establish regional facilities financial incentives, tax credits, grant and loan programs need to be expanded, modified, and created.

Example: Farm tax credits for manure export/compost sales

Incentivize the implementation of Nutrient Management Plans for Animal Feeding Operations (AFOs), Encourage and identify manure management on fields to discourage P applications above crop removal levels, based on soil test recommendations. These fields are identified as those where the field specific P-Index is 'Low'.

Reduce animal feed import by:

- Maximizing crop yield with adaptive management practices incentives for farms or farm groups
- Growing more grain crops locally
- Encouraging pasture based practices with incentives to reduce imported feed need
- Provide a regional grain drying facility associated with a regional digester/incinerator/energy facility to make local grains more available and feasible

Improve current distribution of manure on cropped lands with incentives for optimal (or less) soil test values and nutrient management plans.

Provide capital funding for pilot projects such as:

- Pelletizing
- Gasification and biochar production
- Chemically precipitate or recover phosphorus and exporting phosphorus from the State
- Phosphorus recovery from poultry manure using quick wash process to produce calcium forms of phosphorus fertilizers (remove 90% phosphorus)
- Phosphorus recovery from liquid dairy manure using Struvite Crystallization to produce $MgNH_4PO_4 \cdot 6H_2O$ form of phosphorus fertilizer (slow release fertilizer
- Manure separation through mechanical means or with coagulants, flocculants, or addition of magnesium for struvite precipitation to increase phosphorus precipitation, leave higher phosphorus in solids for composting and lower phosphorus concentrations in liquid for land applications.

Evaluate potential benefits of a phosphorus trading program within watersheds by providing funding for an analysis of cost effectiveness for the installation of phosphorus reduction technologies from waste water treatment plant discharge, or to pay farmers (and/or regional projects) to install and operate a phosphorus removal system from manure. P removal on a local or regional level would allow for easier transport of the nutrients to areas where soil nutrients are needed and allow for the manure to be applied to crop fields to maintain productivity and soil health.

Provide incentives for farms to adopt and apply soil health practices and adaptive management. Soil health refers to the goal of having a highly diverse and functional soil through the use of land management and plants in the soil as much as possible. Incentives to apply soil health practices would help to reduce soil loss and phosphorus transport from fields, reduce water runoff from fields by maintaining or improving water infiltration to soils and potentially reduce nutrient application need through the synergistic effects of land management and soil health. Some incentives related to soil health may include:

- Cover crop seed on any cropped field
- Diversity of seed or plants in cropped/hayed/pastured field
- Purchase of seed equipment to plant crops and cover crops
- Cost of seeding cover crops by custom operators (inter-row seeding at mid or late crop stage, aerial seeding)
- Early seeding of cover crops (September or earlier) for nutrient recovery and soil cover
- Termination of cover crop with alternate methods to chemical only, such as rolling/crimping, harvesting, or winter kill annuals in such a way to maximize nutrient uptake and soil coverage.

Provide incentives to offset costs to production for farms adopting environmentally based management practices. The conversion to new land or crop management practices may incur a drop in product or yield during a transitional time period, which could be detrimental to the immediate economic needs of the farm. The cost offset to yield/productivity could help reduce the risk of converting management practices.

Support the work of the NRCS State Technical Committee: Nutrient Management Subcommittee with representatives from poultry and dairy operations, NRCS, UCONN Extension, DEEP, CT Farm Bureau, CT Dept. of Agriculture, and other stake holders to determine how to best implement these recommendations.

Fund continuing education related to soil nutrient management, manure management and soil health to bring awareness to the existing problems and provide opportunity to learn or develop new solutions on the subject of NPS Phosphorus (and nutrient) reduction.

Citations:

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Richard Meinert. Personal communications

5.3 Phosphorus Fertilizers

5.3.1 Analysis of the Problem and Issues

Public Act 12-155 established controls on fertilizer use on lawns including a formula limit of 0.67% phosphorus for use on established lawns as well as seasonal prohibition on lawn fertilizer applications from December 1 – March 15. Lawn fertilizer may not be applied within 20 feet of a watercourse or on impervious surfaces. These controls do not apply to Golf Courses or agricultural lands.

PA 12-155 also allows the Commissioner of Agriculture to approve distribution of consumer information at the point of sale for fertilizers and adopt regulations. There is no dedicated funding source available for these activities. Educating fertilizer users to choose the right fertilizers, and apply them at the right time and rate to reduce offsite movement of phosphorus can have profound effects on the amount of phosphorus exported to surface waters.

Phosphate ions are effectively bound to iron or aluminum ions in well-drained soil. Wetland soil minerals will not adsorb dissolved phosphate. Application of phosphorus fertilizers to wetlands can result in soluble phosphorus release to surface waters.

Overall reduction of phosphorus in fertilizer and application rates is a cost effective way to reduce pollution in storm runoff. Homeowners typically do not have the same concerns relative to controlling costs as commercial operators and their application rates are not as likely to be carefully measured. Homeowners are likely to continue applying until the package is used up with the idea that if a little is good a lot is better. Golf courses and commercial lawncare companies have greater cost concerns so are less likely to over apply fertilizers. Poorly timed fertilizer application before heavy rainfall, and the significant quantities of soluble nutrients applied over larger acreages can lead to high pollutant loadings. More frequent light applications are preferable to occasional heavier applications for both plants and water quality.

Timing of fertilizer applications relative to rainstorms is a critical variable in controlling soluble phosphate loadings to surface water bodies. Fertilizer applied prior to a very light rain allows the phosphate to infiltrate into the soil profile where it can be bound effectively. Applications prior to rainstorms which cause surface runoff will result in water pollution. Other factors influencing infiltration like slope, soil compaction, sparse vegetation, and soil type can all lead to increased runoff and subsequent pollutant loadings. Raising mowing heights can result in healthier turf and less fertilizer reaching surface waters.

Removing phosphorus from organic lawn fertilizers is difficult because P is present in relatively large quantities in the organic materials from which the fertilizers are derived. Because synthetic fertilizers are much higher in nitrogen than organic fertilizers the amount of phosphorus being applied per pound of nitrogen is much higher when organic fertilizers are used. Phosphorus content in fertilizer is labelled as guaranteed minimum values. Phosphorus content can sometimes be higher than the guaranteed minimum value on the label in organic fertilizers.

The New England Interstate Water Pollution Control Commission organized the Northeastern Regional Turf Fertilizer Initiative, a collaborative effort, completed in January of 2014 that sought to engage the six New England states, New York State, EPA, and industry and non-industry stakeholders in discussion on the contribution of fertilizers applied to lawns to polluted runoff and water quality problems. A final report describing the 33 guidelines developed through this process is available at: http://www.neiwpcc.org/turffertilizer.asp . The set of 33 regional guidelines presented in this report are organized around “5 R’s”: right formulation, right rate, right time, right place, and right supporting actions.

DEEP published guidance on Best Management Practices for Golf Course Water Use in 2006.
http://www.ct.gov/deep/lib/deep/water_inland/diversions/golfcoursewaterusebmp.pdf The document’s primary focus is water conservation, however, recommendations are also made for Wetland Protection, Stormwater Management, Erosion and Sediment Control, Turf Management - Nutrient and Integrated Pest Management (IPM) Plans, and Water Quality Monitoring.

Container nurseries can present unique problems if they are not managed to minimize nutrient runoff. If water soluble fertilizer is applied via the irrigation system a considerable amount of phosphorus may miss the containers and be subject to offsite movement. Because container nursery growing media needs to drain well to prevent root diseases leaching of phosphorus is a concern. Leachate from container media can contain from 60 – 150 lbs. phosphorus/acre/year (Bugbee and Elliott, 1998). CAES has found that certain Connecticut water treatment plant residuals are high in reactive aluminum (Bugbee and Elliott, 1999).

These residuals are often a disposal problem but have the capability of being able to adsorb large quantities of phosphorus. These residuals could be incorporated into buffer zones or detention basins to enhance phosphorus removal.

5.3.2 Recommendations for Fertilizers:

5.3.2.1 Statewide: All Areas

The following general recommendations apply to all of the additional specific areas below.

- Reduce phosphorus applications.
- Apply phosphorus based on soil tests.
- Maintain unfertilized buffer strips between nurseries and water courses.
- Minimize applications of phosphorus fertilizers to nontarget areas.
- Utilize vegetated containment areas for drain discharges.
- Collect runoff and reuse.
- Consider phosphorus removal zones containing water treatment residuals.
- Educate fertilizer users on ways to reduce offsite movement of phosphorus.
- Timing of phosphorus application relative to occurrence of intense runoff events may provide decreases in phosphorus runoff. Applications of P should be applied during times when intense runoff events are less likely.
- Subsurface placement of phosphorus away from the zone of removal in runoff will reduce phosphorus loss potential. Light tilling after application or subsurface injection.
- Manure and soil analysis of phosphorus and nitrogen content determined by soil test labs before land application of manure, conducted before any manure application and used as guidelines in determining application rates.

5.3.2.2 Recommendations for Fertilizers: Lawns and Gardens

- Many newer rotary fertilizer spreaders have deflectors to limit the spread of fertilizer to the side where it is not needed. Their use should be encouraged or, alternatively, the use of drop spreaders that apply fertilizer directly to the ground below should be encouraged.
- Where soil tests indicate adequate phosphorus, an option is for home gardeners to use phosphorus free lawn fertilizers that do not contain herbicides or pesticides that will harm garden plants.
- Maintain unfertilized buffer strips between lawns and gardens and water courses. Utilize vegetated containment areas for drain discharges.

- Encourage fertilizer industry to begin marketing garden fertilizer with reduced or no phosphorus.
- Educate fertilizer users on ways to reduce offsite movement of phosphorus.

5.3.2.3 Recommendations for Fertilizers: Agricultural Croplands

- See the Agriculture Waste and Manures Section 4.2 of this report for more guidance on using manure as a fertilizer and soil conditioner.
- Utilize cover crops.
- Maintain unfertilized buffer strips between croplands and water courses.
- Utilize vegetated containment areas for drain discharges.
- Reduce excess manure and compost applications.
- Utilize no-till farming practices to reduce soil erosion and conservation of phosphorus.

5.3.2.4 Recommendations for Fertilizers: Container Nurseries

- Maintain unfertilized buffer strips between nursery and water courses.
- Minimize applications of liquid phosphorus fertilizers to non-target areas.
- Utilize vegetated containment areas for drain discharges.
- Collect runoff and reuse.
- Consider phosphorus removal zones containing water treatment residuals.
- Educate nursery industry on practices to reduce offsite movement of phosphorus.

5.3.2.5 Recommendations for Fertilizers: Golf Courses

Many issues regarding offsite movement of phosphorus from golf course turf is similar to that discussed previously under home lawns.

- Reduce phosphorus applications. Apply phosphorus based on soil tests.
- Maintain unfertilized buffer strips between fertilized turf and water courses.
- Utilize vegetated containment areas for drain discharges.

5.4 Soil Erosion

Phosphate anions in well drained soils are typically adsorbed quickly to the surfaces of silt or clay particles or to organic colloids. These fine fractions, when eroded by storm runoff, have the capacity to stay suspended and travel downstream where they can exacerbate recreational impairments to surface water bodies, by contributing nutrients which can trigger algae blooms. They can also disrupt habitat functions in wetlands and watercourses leading to further impairments in aquatic life use support. These sediments can also settle out where they adversely impact navigation and water supplies. Sediments can be remobilized by various processes, depending on the water body and its physical and chemical characteristics.

Statutory and regulatory requirements have been in place for many years to minimize the quantities of sediments and nutrients that are contributed to surface water bodies by soil erosion. CT DEEP had recently revised and strengthened its Stormwater Construction General Permit. DEEP has produced both a 2002 Erosion and Sedimentation Control Manual, and Low Impact Development Appendix to provide planning, design concepts, various stormwater management techniques and practices, pollutant removal effectiveness and selection criteria. Links to both documents are available at DEEP’s Stormwater General Permits and Incorporation of Low Impact Development Evaluation web page:
http://www.ct.gov/deep/cwp/view.asp?a=2719&q=459488

Appendix 6 provides a Matrix of Laws which may require Erosion and Sediment Control from the 2002 Connecticut E&S Control Manual.

5.4.1 Agricultural Land Erosion

Up to 90% of the phosphorus transported from cropland is attached to sediment. Thus, erosion control is of prime importance in minimizing phosphorus loss from agricultural land. Because surface runoff is the main mechanism by which phosphorus and sediment are exported from most watersheds, it is clear that phosphorus export will be negligible if surface runoff does not occur.
http://pubs.cas.psu.edu/FreePubs/pdfs/uc162.pdf
This conclusion supports the use of cover crops and soil health implementation which reduces runoff and erosion by increasing infiltration and minimizing soil disturbance. NRCS and DEEP have partnered to provide education, technical and financial support to farmers aimed at minimizing pollution to surface water bodies. EPA has recently released an Agricultural BMP database http://www.bmpdatabase.org/agBMP.html to provide a consistent and scientifically defensible set of data on Best Management Practice.

5.4.2 BMP Methods / Designs and

Related Performance

BMPs to reduce NPS phosphorus pollution rely upon infiltration to the ground, settling out of suspended sediments, and biological uptake of phosphorus. The second and third options often require substantial area to be fully effective. Vegetated buffers to interrupt sheet flow, and grass lined swales, to spread out channelized flows, are commonly recommended.

5.4.3 Erosion Associated with Developed Areas

DEEP administers four Stormwater General Permits: Construction, Industrial, Commercial and MS4 for municipal stormwater systems. DEEP has produced both a 2002 Erosion and Sedimentation Control Manual, and Low Impact Development Appendix to provide planning, design concepts, various stormwater management techniques and practices, pollutant removal effectiveness and selection criteria. Links to both documents are available at DEEP's Stormwater General Permits and Incorporation of Low Impact Development Evaluation web page: http://www.ct.gov/deep/cwp/view.asp?a=2719&q=459488

Generally speaking, DEEP oversees stormwater construction general permit registration if the disturbed area of a construction sites is over 5 acres and municipalities oversee the registration and compliance if the disturbed area is between 1 and 5 acres. Construction projects must comply with the guidelines in the 2002 Connecticut Guidelines for Erosion and Sediment Control, a manual for the design, installation and maintenance of soil erosion and sediment controls that fulfills the requirements of Connecticut's Soil Erosion and Sediment Control Act (see CGS 22a-328, Connecticut General Statutes).

DEEP's Stormwater Construction General Permit requires developers to implement a Stormwater Pollution Control Plan (SPCP) to prevent the movement of sediments off construction sites into nearby water bodies and to address the impacts of stormwater discharges from a project after construction is complete.

All Stormwater Pollution Control Plans (SPCPs) must be approved by a qualified soil erosion and sediment control specialist or a professional engineer, and follow guidelines in the 2004 Connecticut Stormwater Quality Manual. DEEP's 2002 Connecticut Guidelines for Soil Erosion and Sediment Control is recommended as guidance in designing SPCPs.

Encouraging new development to infiltrate stormwater to the same extent as natural landcover is the goal of low impact development and green infrastructure. DEEP's Low Impact Development Appendix to the Connecticut Stormwater Quality Manual and a Low Impact Development Appendix to Connecticut Guidelines for Soil

Erosion and Sediment Control provide consistent guidelines that can assist registrants for stormwater general permits.

5.4.4 Stream Channel Erosion

Erosion of streambeds and banks is an important nonpoint source of sediment and phosphorus threatening the impairment of surface waters in the Northeast. Stream corridors tend to reach a stable state that minimizes erosion and allows for sequestration of sediment and associated pollutants on the floodplain, based on characteristics of watershed and climate[1]. Changes in climate, watershed land use/land cover or disturbance to stream corridor morphology can result in stream channel instability and corresponding increases in erosion and sediment loads[2]. As P is generally adsorbed to soil particles, increases in rates of erosion tend to predict increased P-loads.

Streams responding to climate change and/or disturbance can also become entrenched and disconnected from their floodplains, which increases a stream's erosive power and limits capacity to sequester sediment and associated P along the stream corridor[3]. Streams that are connected to functioning floodplains have reduced erosive power and sediment loads, and consequently reduced P loads.

The most important causes of current and future stream instability and entrenchment in the Northeast are:

- Watershed disturbance including vegetation clearing and conversion to impervious surface resulting in a corresponding increase in peak flows.
- Stream corridor disturbance including riparian buffer degradation, stream channel modifications such channel straightening, gravel mining and bank hardening, and floodplain encroachments such as structural flood control
- More intense rain storms and a corresponding increase in peak flows.

5.4.5 Recommendations: Erosion

- DEEP's Stormwater General Permit program has been in place for many years to reduce sediment inputs to surface water bodies. The Construction General Permit was recently revised with tighter restrictions affecting activities that drain to impaired water bodies. DEEP oversees and enforces activities which affect over 5 acres of disturbed area. Municipalities oversee and enforce projects which disturb less than 5 acres. At a time when budget reductions are occurring in all segments of government, staff resources to

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[1] Rosgen, David. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

[2] Rosgen 1996.

[3] Vermont Rivers Program. 2010. Floodplains Key to the Health of Lake Champlain. White Paper/Report. Available here: http://www.watershedmanagement.vt.gov/rivers/docs/Educational%20Resources/rv_FloodplainsKeytoHealthofLakeChamp.pdf

inspect and enforce stormwater permits should be preserved or augmented where necessary.

- Including potential impacts to stream channel stability in the review of proposed development, especially in floodplains is recommended. More scrutiny should be given to the geomorphic impacts of development, especially actions that will increase peak flows such as vegetation clearing and creation of impervious surface. In some cases cumulative impacts need to be considered and total maximum daily load (tmdl) analyses or watershed based permitting can be implemented. Expanding the use of floodplain restoration, or reconnecting incised streams to their floodplains, can aid in the sequestration of phosphorus-laden sediments during large storm events when the majority of sediment is transported.

5.5 Internal Loading from Lake Sediments

5.5.1 Analysis of the Problem and Issues

In summer thermal stratification occurs in lakes due to differences in density of water as it heats up. Oxygen cannot diffuse to the bottom due to a density stratification at the boundary point known as the thermocline. Water and become anoxic below the thermocline as available oxygen is used up by respiration processes. Thermoclines typically exist at about 18 foot depth plus or minus a few feet in Connecticut lakes.

Water with low dissolved oxygen triggers a reducing environment where bacteria use oxygen from iron oxides, changing the oxidation state of iron from Fe^{3+} to Fe^{2+}. The phosphate ion: PO_4^{2-} which was previously sequestered by iron oxides now becomes soluble and available to plants. When wind mixing occurs, or the lake cools, stratification breaks down, and phosphate in bottom waters mixes with top waters, often triggering a bloom of algae.

Phosphate ion concentrations in Connecticut lakes near the surface are commonly 10-20 parts per billion (ppb). Phosphate ion concentrations in anoxic bottom water often range into the hundreds of ppb in lakes with nutrient loading.

5.5.2 Recommendations

Phosphorus released from sediments under anoxic conditions is called internal phosphorus loading. Treatment options to reduce internal phosphorus loading include introducing compounds that have greater phosphorus binding capacity than iron under anoxic conditions or adding oxygen to bottom waters.

Compounds with aluminum or calcium can be used to bind with phosphorus in the sediments under anoxic conditions. This technique is called **phosphorus inactivation** and although it is not widely used in Connecticut, it is a common lake management technique for deeper lakes with internal phosphorus loading. The cost to implement a phosphorus inactivation project is approximately $1,000 per acre treated. Costs may vary depending on the conditions and the intensity of internal phosphorus loading.

The intent of **adding oxygen to deeper waters by mixing** the thermally separated upper and lower layers of a lake is to keep oxygen concentrations high enough so that phosphorus and iron stay bound in the sediments. Mixing usually requires a compressor connected to a delivery system above the lake bottom. As bubbles of compressed air move up the water column, stratification of the thermally separated layers is broken down so oxygen can diffuse from the atmosphere to the bottom of the lake. If not done correctly, this method can exacerbate internal phosphorus loading by bring up phosphorus rich water from the bottom to the surface of the lake.

Aeration can also be accomplished by **adding oxygen rich water or pure oxygen** to the bottom of a lake. This technique requires equipment with ongoing operation and maintenance costs. The oxygen demand of the area to be aerated should be calculated prior to installing an aeration system so the system can be properly sized. Aeration systems may be more appropriate for utility companies who have staff and funds to maintain and operate the equipment and supplies needed for an aeration system. Bothe of the preceding two strategies require operation and maintenance.

Normally sediments that release phosphorus are in the deeper locations of the lake so **dredging is usually cost prohibitive**. The goal of most dredging projects is to remove sediment in shallower areas to reduce habitat for aquatic plants. Dredging sediments in deeper areas would require specialized equipment, water handling, and permitting. Dredging to reduce internal phosphorus loading has not been used in Connecticut.

Before proceeding to management efforts to control internal phosphorus loading in lakes, an **assessment of all phosphorus loading sources** is recommended. Benefits from controlling or reducing internal phosphorus loading will be short lived if the sources of phosphorus in the watershed are not controlled. DEEP usually recommends that watershed sources of phosphorus be addressed before initiating phosphorus inactivation or aeration projects.

5.6 Onsite Wastewater Disposal / Septic Systems

5.6.1 Analysis of Problems or Issues

Onsite Wastewater Treatment Systems (OWTS), generally referred to as septic systems, serve roughly 1.5 million people in Connecticut, approximately 40 percent of the state's population. These systems are effectively utilized in rural and low-density suburban areas, but can be problematic in higher density situations and lakefront and shoreline settings.

Septic system failures, where untreated sewage breaks out on the surface, can represent a significant threat to groundwater and surface water. Similarly, septic system malfunctions, where no breakout occurs, but site conditions are not conducive to effective onsite treatment of wastewater, have the potential to impact waters of the State, especially when in close proximity to sensitive environmental receptors.

Current OWTS regulations and technical guidance provide a stringent and regulated process for environmentally protective standards, separating leaching systems from groundwater, surface water, and wetland areas. However, older systems that do not meet the current mandated separating distance to groundwater or surface waters or do not provide an even distribution to a leaching system, may not provide such protections. These older OWTS can contribute to the overall phosphorus load to a waterbody. A number of factors are listed here that can contribute to an OWTS not functioning properly:

- **Age and design of system**: Department of Public Health regulations for the design and construction of OWTS became effective in 1982 and are reviewed and updated on a regular basis. Today system designers and installers are much more aware of the necessity of adequate treatment and not just dispersal. In addition, most studies indicate that the average useful life of a leaching (dispersal) system is 30-40 years, and current regulations require a reserve area but do not mandate replacement at 40 years.

- **Lack of maintenance**: OWTS require maintenance to function as designed. Regular maintenance, consisting of septic tank pumping and inspection, is needed every 3-5 years to remove solids buildup. Regular maintenance also provides an opportunity to evaluate the functionality of the system and inspect components if needed, as well as educate owners.

- **User habits**: Septic systems are designed utilizing a design flow, or estimated flow from a structure. Using water in excess of the specified design flow, such as more people in the house, a sump pump, or a water treatment backwash can result in premature failure and overloading of the leaching system. Garbage disposals, cooking and cleaning habits such as excessive grease, and excessive chemical usage can also affect the functionality of the system.

- **Improper siting**: Extensive older (pre 1982) development utilizing OWTS has occurred in areas that today would be considered unsuitable for OWTS. Examples of improper siting include installations of OWTS too close or into groundwater. This can result in inadequate phosphorus removal or treatment. A suitable unsaturated soil layer is the most important part of the septic system.

- **High loading rate or uneven effluent distribution**: Hydraulic overloading of the unsaturated natural soils can result due to many factors. The most common is putting too much sewage effluent into too small of an area. This can overwhelm the natural soils, thereby not allowing for effective phosphorus removal or treatment, or in a worst case scenario causing a surface breakout. Change in use, or intensification of use, can also be a factor in situations where the property has been expanded to accommodate additional residents or where a seasonally occupied home is now occupied on a more frequent, or year-round, basis.

5.6.2 Recommendations

- Through outreach programs at the regional and state level, encourage development of **town-wide wastewater management plans** that evaluate the potential for water pollution in areas of concern based on the five factors above in Section 4.6.1, as they relate to onsite wastewater treatment systems that do not function properly. Such a planning document should also evaluate the range of options available to mitigate or prevent pollution impacts, and recommend one or more strategies to cost-effectively prevent or address those impacts.

- **Establish a state grant or loan program to fund upgrades of OWTS** to current standards.
    - Funding should be directed to local and state agencies directly responsible for regulatory oversight of OWTS.

- **Implement a statewide comprehensive OWTS management program** with ongoing maintenance and inspection requirements.
    - As part of a comprehensive program, the means and resources to **track and manage data** is critical for the administration and ongoing

success of any management undertaking. A data tracking and management system will allow users to identify data trends, identify areas of concern, and implement site-specific measures to reduce P discharge from OWTS systems as they are identified.

- Implement a **point of sale inspection of all OWTS** and require upgrades to systems not meeting a minimum standard.

- Develop phosphorus source controls or restricted use for:
  - Garbage disposals
  - Commercial automatic dishwasher detergents containing phosphorus. Dishwasher detergents with more than 0.5% phosphorus are currently restricted in Massachusetts, Vermont and New Hampshire.

6 Appendices

6.1 Appendix 1 Phosphorus Yield Maps to Non-Tidal Surface Waters

Estimated Yield Categories for Regional Basin Total Phosphorus Maps (kg/km2/yr.)

The maps display the estimated total phosphorus (TP) yield (kg/km2/yr.) for each watershed. The TP yield was estimated using the USGS Northeastern Spatially Referenced Regressions on Watershed (SPARROW) developed by Moore et al. (2011). Where available, updated NPDES daily monitoring report TP data submitted to DEEP by municipal waste water treatment plants (WWTPs) was used. Each map displays a portion of the yield attributed to different aggregated land use activities to estimate land use loadings. These include agriculture, developed, municipal WWTPs and non-point sources (agriculture and developed combined). The estimated yield is partitioned into four categories: low, medium, high and very high. The categories are approximately based on work developed by DEEP (Becker, 2014) that associated different levels of TP yield with changes in the algal community in rivers and streams. Changes were identified at 'Enrichment Factor' (EF) points, which is a scaled measure of TP yield. Significant changes in the algal community were identified at (1) 8.01 kg/km2 (1.9 EF) above which sensitive taxa steeply declined (2) 26.12 kg/km2 (6.2 EF) above which most sensitive taxa were lost and tolerant taxa steeply increased to their maxima and (3) 35.4 kg/km2 (8.4 EF) which appeared to be a saturation threshold beyond which substantially altered community structure was sustained. The low, medium, high and very high map categories correspond as 0 – 8.01 kg/km2, > 8.01 – 26.12 kg/km2, > 26.12 – 35.4 kg/km2, and > 35.4 kg/km2, respectively.

References

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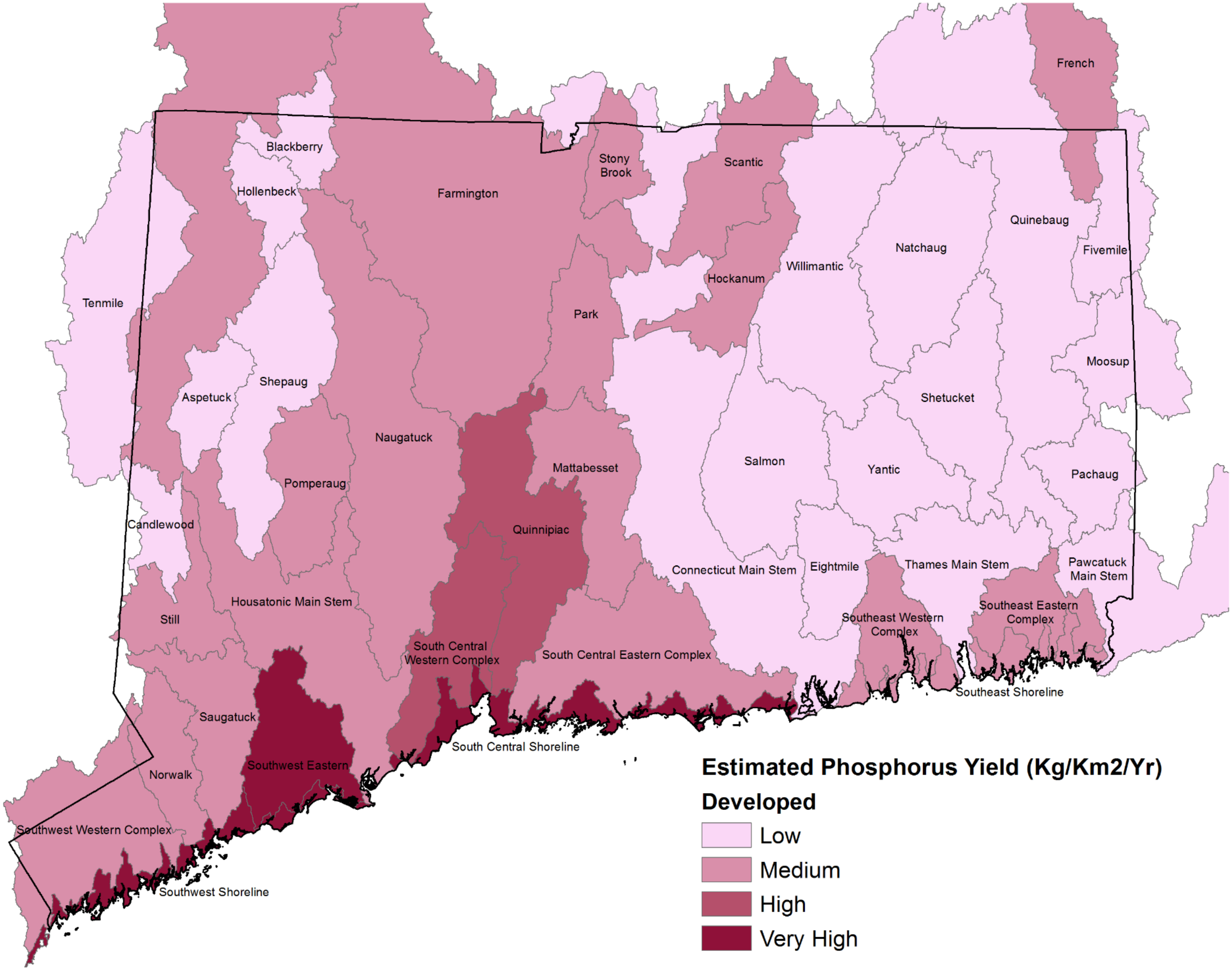
Becker M. 2014. Interim Phosphorus Reduction Strategy for Connecticut Freshwater Non-Tidal Waste-Receiving Rivers and Streams Technical Support Document. Bureau of Water Protection and Land Reuse, Planning and Standards Division. Hartford, CT. Available:

http://www.ct.gov/deep/lib/deep/water/water_quality_standards/p/interimmgntphosstrat_042614.pdf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Aspetuck
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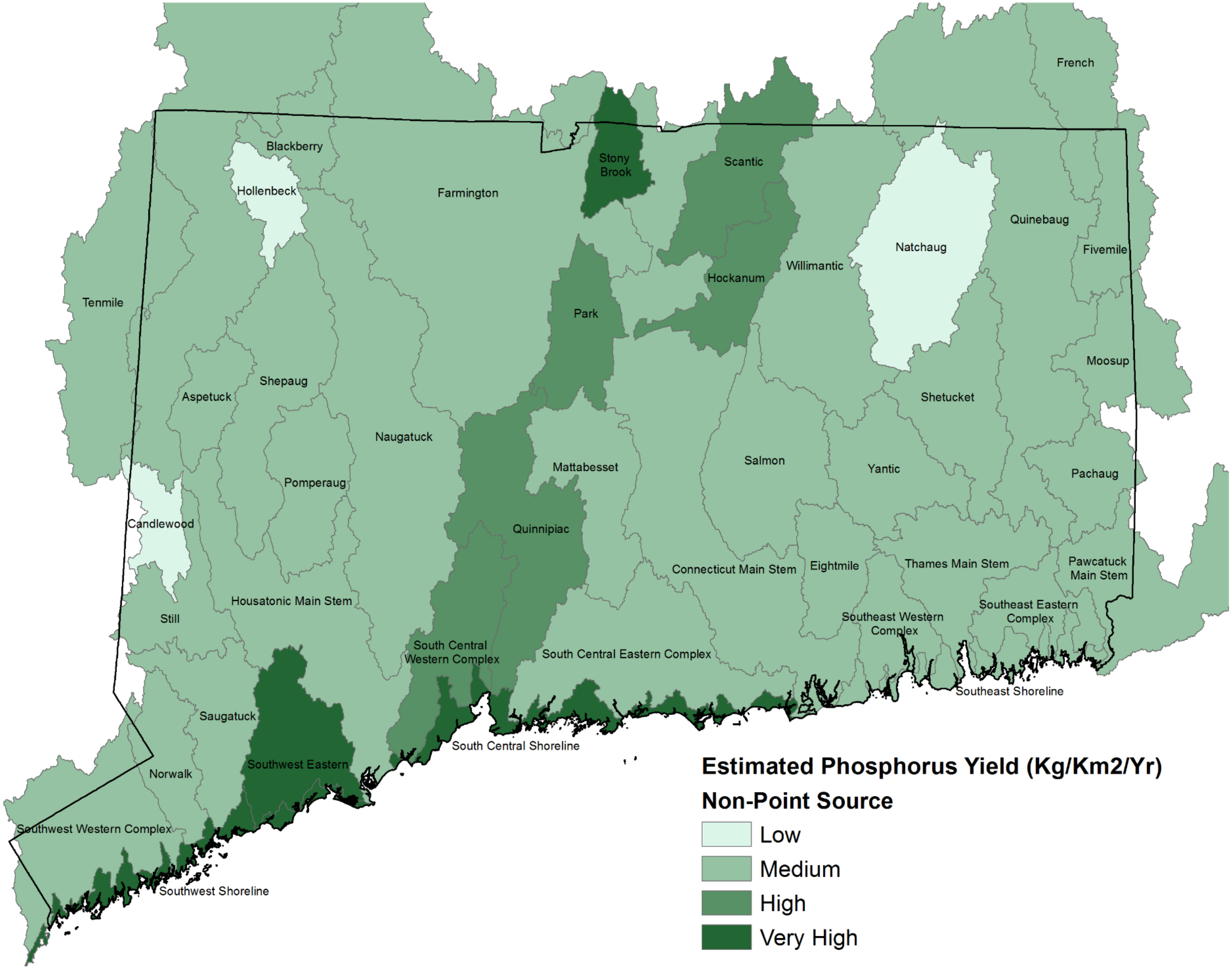
Naugatuck
Salmon
Mattabesset
Yantic
Pachaug
Pomperaug
Candlewood
Quinnipiac
Connecticut Main Stem
Eightmile
Thames Main Stem
Pawcatuck Main Stem
Housatonic Main Stem
Still
Southeast Eastern Complex
Southeast Western Complex
South Central Western Complex
South Central Eastern Complex
Southeast Shoreline
Saugatuck
South Central Shoreline
Southwest Eastern
Norwalk
Southwest Western Complex
Southwest Shoreline
Estimated Phosphorus Yield (Kg/Km2/Yr)
Developed
Low
Medium
High
Very High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Shepaug
Aspetuck
Shetucket
Naugatuck
Salmon
Mattabesset
Yantic
Pachaug
Pomperaug
Candlewood
Quinnipiac
Connecticut Main Stem
Eightmile
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Pawcatuck Main Stem
Housatonic Main Stem
Southeast Eastern Complex
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South Central Western Complex
South Central Eastern Complex
Southeast Shoreline
Saugatuck
South Central Shoreline
Southwest Eastern
Norwalk
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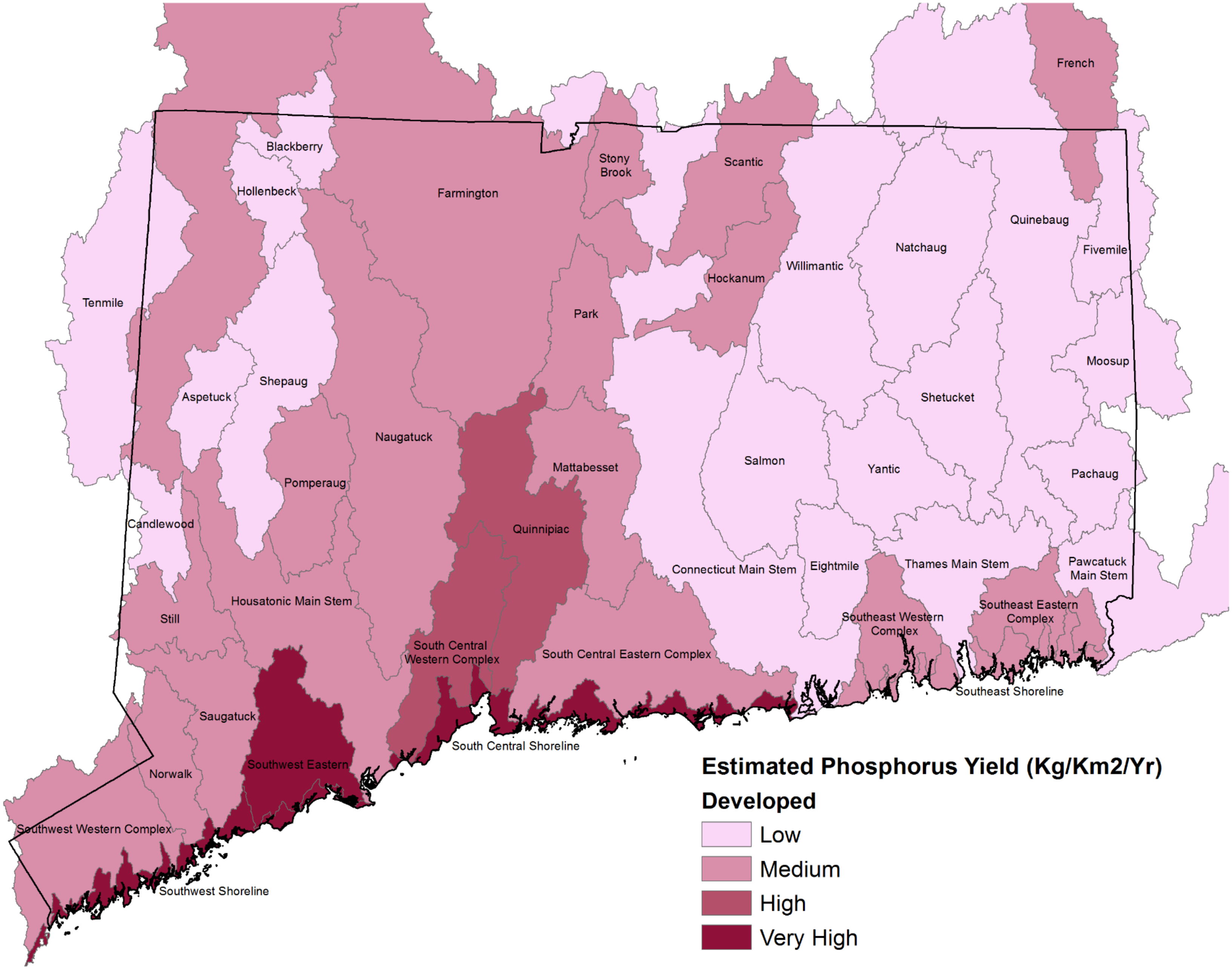
Southwest Shoreline
Estimated Phosphorus Yield (Kg/Km2/Yr)
Non-Point Source
Low
Medium
High
Very High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Southeast Shoreline
Saugatuck
South Central Shoreline
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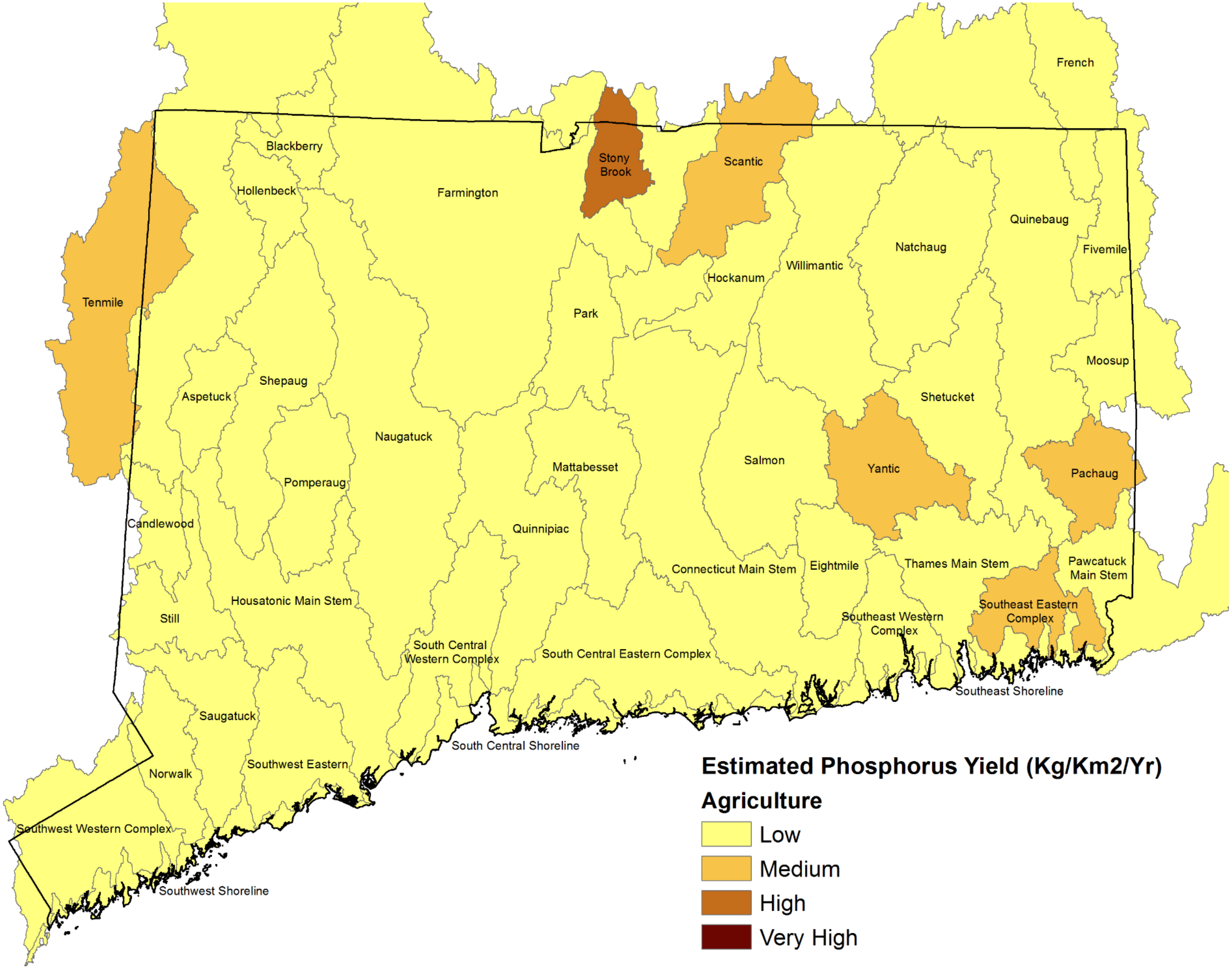
Southwest Shoreline
Estimated Phosphorus Yield (Kg/Km2/Yr)
Developed
Low
Medium
High
Very High


Estimated Phosphorus Yield (Kg/Km2/Yr)
Agriculture
Low
Medium
High
Very High
French
Blackberry
Stony Brook
Scantic
Hollenbeck
Farmington
Quinebaug
Natchaug
Fivemile
Willimantic
Hockanum
Tenmile
Park
Moosup
Shepaug
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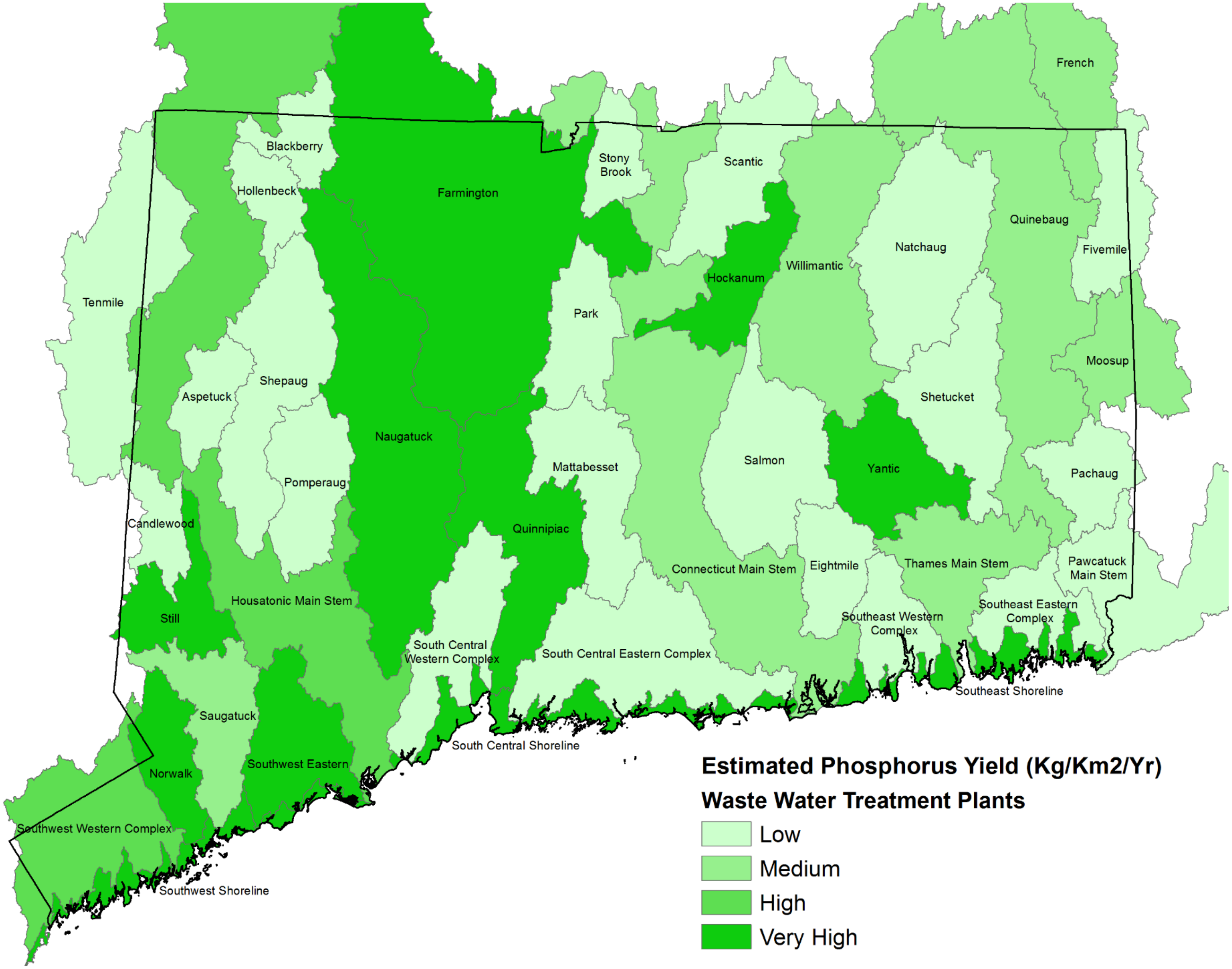
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Southeast Eastern Complex
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Southeast Western Complex
South Central Western Complex
South Central Eastern Complex
Southeast Shoreline
Saugatuck
South Central Shoreline
Southwest Eastern
Norwalk
Southwest Western Complex
Southwest Shoreline
Estimated Phosphorus Yield (Kg/Km2/Yr)
Waste Water Treatment Plants
Low
Medium
High
Very High

6.2 Appendix 2 Urban BMP Performance Efficiency and Costs Analysis

Reducing phosphorus in runoff from urban and suburban areas includes a range of structural and non-structural treatments - best management practices (BMPs) - that vary in removal efficiencies and costs. Structural BMPs are constructed structures designed to capture and treat runoff while non-structural BMPs are programs practices and activities that decrease the amount of phosphorus entering surface waters. Although numerous studies document the costs and performance efficiencies of BMPs data is limited for some BMPs, especially non-structural treatments. Table 1 is a summary of BMP data researched recently by DEEP

6.2.1 BMP Performance Efficiencies

The performance of structural BMPs is influenced by a system's design, installation, and maintenance as well as site conditions, such as the amount of land available, the degree of land development, the form of phosphorus on a site, the phosphorus concentration of inflowing waters, soil type, local climate, and vegetation. In considering the feasibility of a structural BMP type, it is critical to consider these variables along with initial project costs (design, construction, and land costs) and operation and maintenance costs over a 20-year period. For any BMP, it is also important to consider the limitations of the BMP and any supplemental benefits the BMP may provide. For example, a community with few dog owners or few lawn owners would limit the effectiveness of BMPs designed to change behavior through outreach programs aimed at reducing pet waste and changing how lawns are fertilized. Where there are many dog owners, pet waste programs, in addition to reducing phosphorus levels in runoff, also have supplemental benefits like public education, public health and safety, neighborhood beautification, and recreation (CWP 2013).

6.2.2 BMP Costs

In comparing the costs of removing phosphorus and suspended solids (TSS) from runoff waters, phosphorus is more expensive than TSS. Reviewing cost studies for structural and non-structural BMPs is particularly difficult due to differences in the data they report. Some break down costs into three categories – capital costs, maintenance costs, and cost-effectiveness, while others report only on one category. Cost estimates for non-structural BMPs generally do not include the cost of program development.

6.2.3 Structural BMPs

The most cost-effective BMPs for removing phosphorus are infiltration and filtration systems including bioretention units, constructed wetlands, and infiltration basins and trenches (Table 1). Capital costs and cost-effectiveness of structural BMPs, however, can be very site specific. Differences in soil type, bedrock, and slope can cause significant cost variations for the same BMP as can local zoning and permitting conditions, land values, and design features. The design life for most structural BMPs is typically 20 years or greater. In general, design costs for structural BMPs, including site location, surveying, design, planning, and permitting, make up 10% to 40% of the construction budget (King and Hagen 2011).

Operation and maintenance costs, including annual routine maintenance and intermittent (every 3-5 years) maintenance costs, are a substantial portion of stormwater management costs for structural BMPs. In one study, annual maintenance costs as a percentage of capital costs ranged from 5% to 23% (UNH 2012).

Variations in capital and maintenance costs are, in part, dependent on whether a BMP was designed using conventional engineering or a low impact development (LID) approach. Conventional stormwater management focuses on reducing the effects of flooding by conveying stormwater runoff to off-site locations. LID is a method of land planning and engineering design that focuses on managing rainfall on site. The goal of LID is to reduce the impacts of development by replicating the hydrologic conditions of the pre-development landscape. Instead of piping stormwater runoff to watercourse as quickly as possible, LID designs employ techniques to reduce runoff speed and volume and improve runoff quality. The result is a developed landscape with less surface runoff and less pollution entering lakes and streams.

While the environmental and water quality benefits of LID-designed BMPs are more commonly known, there are considerable economic, infrastructure, and planning benefits as well. LID-designed BMPs may have higher capital costs, but lower annual maintenance costs compared to conventional BMPs. Amortized maintenance costs for a retention pond, a conventional BMP, can equal total capital construction costs after only 4.5 years, while amortized costs for LID-designed BMPs, like bioretention, gravel wetland, and porous pavement, equal capital costs after 11 years for bioretention and gravel wetlands and 20 years for porous pavement (UNH 2012).

The economic benefits for construction budgets and project life-cycle costs can also be substantial. For example, in 2009, a LID approach to drainage at a 14-acre New Hampshire condominium development resulted in a 6% reduction ($49,000) in site development expenses compared to the conventional design proposal. Rather than use asphalt paving and typical drainage (curbing, catch-basins, stormwater ponds, outlet structures), the LID design incorporated infiltration and filtration BMPs, roof runoff infiltration trenches, and porous pavement on driveways, sidewalks, and a road. Although porous pavement materials are more expensive than traditional materials, reductions in drainage infrastructure, erosion control, and site clearing resulted in reduced overall costs and more open space on the site. Additionally, by the end of the first winter, property owners reported using substantially less salt for winter de-icing resulting in even greater environmental and cost benefits. In 2008, several LID-designed BMPs were incorporated into a 56-acre New Hampshire retail shopping development resulting in a 26% reduction ($930,000) in stormwater management costs compared to a purely conventional design. Two porous parking lots, totaling 4.5 acres, were installed along with a below-ground reservoir and filtration system and a large gravel wetland to which the lots drained. Although porous paving costs were considerably more expensive, there were substantial savings in site clearing and stormwater infrastructure, primarily large piping. Pre- and post-construction monitoring of waters exiting the gravel wetland showed a high level of treatment for runoff from the site and significant protection for the receiving waters of an already impaired nearby stream. Concentrations of phosphorus and suspended solids were reduced by 84% and 60%, respectively (UNH 2012).

Although the cost benefit of using a LID approach in new developments has been demonstrated, the cost effectiveness of removing phosphorus decreases when BMPs are retrofit vs. new. If municipalities have public works staff, however, the cost of simple retrofits can be reduced. In New Hampshire, a bioretention system was installed in a university parking lot median strip and connected to existing drainage infrastructure. Labor and equipment for retrofitting the existing infrastructure were provided by the facilities department, limiting retrofit costs to design and materials only. Total projects costs were $14,000/impervious acre drained. With labor and equipment provided, costs dropped to $5,500/impervious acre (UNH 2012).

6.2.4 Non-Structural BMPs

Six cost-effective non-structural treatments (BMPs) for removing phosphorus include illicit discharge elimination, enhanced street sweeping, downspout disconnection, education to reduce fertilizer use, and pet waste programs. Illicit discharge elimination and enhanced street sweeping, especially, have great potential to play a significant role in urban stormwater management. Illicit discharges, including leaky sewer pipes, illegal connections, and cross-connections between sanitary sewer lines and storm drains, have been identified as a potentially large contributor to nutrient pollution and, although data on performance and cost is currently limited, correcting these discharges may be a very cost-effective way of reducing phosphorus levels (Lily, et.al. 2012). In Baltimore, for example, it was calculated that phosphorus removed by eliminating one of the identified illicit discharges would be equivalent to building 143 bioretention units, each treating a 0.5 acre of impervious area, at a conservative cost of over $1.7 million dollars

(CWP 2010). While finding and fixing illicit discharges can be costly, once fixed, the problems are permanently remedied at the source.

Street sweeping operations, typically done to maintain appearance and keep storm grates open, can be highly cost-effective at removing phosphorus from stormwater if done more than twice a year, the typical schedule for many public works departments. In Minnesota, a comprehensive 2-year study showed that sweeping frequency, season, and tree canopy coverage substantially impacted the amount of phosphorus removed (Baker, et.al. 2014). Sweeping was highly cost effective when done twice monthly in the spring and fall, especially on roads with relatively high canopy cover from deciduous trees. When compared with the cost of building and maintaining structural BMPs, enhanced street sweeping is far less expensive. In communities with nutrient-impaired waters and relatively high tree canopy cover, especially those in watersheds with specified phosphorus limits, enhanced sweeping can be a valuable tool to meet nutrient reduction goals. To aid communities in comparing the cost and effectiveness of various sweeping frequencies on routes with different canopy covers, a free Street Sweeping Planning Calculator Tool and user manual was developed and can be downloaded by clicking on "Quantifying nutrient removal by street sweeping" (Excel spreadsheet) and "User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping" at http://bit.do/StreetSweeping (Baker, et. al. 2015).

Where infiltration of stormwater is possible, disconnecting downspouts is an easy and cost effective way for homeowners to reduce phosphorus loadings. By directing roof drainage away from foundations and onto gardens, lawns, and landscaped areas, stormwater is removed from the sewer system and slowly soaks into the ground where it is filtered. When water is infiltrated to the ground in well drained soil nearly all the phosphorus is removed, so the efficiency is governed by the infiltrative capacity. In some cases infiltration in severely compacted soil can be enhanced by using a ripping plow and incorporating organic material to enhance soil structure.

Education and outreach programs that aim to reduce fertilizer application rates on lawns, golf courses, and athletic fields can be a cost effective way to reduce phosphorus levels in runoff. Public Act 12-155 limited phosphorus application levels on established lawns and prohibited fertilizer use within 20 feet of a watercourse and on impervious surfaces. Many homeowners with waterfront lots do not understand the water quality value of maintaining naturally-vegetated, unfertilized buffer strips. Residential sources of phosphorus from established parcels could be reduced through intensive public education/outreach programs aimed at homeowners who maintain their lawns and landscapes and manage their yard waste. For new developments, which are not subject to the enacted controls, fertilizer application rates can be limited by conducting soil tests, reducing lot sizes (cluster development), restricting lawn sizes, and/or incorporating more naturally-vegetated buffer areas (Cape Cod Commission 2015). Golf courses, also not subject to the enacted limits, can reduce phosphorus levels in runoff by maintaining no-mow buffer strips around waterways, avoiding fertilizer use in rough areas and before heavy rainstorms, and adjusting application rates based on soil tests.

Pet waste programs can be a cost-effective approach to reducing phosphorus. Data summarizing pollutant loads contributed by pet waste is inconsistent. Dogs produce upwards of 62.7 million pounds per day in the U.S. (DoodyCalls 2014). Dog waste contains phosphorus and pathogens such as bacteria, viruses, and parasites. If left on the ground, these pathogens and phosphorus can make their way to lakes and streams via stormwater runoff. Nutrients can consume oxygen chemically or indirectly by promoting algae blooms which decompose and consume oxygen, and release toxic substances where cyanobacteria are present.

6.2.5 Municipal Stormwater Treatment and Incentive Programs

Municipalities are seeking to address water quality concerns and meet regulatory compliance as their program costs simultaneously climb. Utilization of Low Impact Development strategies can reduce overall project costs associated with stormwater management. The cost-effectiveness of stormwater BMPs can greatly increase if some of the costs are shifted from local government to private landowners. As municipalities develop stormwater management plans, they might consider how to shift some of the cost burden by, for example, establishing stormwater utilities or outreach and incentive programs to encourage landowners to reduce impervious cover or otherwise reduce runoff volume. Stormwater utilities, that assess user fees based on measurable impervious area, can provide a dependable source of revenue and alleviate the need to compete for general tax revenues. In New England, user fees range from approximately \$2-\$12 per month. Annual revenue generated from the fees ranges from approximately \$400,000 in Reading, MA (2006 dollars) to \$2M in Bangor, ME (2012 dollars) and \$4.6M in Fall River, MA (2008 dollars) (AMEC 2014).

Since a large portion of paved area is privately owned, land owner involvement is critical to reducing stormwater runoff in a cost-effective manner. Many municipalities now require new development and redevelopment projects above a certain square footage to manage their stormwater runoff on site as a condition of permit approval. To address runoff from existing development, some stormwater utilities are offering incentives to commercial and residential property owners to retrofit their properties with LID-designed BMPs. Incentives include reduced stormwater fees and construction cost subsidies among others. In Montgomery County, MD, for example, the water department offers rebates to residential (up to \$2500) and commercial (up to \$10,000) property owners that install stormwater BMPs (MCDEP). In Philadelphia, the water department gives a 100% credit for monthly fees to commercial customers who invest in treatments capable of retaining one inch of rainfall on site. The city also gives grant monies to businesses and community organizations to install BMPs that reduce stormwater runoff which, in turn, generates stormwater fee credits and helps lower water bills (Arrandale 2012, NRDC 2012). In 2014, the city launched another grant program that encourages contractors and design/construction firms to develop large scale stormwater retrofit projects with multiple BMPs (City of Philadelphia).

6.2.6 References

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Table 5.2.1 Removal Efficiency, Capital Costs, Maintenance Costs, Type, and Frequency, and Cost Effectiveness for Urban Stormwater Best Management Practices (BMPs).

BMP Type	BMP Description	% Removal Efficiency		Capital Cost	Cost Effectiveness[a]		Maintenance Cost	Maintenance Type/Frequency
		TP (mg/l)	TSS (mg/l)	$	TP $/lb. removed	TSS $/lb. removed	$/acre/year	
Structural Pretreatment BMPs								
Deep Sump Catch Basin	An underground retention system that removes coarse sediment, trash, and debris from stormwater runoff and serves as a spill containment for floatables like oil and grease.	NT[9]	9[11] 25[9] (if hooded)	ND	ND	ND	ND	• Inspect four times annually and at end of foliage and snow removal seasons. • Remove sediment four times a year or when 50% of sump volume is filled.[9]
Oil/Grit Separator	An underground storage tank with three chambers designed to remove heavy particulates, floating debris, and hydrocarbons from stormwater.	ND	25[9]	ND	ND	ND	ND	• Inspect monthly and after major storms. • Clean biannually with a vacuum truck.[9]
Proprietary Separator	A flow-through structure with a settling or separation unit to remove sediment and other pollutants.	ND	ND	ND	ND	ND	ND	Inspect and remove sediment and other pollutants based on manufacturer recommendations.[9]
Sediment Forebay	A pit, bermed area, or cast structure combined with a weir, designed to slow incoming stormwater runoff and facilitate the settling of suspended solids.	ND	25[9] (if off-line)	ND	ND	ND	ND	• Inspect monthly. • Remove sediment at least four times per year. • Mow and re-seed as needed.[9]
Vegetated Filter Strip (various widths)	A uniformly graded area with low-growing, dense vegetation that treats runoff running through it as sheetflow by slowing runoff velocity, trapping sediment, and promoting infiltration.	ND	10[9] (25') 45[9] (50')	ND	ND	ND	ND	• Inspect for erosion and sediment buildup every 6 months. Remove sediment as needed. • Mow frequently and re-seed as needed.[9]
Structural BMPs								
Baffle Box	A structure containing a series of sediment settling chambers.	20[10]		ND	ND	ND	ND	ND
Bioretention Unit/Rain Garden[b] (rain gardens = residential bioretention units)	A shallow, landscaped depression filled with soil mix, topped with a thick layer of mulch, and planted with dense native vegetation. Stormwater runoff collects in the unit and filters through the soil mix, treating the runoff before it reaches groundwater or is conveyed to a discharge outlet, a municipal storm drain, or another BMP.	NT-85[5,11,13] 59[5] (retrofit)	45-97[5,9,11] 63[5] (retrofit)	$25,600/acre drained[11] (2012 dollars) Cost does not include design, permitting or construction supervision.[11]	$2,935-$5,544/lb.[5] (2011 dollars) $12,501/lb.[5] (retrofit) (2011 dollars)	$5.82-$9.53[5] (2011 dollars) $22.25[5] (retrofit) (2011 dollars)	$1900[11] (2012 dollars)	• Inspect monthly for signs of erosion. • Mow, rake, and remove trash and invasive plants monthly. • Mulch, prune and replace dead vegetation annually. • Water plants during initial establishment and drought. • Be careful with snow – do not plow or store snow in unit.[9]
				$160,000/8 rain gardens[3] (2007 dollars)	$2791-$4329/lb.[3] (2008 dollars)	$0.39-$0.46[3] (2008 dollars)	$5,803-$7544 /8 gardens[3] (2008 dollars)	
Constructed Wetland (a.k.a. shallow marsh, pocket wetland, basin/wetland, extended detention wetland)	A shallow constructed pool that temporarily stores runoff creating conditions suitable for the growth of wetland vegetation. Pollutants are removed from runoff through retention and settling and uptake by vegetation.	40-60[5,9] 40[3] (retrofit)	60-80[5,9] 51[3] (retrofit)	ND	$2,847/lb.[5] (2011 dollars) $6,670/lb.[5] (retrofit) (2011 dollars)	$4.49[5] (2011 dollars) $10.99[5] (retrofit) (2011 dollars)	ND	• Inspect twice a year. • Clean forebay annually. • Remove sediment in basin every 10 years. • Include measures to monitor and prevent invasive species in O&M plan.[9]

Detention Pond and Extended Detention Pond (a.k.a. dry pond, dry detention basin, dry extended detention basin)	A low-lying area designed to temporarily retain stormwater runoff that slowly drains to a downstream water body. Extended ponds are designed to hold stormwater for at least 24 hours to allow solids to settle.	NT-80[9,10,11,13]	NT-79[6,9,11]	$16,500/acre treated[11] (2012 dollars)	$10,572 - 21,143/lb.[5] (2011 dollars)	$7.41 - $44.43[5] (2011 dollars)	$2,380 [11] (2012 dollars)	- Inspect outlet structure twice a year for evidence of clogging. - Mow and remove trash and debris at least twice a year. - Remove sediment at least every 5 years.[9]
Drainage Channel	Vegetated open channels designed for non-erosive conveyance of stormwater rather than treatment. Pollutant removal by sedimentation, filtration, and biological activity is limited.	ND	0[9]	ND	ND	ND	ND	- Inspect twice a year for slope integrity, ponding, vegetation health, sediment accumulation and signs of erosion. - Mow and reseed as needed. - Remove sediment/debris at least once a year.[9]
Gravel Wetland (subsurface)	A series of horizontal flow-through treatment cells preceded by a sediment forebay. Stormwater runoff is treated as it passes through the microbe rich gravel substrate.	58[10]	96[10]	$27,400/acre treated[10] (2012 dollars)	ND	ND	$2140[11] (2012 dollars)	- Remove sediment from forebay/treatment cells. - Remove vegetation at least once every three growing seasons.[11]
Hydrodynamic Separators (HDS) (On-line and Off-line)	Proprietary devices that use features to remove sediment, nutrients etc. from urban runoff.	NT-10[5,11]	10-80[5,11]	$18,000-$20,000/acre runoff treated plus $3,000 upstream flow diversion materials and installation[11]	$32,866/lb.[5] (2011 dollars)	$69[5] (2011 dollars)	ND	- Inspect quarterly to assess sediment accumulation. - Remove sediment with a vacuum truck.[11]
Impervious Urban Surface Reduction	A change in land use from impervious to urban pervious.	N/A	N/A	ND	$7,354/lb.[5] (2011 dollars)	$11.96[5] (2011 dollars)	N/A	None.
Infiltration Practices (basins and trenches)	A depression where stormwater runoff is trapped and gradually drains through the bottom and/or sides into the subsoil and eventually into the groundwater.	60-85[5,9,13]	80-95[5,9]	ND	$3252-$3399/lb.[5] (2011 dollars)	$5.53-$5.78[5] (2011 dollars)	ND	- Inspect after major storms for first 3 months then twice a year and when discharges through outlet are high. - Inspect/clean pretreatment devices every other month and after major storms. - Mow grass bottoms, rake stone bottoms, and remove trash, debris, and grass clippings twice a year. [9]
Leaching Catch Basin	A pre-cast concrete barrel and riser with an open bottom that permits runoff to infiltrate into the ground.	ND	80[9] (if with pre-treatment)	ND	ND	ND	ND	- Inspect annually and remove debris. - Remove sediment when basin is 50% filled. - Rehabilitate basin if clogging causes failure.[9]
Media Filtration	Two-chambered underground concrete vaults that reduce pollutants in stormwater runoff by settling out large particles in the first chamber and filtering flow through special media in the second chamber. The type of media used depends on the pollutant targeted.	40-42[6,13]	83[6]	ND	ND	ND	ND	- Inspect filtering media for clogging. - Inspect for standing water and sediment at least twice a year. - Remove trash and debris during inspections. - Annually inspect after large storms to determine if system drains in 72 hours.[9]
Permeable Pavement: Grass Pavers (a.k.a. turf blocks)	Concrete or synthetic paving units with open cells which are filled with soil and planted with turf.	ND	ND	ND	ND	ND	ND	- Inspect annually for signs of deterioration. - Periodically reseed to fill in bare spots. - In winter, do not sand and minimize salt use. - Attach rollers to bottom of snowplows to prevent from catching on pavers.[9]

Permeable Pavement: Permeable Interlocking Concrete Pavement (PICP)	Pervious pavement system comprised of interlocking precast paving units (also called paving stones). Stormwater drains through the joints between the pavers and into a stone sub-base that supports the pavers and stores and treats runoff.	99[11]	99[11]	$4/sf[11] (2010 dollars) Cost is for mechanical installation and increases with hand installation.[11]	ND		ND	ND	- Remove surface debris by air vacuuming or use leaf blower at least twice annually. - Add joint material to replace material that has been transported. - In winter, do not sand and minimize salt use. - Attach rollers to bottom of snowplows to prevent from catching on pavers.[8,11]
Permeable Pavement: Pervious Concrete	Concrete pavement with a higher than normal percentage of pore spaces that allow stormwater to pass through and infiltrate into the ground.	NT[11]	85[11]	$4-$5/sf[11] (2012 dollars) Cost does not include site work and sub-base construction.[11]	ND		ND	ND	- Inspect annually for signs of deterioration. - Use power washer to dislodge trapped particles then vacuum sweep at least twice a year. - Regularly monitor for proper drainage. - In winter, do not sand and minimize salt use.[9,11]
Permeable Pavement: Porous Asphalt	Asphalt pavement with a higher than normal percentage of pore spaces that allow stormwater to pass through and infiltrate into the ground.	20-80[5,11]	70-99[5,6,11]	$26,600[11] (2012 dollars) $2.80-$3.17/sf[11] (2008 dollars) Costs do not include site work and sub-base construction.[11]	$12,563 - (2011	$70,342/lb.[5] dollars)	$22.47-$48.61[5] (2011 dollars)	$1080[11] (2012 dollars)	- Inspect annually for signs of deterioration. - Use power washer to dislodge trapped particles then vacuum sweep 2-4 times annually. - Regularly monitor for proper drainage after storms. - In winter, do not sand and minimize salt use.[9,10]
Retention Pond (a.k.a. wet pond, stormwater pond)	A constructed basin with a permanent pool of water that treats stormwater runoff by allowing sediment and other pollutants to settle.	NT-70[6,9,11]	68-80[6,9,11]	$16,500[11] (2012 dollars)	ND		ND	$3060[11] (2012 dollars)	- Mow and remove trash, debris, and sediment from forebay biannually. - Remove sediment from basin as needed.[9]
Sand & Organic Filter (a.k.a. filtration basin)	A bed of sand or peat (or combination of the two) underlain with perforated underdrains or designed with cells that have inlets/outlets. Stormwater runoff is filtered through the bed before being discharged or conveyed to another BMP.	10-60[5,9,11]	51-80[5,9,11]	$15,200/acre treated[11] (2012 dollars)	$4,542-$4,490/lb.[5] (sand filter) (2011 dollars)		$6.47-$7.04[5] (sand filter) (2011 dollars)	$2810[11] (2012 dollars)	Inspect filters and remove debris after major storms for first few months then every six months.[9]
Subsurface Structure (*e.g.*, infiltration pit, chamber, perforated pipe, galley)	An underground system that captures stormwater runoff and gradually infiltrates it into the groundwater through rock and gravel.	ND	80[9]	ND	ND		ND	ND	- Inspect inlets at least twice annually and remove debris. - Include mosquito controls in O&M plans.[9]
Swale (Stone-lined)	A drainage channel with an erosion-resistant rock lining designed to carry stormwater runoff to an outlet.	NT[11]	50[11]	ND	ND		ND	ND	ND
Swale (Vegetated) (a.k.a. wet swale, dry swale)	A broad, shallow, densely vegetated channel designed to capture and slow stormwater runoff by spreading it horizontally across the landscape, facilitating runoff infiltration into the soil.	NT-90[5,9,11]	50-70[5,9,11]	$14,600/acre treated[11] (2012 dollars)	ND		ND	$820[11] (2012 dollars)	- Inspect for signs of erosion. Repair/replant eroded areas. - Remove sediment and debris annually. - Re-seed swales as needed. - Mow dry swales as needed.[9]
Tree Box Filter	A mini-bioretention unit installed beneath a tree behind a curb. Units can be open-bottomed, where infiltration is desirable, or close-bottomed where infiltration is impossible or undesirable.	NT->50[11]	>80-91[11]	$4,000-$6,000/unit/0.1 acre treated (closed system)[7,11] (2015 dollars)	ND		ND	$100-$500/unit[7,8] (2015 dollars)	- Inspect 1-4 times annually to assure bypass and soils are adequately conveying water. - Remove leaves and trash regularly. - Rake media surface biannually to maintain permeability.

				$8,000-$11,000/unit/0.25-0.75 acre treated (open system)[7] (2015 dollars) Installation: $1500 and up depending on number of units [7,8] (2015 dollars)				- Replenish mulch as needed. - Water plants during initial establishment and extreme drought. [8,9,11]
Urban Stream Restoration	Projects that reduce flooding and erosion and restore, enhance, or protect the natural ecological values of streams.	0.068 lb./ft.[5]	52.5 lb./ft.[5]	ND	$769/lb.[5] (2011 dollars)	$1/lb.[5] (2011 dollars)	ND	ND
Non-Structural BMPs								
Downspout Disconnection	Redirection of downspout from impervious area or storm drain to lawn or other pervious area.	ND	ND	ND	$30/lb.[4] (2014 dollars)	<$1/lb.[4] (2014 dollars)	$0	None.
Fertilizer Use Education/Reduction Program	Program to reduce fertilizer application rates on lawns, golf courses, and athletic fields. Residential application rates are reduced through intensive public education/outreach.	3-10[2]	NT	ND	$311/lb.[2] (2015 dollars)	N/A	$0	None.
Forest Buffer[s]	Area of trees at least 35 ft. wide on either side of a stream, accompanied by other vegetation.	50[5]	50[5]	ND	$1,851/lb.[5] (2011 dollars)	$7.66[5] (2011 dollars)	ND	ND
Illicit Discharge Elimination	Program to correct cross-connections and repair leaky sewers.	100[5]	100[5]	ND	$35-$71/lb.[5] (2011 dollars)	$0.89 - (2011 - $6.69 [5] dollars)	$0	None.
Organic Waste/Leaf Litter Collection	Municipal program to pick-up leaves and other landscape debris on a weekly basis.	5[12]	ND	ND	ND	ND	ND	ND
Pet Waste Program	Municipal program to reduce pet waste via installation of pet waste stations.	ND	NT	ND	$938/lb./pet waste station[4] (2014 dollars)[d]	N/A	ND	- Refill bags. - Empty trash baskets. - Replace damaged baskets.[4,5]
Phosphorus Ban in Fertilizers	Manufacturer requirement to remove phosphorus from lawn fertilizer.	10-33[12]	NT	ND	ND	N/A	$0	None.
Street Sweeping (enhanced) (enhanced sweeping = sweeping more than twice annually)	Pickup of street litter and dirt using a street sweeper more than twice annually.	1-15[5,10,12]	9[5]	ND	<$100/lb. - (spring/fall, high canopy) (2012 $600/lb.[1] (summer, low canopy) dollars)[e]	$10-$11.58 [5] (2011 dollars)[f]	ND	Maintain sweeper as needed.
Urban Tree Planting	Planting trees on urban pervious areas to produce a forest-like condition over time.	ND	ND	ND	$9,621/lb.[5] (2011 dollars)	$46.23/lb.[5] (2011 dollars)	ND	ND

NT = no treatment, ND = no data or insufficient data available, N/A = not applicable

Pretreatment BMPs are used to treat runoff before it reaches another BMP. Proprietary BMPs are listed by category only, not by proprietor. TP = total phosphorus, TSS = total suspended solids.

[a] Cost-effectiveness values for BMPs were generally grouped into cost-effectiveness categories - green (High), yellow (Moderate), red (Low) - for each pollutant. Cut-off values between categories are based on similar cut-offs from the Center for Watershed Protection.

[b] P-removal efficiency is enhanced by adding certain amendments to bioretention soil mixes. Research into bioretention design and soil media amendments is ongoing.

[c] Assumes land use change from urban pervious.

[d] Cost is for Year 1 and includes installation and maintenance of a single pet waste station in an area with lots of dogs (*e.g.*, dog parks, public parks, walking trails). Pet waste stations include sign, trash basket, and bags. Cost assumes a usage rate of 10 bags per station per day. Post Year 1 cost is lower and includes maintenance only.

[e] Based on 392 sweepings from snowmelt to snowfall on streets with 0-20% canopy cover of north-temperate deciduous trees. Assumes use of a regenerative air sweeper.

[f] Cost-effectiveness values dependent on method of calculation (mass loading vs. street lane).

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6.4 Appendix 4 DEEP's Primary NPS Partner Organizations

6.4.1 USDA Natural Resources Conservation Service (NRCS)

Agricultural NPS pollution in Connecticut is addressed primarily through outreach, funding and technical assistance provided by federal and state agencies including the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), USDA Farm Service Agency. NRCS offers technical and financial support to farm businesses in their farm waste efforts through the "Partnership for Assistance on Agricultural Waste Management Systems." Through this partnership, a farm business may obtain waste management planning, facility design, and qualify for financial assistance, as well as help in procuring required permits. Technical assistance is also available in selecting and implementing agricultural BMPs and soil erosion control methods and technologies.

A number of financial and technical assistance programs are implemented by the NRCS through the federal Farm Bill. The Environmental Quality Incentives Program (EQIP) in particular provides financial and technical assistance to agricultural producers to address natural resource concerns and deliver environmental benefits such as improved water quality. Eligible program participants receive financial and technical assistance to implement conservation practices that address natural resource concerns on their land. NRCS delivers conservation technical assistance through its Conservation Technical Assistance Program.

NRCS and DEEP cooperatively offer a variety of technical resources and assistance implementing agricultural BMPs including:

- Livestock exclusion fencing
- Manure collection and storage
- Comprehensive Nutrient Management Plans (CNMPs)
- Cover crops
- Vegetated buffers, filter strips
- Covered heavy use areas
- Diverting clean water
- Soil health

The National Water Quality Initiative Program (NWQI) further helps target water quality impaired watersheds with enhanced NRCS funding and assistance.

6.4.2 US Environmental Protection Agency (EPA)

US EPA provides Clean Water funding under Section 319 NPS funds help support DEEP's Nonpoint Source Program. NPDES Stormwater General Permit authority is delegated to DEEP by EPA. EPA also provides a number of research and technical assistance efforts for NPS and stormwater.

6.4.3 NEW England Interstate Water Pollution Control Authority (NEIWPCC)

NEIWPCC supports state water programs by coordinating activities and forums that encourage cooperation among the states and interstate issues, developing resources that foster progress on water and wastewater issues, representing the region in matters of federal policy, training environmental professionals, initiating and overseeing scientific research projects, educating the public, and providing overall leadership in interstate water management and protection.

6.4.4 Connecticut Department of Public Health

DEEP delegates the authority to regulate onsite wastewater systems which handle less than 5000 gallons per day to the CT Department of Public Health (DPH) who in turn delegate some of that authority to local Health Departments. DPH also administers a program to manage public drinking water supply systems, drinking water supply planning and source water protection.

6.4.5 Connecticut's Soil and Water Conservation Districts

Provide technical advice to a wide range of stakeholders including municipalities and their land use boards. Many of the Conservation District's activities involve helping assure compliance with Storm Water Manual and Erosion and Sedimentation Manual, promoting Low Impact Development and Green Infrastructure on a local level, and planning activities to assure that the important functions of soils and water conservation can be implemented consistently and efficiently statewide.

6.4.6 University of Connecticut (UConn) Cooperative Extension Service: Clear and NEMO Programs, Extension

Centers; Engineering, etc.

CLEAR and NEMO programs. DEEP has had a long relationship with UConn providing Nonpoint Source Education and outreach to Municipal Officials. The Clear program has provided extensive technical expertise and outreach to implement green infrastructure and low impact development practices, as well as analysis of Municipal land use regulations to better enable adoption of these practices. DEEP continues to work with Clear on municipal outreach for NPS and stormwater management.

6.4.7 Connecticut Agricultural Experiment Station (CAES)

CAES provides valuable technical and research science for many agricultural and water-related disciplines. Staff have long been key technical advisors in several important areas of the phosphorus pollution problem, particularly inputs to Connecticut lakes and their role in triggering harmful algal and cyanobacteria blooms, as well as devising strategies to minimize and address other impacts resulting from excess nutrients in runoff.

6.4.8 Municipalities

Connecticut’s 169 municipalities are the primary partner for land use and water quality management activities statewide. They regulate land use through planning, zoning and inland wetlands and watercourses authorities. They also are responsible for implementing MS4 stormwater program.

6.4.9 Connecticut Department of Agriculture

CT Dept. of Agriculture has regulatory authority over fertilizer sales in the State and farmer assistance programs. Their Aquaculture Division also is involved with sanitary surveys and related pollution problems affecting of shellfish areas coastal waters.

6.4.10 Other Important Partners

Regional Councils of Government
Water Utilities
Rivers Alliance of Connecticut
Trout Unlimited
The Nature Conservancy
Local and Statewide Watershed and Lakes Stakeholder organizations
Others, too numerous to mention including: citizens, civic organizations, news media, business and industry, youth groups, schools and universities.