United States
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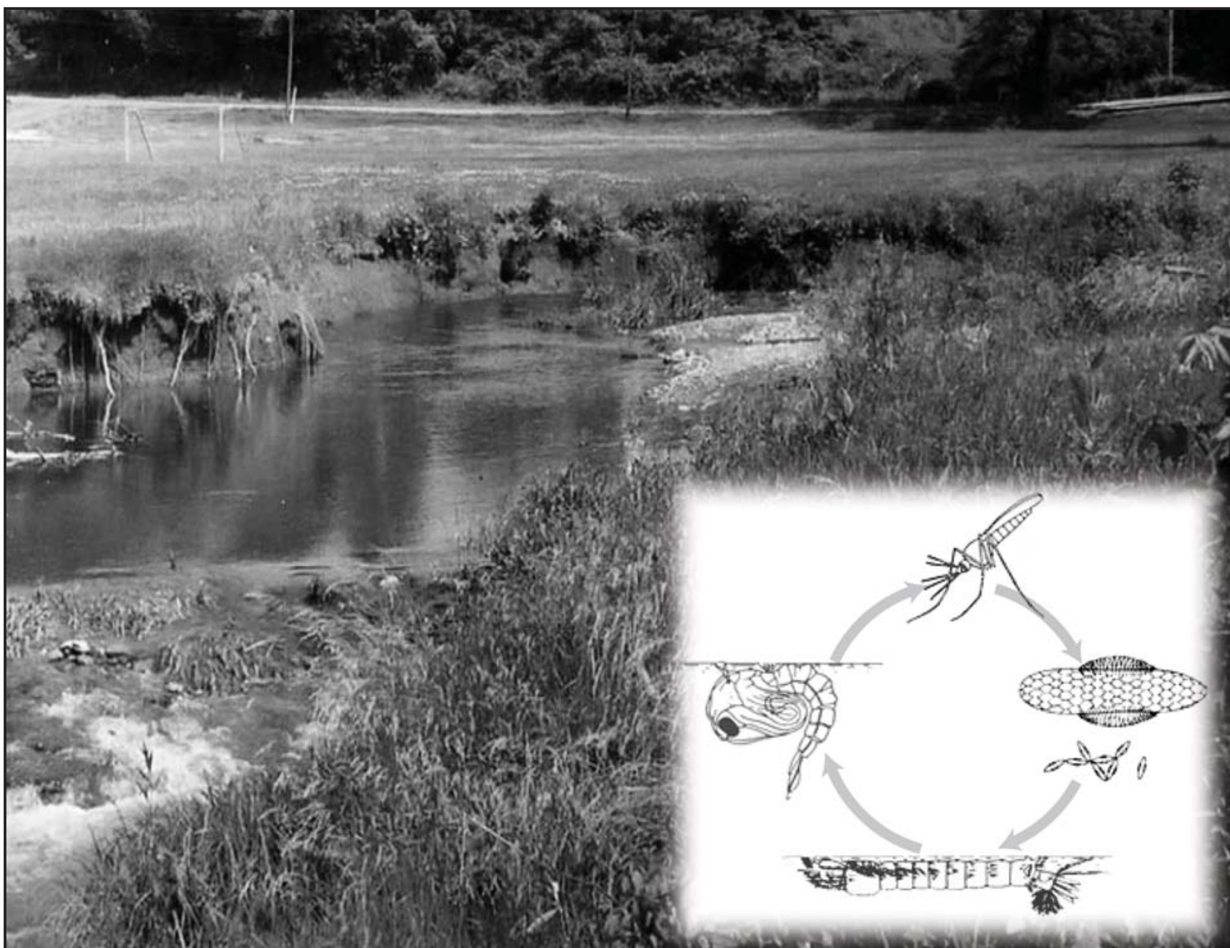
Proceedings of the Workshop on Stormwater Management and Mosquito Control



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Proceedings of the Workshop on Stormwater Management and Mosquito Control

Edited by
Patricia Bradley
U.S. Environmental Protection Agency
and
Frederick W. Kutz, Ph.D.
Consultant in Environmental Sciences

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Abstract

A workshop on various aspects of stormwater management was held at WorWic Community College, Salisbury, MD, on February 9, 2005. The management of stormwater received national prominence as an important part of the Federal Clean Water Act. The workshop emphasized four distinct but related attributes of stormwater management areas: water quality considerations, mosquito production, wildlife habitat and engineering parameters. The objective of the meeting was to develop consensus guidance and recommendations for the construction, modification and maintenance of facilities that promote water quality, limit mosquito production and provide wildlife habitat to the extent possible. Workshop organizers developed a list of expectations that considered the role of stormwater best management practices (BMPs) in the context of legislatively and regulatorily driven objectives, engineering considerations and ecological considerations (wildlife habitat and mosquito production). The results of the workshop indicated that it is possible to achieve water quality objectives and at the same time to limit mosquito production in stormwater management facilities. The success of simultaneously resolving these two objectives rest with site specific planning and flexible, innovative engineering solutions. A critical task associated with stormwater management areas is periodic maintenance. Maintaining stormwater areas falls to the property owner. In most cases, the owner is an individual or a homeowners' association unaware that these areas require ongoing and sometimes extensive periodic maintenance. The existence and effects of predators on mosquito populations in stormwater management facilities remain somewhat unknown; certain species of fish appear to be the best predators. Similarly, the use of stormwater areas as wildlife habitat has been poorly explored. Presentations made at the workshop can be found on the EPA Web site at http://www.epa.gov/maia/html/swmprog.html.

Keywords: Stormwater management facilities, mosquito production, wildlife habitat, stormwater engineering, ecological services, mosquito control, Clean Water Act

Acknowledgements

Many people and organizations assisted in the planning and implementation of the Stormwater Workshop. Their contributions ranged from making individual suggestions, to working on the steering committee and providing services needed to hold a successful workshop. Acknowledgement with thanks is made for all of their efforts.

We gratefully acknowledge the following organizations for providing either financial or in-kind support for the workshop:

Delaware Center for the Inland Bays
Delaware Department of Natural Resources and Environmental Control
Maryland Coastal Bays Program
Maryland Department of Agriculture
Maryland Department of the Environment
Maryland Pesticide Advisory Committee
U.S. Environmental Protection Agency – MAIA Team
WorWic Community College

The major planning and implementation for the workshop was accomplished by using a steering committee. The steering committee initiated and managed all aspects of the workshop (Table 1, pg 2).

The appropriate citation for this report is:

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Contents

A Workshop on Stormwater Management and Mosquito Control

Presented by:
Frederick W. Kutz, Ph.D.[1], 4967 Moonfall Way, Columbia, MD 21044

Stormwater management has been a subject generating controversy since its inception under the Federal Clean Water Act. Most stormwater management strategies include the use of a collection basin, pond or area into which stormwater from roads, parking lots, etc., drains. The principal purpose of these ponds is to provide treatment that will improve the quality of the water as it drains into the ground water layers. The natural processes in the pond theoretically will reduce the levels of nutrients, sediment and toxic pollutants in the water. Some observers have noted that these ponds provide limited habitat for wildlife and waterfowl.

Stormwater management areas require periodic maintenance. The task of maintaining stormwater areas falls to the property owner. In most cases, the owner is an individual or a homeowners' association. Some individuals or associations seek professional support while others, particularly those with dry ponds, choose to manage them on their own. Still other property owners may not even be aware that these areas require ongoing and sometimes extensive periodic maintenance.

Certain types of these areas (both well maintained and poorly maintained) have the potential to provide productive larval habitat to certain species of mosquitoes (Banks 2003 and Walton 2003). The adults of several species of mosquitoes found in these areas have been incriminated as efficient vectors of human and animal diseases, i.e., West Nile virus. The presence of these vector species within a developed area presents public health and economic challenges that requires some type of mitigation (Zohrabian et al. 2004). Mosquito control in these management areas usually involves the use of pesticides. In certain pond environments, however, populations of predatory fish and perhaps some other animals seem to contribute to control of mosquito larvae.

These attributes of water quality improvement, limited habitat provision and mosquito production when considered as an assemblage pose conflicting and complex problems for all concerned. In many cases the exact location of these areas is unrecorded. Also, the efficacy of the areas in providing their environmental services is not monitored. Only limited information is available on non-chemical means of mosquito control. Stormwater management area maintenance is lacking in many locations. The grand convergence of these factors provides ample justification for convening a workshop to discuss stormwater management with emphasis on mosquito control in an open, non-confrontational forum.

Objective

This workshop focused exclusively on stormwater management areas in the Coastal Plain of Maryland and Delaware. It emphasized four distinct but related attributes of these structures: water quality considerations, mosquito production, wildlife habitat and engineering parameters. The objective of the meeting was to develop consensus guidance recommendations for the construction, modification and maintenance of these facilities that promote water quality, limit mosquito production and provide wildlife habitat to the extent possible.

The Steering Committee developed a list of expectations for the workshop to aid in guiding the discussions and focusing comments. Each participant was requested to consider the role of stormwater BMPs in the context of legislatively/regulatorily driven objectives, engineering considerations and ecological considerations (wildlife habitat and mosquito production).

[1]Although Dr. Kutz is an independent consultant in environmental sciences, his efforts on behalf of the workshop were voluntary as a contribution to his work as a member of the MD Pesticide Advisory Committee.

Participants were asked to arrive at the workshop prepared to discuss their thoughts on the following six issues:

1. Which stormwater BMPs have the greatest potential for mosquito production?
2. What maintenance practices, by BMPs, would reduce mosquito production and improve BMP effectiveness?
3. What mosquito control practices are recommended for different BMPs?
4. What re-engineering designs might decrease mosquito production but retain wildlife habitat and BMP efficiency?
5. What recommendations are there for increasing public awareness and knowledge about the need for stormwater BMPs and the potential for mosquito production and control?
6. What research is needed to contribute to answering the five questions above?

This workshop was considered a pilot effort. The members of the Steering Committee hope that if deemed successful by participants, other similar workshops may be convened in the Mid-Atlantic area.

Date and Venue

The workshop was a one-day session held on Wednesday, February 9, 2005, in the Academic and Administrative Building, AAB III, WorWic Community College, Salisbury, MD.

Workshop Products

These proceedings of the workshop were assembled, published and distributed by the U.S. EPA to each participant. Additionally, all presentations made at the conference can be found on the EPA Web site at www.epa.gov/maia.

Table 1. Steering Committee for the MD-DE Stormwater Workshop

Steering Committee for the MD-DE Stormwater Workshop		
Cyrus R. Lesser MD Dept. of Agriculture 410-841-5870 lessercr@mda.state.md.us	Charlie Wallis MD Dept. of the Environment 410-537-3543 cwallis@mde.state.md.us	Roman Jesien MD Coastal Bays Program 410-213-2297 science@mdcoastalbays.org
Edward A. Lewandowski DE Center for the Inland Bays 302-645-7325 director@inlandbays.org	M. Patricia Bradley EPA Mid-Atlantic Integrated Assessment Team 410-305-2744 bradley.patricia@epa.gov	William H. Meredith DE DNR and Environmental Control DE Mosquito Control Section 302-739-9917 william.meredith@state.de.us
Frederick W. (Rick) Kutz 410-730-8865 rick.kutz@comcast.net	Lynne Lewis EPA MAIA Team 410-305-2751 lewis.lynn@epa.gov	Kent Thornton FTN Associates 501-225-7779 kwt@ftn-assoc.com

Presented by:
Kevin Magerr, USEPA
(Written by: Patricia Bradley, USEPA)

Stormwater Primer

When it rains, or when snow melts, the resulting water may be absorbed into the ground or it may run off the land surface into a nearby lake, stream, or estuary.

Pervious surfaces, such as meadows and woodlands, absorb and infiltrate rainfall, and generate very little stormwater runoff. Impervious surfaces such as paved streets, driveways, sidewalks, parking lots, and building rooftops prevent stormwater from naturally soaking into the ground. Stormwater runoff from residential, commercial and industrial sites picks up fertilizers, dirt, pesticides, oil and grease, heavy metals, and many other pollutants.

Stormwater runoff is responsible for 21 percent of impaired lakes and 45 percent of impaired estuaries in the United States. In the Mid-Atlantic Region alone, stormwater is responsible for 5,265 miles of impaired streams. These impacts are caused not only by the quality of runoff, but also by its quantity, as a high volume of flow contributes to erosion and sedimentation, and impacts aquatic habitats.

Clean Water Act

In 1948 Congress passed the Federal Water Pollution Control Act, 33 U.S.C. §§ 1251-1387, commonly known as the Clean Water Act (CWA). Since 1948, the original statute has been amended to authorize additional water quality programs, standards and procedures to govern allowable discharges, funding for construction grants and general program funding. Section 402 of the 1972 amendments established the National Pollutant Discharge Elimination System (NPDES) to authorize EPA issuance of discharge permits (33 U.S.C. 1342).

The CWA was amended in 1987 to require implementation of a comprehensive national program for addressing stormwater discharges. EPA issued Phase I of the NPDES Stormwater Program in 1990 requiring NPDES permits for stormwater discharges from large municipalities and certain industrial sources (including construction sites disturbing at least 5 acres.). Permits from these sources were required to be submitted beginning in 1992. EPA issued Phase II of the NPDES Stormwater Program in 1999 to require NPDES stormwater permits from smaller cities and smaller construction sites and public entities that own or operate a municipal separate storm sewer system (MS4).

NPDES is administered through EPA Regions or state offices within those regions that have been granted the authority by EPA. Most states have been delegated authority to run the NPDES permitting program and issue NPDES stormwater permits within their state boundaries. EPA regional offices still issue NPDES stormwater permits in nine states/ territories (AK, AZ, DC, ID, MA, ME, NH, NM, and PR) and on federal facilities or Native American lands in some delegated states.

EPA Region 3

The Mid-Atlantic regional office of the U.S. Environmental Protection Agency, is responsible for programs in Delaware, Maryland, Pennsylvania, Virginia, West Virginia and the District of Columbia. Headquartered in Philadelphia, the region has field operations and laboratories in Wheeling, WV, Annapolis and Ft. George G. Meade, MD, and Pittsburgh, PA.

The Water Protection Division is responsible for the management and implementation of the Region's programs to protect, preserve, and enhance water resources. The Division administers programs authorized by the Clean Water Act (CWA) and the Safe Drinking water Act (SDWA). Along with the administration of programs, the Division assists the Mid-Atlantic states, localities, and interstate commissions in developing comprehensive environmental programs for the achievement of environmental and public health goals and standards, and oversees delegation of programs and state implementation of these delegated programs.

EPA Mid-Atlantic delegates the administration of the NPDES program to the states of Delaware, Maryland, Pennsylvania, Virginia and West Virginia. However, EPA administers the NPDES program for the District of Columbia.

The Office of Watersheds administers the permit tracking process, while the Office of Compliance & Enforcement administers the enforcement of the NPDES Permitting Program. EPA Region 3's Stormwater Web site is:
http://www.epa.gov/reg3wapd/stormwater/index.htm

The NPDES Stormwater Program

Municipal. A municipal separate storm sewer system (MS4) is a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains):

- Owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage districts, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges to waters of the United States;
- Designed or used for collecting or conveying stormwater;
- Which is not a combined sewer; and
- Which is not part of a publicly owned treatment works.

The Stormwater Program for MS4s is designed to reduce the amount of sediment and pollution that enters surface and ground water from storm sewer systems to the maximum extent practicable. Medium and large MS4 operators are required to submit comprehensive permit applications and are issued individual permits. Regulated small MS4 operators have the option of choosing to be covered by an individual permit, a general permit or a modification of an existing Phase I MS4's individual permit.

Industrial Facilities. Operators of industrial facilities included in one of the 11 categories of stormwater discharges associated with industrial activity that discharge or have the potential to discharge stormwater to a MS4 or directly to waters of the U.S. must obtain coverage under an NPDES industrial stormwater permit, unless conditionally excluded. The 11 categories are:

1. Facilities with Effluent Limitations
2. Manufacturing
3. Mineral, Metal, Oil and Gas
4. Hazardous Waste, Treatment, or Disposal Facilities
5. Landfills
6. Recycling Facilities
7. Steam Electric Plants
8. Transportation Facilities
9. Treatment Works
10. Construction Activity
11. Light Industrial Activity

Construction. Stormwater runoff from construction activities can have a significant impact on water quality. Sediment runoff rates from construction sites are typically 10 to 20 times greater than those of agricultural lands, and 1,000 to 2,000 times greater than those of forested lands. During a short period of time, construction sites can contribute more sediment to streams than can be deposited naturally during several decades. The NPDES Stormwater program requires operators of construction sites one acre or larger (including smaller sites that are part of a larger common plan of development) to obtain authorization to discharge stormwater under an NPDES construction stormwater permit.

Stormwater Best Management Practices (BMPs). There are a wide variety of stormwater BMPs that industry, municipalities, construction sites and even homeowners can adopt.

Stormwater Ponds. Ponds are designed to temporarily retain stormwater to keep it from affecting the quality of streams, lakes, or wetlands. Nationally there are tens of thousands of stormwater ponds. These ponds, depending on their design, serve three main purposes:

1. To capture stormwater to prevent flooding,
2. To detain and slow the rate of runoff to reduce stream channel erosion and habitat degradation; and
3. To capture and hold sediment and other pollutants that are present in runoff.

TYPES OF PONDS

Wet Ponds (Retention ponds).
Wet ponds are stormwater control structures that provide both retention and treatment of contaminated stormwater runoff. A wet pond consists of a permanent pool of water into which stormwater runoff is directed. Runoff from each rain event is detained and treated in the pond until it is displaced by runoff from the next storm. By capturing and retaining runoff during storm events, wet detention ponds control both stormwater quantity and quality.

Dry Ponds (Detention ponds).
A dry pond is designed to capture and slowly release runoff water for a period of 72 hours or less after a precipitation event. Dry ponds do not treat the stormwater and are typically constructed in areas where flood control is the greatest concern.

Non-Structural Controls – Infiltration. An infiltration BMP is designed to capture a volume of stormwater runoff, retain it and infiltrate that volume into the ground. There are a variety of infiltration BMPs, including:

- ***Rain Gardens.*** Rain gardens are a way for homeowners and businesses to reduce polluted runoff. A rain garden is a shallow, constructed depression that is planted with deep-rooted native plants and grasses, and positioned to receive runoff from impervious surfaces. Rain gardens slow down the rush of water from impervious surfaces, hold the water for a short period of time, and allow it to naturally infiltrate into the ground.

- ***Biofiltration.*** Biofiltration involves treating stormwater using microbial soil processes, infiltration, evaporation, and appropriate plantings. Instead of the typical landscape islands that are set higher than paved grade (and which often require supplemental irrigation), these biofiltration landscape islands are recessed, and the pavement is graded so that surface flow is into, rather than away from, these areas.

- ***Vegetative Swales.*** Swales are broad, shallow channels with a dense stand of fine, close-growing, water-resistant grass covering the side slopes and bottom. Swales can be natural or manmade, and are designed to trap sediments, promote infiltration, and reduce the flow velocity of stormwater runoff.

- ***Reduce Impervious Surfaces.*** Reducing impervious surfaces helps minimize water velocity and runoff. Site design and planning to reduce impervious surface can help alleviate its negative effects. Reducing impervious surface often requires innovative techniques such as:

Narrower Streets. Narrower streets reduce the amount of impervious surface created by new residential development, and in turn, reduce the stormwater runoff and associated pollutant loads. Currently, many communities require residential streets that are 32 to 40 feet wide. These wide streets provide two parking lanes and two moving lanes. In many residential settings, streets can be as narrow as 22 to 26 feet wide without sacrificing emergency access, on-street parking or vehicular and pedestrian safety. Even narrower access streets or shared driveways can be used when only a handful of homes need to be served.

Elimination of Cul-de-Sacs. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a stormwater perspective, cul-de-sacs create a huge bulb of impervious surface, increasing the amount of stormwater runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious surface created at a site.

BMP Database. The American Society of Civil Engineers has developed a comprehensive database on BMP performance. The project, which began in 1996 under a cooperative agreement between the American Society of Civil Engineers (ASCE) and the U.S. Environmental Protection Agency (USEPA), now has support and funding from a broad coalition of partners including the Water Environment Research Foundation (WERF), ASCE Environmental and Water Resources Institute (EWRI), Federal Highway Administration (FHWA) and the American Public Works Association (APWA). Wright Water Engineers, Inc., and GeoSyntec Consultants are the entities maintaining and operating the database clearinghouse and Web site, answering questions, conducting analyses of newly submitted BMP data, conducting updated performance evaluations of the overall data set, disseminating project findings, and expanding the database to include other approaches such as Low Impact Development techniques. The database itself is downloadable to any individual or organization that would like to conduct its own assessments. On this Web site, you can obtain:

- The minimum protocols for submitting BMP monitoring studies for inclusion into the database;
- Guidance for monitoring stormwater BMPs to meet these protocols;
- Data entry software to store and report BMP monitoring study data;
- Performance summaries for individual BMPs through the on-line searchable database containing roughly 200 BMPs;
- Statistical summaries of the overall BMP database;
- Statistical summaries of performance by BMP types (e.g., wet ponds);
- Technical reports describing the statistical techniques recommended for analyzing BMP performance and the results of performance evaluations;
- Published papers from conference proceedings and journals on the BMP database; and other useful information.

The long-term goal of the project is to provide better understanding of factors influencing BMP performance and help to promote improvements in BMP design, selection and implementation. EPA and ASCE invite organizations that have conducted BMP performance monitoring to submit their data to the database and share their findings with the public. The database Web site is: www.bmpdatabase.org

Recent Concerns Regarding Mosquito Management

Stormwater management programs always address public health and safety, largely from the perspective of flood control and the reduction of waterborne pathogens. Unfortunately, mosquito management is often overlooked. Mosquito management is essential to prevent disease transmission and maintain quality of life and must be integrated into every stormwater program.

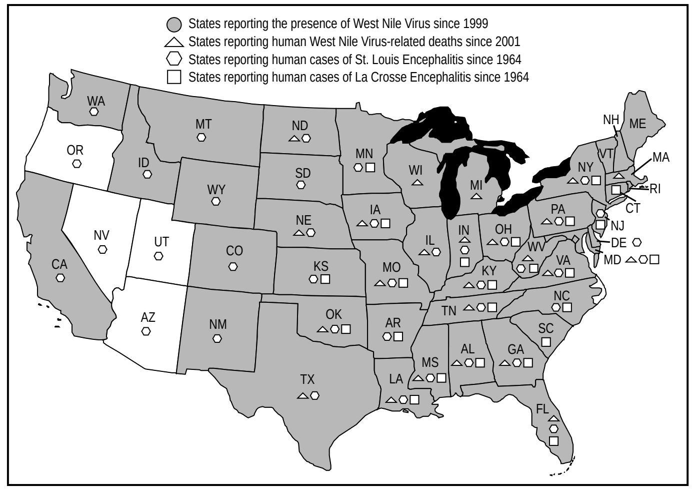
Stormwater management structures can be a problem when they hold water long enough to allow mosquito breeding. Local vector-control agencies (where they exist) or environmental health programs should be consulted during preconstruction design review to ensure that vector breeding habitat is minimized. These agencies and programs also should be consulted when developing maintenance schedules for stormwater management structures. Even those stormwater facilities that are properly designed and constructed to minimize mosquito breeding habitat may collect standing water if they are not maintained properly, thus creating the potential for mosquito breeding.

The Mid-Atlantic mosquito season extends from the vernal equinox past the autumnal equinox into October. Mosquitoes are true flies and like other insects have a development cycle involving complete metamorphosis from the egg to the adult stage. Mosquito eggs are laid singly or in clusters on water or in mud and debris near water prone areas. Tiny larvae hatch from the eggs and develop in the water. The larvae feed on a variety of microorganisms and organic matter in the water, and develop through four larval stages to the pupal stage. Adult mosquitoes emerge from the pupal stage and fly away. Male mosquitoes feed on nectar and do not bite for blood; female mosquitoes of most species require a blood meal to develop their eggs, and may bite several times during their lifetime. Female mosquitoes not only bite people, but also other animals including birds, mammals, frogs, and snakes.

Mosquito breeding potential depends on the depth and location of standing water. Ponds that are uniformly deep, with steep side slopes, resident populations of larvae-eating fish (particularly *Gambusia* minnows), and certain species of aquatic insects such as dragonfly niads might not produce a significant number of adult mosquitoes. In contrast, certain types of stormwater management practices that are characterized by ephemeral shallow water habitat and/or dense growth of emergent vegetation provide excellent mosquito breeding habitat. The limiting factors are the longevity of the aquatic habitat, and the duration of the mosquito species' life cycle (that is, time from egg hatch to emergence of adult mosquitoes from the water).

Some mosquito species may stay nearby their breeding areas and travel limited distances, other species can fly miles from their breeding habitat.

Encephalitis. Encephalitis literally means an inflammation of the brain, but it usually refers to brain inflammation caused by a virus. It is a rare disease that occurs in approximately 0.5 per 100,000 individuals—most commonly in children, the elderly, and people with weakened immune systems. Mosquitoes can transmit the viruses for several types of encephalitis, including West Nile encephalitis, St. Louis encephalitis, La Crosse encephalitis, and eastern equine encephalitis.



(Source: mosquitobuzz.com, modified for B/W printing)

- ***West Nile Encephalitis (WNE).*** The West Nile virus (WNV) can cause a West Nile encephalitis. Although mainly a bird disease, WNV afflicts horses and humans as well. With exception of organ transplants or blood transfusions, WNV is not spread from person to person, and there is no evidence that a person can get infected by handling live or dead infected birds, although handling WNV-suspect birds while wearing gloves or with tools is a good precaution. About 80% of the people who contract WNV have no symptoms; others get only a mild flu-like illness with fever, headache, and sore throat. For a small percentage of people (primarily elderly), WNV leads to infection of the central nervous system, resulting in a sudden fever and severe headache, which can be followed quickly by seizures and coma; the death rate for patients who experience this level of infection is about 5-10%.

  Since WNV was first isolated in 1937, it has been known to cause infection and fevers in humans in Africa, West Asia, and the Middle East. Human and animal infections were not documented in the Western Hemisphere until the 1999 outbreak in the New York City metropolitan area. Since then, the disease has spread across the United States. According to the federal Centers for Disease Control and Prevention (CDC), in 2003 there were 9,862 human cases in 45 states, with 264 deaths. Mid-Atlantic statistics for 2003 include: Delaware (17 cases, 2 deaths), Maryland (73 cases, 8 deaths), New Jersey (34 cases, 3 deaths), Pennsylvania (237 cases, 8 deaths), Virginia (26 cases, 1 death), West Virginia (2 cases, 0 deaths), and District of Columbia (3 cases, 0 deaths). In 2004 there were 2,539 human cases in 40 states, with 100 deaths. Mid-Atlantic statistics for 2004 include: Maryland (16 cases, 0 deaths), Pennsylvania (5 cases, 2 deaths). Nothing was reported to CDC for Virginia or West Virginia.

- ***La Crosse Encephalitis (LAC).*** La Crosse encephalitis was discovered in La Crosse, WI in 1963. Since then, the virus has been identified in several Midwestern and Mid-Atlantic states. During an average year, about 75 cases of LAC encephalitis are reported to the CDC. Most cases of LAC encephalitis occur in children under 16 years of age. LAC virus is cycled between the daytime-biting mosquito, *Ochlerotatus triseriatus*, and vertebrate amplifier hosts (chipmunks, tree squirrels) in deciduous forest habitats. If the female mosquito is infected, she may lay eggs that carry the virus. People are not an important part of the life cycle of the virus. In rare cases, however, people who live in or visit an area where the virus occurs can be infected by the bite of an infected mosquito. After infection, the virus invades the central nervous system, including the spinal cord and brain. LAC is usually a mild illness, with fever, headache, nausea, vomiting, and tiredness. People with severe disease, primarily children, can have seizures, coma, paralysis and lasting brain damage.

- ***Eastern Equine Encephalitis (EEE).*** Eastern equine encephalitis is also caused by a virus transmitted to humans and equines by the bite of infected mosquitoes that live in marshes and swamps. Mosquitoes contract the virus by first feeding on birds. In the Mid-Atlantic region, salt marsh mosquitoes such as *Ochleratatus sollicitans* and freshwater mosquitoes such as *Aedes vexans* transmit EEE to humans. As with WNV, EEE is cycled in reservoir host birds by *Culiseta melanura*.These mosquitoes feed only on birds, not on humans or other mammals. The EEE virus escapes from the swamp habitat in mosquitoes that feed on both birds and mammals, thus becoming “bridge vectors”. These mosquitoes can transmit the virus to animals (including horses) and people. EEE is much more virulent but fortunately much rarer than WNV. After EEE infection occurs, the virus often invades the central nervous system, including the spinal cord and brain. About a third of EEE patients die from the disease, with children and the elderly most susceptible. Of those who survive, many suffer permanent brain damage and require lifetime institutional care. EEE virus was first identified in the 1930s and currently occurs in locations along the Eastern Seaboard, the Gulf Coast and some Midwestern locations of the United States. CDC reports about five human cases of EEE per year in the United States.

- ***St. Louis Encephalitis (SLE).*** SLE is now the second most common mosquito-transmitted human pathogen in the U.S., having been superceded by WNV. While periodic SLE epidemics have occurred only in the Midwest and Southeast, SLE virus is distributed throughout the lower 48 states. Since 1964, there have been 4,437 confirmed cases of SLE with an average of 193 cases per year (with a range of 4 to 1,967). However, less than 1% of SLE viral infections are clinically apparent and the vast majority of infections remain undiagnosed. Illness ranges in severity from a simple headache and fever to meningoencephalitis, with an overall fatality of 5-15 % in patients severely afflicted with SLE. The disease is generally milder in children than in adults, but in those children with the virus, there is a high rate of encephalitis. The elderly are at highest risk for severe disease and death.

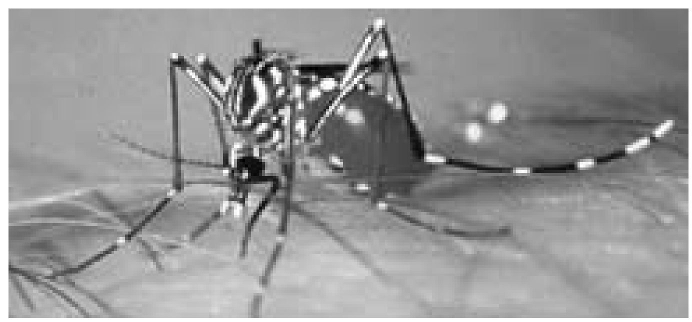
During the summer season, SLE virus is maintained in a mosquito-bird-mosquito cycle (by *Culex* mosquitoes).

Other Mosquito-Borne Diseases

- ***Malaria.*** At one time, malaria (carried by Anopheles mosquitoes) was common in the Mid-Atlantic but due to progressive mosquito control programs and modern medicine, it has been virtually eradicated in the U.S. and other developed countries which practice mosquito control and provide a high standard of living for their residents. However, malaria continues to affect hundreds of people in this country every year. In 2000, health care workers reported 1,400 cases of malaria to the CDC. Malaria reported in the U.S. is typically acquired during trips to malaria-endemic areas of the world and, therefore, is often called travelers' or imported malaria. Malaria has been diagnosed in some U.S. soldiers returning from Afghanistan. Recently cases have been reported in Florida, southern California, and Virginia. In these instances, infected migrant workers were either directly implicated or suspected.

- ***Canine Heartworm.*** Canine heartworm disease occurs worldwide in tropical, subtropical, and some temperate regions. Until the late 1960s, the disease was restricted to southern and eastern coastal regions of the United States. Now, however, cases have been reported from dogs native to all 50 states. For most of North America, the danger of infection is greatest during the summer when temperatures are favorable for mosquito breeding. In the southern U.S., especially the Gulf Coast and Florida, where mosquitoes are present year-round, the threat of heartworm disease is constant. Canine heartworm is common in the Mid-Atlantic and is transmitted by a variety of *Ochlerotatus* and *Aedes* mosquitoes. The mosquito bites a dog with heartworm infection, collects some of the microscopic heartworm offspring and then, after a couple of weeks, passes these on to another dog. Prophylactic drugs are available from veterinarians to prevent dogs from contracting this disease.

- ***Dengue Fever.*** Dengue fever is primarily a disease of the tropics, and the viruses that cause it are maintained in a cycle that involves humans and *Aedes aegypti*, a domestic, day-biting mosquito that prefers to feed on humans. *Aedes aegypti* is now once again well established in the southern states, from Texas to South Carolina, and more recently in Maryland and New Jersey. While dengue fever is rarely fatal, the symptoms include fever, painful headaches, eye, joint and muscle pain and a rash on the arms or legs. From 1977 to 1994, a total of 2,248 suspected cases of imported dengue were reported in the United States.



This is a female *Aedes aegypti* mosquito engorged with blood while feeding. Dengue viruses are transmitted during the feeding process.

- ***Rift Valley Fever (RVF).*** Rift Valley Fever is an acute viral disease that causes fever in domestic animals (such as cattle, buffalo, sheep, goats, and camels) and humans. The virus usually lies dormant in the eggs of *Aedes* mosquitoes. During heavy rains and floods, the eggs hatch large numbers of infected mosquitoes that feed on livestock and spread the virus. Other species of mosquitoes, and possibly other biting insects, can also become infected and spread the disease. The occurrence of disease in a large number of domestic animals is referred to as an "epizootic." The presence of a mosquito-borne epizootic can lead to an epidemic in humans.

RVF is more deadly than WNV. RVF has not occurred in the U.S. (through 2005). However, there has been concern that it could become permanently established in the U.S. if it does enter the country. People with Rift Valley fever usually have flu-like symptoms but may develop complications such as kidney or liver disease. In outbreaks of RVF, the death rate has been about 15% for those seriously ill.

- ***Yellow Fever.*** Yellow fever virus is believed to have originated in Africa and spread by trading ships to the New World. During the 1700s and 1880s, yellow fever was one of the most dreaded diseases in the port cities of the United States. The last outbreak of yellow fever in the U.S. occurred in New Orleans and the Mississippi delta in 1905.

  During the 1970s, weakening of *Aedes aegypti* control programs allowed reinfestation of this vector in South America. In 1997-98, a limited outbreak of yellow fever occurred in Santa Cruz, Bolivia, which probably represented the first episode of urban yellow fever in South America since 1954. The factors that permitted this outbreak included *Aedes aegypti* infestation, low rates of vaccination, and the proximity of human habitation to areas of endemic infection. The number of patients with jungle and urban yellow fever also has increased markedly in sub-Saharan Africa since the 1980s. Because *Aedes aegypti* infests the southeastern U.S., the possibility exists that urban yellow fever may return to this country.

  Mosquitoes are a part of the ecosystem. Trying to fully eradicate them would cause adverse environmental consequences. We can take steps to limit mosquito habitat, and people can take steps to reduce their risk of exposure. If stormwater management systems are well designed and managed, the risk of mosquito-borne disease is reduced. However, vigilance is required.

Current Activities

Interpretive Statement on Pesticides and Water/Proposed Rule. In recent years, courts have been faced with the question of weather the Clean Water Act requires an NPDES permit for pesticide applications (e.g., *Headwaters, Inc. v. Talent Irrigation District).* As a result, public health authorities, natural resource managers, and others who rely on pesticides, have expressed to EPA their concern and confusion about whether they have a legal obligation to obtain an NPDES permit when pesticides are applied to or over waters of the United States.

In January 2005, EPA published an interpretive statement outlining circumstances under which NPDES permits are not required to apply pesticides to waters of the United States. The statement and proposed rule reflect EPA's long-standing policy that a CWA permit is not required where application of a particular pesticide to or over water is consistent with requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Any pesticide that is approved for use in the U.S. must undergo extensive study and review to help ensure that, when properly used, it does not pose unreasonable risk to human health and the environment. The EPA's Final Rule regarding this matter is expected to be issued before the end of 2006.

National Management Measures to Control Nonpoint Source Pollution from Urban Waters (EPA 841-B-05-004, November 2005). This guidance helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. These scientifically sound techniques are the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Stormwater Permit Programs.

EPA Guide for Operating and Maintaining Stormwater BMP Facilities
This is an upcoming BMP dealing with dry detention ponds and infiltration systems for stormwater management, supposedly to be developed during 2006-2007, as opposed to the BMP for wet/retention ponds (below).

Ponds and Wetlands BMP Maintenance Guide. The draft "Stormwater Pond and Wetland Maintenance Guidebook", prepared by the Center for Watershed Protection for Tetra Tech under a contract for the U.S. EPA Office of Science and Technology, is now available for download. The final version of this BMP is expected to be released before the end of June 2006; extensive input was provided to EPA by the American Mosquito Control Association (AMCA) prior to the final publication of this document, and mosquito control will be addressed in these types of BMPs in the future.

This guidebook addresses maintenance through the lifecycle of a facility, from design to major repairs. Eight common maintenance concerns are described in detail including access difficulties that are commonly encountered by inspectors or maintenance contractors and a concise list of pipe failure mechanisms in stormwater ponds and wetlands.

Designers and plan reviewers will find the Chapter on "Designing for Low Maintenance Ponds and Wetlands" to be helpful in understanding the links between design features and long-term performance. Those responsible for signing off on the construction or planning-for-construction inspection can find highlights on items to keep an eye on during construction to prevent future problems. The meat of the guidebook comes as eight profile sheets, addressing each of the common maintenance concerns. "Problems to Inspect for" are described in detail, as are preventative and corrective actions. Color photographs visually depict the problems described.

When used by the inspector, program manager, designer, and owner of stormwater facilities in NPDES Phase I and II communities, this guidebook can be a starting place for a stormwater pond and wetland maintenance program.

You can download the guidebook by visiting http://www.stormwatercenter.net and clicking on Program Resources and then STP Maintenance Resources.

Stormwater Contacts

EPA Headquarters
Jack Faulk 202-564-0768
Rod Frederick 202-566-1197
EPA Region 3
Paula Estornell 215-814-5632
Chad Harsh 215-814-2633

Overview of Stormwater Management Regulations in Delaware

Presented by:
Randy Greer, Delaware Department of Natural Resources and Environmental Control (DNREC)

The National Pollutant Discharge Elimination System (NPDES) permit program regulates the discharge of pollutants to waters of the United States. The 1987 amendments to the Federal Clean Water Act added stormwater to the NPDES permitting universe. EPA issued regulations in 1990 requiring NPDES permits for stormwater discharges from large municipalities and certain industrial sources (including construction sites disturbing five acres or more). Permits from these sources were required to be submitted beginning in 1992. EPA issued new regulations in 1999 to require NPDES stormwater permits from smaller cities and smaller construction sites.

In the 1970s some of the Mid-Atlantic states (beginning with Maryland in 1970 and Delaware in 1979) began to develop state programs in anticipation of federal regulations. In 1984 Maryland again led the nation within statewide stormwater management laws, and Delaware established a combination Sediment and Stormwater Law and Regulations in 1991. The Delaware General Permit for Construction Activities is the most recent to be revised in 2004.

Under the current Delaware Sediment and Stormwater Law and Regulations, all land disturbing activity over 5,000 ft^2 is covered by the regulations. There are exemptions for:

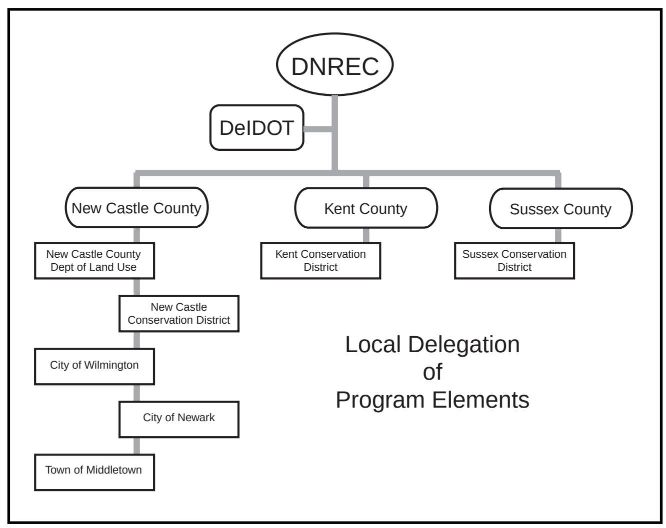
- Agricultural land management practices
- Emergency projects
- Land disturbing activity less than 5000 ft^2

Of late, more agricultural activities are being included in nutrient management and conservation plans to provide for increased water quality protection.

All land disturbing activity over 5,000 ft^2 (unless exempted) must have an approved sediment and stormwater plan. The plan must cover:

- Temporary erosion and sediment control measures that are to be implemented during construction;
- Construction management measures that will reduce pollution during construction;
- Post construction stormwater practices for water quality and quantity.

The Sediment and Stormwater Program is delegated throughout the State to eight local program jurisdictions. These are the agencies that will be reviewing, approving and inspecting the project.



Each plan will have a place for the owner/developer to certify to DNREC or the approval agency that:

- All responsible persons will have attended DNREC sponsored training;
- All land disturbing activity shall be done pursuant to the approved plan;
- DNREC and/or their authorized representatives have the right to enter the site to inspect the construction for compliance with the approved plans.

All Erosion and Sediment Control practices must be designed in accordance with the Delaware Standards and Specifications for Erosion and Sediment Control 2003. The Delaware ESC Handbook can be ordered online from DNREC (www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/stormwater.htm).

The Sediment and Stormwater Regulations require that all disturbed areas that have not been graded for a period of 14 calendar days, be temporarily or permanently stabilized. The regulations require that grading and construction be accomplished in grading phases so that no more than 20 acres is being actively graded at once. This requirement can be met and the project can move forward by using temporary stabilization and good sequencing.

The Regulations allow certain projects to have a standard plan for Erosion and Sediment (E&S). This would include minor earth disturbance for a single residential home.

The Regulations allow the requirement (by the approval agency) of a Certified Construction Reviewer or CCR to inspect a site. They also require that all active construction sites are inspected and that inspection reports be written and distributed to the parties involved. Onsite personnel should also inspect the E&S measures on a weekly basis and after each rainfall event. There are provisions for enforcement and penalties for noncompliance with the provisions of the Sediment and Stormwater Law and Regulations.

What is a TMDL?

TMDL stands for Total Maximum Daily Load.

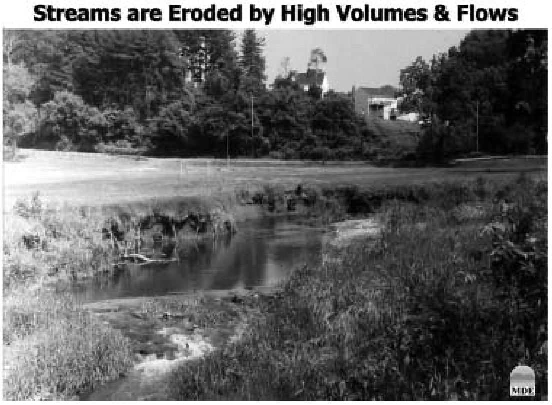
The TMDL represents the maximum amount of a pollutant allowed to enter a waterbody by law so that the waterbody will meet and continue to meet the water quality standards for that particular pollutant.

Pollutants are anything that prevents a waterbody from attaining the national goal of being “fishable and swimmable.”

Common pollutants include sediment metals (often from mining activities), toxic chemicals, fecal coliform bacteria, pH, and excessive nutrients.

Presented by:
Charlie Wallis, Maryland Department of the Environment (MDE)

Clearly, any standing water has the potential to promote mosquito growth. Some stormwater management practices use ponded water to promote water quality improvement. Therefore, there is the potential for contributing to mosquito problems. However, stormwater management is essential to mitigate the adverse effects of development on the environment. These effects include increased flooding, water quality impairment, reduced groundwater recharge, and stream channel erosion.



Maintenance of constructed facilities is of paramount importance to their function. The state and local governments make efforts to inspect both publicly and privately owned stormwater management facilities. These efforts can certainly improve. A greater public awareness of the value of these facilities will help in making increased funding available so that better maintenance can be achieved. A lack of maintenance typically results in diminished pond performance, poor drainage, and promotes mosquito population growth. Temporary sediment and erosion control measures employed during construction also benefit from increased maintenance activity.

The state of Maryland revised its stormwater management regulations in 2000. Included in the revisions were changes in design requirements that reduce the potential for mosquito breeding. Specific changes include:

Greater flexibility of practice selection based on site specific conditions. Previously, certain practices were required because it was believed they would provide the greatest improvement to water quality. Over time it became evident that site conditions had a significant influence on practice performance. Forcing a specific practice to be used where it was impractical often led to poor drainage and eventually failure. Using the appropriate practice will result in less frequent occurrences of poor drainage and stagnant water.

Improved drainage performance. Not all stormwater management practices require extended ponding of water. Any practice that is not designed with a permanent pool is required to drain within 48 hours after a storm event. If a practice does involve longer retention times, then features are to be incorporated to promote mixing of incoming runoff and reduce stagnation.

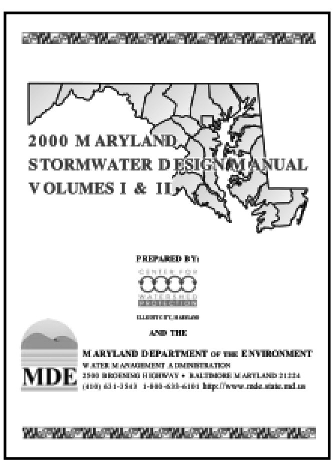
Improving the design of permanent pools. Research clearly shows that varying the depths of permanent pools reduces mosquito breeding habitat. Portions of all new ponds have to be a minimum of 4 feet deep. Other areas of ponds that have varying shallower depths are to be planted with aquatic vegetation. This results in habitat for natural predators of mosquitoes such as dragonflies, birds, fish, and frogs.

Encouraging better site design practices that reduce the need for structural stormwater management features. Development alters natural drainage and creates the need for stormwater management. Following new design criteria minimizes the generation of pollutants and reduces the concentration of runoff. Following the nonstructural measures promoted by the State in some cases can eliminate the need for a pond altogether.

Considerable development is occurring on the lower Eastern Shore of Maryland. Development leads to negative impacts on the land and environment, including increased flooding, pollution, stream channel erosion, and degradation of aquatic life. Stormwater management attempts to mitigate these negative effects.

Stormwater management practices can vary widely between jurisdictions. The factors that can affect stormwater management practices include:

Property Rights. Public statements often do not reflect an understanding of the land development process. If a site is developed, then its' stormwater impacts must be addressed on site, prior to the runoff leaving the site. A developer cannot flood a downstream property owner. Typically a developer plans stormwater management to maximize sellable lots rather than minimize environmental impacts.



Federal Clean Water Act. National Pollutant Discharge Elimination System (NPDES) regulates point discharges at the end of a pipe. Originally applied to industrial and wastewater treatment plants, the definition has been expanded to include municipal storm sewer systems.

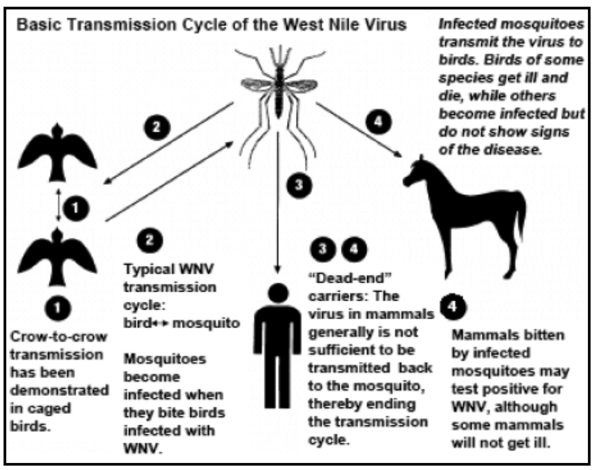
Maximum Extent Practicable – The standard that stormwater management practices are supposed to meet. Municipal NPDES has wide applicability in Maryland. A large database of stormwater information exists, and efforts are underway to make this information more accessible.

Maryland's Stormwater Management Program. Its authority is in State law and regulation. Hurricane Agnes in 1972 caused widespread destruction and provided the impetus for the laws that created Maryland's Stormwater Management Program, which was up and running by 1984. Local government has authority except for state and federal projects. The State reviews local programs for conformance with state regulations and provides technical advice. Maryland revised its regulations in 2000 including the introduction of a Design Manual. Anecdotally, Hurricane Floyd in 1999 exceeded the 100 year rainfall in many locations in the State, yet major flooding was limited to the Northeast watershed. Hopefully the Stormwater Management Program is beginning to provide a benefit.

A National Perspective

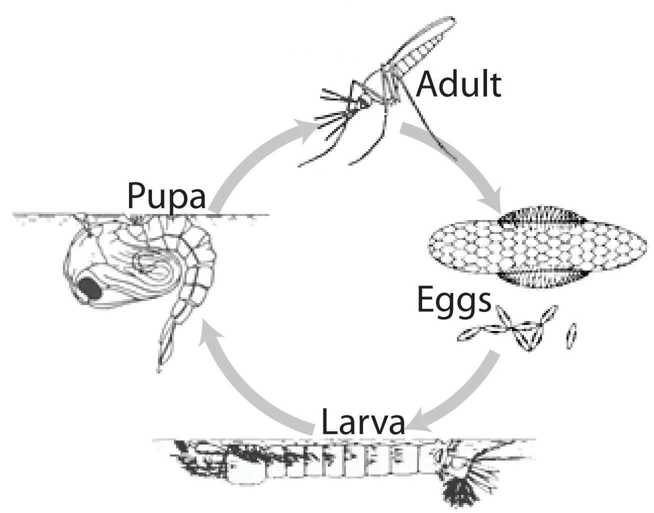
Presented by:
Joe Conlon, American Mosquito Control Association (AMCA)

The introduction and spread of West Nile Virus in the U.S. has reawakened an appreciation of mosquitoes as vectors of diseases. I use the term "reawakened" advisedly, for mosquito-borne diseases were once quite prevalent in the U.S. and, indeed, played a major part in shaping our nation's destiny. These diseases no longer claim victims in the U.S. as a matter of course largely due to the exemplary efforts of organized mosquito control agencies, in conjunction with an enlightened and effective public health infrastructure.



As early as 1905, mosquito control pioneers recognized the value of a diversified approach by integrating surveillance, source reduction, personal protection, and chemical and biological control. Early control methods consisted of ditching, draining, and/or filling marshes, applying oils to water to kill immature mosquitoes, and insecticide sprays against adults. The first districts were established in New Jersey in 1912. California and Florida followed suit in 1915 and 1925, respectively. In the ensuing years, mosquito control districts and state agencies were established nationwide. Mosquito control personnel refined their methods through applied research and assisted federal and state agencies in developing certification criteria to ensure conformance to stringent safety standards. Vector control programs continue to progressively adopt the use of integrated mosquito management methods. These strategies, endorsed by the CDC and EPA, are comprehensive and specifically tailored to safely counter each stage of the mosquito life cycle. Control of immature stages through water management and source reduction, where compatible with other land management uses, is a linchpin of this strategy.

Mosquito Life Cycle



Each of the 176 species of mosquitoes currently recognized in the U.S. utilizes preferred aquatic habitats for breeding. These habitats vary widely, from salt marshes to scrap car tires. Virtually any collection of stagnant water is fair game, with some species successfully utilizing even soda bottle caps. Factors favoring choice of breeding habitat depend upon the mosquito species involved. Many types of stormwater management systems provide standing water habitats suitable for mosquito development, particularly retention ponds, bioretention basins, and a variety of above and below-ground devices that incorporate sumps, vaults or catch basins.

Mosquito breeding associated with wetland habitats and flood-control devices is coming under increasing scrutiny by the scientific community. A landmark study conducted (between 1999-2001) by the California Department of Health Services Vector-borne Disease Section identified at least five separate mosquito genera utilizing BMPs nationwide for breeding. Of the 72 agencies that participated in this study, 86% reported mosquitoes breeding in local BMPs. Ominously, several putative vector species of West Nile virus and other encephalitides were strongly associated with poorly maintained BMPs (Metzger et al. 2002). This corroborates data from a 1993 Florida study that reported 180 out of 238 (76%) stormwater systems surveyed for breeding were mosquito productive (Santana et al. 1994) in addition to a 1988 Maryland study that reported approximately 50% of dry and wet stormwater ponds located in housing and industrial developments breeding mosquitoes (Dorothy and Staker 1990). The proximity of urban and peri-urban BMPs breeding large numbers of vector mosquitoes to large human populations is of concern to mosquito control personnel because it substantially increases the probability of disease transmission to humans, including West Nile virus.

Mosquito Larval Habitats

Habitat	Type	Species
Temporary Pools		
	Freshwater	*Ochlerotatus dorsalis, Aedes vexans*
		Psorophora confinnis & ciliata
	Brackish	*Oc. sollicitans & taeniorhynchus*
Permanent Pools		
	Polluted	*Culex tarsalis, salinarius & pipiens*
	Clean	*Anopheles spp.*
		Culiseta melanura
		Coquillettidia perturbans

Safe and adequate access to stormwater management systems is a crucial program element and should be considered in all phases of design, construction, and in the operations and maintenance plan. Designs that provide reductions in maintenance requirements are crucial for agencies with limited manpower resources. However, all systems require regular maintenance to ensure optimal performance and mosquito suppression. This also comes at a significant cost to agencies.

Even well-designed and maintained systems will require programmed corrective mosquito control efforts to address mosquito populations escaping natural predation in retention ponds, etc. Failure to consider the full inventory of remedial larvicidal measures, where indicated, to control immature mosquitoes in their aquatic stages will have the perverse effect of increasing reliance upon adulticides to control adult mosquitoes following their emergence and widespread dispersal.

Provisions of the CWA mandating measures to reduce pollution through the use of stormwater management systems provide both significant challenges and opportunities to those charged with protecting the public's health. A proactive rather than reactive approach to addressing issues can mitigate their untoward effects. Thus, communication between those charged with stormwater management and public health agencies at every level and step in the process can produce results satisfactory to the interests of both parties and, most importantly, the public that they both serve. Partnerships are needed to promote responsible stewardship of water resources. Active collaboration and funding on site surveys, design, construction, maintenance and operations protocols for stormwater management systems will promote and maintain a balance between water quality improvement and vector control–they are not mutually exclusive.

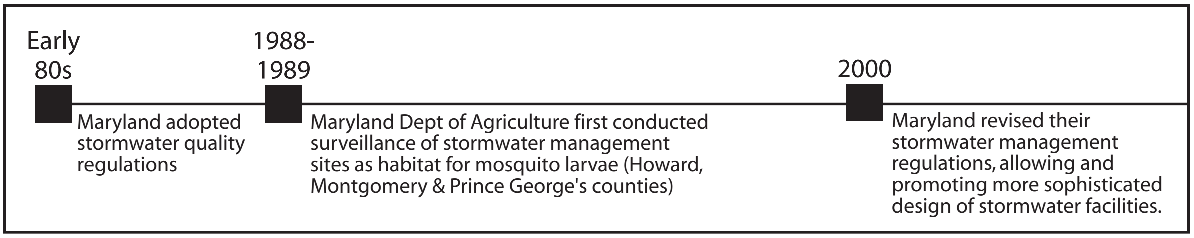
The continued increase in worldwide tourism and trade virtually guarantees further challenges from exotic diseases requiring ready control expertise to prevent their establishment and spread. Should these emerging mosquito-borne diseases of man and animals settle into the American public health landscape, particularly as an unintended consequence of otherwise laudatory environmental policy initiatives, we will have only ourselves to blame, for we have the means to control these diseases within our grasp. A robust inter-agency cooperation in the design and implementation of stormwater management programs is a cornerstone of this national effort. We must remain prepared to accept and meet these challenges – our citizens and our nation's wildlife deserve no less.

Future threats

Rift Valley Fever
Japanese Encephalitis
Murray Valley Encephalitis

Stormwater Management Areas as Mosquito Larvae Habitat in the State of Maryland

Presented by:
Cyrus R. Lesser and Jeannine Dorothy, Maryland Department of Agriculture



Mosquito control is provided throughout Maryland by public agencies. The Maryland Department of Agriculture provides direct service in the City of Baltimore and 19 of Maryland's 23 counties. In Calvert, Caroline and Queen Anne's Counties, mosquito control is provided by county government. Participation in the mosquito control program is voluntary and at the discretion of community associations, towns and residential groups. Participation in the mosquito control program is greatest in the coastal plain of Maryland and in the metropolitan area between Baltimore and Washington, D.C.

The state of Maryland adopted stormwater quality regulations in the early 1980s and was one of the first states to do so. State regulations follow federal regulations and are contained in Title 4, Subtitle 2 of the Environment Article of the Annotated Code of Maryland. The regulations are promulgated by the Maryland Department of the Environment and administered by counties and municipalities. These regulations are designed to protect the waters of the State from adverse effects of stormwater runoff from areas developed for residential, industrial and business uses. Both federal and state stormwater regulations fail to adequately address public health concerns related to mosquitoes and mosquito-borne disease.

The Maryland Department of Agriculture first conducted surveillance of stormwater management sites as habitat for mosquito larvae during 1988-1989. The initial survey was conducted in Howard, Montgomery and Prince George's Counties. In that era of stormwater design, diversity of management options was generally limited to permanently wet 'retention' basins and temporarily wet 'detention' basins. The survey in the late 1980s monitored 139 sites and found that mosquito production in both retention and detention basins were approximately the same. Subsequent evaluation discovered that retention basins provide excellent habitat for *Gambusia holbrooki* (mosquitofish) and a stocking program of these fish to permanently wet basins alleviated the mosquito breeding problem. Mosquito breeding in temporarily wet detention basins was managed by use of pesticides to control mosquito larvae because the sites were not suitable for the stocking of mosquitofish.

In 2000, stormwater management regulations in Maryland were revised, allowing and promoting more sophisticated design of stormwater facilities. The construction of permanently wet retention basins declined and the construction of stormwater wetlands, infiltration practices, filtering practices and non-structural practices increased following the 2000 revision of regulations. The current designs of stormwater management facilities in Maryland are frequently conducive to mosquito breeding because they promote shallow water detention. Surveys by MDA entomologists have found that stormwater wetlands, bioswales, infiltration trenches, infiltration basins, filtering practices and vegetated open channels that capture and detain runoff provide good habitat requirements for mosquito larvae and do not provide habitat for sustainable populations of predators; or if predator habitat is available, access to mosquito breeding habitat is restricted. The mosquito breeding problem in stormwater sites is caused by design criteria, lack of maintenance, or a combination of the two. Because they are located within or adjacent to residential areas, business locations and schools, mosquitoes produced in stormwater sites have a disproportionately large impact on human populations.

Design Criteria
Lack of Maintenance
Proximity to Human Population
Lack of Central Tracking Mechanism
Ineffective Inspection and Maintenance
Confusion over Ownership

Other issues impacting mosquito management in stormwater sites in Maryland include a lack of an effective central tracking mechanism to locate and enumerate stormwater facilities, ineffective inspection and maintenance of existing sites, and confusion about ownership of the sites. The state provides oversight on these issues, but it is the responsibility of local jurisdictions to administer the actual permitting and review of stormwater facilities construction. Few counties have the resources to provide real time tracking of site locations or provide regular monitoring of sites to determine the need for maintenance. These issues vary by jurisdiction, but in general counties are hard pressed to meet the unfunded state mandate regarding stormwater management. In many Maryland jurisdictions, the legal ownership of a stormwater facility is transferred from a developer to the local community association and responsibilities for maintenance, etc., are also transferred to the community. Often, the stormwater regulations are poorly understood, if known at all, by the community group.

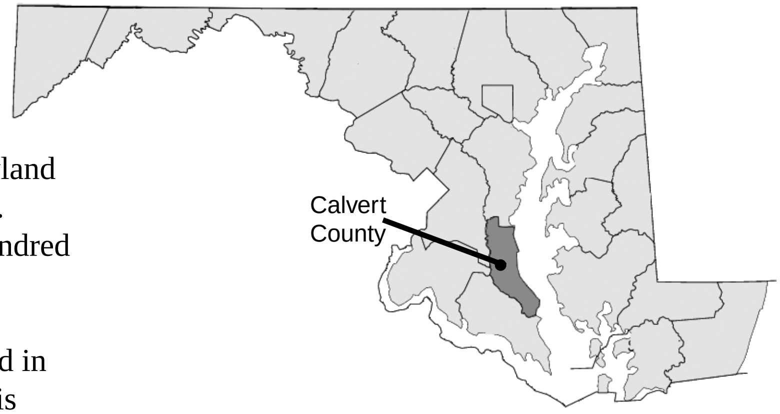
Mosquito management must be given greater attention and consideration in the planning, design and operational phases of stormwater facilities in Maryland. Federal and state regulations should be reviewed and amended to include mosquito control and public health considerations of stormwater management. A centralized database of stormwater facilities should be kept by the Maryland Department of the Environment. This should include information on the exact location and design type of each site, as well as the maintenance history and these data should be readily available to mosquito control managers at the State and County levels.

Centralized Database of Stormwater Facilities

location of facility	design
maintenance history	owner

Stormwater Management Structures and Mosquito Production in Calvert County, MD

Presented by:
V. Wilson Freeland, Calvert County Mosquito Control Program



Calvert County is located in southern Maryland, bordering the Patuxent River and Chesapeake Bay. It has a landmass of about 217 square miles and contains over 100 miles of shoreline. Calvert is the smallest of the Maryland counties but ranks second in population growth. Calvert is currently home to more than eight hundred (800) Stormwater Management Structures.

Historically, the primary mosquito species found in the county have been salt marsh mosquitoes; this trend is changing. We are now seeing increases in floodwater and permanent water species, specifically *Culex restuans, salinarius* and *Aedes vexans*. While stormwater management structures cannot be considered as the sole source of the mosquito population affecting this trend, they are certainly contributing factors. The issues with stormwater management structures, from a mosquito control viewpoint, lie mainly with their design and maintenance. Retention, detention and bio-retention structures require considerable man-hours to survey, document and, when required, treat. Bio-retention structures are fairly new designs that create the most problems in regard to mosquito production. These structures appear designed to mimic natural wetlands. Their water depth is very shallow when filled and the structure is planted with wetland vegetation. Large broods of *Aedes vexans* are commonplace when the structures fail to dry in seven days or less. The habitat is usually void of natural predators and, when predator populations are present, their numbers lag well behind mosquito larvae development.

Detention structures that function properly will not produce mosquitoes. However, without annual maintenance, most begin holding water much longer and become ideal habitat for the previously mentioned species. Detention structures are designed to allow stormwater to slowly percolate into the ground water or are designed with a weep structure that slowly releases water from the structures discharge. When the bottoms of these detention structures become covered with silt or vegetation, the percolation process is severely restricted and these detention structures begin acting as retention structures.

Retention structures can produce large populations of *Culex restuans* and *Anopheles quadramaculatus*. Most of these structures will hold water indefinitely and can be stocked with fish that provide excellent biological control. Unfortunately there are retention structures that become dry enough not to support fish. These structures need to be restocked or chemically treated to control mosquitoes throughout the season.

The maintenance of the structure is critical to its function and to its efficiency in producing mosquitoes. Maintenance issues arise when, in most cases, the developer of the property transfers the land to the community association or, in some cases, to an individual owner. In both circumstances the new property owner is usually completely unaware of their responsibilities to maintain the stormwater structure.

In Calvert County the inspection of stormwater structures is delegated to the Department of Public Works. Three full time Erosion and Sediment Control Inspectors, as a part of their duties, carry out inspections at one year, three year, six year and twelve year intervals. Maintenance requirements can include removing trees and shrubs from the dikes of the structure, cleaning the out flows of debris, and removing sediment from the basin of the structure. In some cases maintenance costs can be considerable, and the new property owner finds that they must bare these costs alone.

Presented by:
William Meredith, Thomas Moran, and Darin Callaway, DNREC

We like SWMBs, but mosquitoes do too. The Delaware Mosquito Control Section, being an integral part of the State's fish-and-wildlife management agency, strongly supports the use of stormwater management basins (SWMBs) for their water quality improvement benefits and for whatever wildlife habitats they might provide. Because of these environmental benefits, statutes, regulations and policies have been implemented at federal, state, county and municipal levels that mandate the use of SWMBs and other types of BMPs to help improve the water quality of surface runoff. The Section knows that not every SWMB is a problematic producer of mosquitoes; but unfortunately many are, and the trick is recognize which ones produce excessive amounts of mosquitoes and to act upon such knowledge. We also know that the relative contribution of any individual SWMB to local mosquito problems is dependent upon other sources of mosquitoes too, from either natural or other man-made sources, and originating from nearby or remote locations. In some areas a SWMB might be solely responsible or highly contributory to local problems; in other areas, a SWMB's contribution might be nil or very minor. We often receive alarmed calls from the public or their elected officials about actual or potential mosquito production problems emanating from individual SWMBs, especially now with the public's concern for transmission of West Nile virus. We tell callers that indeed there could be a problem but that the sky is not falling, not to worry, and we will take control actions as warranted.

The challenges we face. Delaware has plenty of natural mosquito production habitats in that about 8% of the state's surface area is tidal wetlands and another 10% is some type of freshwater wetlands. All kinds of wetlands can produce excessive amounts of mosquitoes, including natural, "healthy" wetlands, whether they are salt marshes, freshwater marshes, forested swamps, woodland pools or Coastal Plain ponds. Degraded wetlands will also cause mosquito production problems, whether these wetlands have been altered by hydrological modifications, sedimentation, filling, pollution runoff or other factors—often the mosquito production in these degraded areas is worse than in "healthy" wetlands, and sometimes not. Man-made wetlands can also produce excessive amount of mosquitoes, including SWMBs and constructed mitigation wetlands (e.g., highway wetlands compensation projects); man-made containers of all sizes and configurations can hold water that (function as wetlands environments) and provide mosquito breeding habitat. These natural habitats whether "healthy" or degraded, in combination with man-made sources, produce 57 species of mosquitoes in Delaware, of which 19 will bite humans, and 17 are of concern for transmission of mosquito-borne diseases. As such, we have plenty of control challenges to address, which in part now also include trying to deal with more than 1500 SWMBs scattered around the state (with about two-thirds of these SWMBs in New Castle County and the remaining one-third in Kent and Sussex Counties). Species of concern for breeding in SWMBs include *Culex pipiens*, *Cx. salinarius*, *Cx. restuans*, *Aedes vexans*, *Ochlerotatus japonicus*, and *Coquilletidia perturbans*, having both quality-of-life (nuisance) and disease vector concerns. Other mosquito species of concern also breed in SWMBs, and the extent of their contributions to the overall problem needs more study.

Are natural predators enough? Mosquitoes have many types of natural predators, preying upon both larval immature mosquitoes (e.g., dragonfly naiads, water boatmen, backswimmers, predacious diving beetles, water striders, salamander larvae, native fishes) and adult mosquitoes (e.g., dragonflies, purple martins, swallows, bats). However, it is a fallacy to think that natural predators are enough to keep mosquito populations at levels expected and demanded by modern society. Even natural populations of predators living in balanced, "healthy" wetlands may not provide sufficient control. The situation often becomes worse (in degraded wetlands) where predators might be scarce or absent. Mosquitoes have evolved to be able to "outrun" their natural predators at the population level by being chronically present in intolerable numbers or having horrendous, sporadic population eruptions. This is why modern-day mosquito control programs are in business: Quite simply, we're doing what Mother Nature can't do!

How do we control mosquitoes? The Delaware Mosquito Control Section, like all modern-day mosquito control programs, uses an Integrated Pest Management (IPM) approach, where surveillance and monitoring of mosquito populations and the diseases they carry is key. When control actions are needed, we always prefer non-chemical, source reduction measures. In salt marshes this might involve the selective installation of shallow ponds and ditches known as Open Marsh Water Management (OMWM), done to eliminate mosquito egg-deposition and larval rearing habitats and to encourage predation on mosquito larvae by native fishes. Around residences or businesses, we encourage good water sanitation practices by property owners in order to remove standing water habitats that can breed mosquitoes. For SWMBs, we want to encourage (to the extent practicable) basin engineering designs, water and vegetation management practices, and good maintenance practices to help lower or eliminate mosquito breeding. In some situations it is possible to help control mosquitoes by introducing larval-consuming fishes (e.g., *Gambusia* stocking), but for several environmental and practicable reasons this has only limited utility.

The role of insecticides. As part of the IPM approach, when source reduction measures either fail or cannot be employed, then it is necessary to use chemical controls, either larvicides or adulticides. Our preference is to use larvicides first (e.g., Bti, methoprene, temephos), since applications of larvicides are more localized and results in less exposure to humans. Adulticides (e.g., naled, malathion, permethrin, resmethrin, sumithrin) are tools of last resort, but because of the challenges via other means, it is often necessary to use adulticides. Spray applications are typically more widespread due to the dispersed nature of adult mosquitoes; hence, there is more exposure to humans. But no matter what type of chemical controls we might have to use, the U.S. Environmental Protection Agency (EPA) has scientifically determined that EPA-registered mosquito control insecticides, when applied in accordance with all product label requirements and conditions, "pose no unreasonable risk to human health, wildlife or the environment."

Needed thinking and actions. The Delaware Mosquito Control Section has three hopes for the outcome of this Stormwater Management and Mosquito Control Workshop, involving some new thinking by several parties and taking actions where possible:

1. Realistic recognition by all parties that SWMBs can often cause mosquito production problems (i.e., do not take a "head-in-the-sand" approach that this is not true);

2. To the extent practicable, implement source reduction practices in design and management of SWMBs to reduce mosquito production, without unduly compromising important values and functions of SWMBs for good water quality and wildlife habitats;

3. For whatever excessive mosquito production in SWMBs that cannot be controlled by source reduction, recognize the need to treat such SWMBs with larvicides. Do <u>not</u> bemoan our having to use chemical controls, which many "environmentalists" are often prone to do in almost knee-jerk manner. In

<u>Try not to build this!</u> Based upon our Delaware experience and observations in the field, what we believe would constitute a blueprint or recipe in SWMBs to create "mosquito-breeding heaven" would have the following features – obviously, any steps that could be taken to reduce or eliminate such features, without unduly compromising the primary environmental goals and functions of SWMBs, we encourage to be taken. Here is a listing of some "nasty" features to help build mosquito-friendly environs – <u>don't do this!</u>

- Have uniformly shallow water depths throughout a basin, without deeper reservoirs for predator survival during droughts, drawdowns, or times of poor water quality.
- Have shallow, gently sloping sides along basin margins.
- Have the entire basin periodically dry-out and then reflood to hold water for >5 consecutive days.
- Have water levels along basin margins fluctuate to cause wet-dry-wet conditions in isolated edge pockets.
- Have basin choked with emergent or floating vegetation.
- Have lots of organic material get into the basin (e.g., grass clippings).
- Have little water flow or changeover of basin waters, creating stagnant conditions.
- Locate these SWMBs among or nearby where people live (where they unfortunately often must be located for their primary water quality functions!).

many locations or situations, the need to use larvicides might well be the reality, an unavoidable aspect or cost of creating and using SWMBs.

Case examples in Delaware. In trying to "bring home" these problems (through photographed case studies), we present (to the Workshop's audience) several examples of types and extent of mosquito production problems in SWMBs and types of control actions to implement. Historically, the most use of SWMBs has been in heavily populated and urbanized areas of northern New Castle County above the C&D Canal, and indeed there might now be more than 1000 SWMBs in this area, with many of these basins continuing to present problems. However, the burgeoning growth of this County south of the Canal, with subdivisions seemingly popping up everywhere, has also led to a spread of SWMBs into areas where the demand for mosquito control was historically low. There are of course many natural sources of mosquito production also at play here. In downstate Delaware, particularly in eastern Sussex County where human populations are booming due to the coastal resort (beach) economy and retirement relocations, the recent proliferation of SWMBs is also quite daunting to our control program. If there is one theme that we want to convey in these case examples, it is that wherever basin engineering designs, water and vegetation management practices, and good attention to necessary maintenance and upkeep of SWMBs can be accommodated or undertaken to reduce or eliminate mosquito breeding, we implore our stormwater management and water quality colleagues to do so. Given the nature and perhaps conflicting goals of some of these SWMBs in relation to mosquito production and control, by no means are we saying that such new measures will fully eliminate the necessity for mosquito control programs to inspect SWMBs and to treat them as warranted; rather, whatever you can do here to help the cause, please do so!

Scientific survey. While the Mosquito Control Section has generated operational information in regard to many of the SWMBs causing us problems, until recently we have not had the luxury or resources for undertaking a systematic, large-scale, scientific look at the situation. In large measure this has now been remedied by completion of a two-year scientific survey of mosquito production in SWMBs, contractually performed in the summers of 2003 and 2004 by Dr. John Gingrich (Dept. of Entomology and Wildlife Ecology, University of Delaware). This study systematically and repetitively examines over 90 sites around the State representing a variety of SWMB habitats, plus several constructed wetland mitigation sites associated with highway development projects. Dr. Gingrich's findings report upon the species and extent of mosquito production found in these systems relative to a basin's physical and biotic features. The Mosquito Control Section initiated this project, helped design the sampling strategy, and provided the funding to carry it out. Dr. Gingrich's findings were reported at the Workshop and are found elsewhere in these Proceedings.

For further information, please contact: William H. Meredith, Mosquito Control Section, Division of Fish and Wildlife, DNREC, 89 Kings Highway, Dover, DE 19901. Phone: 302-739-9917. Email: William.Meredith@state.de.us.

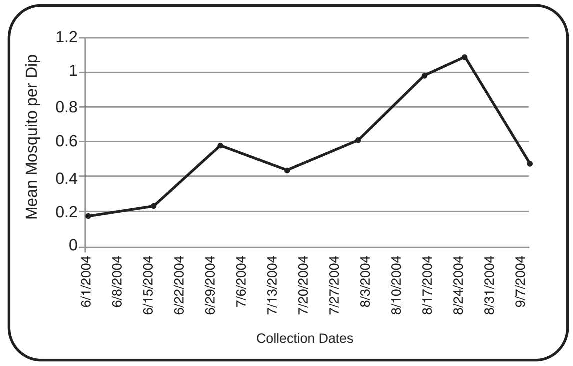
Predictors of Mosquito Abundance in Stormwater Ponds in Delaware

Presented by:
Jack Gingrich, Department of Entomology and Wildlife Conservation, University of Delaware

Our primary objective was to evaluate the relationship between different types of BMPs/ wetlands, mosquito species, and their abundance in four different pond types: a) retention ponds; b) detention ponds; c) CREP ponds; and d) constructed wetlands. Ancillary objectives included: 1) Determining the physical and biological attributes of good and poor mosquito habitats among the various types of stormwater catchments; 2) determining biotic factors that might influence mosquito abundance; 3) where vector species occur, determining the species associations present; and 4) establishing the relationship between various water quality factors and mosquito abundance. Ultimately, we sought to find predictors of mosquito abundance in these stormwater ponds.

There are seasonal differences in larval mosquito abundance in stormwater ponds. Abundance is generally much elevated in August and September. Among the various pond types, detention ponds are generally much better producers of mosquitoes than other pond types, including retention ponds, wetlands, and usually, CREP ponds. Shallow retention ponds are more apt to have abundant mosquito subsites than steep ponds. Partially or fully shaded ponds are also more likely to exhibit an abundance of mosquitoes. Invertebrate predator numbers are inversely correlated with mosquito abundance. Water quality factors are difficult to quantify with respect to mosquito abundance, and statistical analyses at this date are incomplete. Nevertheless, orthophosphate appears to be positively correlated with overall mosquito abundance, while chloride ion presence appears to be inversely correlated.

Seasonal Mosquito Distribution, All Ponds



With respect to vector species of concern, *Culex pipiens, Cx. salinarius, Cx. restuans, Aedes vexans,* and *Ochlerotatus sollictans* appeared to have some associations with specific vegetation groups, including grasses, *Ludwigia*, duckweed, sedges, *Phragmites*, and rushes, depending upon species. Overall, ponds that are heavily vegetated around the periphery appear to have abundant mosquito activity. However, there were no statistically significant associations. Concerning mosquito-mosquito associations, *Culex pipiens* was very often associated with *Cx. salinarius*, while *Ae. vexans* was sometimes associated with *Oc. sollicitans*.

Relationships between Mosquito Species and Vegetation

Cx. salinarius appears to be associated with duckweed and phragmites, but correlated with *Cx. pipiens* in early season only

Cx. pipiens associated with *Ludwigia*, grasses, loosestrife, correlated with *Cx. salinarius*

Oc. sollicitans is associated with rushes and *Ae. vexans*, but not correlated

Ae. vexans is associated with sedges and but not correlated

Association
Two variables that are related.
Association does not imply causation.

Correlation
A measure of the linear relationship between two variables.

Even though mean mosquito abundance per dip may sometimes appear to be low, this is often misleading; sites with low abundance or even zeroes drag down the overall means, as do seasonal periods of low abundance. From an operational standpoint, there were many times and sublocations where the abundance was high enough (> 10 per dip) to have triggered operational measures.

Preliminary Predictors of High Mosquito Producing Ponds

- Ponds with shallow, heavily vegetated edges
- Shaded or partially shaded ponds
- Low predator numbers
- Possible Associations—if vegetation is skewed towards grasses, sedges, algae, duckweed, loosestrife, *Alisma, Phragmites*
- High phosphate content—no stats, but likely association

Ecosystem and Wildlife Habitat Considerations in Stormwater Management

Presented by:
Roger Tankersley, Jr and Mark H. Wolfe, Tennessee Valley Authority

Stormwater management is progressively a concern for states, municipalities, and water control districts as well as for the industries, businesses, and developments that occur within those jurisdictions. Incorporating wetland habitats into passive stormwater management design can increase the overall benefit of stormwater treatment plans, provide key habitats in areas that are usually habitat deficient, and provide opportunities for public education on wetland issues. We present many of the important concepts and issues related to successful integration of wildlife habitat into passive stormwater control.

Key to successful integration of wildlife habitat is an understanding of the types of wetland habitats located in your region. The Hydrogeomorphic Classification of Wetlands (Brinson 1993) is an excellent way to assess what plants and animals may occur in your area, and to understand the moisture regime they require for year-round survival. Hydrogeomorphic classification incorporates the geomorphic setting (landform shape, topographic position), water source, and hydrodynamics (energy level and direction of water flow) into a succinct description of wetland type. The key advantage for constructed wetlands is that these factors can be assessed before construction, and similar wetlands can be visited to identify target plants that should be used to mimic natural wetlands.

Most stormwater wetlands are small and isolated. To maximize the benefit of establishing wildlife habitat, planners should consider the regional landscape configuration of existing wetlands and attempt to locate constructed wetlands nearby. Existing wetland location and size can be assessed using the National Wetlands Inventory (NWI, http://wetlands.fws.gov). On larger construction sites, this regional consideration may mean a simple adjustment of wetland location from one side of the site to the other. If there are no nearby wetlands, locating the site near intact blocks of other habitat types (forested upland, green infrastructure sites) will still increase the ecological value of the wetland. By providing landscape connectivity between existing habitats and newly established wetlands, planners can foster the movement of plants and animals across the landscape, and more fully integrate stormwater wetlands into the natural environment.

We developed several prototype constructed wetlands to illustrate integration of ecological function into stormwater management; these prototypes can be viewed in our presentation at http://www.epa.gov/maia. Our designs attempt to mimic natural, depressional wetlands with overland inflow and evaporation or groundwater discharge outflow. All designs meet EPA standards for trapping overland flow and preventing pollutants from reaching groundwater. We believe a tiered design, with several topographic levels providing slightly different habitats ranging from fully inundated to well drained soils, provides the best year-round diversity of habitats while maintaining stormwater capture functions. Where ecologically enhanced stormwater wetlands are used, particularly in an urban environment, planners may also realize a public relations benefit through the use of walking paths or boardwalks constructed around the retention system. Birdwatchers, teachers, and general wildlife watchers are known to visit constructed wetlands, and signage at these sites provide an excellent opportunity for communicating how stormwater control can enhance the natural environment. In new housing developments, the wetlands can provide a scenic focal point for the neighborhood and may enhance property values. With relatively little additional effort, site planners can greatly enhance both the biological function and the scenic value of stormwater wetlands.

Overview of Stormwater Best Management Practices (BMPs) in Delaware

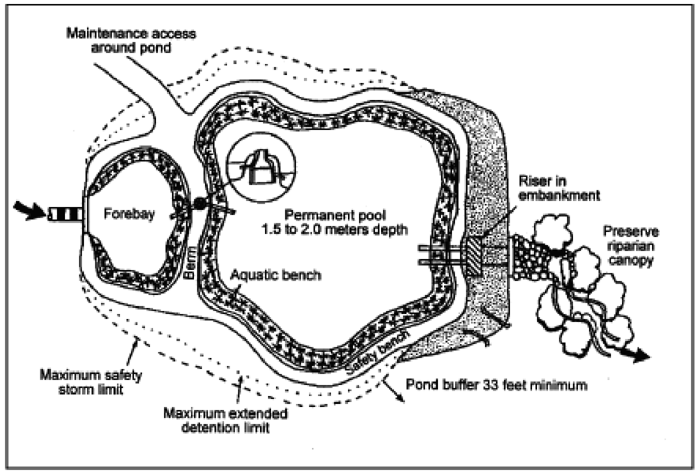
Presented by:
Randy Greer, DNREC

The stormwater management practice with which most people are familiar is the stormwater management pond or basin. Runoff is collected in the pond and either held there to be released at the pre-development discharge rate, or the runoff is infiltrated into the ground. Stormwater ponds can be permanently wet, with typically three to four feet of water. They may also be dry, only containing water during rain events. They can be designed with an outlet structure to release water into a ditch or stream, or they can be designed without an outlet structure, allowing the runoff volume to infiltrate into the existing soil.

Any of these types of ponds may be excavated. They may also be created by constructing an embankment, or dam, through a depression to develop a pond area. Ponds may also be a combination of embankment and excavation. All stormwater management ponds in the State must be designed and constructed in accordance with USDA Natural Resources Conservation Service's Pond Code 378.

A properly designed wet pond will always contain a pool of water, regardless of when the last rain event occurred. The permanent pool may be supported by groundwater, or totally supported by runoff generated throughout the watershed draining to the pond. Ponds designed to be wet that are constructed in areas of sandy soil may need to be lined with clay or a synthetic liner to prevent the permanent pool from infiltrating.

A wet pond will contain approximately three to four feet of water depth within the permanent pool. Enough volume is provided above the elevation of the permanent pool (to the top of bank of the pond) to store and contain the developed runoff and discharge it at pre-development rates. To achieve the water quality objectives of the *Sediment and Stormwater Regulations*, the quality storm runoff should be held in the pond and released over a twenty-four hour period. This time delay allows for settling of 80% of the suspended solids that enter the basin in the runoff.



Schematic of a wet pond showing aquatic and safety benches (Source: Schueler, 1987)

The side slopes of stormwater management basins are designed to be no steeper than 3:1. A 3:1 slope can be mowed and maintained more easily than steeper slopes and they can be traversed by foot with little difficulty.

Wet ponds are designed with benches, or level areas, around the pond for safety. Two ten foot wide benches should be provided: one at one foot above the permanent pool elevation and one at one foot below the permanent pool elevation. If someone were to fall while walking along the top of bank of the pond and roll down the pond slope, they would come to rest on the bench above water. If the same person were walking along the water's edge and slipped, they would only fall into a foot of water, rather than three or four feet. These benches have the added benefit of providing a good environment for the establishment of aquatic grasses and other vegetation. In addition to providing habitat for pond-dwelling critters, this vegetation can create a screen that discourages people from wandering too close to the open water.

People are often concerned about mosquitoes breeding in stormwater management ponds. If the pond is designed properly, with three to four feet of depth in the permanent pool, an aquatic ecosystem will become established in the pond with fish, frogs and other predators to keep mosquito larvae in check.

Another concern with stormwater ponds is that they will become cattail- or phragmites-infested holes in the ground. Again, if the pond is designed and constructed properly, the water depth will be greater than what is optimum for the growth of these invasive species. Both can be managed through mechanical removal or chemical means if they are introduced into the pond. Furthermore, if a "pondscaping" plan is implemented, more desirable aquatic species like reeds and rushes will become established and out-compete the invasive species.

Forebays are established at the pond inlets to capture sediment as runoff enters the stormwater management basin. Forebays are contained areas at the inlets that are deeper than the remainder of the pond to allow for sediment accumulation. By allowing a place for sediment to settle at the inlet, maintenance of the stormwater pond is easier. Maintenance can be confined to excavating the accumulated sediment from the forebay, rather than dewatering the basin to muck out the sediment from the entire pond bottom.

Pond inlets should be designed to be as distant from the outlet structure as possible. Doing so provides for the longest flow path between inlet and outlet, allowing for the most sediment settling time to occur. Inlets that are too near the pond outlet can result in "short circuiting" of the flow and reduced pollutant removal.

The original urban stormwater BMP is the dry basin. Dry stormwater basins do not contain a permanent pool and remain in a turf condition until a rain event. During the storm, runoff is stored in the basin and discharged at pre-development rates. This approach works well for flood control, or stormwater quantity management, but provides little pollutant removal capabilities, or stormwater quality management. By introducing extended detention in dry basins, runoff from the quality storm events must be held in the basin and released over a twenty-four hour period to allow sediment and other pollutants to settle out. Better sediment removal capabilities are seen when runoff is introduced to a permanent pool rather than into a dry basin. To achieve better quality treatment from dry extended detention basins, oversized forebays at the inlets and a micropool prior to the pond outlet provide the necessary pool area for sediment removal, while maintaining a dry basin for management of larger storm events.

Ponds are classified by USDA Natural Resources Conservation Service's Pond Code 378 as either embankment or excavated ponds. In an embankment pond, fill material is used to create a dam to pond water. In an excavated pond the entire basin is excavated below the existing grade. Ponds may also be a combination of embankment and excavation. Any basin, wet, dry or infiltration, may be excavated or embankment.

All of the components necessary to construct the pond embankment and outlet structure will be designed and detailed on the approved plan. The principal spillway is composed of the outlet structure and the outfall pipe. The outlet structure may be a corrugated metal standpipe or a modified concrete catch basin, each with orifices and/or weirs to discharge the various design storm flows. The outfall pipe is connected to the outlet structure and carries the discharge flow through the embankment to the point of discharge in the stream. The outfall pipe can be constructed of various materials; the pipe diameter, length, slope, and material should be detailed on the plan. The outfall pipe joints and the connection to the outlet structure must all be watertight. Rock outlet protection must be provided at the discharge end of the outfall pipe to dissipate energy and protect the area from erosion.

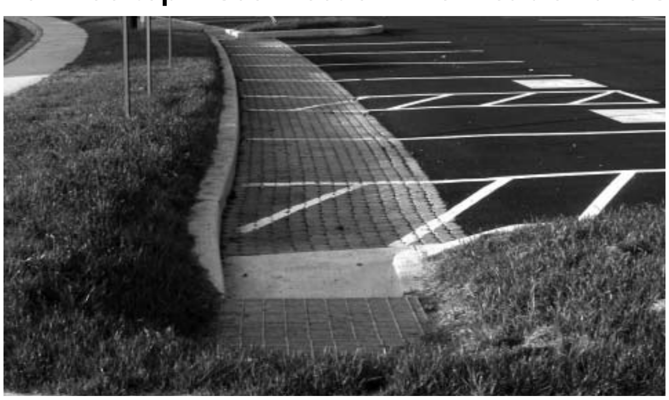
Infiltration is a stormwater management practice that may be designed throughout the state, but is most commonly seen in the coastal areas of Sussex County where soil is sandy and infiltration rates are high. In an infiltration facility, all of the runoff will be discharged back into the ground, not surface discharged into a ditch or stream.

Infiltration can occur in open ponds or basins, in underground manifold systems, and in trenches. An infiltration basin will be dry until a rain event occurs. After a rain, runoff from the watershed is stored in the infiltration basin until the existing soil can take that runoff in through infiltration. In an underground infiltration manifold system, runoff is conveyed through a surface inlet into a perforated pipe system that is laid in a stone bed. The pipe and stone provide volume to store the runoff until it is able to infiltrate.

Less common infiltration practices include trenches, pavers, and porous pavement. In an infiltration trench, runoff enters a stone-filled trench by surface flow and is held there until the runoff infiltrates.

Pavers provide openings in the parking surface where water is conveyed to a stone reservoir layer below to allow the runoff to infiltrate. Pavers should only be used in overflow parking situations where their useful life will not be shortened by excessive amounts of sediment, oil and other pollutants.

Non Rooftop Disconnection—Permeable Pavers



Porous pavement contains less fine aggregate in the mix to allow water to flow through the pavement to the stone reservoir below where runoff will be held until it is able to infiltrate into the existing soil.

Porous pavement requires regular maintenance, including vacuuming and power washing to prevent sediment from sealing off the surface.

Infiltration systems, particularly underground systems, must have a suspended solids filter to remove sediment from the runoff before it enters the infiltration system. Sediment can easily clog the bottom of an infiltration facility, causing it to fail. In most cases, vegetation in the form of a grassed swale is used as a suspended solids filter, but occasionally a structural filter will be used at the catch basin.

Infiltration practices are normally designed to manage the quality storm runoff, and can be used to manage larger storms if the soils and measured infiltration rate permit. However, a safe overflow must be provided to bypass larger storm events through the infiltration practice.

Infiltration trenches and basins must be sized to adequately infiltrate the design runoff volume within 48 hours. Statistically, Delaware receives rainfall every three days, so the infiltration system must drain within 48 hours so that the facility volume is available for storage of runoff from the next storm event.

Green Technology BMPs include conservation site design, impervious area disconnection, conveyance of runoff through swales and biofiltration swales, filtration through filter strips, terraces, bioretention facilities, and recharge through infiltration facilities. The Green Technology approach is designed to intercept runoff from rooftops, parking lots and roads as close as possible to its source, and direct it into vegetative recharge and filtration facilities incorporated into the overall site design and runoff conveyance system.

Incorporating stormwater management into the core of the site design for a new development allows stormwater to be treated as a resource rather than as an afterthought. Conservation site design takes into account the ideas of low impact development (LID) that were discussed earlier in the Principals of Stormwater Runoff section. By clustering development, leaving areas undisturbed, and reducing impervious surfaces by narrowing streets and using gravel drives rather than asphalt or concrete, less runoff is developed. Constructing open swales and creating natural areas to which to direct runoff allows for recharge of that runoff rather than surface discharge into streams.

The benefits of LID extend beyond water quality. While less impervious surfaces, greater amounts of open space, open swales, and buffers all have the benefit of increased infiltration rates and lowered volumes of runoff to mimic the pre-development hydrology, there are other benefits as well. Leaving forested areas, wetlands, and open spaces in their pre-development condition preserves habitat for the plants and animals living in that ecosystem. Providing or maintaining open space is a benefit to the community in a residential area and enhances property values. People want to have open space around them, as is evident by the popularity of golf course living.

Environmentally Sensitive Design

Impervious areas such as rooftops can be "disconnected" by directing downspouts onto grassed areas to allow the roof water to infiltrate and recharge groundwater. This is preferable to piping the roof water directly from the house or building to the driveway, street, or storm drain system where it will be collected and discharged into the stormwater facility or receiving stream with no recharge at all. Roadways and parking areas can be "disconnected" by allowing them to sheet flow off into grassed swales or open areas. Runoff in swales, while being conveyed to the discharge point, has a significant chance of recharging while runoff in a pipe collection system is totally conveyed to the downstream water body, with no reduction in volume.

Structural Practices—Filtering Systems

Biofiltration swales convey runoff at shallow flow depths through wide swales. Swale bottom widths are generally two to eight feet wide, but can be wider if a level spreader is provided to spread flow evenly throughout the swale bottom. The design depth of flow for the quality storm is one half the swale vegetation height to provide the maximum grass contact and filtration. Biofiltration swale vegetation is maintained at a height of six to eight inches, allowing for a design flow depth of three to four inches.

Biofiltration Swale

Biofiltration swales can be very effective in removing Total Suspended Solids (TSS) and adsorbed metals, although they are less effective in removing nutrients. While swales are not thought to be capable of quantity management, designs incorporating check dams can provide control of peak flows.

Filter strips are designed based on the same principal as biofiltration swales. They spread runoff uniformly over a filtering surface of vegetation, providing infiltration and pollutant removal. Filter strips can provide substantial treatment if they are not overloaded by sediment and runoff. They are best suited for treating small areas of impervious surfaces.

Structural Practices—Filtering Systems

Bioretention facilities are landscaped pocket depressions designed to infiltrate runoff through an engineered soil media. The media is porous, containing washed sand, peat, and triple shredded hardwood mulch. The quality storm runoff is stored in a depression on the surface, then the runoff filters through the porous media and either infiltrates into the existing soil or is discharged through the underdrain. During the growing season, plants in the bioretention facility use nutrients in the runoff, providing for some pollutant removal in that fashion.

When bioretention facilities are incorporated into the landscape, they can provide substantial filtering and nutrient transformations before runoff is discharged into the conveyance system. Originally bioretention was designed to treat only the quality storm and bypass the larger storms; however, they have been proven to provide some peak flow attenuation, making bioretention an option for quantity treatment as well.

Most Green Technology BMPs incorporate infiltration as part of the treatment process. However, infiltration trenches located in swales can be considered a Green Technology BMP of their own. Infiltration trenches in swales provide additional wetted surface area and storage volume, and often they can be designed to penetrate shallow impermeable soil profiles to recharge deeper soil horizons. The same design criteria would apply for these infiltration trenches as other, more traditional, infiltration practices. Pretreatment measures are extremely important in the design of infiltration trenches since high sediment pollutant loadings will cause failure.

There are methods of treating runoff in urban settings other than construction of a pond or infiltration system. Structural BMPs such as filtration systems including sand filters, gravity and/or swirl separators and catch basin inserts are available when space does not allow for the construction of traditional BMPs, as when a site is being redeveloped. These types of BMPs are not applicable when stormwater quantity management is required; they are quality treatment practices only. Furthermore, only the sand filter has been approved as a stand-alone quality treatment practice. The other types of units may be used in a treatment train approach on a case-by-case basis.

Engineered stormwater management filtration BMPs are structural units that allow for runoff to flow through media such as sand, polymeric materials, activated carbon, compost, etc., to remove pollutants. The quality storm, or first flush, of runoff is treated for pollutant removal while larger flows bypass the system. The medium used determines the type of pollutants that are removed. Sand has the capability to remove sediment and hydrocarbons. Polymer materials are formulated for hydrocarbon removal. Activated carbon is used to remove organics and metals in addition to hydrocarbons. Nutrients are removed in compost media.

Each proprietor of a filtration system has a specialized medium targeted to certain pollutants; however, many of the manufacturers now offer the option of various media to target site-specific pollutant loads. Filtration BMPs such as the sand filter, Aqua-Filter, Ultra Hydro-Kleen and StormFilter all require monitoring and periodic maintenance which is more intensive than traditional stormwater practices such as ponds. Eventually, the filtration media will need to be removed and replaced; the time between replacements of media is dependent upon pollutant loading.

The sand filter is the only engineered structural BMP that has been approved in Delaware as a stand-alone stormwater quality treatment practice. The sand filter is a linear concrete unit with two chambers running the length of the filter. One chamber has a grate at the surface; this is called the sedimentation chamber. Runoff flows from the surface of a parking lot, through the grate, and into the sedimentation chamber. This chamber is 18 inches deep and stays wet. It is here that the largest sediment particles settle out. Water from the sedimentation chamber overflows through a series of weirs into the second chamber, the filtration chamber. The filtration chamber has a solid cover so that no runoff goes directly into the filtration chamber. The filtration chamber is filled with 18 inches of sand. As the runoff percolates through the sand, smaller sediment particles and other pollutants such as oil and grease are filtered out. Once the runoff filters through the 18 inches of sand it is discharged through a low flow underdrain pipe into the storm drain system.

Many engineered stormwater treatment structures are available for treatment of the first flush of runoff. Products such as Stormceptor, Vortechs, CDS (Continuous Deflective Separation), BaySaver, Aqua-Swirl, and Downstream Defender use gravity and/or swirl separation to remove pollutants such as sediment, oil and grease, trash and debris from the runoff stream. Gravity separation is achieved by forcing runoff through a series of baffles to collect both floatable pollutants and settleable solids. Units that use the swirl technique, also known as vortex or hydrodynamic technology, do so by deflecting the runoff as it enters the unit, taking advantage of the energy in the flow itself, and propelling that runoff into a vortex. Sediment is caught up in the swirling flow path to settle out later.

Engineered stormwater treatment structures require more intensive monitoring and maintenance than more traditional methods of stormwater management. They are suited to highly or totally impervious sites. They are designed to treat small storm events such as the quality storm, and require a bypass for peak flows of larger storms. They all are constructed underground, taking up no developable land. These units adequately trap floatable pollutants, such as oil and grease and trash and debris, as well as heavier settleable solids, but they are not effective at removing suspended solids and soluble pollutants such nutrients. For these reasons, these units have not been approved as stand-alone stormwater quality treatment practices. They may be used as part of a treatment train, or in redevelopment projects where land availability is limited.

Catch basin inserts are varied in how they function and in the level of pollutant removal they provide. Some catch basin inserts are simple gross pollutant removal systems, while others employ filtration media for removal of oil and grease, hydrocarbons, particulate metals, and sediment. What these inserts do have in common is their ability to be inserted into a new or existing catch basin. This allows them to be used extensively in retrofit projects and in redevelopment projects where space is limited for stormwater management facilities. As will all of the engineered structural BMPs, catch basin inserts are only approved for use as part of a treatment train on a case-by-case basis.

There are many varied type of stormwater management BMPs. There is not one BMP that is applicable to all sites. Each of them has their place. Some sites may even have two, three, four, or more different types of practices, all with same goal:
to enhance the quality of runoff from the site and provide flood control.

Summary

Traditional Approaches
- Wet Ponds
- Dry Ponds
- Infiltration

Structural BMPs
- Filtration Systems
- Separation Units
- Catch Basin Inserts

Green Technology BMPs
- Conservation Design
- Disconnect Impervious Surfaces
- Biofiltration Swales
- Filter Strips
- Bioretention
- Infiltration

Facilitated Discussion

Presented by:
Kent Thornton, FTN Associates

Following the presentations, a discussion among participants was facilitated to:

1. Address questions that were not raised during the presentations because of time constraints;
2. Identify characteristics of stormwater retention basins that would achieve desired water quality goals and minimize mosquito production; and
3. Identify approaches for improving public knowledge about:
   a. mosquito production and disease transmission;
   b. contribution of stormwater retention/ detention basins to mosquito problems; and
   c. contribution of stormwater retention/ detention basins to achieving water quality standards.

Questions

Questions and responses raised during the facilitated discussion session included:

1. Because maintenance is so important to the effective operation of stormwater basins, can the maintenance requirements be included as part of the NPDES permit?

   Delaware has created a Task Force to evaluate the current regulatory requirements for maintenance and provide recommendations for ensuring stormwater basins are maintained. In Maryland, stormwater basin inspection agreements are included as part of the 2000 stormwater regulations. Under these regulations, stormwater basins are inspected every three years and recommendations provided to the owner for maintenance. The EPA might be able to incorporate maintenance requirements as part of the Municipal Separate Storm Sewer System regulations. Additional avenues for ensuring maintenance of stormwater basins and practices are being pursued by both of the states and EPA. In Maryland, maintenance is included in the NPDES MS4 permits and regulations. However, there are no federal, Delaware, or Maryland regulations that satisfactorily address maintenance of stormwater sites for mosquito control.

2. Where does the public think mosquito problems arise?

   This depends on where they live in the States, and the location of the stormwater basin. If wetlands are prevalent in the community, the public might view the wetlands as the culprit and want to take action to eliminate or treat the wetlands. Leading public perceptions of wetlands are as swampy, snake and mosquito-infested areas. Because stormwater wetlands typically are located near houses, the stormwater sites are likely to be viewed as the culprit. In some instances, stormwater wetlands do contribute to mosquito production, but this is not always the case. Public education must be part of integrated stormwater management for stormwater control, mosquito reduction, and wildlife habitat enhancement.

3. Where do mosquito problems occur and why?

   The geographic location of mosquito problems, the specific mosquito species, land use and ownership, and season are all considered by mosquito control agencies when complaints are received. The relative importance of mosquito production in stormwater basins varies according to the design and maintenance of the site, mosquito-borne disease activity in the area, public tolerance of mosquito annoyance, and the proximity of natural mosquito producing wetlands.

Land use and property management by owners can contribute to mosquito production by supporting areas that pond or catch water (e.g., roof gutters, tires, open containers, poorly drained areas). The source, or location, of mosquito problems varies by season. In the spring, mosquito production in natural habitat occurs most commonly in areas experiencing seasonal flooding. In the summer low flow period, mosquito production in natural wetlands occurs most commonly in permanent and temporary pools. Mosquito production can occur at any time in stormwater sites, but most commonly occurs during the summer, particularly in shallow water stormwater basins with abundant emergent vegetation and few, or no predators of mosquito larvae. Land use and property management by owners can contribute to mosquito production in stormwater basins. Deep water detention basins with high levels of sedimentation and/or accumulation of rubbish must be regularly maintained by dredging to prevent the creation of shallow water mosquito breeding areas. The particular species of mosquito is also important. Different mosquito species are associated with temporary pools of water versus permanent pools, and different species are vectors for different diseases. Finally, tolerance to mosquitoes varies significantly among individuals, from any mosquitoes considered intolerable by some to tolerance of a bite every minute by others. All these factors are considered in the mosquito control approach.

4. What assurances are there that pesticide use will not be more harmful than West Nile Virus (WNV)?

   Any pesticide in use for mosquito control has gone through extensive research and risk assessment modeling as part of the EPA pesticide registration process. In addition, these pesticides can only be used by, or under the supervision of, a licensed pesticide applicator according to the registration requirements. These conditions reduce the risk of adverse effects to human health, wildlife or the environment from exposure to pesticides used for mosquito control. This opinion is supported by a recent court ruling and by EPA's pending Final Rule that an NPDES permit is not required for applications of insecticides registered as mosquito larvicides to bodies of water.

Stormwater Retention Basins and Minimizing Mosquito Production

The optimal design for a stormwater retention basin that minimizes mosquito production would achieve the following desired goals:

1. Satisfy the regulatory requirements of the Clean Water Act for stormwater control.
2. Control flooding/water quantity in downstream systems (MD, DE).
3. Support water quality standards of the receiving waters by attaining NPDES requirements to:
   a. Reduce total suspended solids by 80% (DE, MD)
   b. Reduce total phosphorus loads by 40% (MD)
4. Protect or improve the receiving stream channel and riparian habitat.
5. Provide for easy maintenance.

These criteria are already part of the Delaware and Maryland Stormwater Design Manuals for stormwater management basins and include:

For Wet Ponds

- Steep slopes (no steeper than 3: 1, with 4:1 slopes preferred),
- Minimal vegetation (< 20% of the surface area), which does not choke the basin,
- Permanent open water 3-4 feet deep (i.e., deep enough it does not dry out and provides for fish habitat), and
- Sidewall benches for public safety.

For Dry Ponds

- Pond does not hold water for longer than 48-72 hour period.

These design criteria, with the possible exception of sidewall benches, should minimize mosquito production in both wet and dry ponds. The sidewall benches may retain shallow, pooled water where natural predators might not be able to prey on mosquito larvae. In addition, these benches can become colonized by vegetation, which can create habitat for mosquito production. Public safety, however, cannot be compromised. An alternative design should be sought that has side benches to protect the public, but as narrow as possible without compromising safety, that drain readily toward the basins interior, and that minimize colonization by emergent vegetation.

Stormwater basin inflow/outflow designs are adequate to achieve stormwater goals and, if properly maintained, should minimize mosquito production. However, water can pool in the interstices of the outflow riprap or energy dissipater, creating a habitat for mosquito production. Multiple sized aggregate was discussed, but the velocities during storm flow would likely scour small aggregate. Concrete or other solid materials for energy dissipation crack during freeze-thaw cycles, so properly sized rip-rap is considered the best choice. Substrate having good drainage or percolation characteristics under the riprap might also be explored. This is an area that could also benefit from design research.

Maintenance is an important issue associated with stormwater basins. Many stormwater basins are under private ownership. In many instances, the owner or community association does not realize they are responsible for the maintenance of the stormwater basins, which can be expensive. In addition there are no, or limited, government funds available to off-set maintenance costs. In Maryland, regular basin maintenance is part of the Stormwater Management Plan or Stormwater Pollution Prevention Plan. Stormwater systems are reviewed and inspected every three years.

At present, there are no requirements in the Delaware, Maryland, or federal stormwater regulations, policies, or guidelines to consider and manage for the unintended consequence of mosquito production in stormwater management sites. Given the concerns over mosquito-borne diseases, guidelines are needed. A positive step along these lines was taken when the EPA's Office of Waste Water invited the American Mosquito Control Association in May 2005, to help revise the EPA's final draft for the Agency's "Stormwater Pond and Wetland Maintenance Guidebook" (a BMP for wet/retention stormwater management ponds and their associated wetlands.

Public Education

Educating the public about the regulatory requirements for stormwater systems and factors associated with mosquito production was raised as an important topic. The following suggestions were offered to improve public education:

1. Frequent meetings with stakeholders to develop trust and reinforce information;
2. Use of public service announcements;
3. Use of agency and non-governmental organization newsletters, brochures, and Web sites;
4. Providing factual messages that emphasize that:
    a. There are multiple objectives for stormwater management basins (flood

control, water quality improvement, etc.).

b. Mosquito production can occur in stormwater basins and might become a problem.
c. There are multiple mosquito species, each with different habitat requirements and different risks to human populations.
d. Reducing the amount of water, sediment, and nutrients entering stormwater basins can improve the quality of the water stored in the stormwater basins so they can support natural controls on mosquitoes (e.g., insect, fish predators).
e. Use of natural controls can reduce mosquito production, but natural controls will not eliminate mosquito production.
f. The importance of identifying the issues within communities, including individual tolerance of mosquitoes, and concerns over West Nile virus, pesticide use, mosquito production, and stormwater basins.

5. Risks from stormwater pollutants, mosquito vectors for West Nile virus, and pesticide use in mosquito control can all be reduced. There is some disagreement among the public about what constitutes the greatest risk: for some, the risk of West Nile virus exceeds the risk from pesticide exposure; for others, concern about pesticide exposure for children exceeds concern over West Nile virus. However, the preponderance of peer reviewed scientific evidence indicates that pesticides, when used according to label directions for larval and adult mosquito control, pose minimal risk to human health and environmental quality. The documented negative impacts of mosquito-borne diseases in the U.S., such as West Nile virus, eastern equine encephalitis, western equine encephalitis, etc., have been much greater on human health and wildlife populations than the impact of mosquito control insecticides.

Delaware held a series of workshops to provide information to the public about stormwater basin management, and maintenance requirements. These workshops were effective in bringing stakeholders together, resolving conflicts that were arising among stakeholder interests and regulatory agency requirements, and providing factual information on all issues. A similar workshop format might be useful in providing information to the public on stormwater basin management, mosquito production, West Nile virus transmission, and pesticide use. EPA has a Web site that provides fact sheets on responsible pesticide use for mosquito control that would be useful for public education.

Other Issues

While stormwater basins can be effective in achieving water quality goals and minimizing mosquito production, better watershed management practices can significantly reduce inflow volume and pollutant loads. Environmentally Sensitive Design (ESD) or Low Impact Development (LID) techniques, using green technologies, enhance filtration/infiltration and reduces pollutant loading. Information on ESD is available in the Maryland Design Manual and from the Newcastle model. The key is to focus on reducing impervious surface area and sheet flow through buffer areas, encouraging natural conservation, and promoting sustainable development.

Summary

A Stormwater Management Workshop was held on February 9, 2005, at WorWic Community College, Salisbury, Maryland to discuss stormwater management basins and their role in mosquito production and potential for wildlife habitat. Participants represented state, federal, and local governments; engineers; mosquito scientists and control specialists; non-governmental organizations; homeowners' associations; and interested members of the public.

The regulatory requirements for stormwater management under both federal (EPA) and state statutes (DE, MD) were presented. Stormwater management is regulated through the NPDES program within EPA and state agencies with designated authority. Stormwater regulations include specific requirements for flood control and total suspended solids reductions (> 80%) in both DE and MD, with MD also requiring at least a 40% reduction of stormwater total phosphorus loads.

Mosquito production and mosquito control programs were discussed both from a national perspective and state perspective (DE and MD). There was a general recognition that stormwater basins can contribute to mosquito production problems, particularly if these basins are not adequately maintained. As with any biological organism, mosquito production and control is a complex issue, that depends upon the specific mosquito species, species feeding times, disease-specific vectors, unique habitat requirements, and natural controls. Mosquito control programs are tailored to specific locations, habitats, community characteristics, mosquito species, and season of the year.

The wildlife habitat potential of stormwater basins has not been extensively investigated. However, stormwater basins have the potential to provide the ecological conditions that favor natural aquatic predators of mosquitoes, including permanent pools, complex emergent/submergent vegetation structure, complex food webs, and good water quality. While natural mosquito predators often won't reduce mosquito populations to levels desired by local communities, mosquito predator populations should be encouraged through stormwater basin design and management

Engineering considerations for stormwater management practices are included in design manuals for both Delaware and Maryland, and are used by the construction, development, municipal, and industrial communities in designing stormwater systems. As within any built structure, maintenance is the linchpin for successful operation of stormwater systems.

A facilitated discussion followed the presentations. A question and answer period initiated the discussion. Following this question and answer period, workshop participants discussed the optimal design for a stormwater management site that would achieve water quantity/quality goals and minimize mosquito production. In general, the current designs for stormwater basins (wet basins) in both Delaware and Maryland satisfy the optimal design criteria, although some minor design changes are warranted. The principal design feature that might contribute to mosquito production and invasive vegetation are sidewall benches that are required by Delaware for public safety. There was also concurrence that stormwater detention (dry) basins would not be problematic for mosquito production if they fully dried after their designated 24-72 hour wet periods. Mosquito production problems frequently occur when these systems retain water past 5-7 days, either because of heavy or frequent rains, improper design or construction, and/or inadequate maintenance. Maintenance was discussed as a critical issue in the successful operation of stormwater management systems whether they are retention or detention ponds. There was some discussion of incorporating maintenance requirements in NPDES stormwater permits. Maryland regulations do

include maintenance. Suggestions for improving public education were also provided by workshop participants.

The workshop provided an effective forum for showcasing and discussing different perspectives on stormwater management practices and mosquito production. It is hoped the constructive impacts of this workshop won't only be felt at municipal, county, or state levels in Delaware and Maryland, but also at a national level.

At the national level and as a direct consequence of the workshop, interactions between EPA and the American Mosquito Control Association (AMCA) were initiated in May 2005, with the focus on having the AMCA help revise the EPA's final draft for the Agency's "Stormwater Pond and Wetlands Maintenance Guidebook" (a BMP for wet/retention stormwater management ponds and their associated wetlands).

Written by:
Frederick Kutz, Consultant in Environmental Sciences
and Roman Jesien, MD Coastal Bays Program

The Stormwater Workshop was successful in bringing together people of diverse disciplines and venues; attendance filled the largest room at WorWic Community College. During this one-day event, both formal and informal discussions occurred throughout the workshop. Many of the central issues involving stormwater management, mosquito production, wildlife habitat and engineering considerations emerged and were discussed openly in a non-confrontational environment. However, the central focus of the Workshop was broad, and thus, some issues were either insufficiently discussed or **did not surface** at all because of time constraints. The objective of this chapter is to outline some of these remaining issues for future consideration.

Location, Location, Location!

This old adage of real estate contains a certain truth about stormwater management facilities. No central geospatial inventory of stormwater management facilities exists; so for the most part, many locations are unknown. Therefore, much information about the types of facility, their upkeep, their ownership and their functioning is unknown. Action is needed to remedy this lack of knowledge.

Best Management Practices (BMPs)

This is a widely used term in engineering science. In most cases, BMPs are supported by research results that confirm that BMPs are accomplishing intended results. In stormwater management systems, however, wide latitude has emerged in the configurations and locations of these structures. Studies need to continue to confirm that BMPs are in fact accomplishing their intended ecological functions.

Provision of Wildlife Habitat

One of the disappointing features of the Workshop was the lack of discussion on the habitat value of stormwater management facilities (SMFs). SWFs can possess characteristics common to degraded wetlands that include: wide fluctuations in water levels, and water contaminated with high nutrient, sediment, metal and in some locations, high chloride loads. The degraded physical and chemical characteristics are typically manifest in low plant diversity dominated by tolerant (e.g., cattail) and invasive plants (e.g., Phragmites, purple loosestrife) and low animal diversity that can be dominated by nuisance pests such as mosquitoes. Therefore, it is paramount to minimize stormwater runoff wherever possible. Infiltration of storm runoff through maintenance of pervious surfaces should be strongly promoted.

However, in spite of degraded conditions, SWFs, such as retention basins containing a permanent pool, can serve as beacons of aquatic habitat amidst heavily urbanized landscapes. Depending on water quality, tolerant fish and insect predators can survive in SMFs and can provide effective control on mosquito production. Also, SMFs can provide marginal habitat for birds and mammals in areas that would otherwise be without access to standing water. More ecological research is needed to address these complex habitat issues.

Predation

Stormwater management facilities are inhabited by a diverse group of animals; if satisfactory habitat exists, this species list will include predators of immature mosquitoes. To further complicate this managed ecosystem, different types of facilities at different locations might be influential in determining the kinds of animals and plants found in their environs. Few studies have elucidated the degree of predation that these animals might provide. Adults and immature stages of a number of insects present in stormwater management systems have been shown to be predatory on immature mosquitoes, but their influence on population dynamics appears to be undetermined. Most observations indicate that predation does occurs, but not to the extent of providing effective population control. However, not all stormwater ponds produce excessive amounts of mosquitoes warranting control, so it can probably be assumed that the natural predators in such non-problematic ponds play some role in helping to limit mosquito production. More research is needed to demonstrate the role of predation in population dynamics of stormwater management facilities, and particularly whether some biological control mechanism may be possible.

Innovative Stormwater Management Facilities

Within the last several years, stormwater management guidance has been enhanced to encourage a wider variety of approaches. In fact, many other designs are available to supplement the traditional approach of constructing ponds. Designers of stormwater management systems should be encouraged to use these newer technologies that would reduce mosquito production, particularly in suburban settings.

Harmonization with Natural Landscape

To the extent possible, location of SMFs should consider the features of the environment to describe the contributing drainage area. Natural wetlands should be separated from SMF treatment and only fully treated stormwater should be allowed to enter wetlands. According to recommendations from the Center for Watershed Protection (http://www.cwp.org), there should be no increase in average discharge to the wetland if treated discharge does enter the wetland.

Maintenance

A simple truth in stormwater management is that facilities require periodic maintenance. Without this required maintenance, it is doubtful that the ecological services expected of these facilities will be provided. Additionally, poorly maintained facilities contain the necessary environment for mosquito production, and in many cases, diminished wildlife habitat. More effort is needed to identify poorly maintained facilities and persuade the owners of them to provide the periodic care critical for their effective operation.

Post Conference Success Story

One positive result of the Stormwater Workshop was an invitation issued by the EPA Assistant Administrator for Water to the American Mosquito Control Association (AMCA) to become more involved with the process of drafting stormwater management guidelines. The Office of Water at EPA is charged under federal law with implementing the Clean Waste Water Act that contains regulatory authorities for stormwater. The AMCA is a professional organization of mosquito control workers and scientists with a mission to provide leadership, information, and education leading to the enhancement of health and quality of life through the suppression of mosquitoes and other vector-transmitted diseases, and the reduction of annoyance levels caused by mosquitoes and other vectors and pests of public health importance.

As an outcome of the workshop, in May 2005, on behalf of AMCA, William Meredith (Delaware Mosquito Control Section) met in Washington, DC with Nikos Singelis (EPA Office of Waste Water Management) and other EPA staff from the EPA’s Office of Water to discuss how mosquito control concerns could be better addressed relative to the construction and management of stormwater ponds and other stormwater management facilities. This very productive meeting quickly led to formation of an AMCA Stormwater Management Committee that, in June 2005, reviewed and commented upon the EPA's final draft for the Agency's "Stormwater Pond and Wetland Maintenance Guidebook". The AMCA submitted an extensive set of comments and recommendations for EPA to consider. It is anticipated that EPA will incorporate most of these comments and recommendations into its final BMP for wet/retention ponds, targeted for completion by the end of June 2006. During the May 2005, meeting, the AMCA was also told that when EPA prepares its BMP for dry/detention stormwater ponds targeted for development in 2006-07, that the AMCA will be invited to help in its crafting.

The Steering Committee for the Workshop is delighted with the emergence of this spirit of cooperation.

AMCA Position Paper

Stormwater Management Facilities and Mosquito Production

Issues

Regulations issued under the Clean Water Act require that pollution associated with stormwater runoff be reduced through the use of Best Management Practices (BMPs), but if these BMPs are not carefully designed, implemented and managed in a manner that also considers mosquito production concerns, significant quality-of-life and human health problems can arise. The EPA implements this water quality program, but until very recently had essentially ignored in their regulations and BMPs public health risks associated with mosquitoes, leading uninformed permit holders to create new health threats and public nuisances, while often trapping local governments between conflicting requirements. Additionally, regulations or opinions issued by the U.S. Fish and Wildlife Service (USFWS) for protection of endangered species frequently prohibit or sharply limit mosquito control practices or maintenance activities that might prevent or reduce mosquito production in stormwater facilities.

Background

EPA's "Phase II" stormwater requirements could dramatically increase the number and extent of urban and suburban stormwater treatment facilities (e.g., dry/detention or wet/retention ponds, infiltration swales, etc.) over the next few years. At hearings in October 2002, before a House Subcommittee, speakers from the AMCA, CDC, and EPA all acknowledged potential mosquito problems associated with stormwater management systems. These hearings were driven by pressing concerns over the emergence and spread of West Nile virus especially in the context of mosquito problems due to poorly maintained facilities. Unfortunately, EPA was not quick to implement any corrective measures. [EPA had also notified stormwater managers that any activities in stormwater facilities that might harm organisms listed under the Endangered Species Act are subject to enforcement actions under that Act.] However, more recently and more encouragingly, as aftermath of an EPA-sponsored workshop (February 2005) that examined stormwater management and mosquito production problems in Maryland and Delaware, and along with a follow-up meeting with EPA officials in Washington, D.C. in May 2005, the AMCA has seemingly now triggered a bright, new era within EPA relative to these matters, in now getting the Agency to better recognize these mosquito production problems and adopt some solutions.

Discussion

Despite past problems with having EPA acknowledge and address—in their regulations, BMP guidance documents and factsheets—a wide range of mosquito production problems associated with stormwater management facilities, during the summer of 2005, EPA's Office of Waste Water Management (the federal regulatory authority for stormwater management) invited the AMCA to make revisions to an OWWM draft factsheet titled "Stormwater Structures & Mosquitoes." The AMCA then proceeded to extensively undertake and produce an acceptable final product. The AMCA was also invited by the OWWM this past summer to help critique and revise a voluminous draft BMP for wet/retention stormwater management systems titled "Stormwater Pond & Wetland Maintenance Guidebook," which the AMCA then extensively undertook, and we are waiting optimistically to see how EPA has accommodated our input. During 2006 we understand that the OWWM will also invite the AMCA to help craft and review a BMP focused upon dry/detention stormwater management ponds and infiltration treatment systems. All of this is very refreshing, and seems to mark a new era of collaboration with EPA regarding mosquito problems and their remedies.

Needed Actions

The AMCA should continue to request of EPA and take advantage of all opportunities to help the OWWM craft regulations, policies, BMP guidance documents, factsheets, and other instruments that touch upon mosquito production/control issues in stormwater management facilities, working with EPA in professional and collegial manner. It seems that a new era of cooperation and interaction with EPA has now emerged regarding these matters, one that must be cultivated and nurtured by the AMCA. In regard to BMPs, the AMCA should work with EPA to help ensure that the state, county and municipal stormwater management agencies charged with constructing and managing stormwater facilities adhere to all mosquito control aspects of these BMPs, with EPA achieving such compliance through federal regulations, grant conditions, education programs, etc. Similar attention and breakthroughs that better accommodate mosquito control needs/practices are also now needed with both EPA and USFWS in regard to what to do (or can be done) when encountering endangered species in stormwater management facilities, especially for addressing maintenance needs within these systems.

AMCA Position Paper – Spring Washington Conference, 2006

Workshop Attendees

Adkins, Jared
Kent Conservation District
800 Bay Road #2
Dover, DE 19901
P: 302-741-2600, ext. 3
Jared.adkins@state.de.us

Anderson, Robert
University of Delaware
Dept. of Entomology
Newark, DE 19716
P: 856-854-5533
rdand@udel.edu

Bason, Chris
James Farm
RR 1, Box 230C
Ocean View, DE 19970
P: 302-537-1680
chrisbason@inlandbays.org

Blazer, Gail
Town of Ocean City
301 Baltimore Avenue
Ocean City, MD 21843
P: 410-289-8825
sblazer@ococean.com

Blazer, Dave
Maryland Coastal Bays Program
9609 Stephen Decatur Hwy
Berlin, MD 21811
P: 410-208-3619
director@mdcoastalbays.org

Brittingham, Phillip
MDA-Mosquito Control
27722 Nanticoke Rd, Unit 2
Salisbury, MD 21801
P: 410-632-3767

Buehl, Eric
Center for MD Inland Bays
16529 Coastal Highway
Lewes, DE 19958
P: 301-645-7325
habitat@inlandbays.org

Cain, Carol
MD Coastal Bays Program
9609 Stephen Decatur Hwy
Berlin, MD 21811
P: 410-213-2297
technical@mdcoastalbays.org

Cantwell, Mike
MD Dept of Agriculture
50 Harry S. Truman Parkway
Annapolis, MD 21401
P: 301-927-8357
macmda@cs.com

Caraway, Kenneth
DE Mosquito Control
1161 Airport Rd
Milford, DE 19963
P: 302-422-1512
Kenneth.caraway@state.de.us

Carey, Nathan
New Castle County
807 Old Churchmans Road
New Castle, DE 19720
P: 302-388-9985
ncarey@co.new-castle.de.us

Charland, Jay
Assateague Coastal Trust
PO Box 731
Berlin, MD 21811
P: 443-235-2014
Coastkeeper@actforbays.org

Comstock, Steve
MD Dept of the Environment
1800 Washington Blvd
Baltimore, MD 21230
P: 410-537-3543
scomstock@mde.state.md.us

Conlon, Joe
American Mosquito Control Assoc.
1500 Millbrook Ct
Orange Park, FL 32003
P: 904-215-3008
amcata@bellsouth.new

Cook, Heather
Ocean Pines Assoc.
239 Ocean Parkway
Ocean Pines, MD 21811
P: 410-208-0208
heatherEcook@verizon.net

Coyman, Sandy
Worcester Co. Dept of Comp. Plan
Snow Hill, MD 21863
P: 410-632-5656
scoyman@co.worcester.md.us

Cummins, Carolyn
Worcester County
9628 Oceanview Lane
W. Ocean City, MD 21842
P: 410-213-0586
ccummins@dmv.com

Davis, Vince
Del. DOT
PO Box 778
Dover, DE 19901
P: 302-760-2180
Vince.davis@state.de.us

Dawson, Steve
MDE, Non-tidal Wetlands
PO Box 417
Sharptown, MD 21861
P: 410-543-6703 (pager)
sdawson@mde.state.md.us

Devlin, Larry
Worcester Co. Planning Commission
352 Ocean Parkway
Ocean Pines, MD 21811
P: 410-208-0208
devlincook@verizon.net

Dorothy, Jeannine
MD Dept of Agriculture
6701 Lafayette Avenue
Riverdale, MD 20737
P: 301-927-8357
Skeetermd1@cs.com

Dyott, Steve
Town of Federalsburg
PO Box 471
Federalsburg, MD 21632
P: 410-754-8173
hsdyott@hotmail.com

Ferguson, Dave
Ocean Pines Assoc.
239 Ocean Parkway
Ocean Pines, MD 21811
P: 410-641-7717, ext. 3001
dferguson@oceanpines.org

Ferrao, Patricia
MD Dept of Agriculture
50 Harry S. Truman Pkwy
Annapolis, MD 21401
P: 410-841-5928
ferraopn@mda.state.md.us

Francis, Woody
Corps of Engineers-Baltimore
PO Box 1715
Baltimore, MD 21203-1715
P: 410-962-5689
woody.francis@nab02.usace.army.mil

Freeland, V. Wilson
Calvert Co. Dept of General Services
175 Main Street
Prince Frederick, MD 20678
P: 410-535-1600, ext. 2299
freelavw@co.cal.md.us

Gertler, Ed
MDE-Industrial Discharge Permits
1800 Washington Blvd
Baltimore, MD 21230
P: 410-537-3651
egertler@mde.state.md.us

Gingrich, Jack
Univ. of Delaware
Dept. of Entomology
Newark, DE 19716
P: 301-831-1308
Gingrich@udel.edu

Goeller, Debbie
Worcester Co. Health Dept.
PO Box 249
Snow Hill, MD 21863
P: 410-632-1100
debbiegoeller@dhmh.state.md.us

Greer, Randy
DE Dept of Nat Res & Env Control
89 Kings Hwy
Dover, DE 19901
P: 302-739-4411
Randell.greer@state.de.us

Higgins, Michael
US Fish & Wildlife Service
177 Admiral Cochrane Drive
Annapolis, MD 21401
P: 410-573-4520
Mike_j_Higgins@fws.com

Jesien, Roman *
MD Coastal Bays Program
9609 Stephen Decatur Hwy
Berlin, MD 21811
P: 410-213-2297
science@mdcoastalbays.org

Johnson, Carl
12 Riverside Ct.
Berlin, MD 21811
carlbarbe@earthlink.net

Kincaid, Joseph P.
MDE-Tidal Water Div.
1800 Washington Blvd
Baltimore, MD 21230
P: 410-961-4044
jkinaid@mde.state.md.us

Krumrine, Beth
DE Dept of Nat Res & Env Control
89 Kings Highway
Dover, DE 19901
P: 302-739-4411
Beth.krumrine@state.de.us

Kutz, Frederick (Rick) *
4967 Moonfall Way
Columbia, MD 21044
P: 410-730-8865
rick.kutz@comcast.net

Lembeck, Larry
MDA/Mosquito Control
27722 Nanticoke Rd, #2
Salisbury, MD 21801
P: 410-843-6626
lalembeck@yahoo.com

Lesser, Chris
DE Mosquito Control
1161 Airport Rd
Milford, DE 19963
P: 302-422-1512
Christopher.lesser@state.de.us

Lesser, Cyrus *
MD Dept of Agriculture
50 Harry S. Truman Pkwy
Annapolis, MD 21801
P: 410-841-5870
lessercr@mda.state.md.us

Lewandowski, Edward *
DE Center for the Inland Bays
467 Highway One
Lewes, DE 19958
P: 302-645-7325
director@inlandbays.org

Limpert, Roland
MD Dept of Nat Resources
Tawes State Office Bldg.
Annapolis, MD 21401
P: 410-260-8333
rlimpert@dnr.state.md.us

Magerr, Kevin
US EPA
1650 Arch Street
Philadelphia, PA 19104
P: 215-814-5724
Magerr.kevin@epa.gov

Matuszak, Diane
MD Dept of Health & Mental Hygiene
201 W. Preston St., #320
Baltimore, MD 21201
P: 410-767-1255
dmatuszzak@dhmh.state.md.us

Mayer, George E. Jr.
Town of Federalsburg
PO Box 471
Federalsburg, MD 21632
P: 410-754-8173
grantmainstreet@hotmail.com

McCabe, Chris
Worcester County
D.R.P. Sun/SEC
Snow Hill, MD 21863
P: 410-632-1200 x1143
mccabe@worcester.state.md.us

McNatt, Stacy
New Castle County Government
87 Reads Way
New Castle, DE 19720
P: 302-395-5415
smcnatt@co.new-castle.de.us

Meadows, Bob
DNREC
1024 Old County Rd
Newark, DE 19202
P: 302-836-2558
robert.meadows@state.de.us

Meredith, William H. *
DE DNR - Mosquito Control Section
89 Kings Hwy
Dover, DE 19901
P: 302-739-3493
william.meredith@state.de.us

Moran, Thomas
DE Mosquito Control
2430 Old County Road
Newark, DE 19711
P: 302-836-2555, ext.103
Thomas.moran@state.de.us

Moreno, David
Wicomico Co. Health Dept.
108 E Main St
Salisbury, MD 221801
P: 410-546-4446
davem@dhmh.state.md.us

Munson, Katherine
Worcester Co. Comp Planning
Snow Hill, MD 21863
P: 410-632-5651
kmunson@co.worcester.md.us

Newlin, Scott
DE DNR
89 Kings Hwy
Dover, DE 19901
P: 302-422-1512
Scott.newlin@state.de.us

Orth, Rebecca
DE Mosquito Control
2430 Old County Rd
Newark, DE 19402
P: 302-836-2555
Rebecca.orth@state.de.us

Palalay, Sal
DE Dept of Transportation
PO Box 778
Dover, DE 19901
P: 302-760-2191
Salvador.palalay@state.de.us

Phipps-Dickerson, Mary
Wicomico Co. Health Dept.
108 E Main St
Salisbury, MD 21801
P: 410-546-4446
marypd@dhmh.state.md.us

Possident, Tom
Worcester County Health Dept.
Snow Hill, MD 21803
P: 419-352-3234
tomp@dhmd.state.md.us

Potetz, Ed
Worcester County Health Dept.
Snow Hill, MD 21803
P: 410-352-3234
edp@dhmh.state.md.us

Rutherford, Jamie
DE DNREC
89 Kings Hwy
Dover, DE 19901
Jamie.rutherford@state.de.us

Sachs, Herb
MD Dept. Environment
1800 Washington Blvd
Baltimore, MD 21230
P: 410-537-3731
hsachs@mde.state.md.us

Sanghavi, Sonal
MD State Highway Admin.
707 N. Calvert Street
MS-C-201
P: 410-545-8414
ssanghavi@sha.state.md.us

Saveikis, David
Delaware Mosquito Control
1161 Airport Rd
Milford, DE 19963
P: 301-422-1512
David.saveikis@state.de.us

Schamberger, Dan
MDA-Mosquito Control
27722 Nanticoke Rd. #2
Salisbury, MD 21801
P: 410-543-6626
dschamberger@ccisp.net

Schofield, Dave
MDA-Mosquito Control
27722 Nanticoke Rd #2
Salisbury, MD 21801
P: 410-543-6626
dschofield@ccisp.net

Scott, Michael
Dept. of Geography and Geosciences
Salisbury Univ.
Salisbury, MD 21801
P: 410-543-6456
msscott@salisbury.edu

Setting, Mary Ellen
MDA
50 Harry S. Truman Pkwy
Annapolis, MD 21401
P: 410-841-5872
Settingm@mda.state.md.us

Shockley, Robert E.
Worcester County
DCAN Review
Snow Hill, MD 21803
P: 410-632-1200, ext. 1141

Silaphone, Keota
Worcester County Dept of Comp. Plan
Snow Hill, MD 21863
P: 410-632-5651
ksilaphone@co.worcester.md.us

Spagnolo, Ralph
US EPA
1650 Arch Street
Philadelphia, PA 19104
P: 215-0814-2718
Spagnolo.ralph@epa.gov

Stachurski, Dan
President, Ocean Pines Assoc.
60 Beaconhill Rd
Berlin, MD 21811
P: 410-208-9760
Danielbz@earthlink.net

Swan, Chris
Dept of Geography & Env Systems
UMBC
1000 Hilltop Circle
Baltimore, MD 21250
P: 410-455-3957
cmswan@umbc.edu

Tankersley, Roger
TVA
400 W. Summit Hill Dr.
Knoxville, TN 37902-1499
P: 865-632-7931/
rdtankserley@tva.gov

Thornton, Kent *
FTN Associates
3 Innwood Circle
Suite 220
Little Rock, AR 72211
P: 501-225-7779
kwt@ftn-assoc.com

Tudor, Ed
Worcester County Gov.
1 Market Street
Snow Hill, 21863
P: 410-632-1200
ddrp@co.worcester.md.us

Walch, Marianne
Delaware DOT
PO Box 778
Dover, DE 19903
P: 302-0760-2195
Marianne.walch@state.de.us

Wallis, Charlie *
MD Dept of the Environment
1800 Washington Blvd
Baltimore, MD 21230
P: 410-537-3543
cwallis@mde.state.md.us

Watson, Jessica
SCD
23818 Shortly Rd
Georgetown, DE 19947
P: 302-856-2105
Jessica.watson@state.de.us

Webb, Elaine Z.
DNREC
89 Kings Hwy.
Dover, DE 19901
P: 302-739-411
Elaine.webb@state.de.us

Zarebicki, Paul
DE Mosquito Control
1161 Airport Rd
Milford, DE 19963
P: 302-422-1512
Paul.zarebicki@state.de.us

**Steering Committee members*

Glossary

Activated Carbon: a highly adsorbent form of carbon used to remove odors and toxic substances from liquid or gaseous emissions. In waste treatment, it is used to remove dissolved organic matter from waste drinking water. It is also used in motor vehicle evaporative control systems.

Adsorb: to gather (a gas, liquid, or dissolved substance) on a surface in a condensed layer, as when charcoal adsorbs gases. In other words, adsorb means to store a substance on the surface of something.

Adulticides: insecticides applied to kill adult mosquitoes. Their use is an important part of an effective mosquito management program, based on mosquito surveillance information.

***Aedes vexans*:** one of the most widespread pest mosquitoes in the world. *Aedes vexans* is found in every state in the U.S. including Alaska and Hawaii. Virtually any transient water can support *Ae. vexans* larvae, but rain pools in unshaded areas produce the largest broods. The species is most common in grassy pools that border wooded areas but specimens can be encountered in partially shaded woodland pools, roadside ditches, and vernal pools in open fields on Delmarva Peninsula during summer, this species is probably the major mosquito problem originating from woodland pools.

Aggregate: term for the crushed stone or rock needed to fill in an infiltration device such as a trench or porous pavement. Clean-washed aggregate is simply aggregate that has been washed clean so that no sediment is included.

***Anopheles quadrimaculatus*:** historically, this mosquito is the most important vector of malaria in North America and today is a major host of the nematode that causes canine heartworm. This species prefers habitats with well-developed beds of submergent, floating leaf or emergent aquatic vegetation. Larvae are typically found in sites with abundant rooted aquatic vegetation, such as rice fields and adjacent irrigation ditches, freshwater marshes and the vegetated margins of lakes, ponds and reservoirs.

Aqua-Swirl™ Concentrator: provides for the removal of sediment (TSS) and free-floating oil and debris. Swirl technology is a proven form of treatment utilized throughout the stormwater and wastewater industry.

Aquatic: relating to or consisting of or being in water; “an aquatic environment.”

Asphalt: a brownish-black solid or semisolid mixture of hydrocarbons and other materials obtained from native deposits or as a petroleum byproduct, used in paving, roofing, and waterproofing.

Assemblage: collection; several things grouped together or considered as a whole.

Backswimmers: a tiny insect that is no more than half an inch in length, spends its entire life in the water, and with the exception of surfacing for air most of that time is swimming on its back. Found in the Hemiptera order of true bugs, the backswimmer is part of the Notonectidae family. They can usually be observed swimming just below the surface in still waters such as those found in ponds, the calm surfaces of some streams, lakes, swamps and small fresh water inlets of some rivers. Backswimmers are carnivorous, eating other insects, tadpoles, small fish and crustaceans.

Bats: members of the mammalian order Chiroptera, which means “winged hand.” They represent our only true flying mammals. Bats are not flying mice or rats. In fact, they are not even closely related to rodents. With the exception of only a very few species of bats found in the Southwest that feed on nectar, pollen and fruit, the 40 different bat species of the U.S. feed exclusively on insects. The species that are most commonly found around urban communities are the “colonial bats”, which include the big brown bat, *Eptesicus fuscus*, the little brown bat *Myotis lucifugus*, and the Mexican free-tailed bat, *Tadarida brasiliensis*. Bats may be both opportunistic and selective in their feeding, and several factors are involved as to which specific insects might be consumed in the greatest quantity. In general, research has shown that the little brown bat feeds on soft bodied insects such as moths, flies, midges, mosquitoes and mayflies.

BaySaver™ Separation System: a stormwater treatment system that is designed to efficiently and economically remove suspended solids, hydrocarbons, debris and other pollutants from stormwater runoff. They have been installed across the country and accepted by many communities and watershed areas as the stormwater Best Management Practice (BMP) device of choice.

Best Management Practice (BMP): methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.

Biofiltration Swale (Bioswale): a long, gently sloped, vegetated ditch designed to filter pollutants from stormwater. Grass is the most common vegetation, but wetland vegetation can be used if the soil is saturated.

Bioretention Basins: landscaped depressions or shallow basins used to slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by a number of physical, chemical and biological processes. The slowed, cleaned water is allowed to infiltrate native soils or directed to nearby stormwater drains or receiving waters. Bioretention basins are typically associated within small areas of land with residential usage or with parking lots where the islands become visually pleasing stormwater treatment centers.

Bioretention: a water quality practice that utilizes landscaping and soils to treat urban stormwater runoff.

Bti (*Bacillus thuringiensis israelensis*): is a bacterium or bacterially-produced toxin that is larvicidal for mosquitoes. Bacterial spores of Bti must be actively ingested by mosquito larvae (rather than acting as an external contact poison.

Chesapeake & Delaware Canal (C&D Canal): one of only two commercially vital sea-level canals in the United States. The C&D runs 14 miles long, 450 feet wide and 35 feet deep across Maryland and Delaware, connecting the Delaware River with the Chesapeake Bay and the Port of Baltimore. The C&D Canal is owned and operated by the U.S. Army Corps of Engineers, Philadelphia District.

Catch Basin (a.k.a., storm drain inlet, curb inlet): an inlet to the storm drain system that typically includes a grate or curb inlet where stormwater enters the catch basin and a sump to capture sediment, debris and associated pollutants. They are also used in combined sewer watersheds to capture floatables and settle some solids. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump), and routine maintenance to retain the storage available in the sump to capture sediment.

Catch Basin Inserts: used to filter runoff entering the catch basin. The most frequent application for catch basin inserts is for reduction of sediment, oil, and grease in stormwater runoff.

Cattail: tall erect herbs with sword-shaped leaves; cosmopolitan in fresh and salt marshes.

CDS (Continuous Deflective Separation): a technology developed to meet a community demand for an effective method of removing gross pollutants from stormwater. The Continuous Deflective Separation (CDS) technology overcomes the clogging, reduced efficiency and capacity problems experienced by direct filtration systems by using controlled fluid flows through a non-blocking screen.

Certified Construction Reviewer (CCR): an individual who has passed an approved training course and who provides on-site construction review for sediment control and stormwater management in accordance with state stormwater regulations.

Channel: a passage for water (or other fluids) to flow through; "the fields were crossed with irrigation channels"; "gutters carried off the rainwater into a series of channels under the street."

Chloride Ion: formed when the element chlorine picks up one electron to form the anion (negatively charged ion) Cl^-. The salts of hydrochloric acid HCl contain chloride ions and are also called chlorides. An example is table salt, which is sodium chloride with the chemical formula NaCl. In water, it dissolves into Na^+ and Cl^- ions. Although chloride is a naturally occurring element, it also reflects as a contaminant of human use.

Clean Water Act: legislation that provides statutory authority for the NPDES program; Public law 92-500; 33 U.S.C. 1251 et seq. Also known as the Federal Water Pollution Control Act.

Coastal Plain: an area of relatively low land of variable width lying between uplands and the sea. The Mid-Atlantic Coastal Plain extends inland from the Atlantic Ocean, south of Long Island, to the Fall Line, where the hilly Piedmont begins. It is arbitrarily separated from the South Atlantic Coastal Plain at the Virginia-North Carolina border (with the exception of the Great Dismal Swamp in the southeast corner of Virginia, which is grouped in the southern area). The area was formed by shifting sea levels and alluvial deposition from rivers draining mountains to the west. Water continues to be a dominant feature of the landscape, creating forested wetlands and salt marsh and shaping barrier island and bay complexes. Upland forests on the remaining land graded in composition from pine dominated areas on the outer Coastal Plain (nearer the coast) to hardwood forests on the inner Coastal Plain. This was the site of the first successful English settlement in North America, and the natural landscape has been altered by European culture for nearly four centuries.

Collection Basin: stormwater from roads, parking lots, etc., is drained.

Compost: the relatively stable humus material that is produced from a composting process in which bacteria in soil mixed with garbage and degradable trash break down the mixture into organic fertilizer.

Concrete: a mixture of sand, coarse aggregate (crushed gravel or crushed stone), Portland cement and water correctly called Portland cement concrete. The wet mixture is placed in a form or trench and dries to a hard material.

Conservation Site Design: a method that requires dwelling units to be clustered (grouped) on smaller lots on a select part of the parcel, thus, leaving a portion of the parcel as dedicated open space. Conservation Design for Stormwater Management places less emphasis on structural stormwater practices—such as large ponds and sand filters—and emphasizes site design that reduces impervious areas. Conservation Design approaches also highlight the value of a water-budget approach to site design where recharge of rainfall is a primary design consideration.

Constructed Wetlands: wetlands that are created by humans, sometimes in places where there were no wetlands before. These constructed wetlands mimic nature by mechanically filtering, chemically transforming, and biologically consuming potential pollutants in the wastewater stream.

Coquilletidia perturbans**:** a mosquito associated with cattail marshes as well as other emergent freshwater vegetation. The submerged larvae attach themselves to the stems and roots of the emergent vegetation and obtain oxygen from them. When disturbed the pupae and larvae will burrow into the mud. This behavior makes control of the larvae of this species very difficult.

CREP (Conservation Reserve Enhancement Program): focuses on protecting water quality and improving wildlife habitat through the planting of forested buffers in pasture or cropland next to streams and ponds. CREP shares the cost of fencing and other practices needed to exclude livestock from the buffer zone, preventing erosion and filtering out sediment, nutrients and other forms of pollution in stormwater runoff. In addition, the program shares the cost of establishing water sources in pastures and planting hardwood trees and shrubs in buffer zones. Finally, the CREP program makes rental payments on contracted acres for 10 or 15 years as well as providing financial incentive payments to the landowner for agreeing to set aside the land in the buffer zone for the term of the contract.

Culex restuans**:** a common mosquito in the eastern and central United States. *Culex restuans* utilizes an exceptionally wide range of larval habitats. The types of water used by this species can vary from nearly clear to grossly polluted. A partial list of larval habitats includes: temporary ground water, the edge of grassy swampland, sphagnum bogs, road side ditches, tire ruts, hoof prints, discarded buckets, tires, catch basins, sewage effluent and septic seepage. Some consider them as troublesome biters, although others say they rarely bite humans. Flight range 1 to 2 miles. May transmit Western Equine Encephalitis.

Culex salinarius**:** a widespread mosquito (facultative avian feeder) that reaches greatest abundance along the Atlantic and Gulf Coasts of the U.S. Larvae are found in fresh or brackish water and salt marshes that contain a great deal of emergent and decaying vegetation. Impoundments have been shown to be an excellent source of *Cx. salinarius*. Adult females of the species host seek within the first 2 or 3 hours after sunset, but may be active in non host-seeking pursuits just prior to sunrise. Studies have also indicated that *Cx. salinarius* appear to be most abundant at elevations of 20 ft. or more. In addition, they are indiscriminate in their bloodmeal preferences, and are efficient vectors of St. Louis encephalitis (SLE) and in the Mid-Atlantic region are also vectors for West Nile virus.

Dam: barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

Depressional Wetlands: occur in topographic depressions that have closed contours on three sides. Elevations within the wetland are lower than in the surrounding landscape. The shapes of depressional wetlands vary, but in all cases the movement of surface water and shallow subsurface water is toward the lowest point in the depression. The depression may have an outlet, but the lowest point in the wetland is somewhere within the boundary, not at the outlet.

Detention: the collection and temporary storage of stormwater, generally for a period of time ranging from 24 to 72 hours, to provide for treatment through primarily physical, biological, and—to a much lesser degree—chemical processes with subsequent gradual release of stormwater to downstream receiving waters.

Detention Basins: structures which are built to detain precipitation for short periods. They are normally dry, but are designed to detain surface water temporarily during, and immediately after a runoff event. Their primary function is to attenuate the storm flows by releasing flows at a lower flow rate. There are no gates or valves allowed on the outlet so that water can never be stored on a long-term basis. By design and unless reflooded or further inundated, detention basins should go completely dry within 24-72 hours of a rewetting or refilling event.

Ditching: digging a path for water that drains the surrounding land and alters naturally existing water flow through the area.

Downstream Defender™: a treatment device engineered to capture settleable solids, floatables, oil and grease from stormwater runoff. It is one of the family of advanced Hydrodynamic Vortex Separators provided by HIL Technology, Inc. that augments gravitational forces with complex but stabilized vortex forces to maximize solids/liquids separation. The result is a compact separator that requires a smaller land area than conventional gravitational sedimentation. A floatables trap is incorporated within the same vessel.

Dragonfly: an insect belonging to the Order Odonata, and characterized by large multifaceted eyes, two pairs of strong transparent wings, and an elongated body. Dragonfy adults typically eat mosquitoes, midges and other small insects like flies, bees, and butterflies. They are usually found around lakes, ponds, streams, and wetlands for the reason that their larvae (known as naiads) are aquatic; dragonfly larvae will consume mosquito larvae. Dragonflies do not bite or sting humans.

Dry Ponds: are stormwater basins that are designed to intercept a volume of stormwater runoff and temporarily impound the water for gradual release to the receiving stream or storm sewer system and as such, are also known as detention ponds. Dry ponds are typically on-line, end-of-pipe BMPs. Dry ponds are designed to completely empty out between runoff events (by design within 24-72 hours), and therefore provide mainly runoff rate control as opposed to water quality control. Dry ponds can provide limited settling of particulate matter, but a large portion of this material can be resuspended by subsequent runoff events. Therefore, dry ponds should be considered mainly as practices used to reduce the peak discharge of stormwater to receiving streams to limit downstream flooding and to provide some degree of channel protection while also providing some limited water quality benefits.

Duckweed: any small or minute aquatic plant of the family Lemnaceae that float on or near the surface of shallow ponds.

Eastern Equine Encephalitis (EEE): is spread to horses and humans by infected mosquitoes. It is among the most serious of a group of mosquito-borne arboviruses that can affect the central nervous system and cause severe complications and even death. EEE is found in North America, Central and South America, and the Caribbean. It has a complex life cycle involving birds and specific types of mosquitoes that cycle EEE among birds including several *Aedes*, *Ochlerotatus* and *Culex* species and *Culiseta melanura*. Other types of mosquitoes, in particular *Ochlerotatus*, *Aedes* and *Coquilletidia* species are known as "bridge vectors" for EEE, in that they might first feed upon an EEE-infected bird, and then take a subsequent bloodmeal from humans or horses, passing EEE on to these mammals. EEE is a virulent arbovirus, and humans who contract EEE are fortunate if their symptoms range from none at all to only a mild flu-like illness with fever, headache, and sore throat. More serious infections of the central nervous system lead to a sudden fever and severe headache followed quickly by seizures and coma, with children and the elderly most prone to more severe cases. About a third of these patients die from the disease. Of those who survive, many suffer permanent brain damage and require lifetime institutional care. There is no specific treatment. A vaccine is available for horses, but not humans.

Eastern Shore of Maryland: the eastern side of the Chesapeake Bay. The region is characterized by tiny historic towns, meandering creeks, beautiful natural areas, crabs and clams.

Ecological Function: the role that any process, species, population, or physical attribute plays in the interrelation among living or non-living components of ecosystems. Ecological functions include hydrologic transfers and storage of water, biogeochemical transformations, primary productivity, decomposition, and the ability to provide habitats for dependent species and the diversity of species and organization they support.

Ecological Value: a measure of the significance or interest of an area as a habitat supporting species of flora and fauna.

Efficacy: the ability to produce an effect, usually a specifically desired effect.

Embankment: a structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

Emergent: a type of plant rooted in shallow water but supporting stems and leaves that reach and grow up out of the water; cattails and arrowhead are emergent plants.

Encephalitis: a viral disease transmitted by infected mosquitoes. It affects the central nervous system causing fever and depending upon the form of encephalitis, can often be fatal. The youngest and oldest segments of the population are usually the most susceptible. Many viruses cause encephalitis and occur in the U.S. every year. Three different encephalitides occur in Maryland: Eastern equine encephalitis (EEE), West Nile encephalitis (WNE), and St. Louis encephalitis (SLE). The former is fatal in about a third of all infections while fatality rates for WNE and SLE are much lower. These viral diseases have three cycles. The first is the maintenance cycle in the wild reservoir hosts (birds); the second, an amplifying cycle in a susceptible domestic or wild host (domestic animals or birds); and the third may affect the human population or horses. Humans who become infected with EEE, WNE, or SLE do not have enough of the virus in their blood to infect other mosquitoes that bite them.

Endangered Species Act (ESA): provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The U.S. Fish and Wildlife Service of the Department of the Interior maintains the list of endangered species and threatened species. Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees. Anyone can petition FWS to include a species on this list. The law prohibits any action, administrative or real, that results in a "taking" of a listed species, or adversely affecting habitat. Likewise, import, export, interstate, and foreign commerce of listed species are all prohibited.

Energy Dissipater: a rock or concrete structure designed to reduce the velocity of the flow exiting a culvert to prevent erosion of the streambed and banks.

Entomologists: scientists who study insects.

Environmentally Sensitive Design (ESD): practices that attempt to limit impervious cover or pavement, and protect or create green/open space at the site level. Site design practices include minimizing street widths, reducing set backs, adopting smaller lot sizes or clustering housing units.

Erosion: the wearing away of land surface by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging.

Evaporation: the process by which a liquid changes into a gas.

Excavate: the process of digging out or around something.

Exotic Disease: any disease believed to be historically absent from the U.S. and its territories that has a potential significant health or economic impact.

Fill: man-made deposits of natural soils or rock products and waste materials.

Filter Strip: strip or area of vegetation used for removing sediment, organic matter, and other pollutants from runoff and wastewater.

Food Webs: the interconnected feeding relationships in an ecosystem. These relationships can be complex; some organisms may feed on more than one trophic level, or changes may occur depending on a species' life history stages or the availability of food.

Forebay: an extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond BMP.

***Gambusia holbrooki* (mosquitofish):** a species of freshwater fish. It is a member of the family Poeciliidae of order Cyprinodontiformes. It is important in mosquito control, with *G. holbrooki* being the native mosquito fish of the eastern U.S. along the Atlantic and Gulf coasts (*G. affinis* is a more western and inland species of mosquitofish that should no longer be introduced or used for mosquito control along the Atlantic or Gulf coasts).

Genera: in biology, a genus (plural genera) is a grouping in the classification of living organisms having one or more related and morphologically similar species. In the common binomial nomenclature, the name of an organism is composed of two parts: its genus (always capitalized) and a species modifier. An example is *Homo sapiens*, the name for the human species which belongs to the genus *Homo*.

Geomorphic: relating to the way the land is formed (rock, soil, and water).

Grade: to finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Gravel: 1) aggregate consisting of mixed sizes of 1/4 inch to 3 inches which normally occur in or near old streambeds and have been worn smooth by the action of water. 2) a soil having particle sizes, according to the Unified Soil Classification System, ranging from the No. 4 sieve size, angular in shape, as produced by mechanical crushing.

Gravity and/or Swirl Separators: a group of stormwater treatment technologies that includes a wide variety of proprietary devices that have been developed in recent years. These devices are modifications of traditional oil/particle separators that commonly rely on vortex-enhanced sedimentation for pollutant removal. They are designed to remove coarse solids and large oil droplets and consist primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems. In these structures, stormwater enters as tangential inlet flow into the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater. Some devices also have compartments or chambers to trap oil and other floatables.

Green Infrastructure: the ecological processes, both natural and engineered, that act as the natural infrastructure. It includes ditches, creeks, wetlands, parks, open space, trees, green roofs, gardens, working lands, aquifers and watersheds that supply drinking water.

Ground Water: the supply of fresh water found beneath the Earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants or leaking underground storage tanks.

Groundwater Discharge: the flow or pumping of water from an aquifer.

Groundwater Recharge: the natural process of infiltration and percolation of rainwater from land areas or streams through permeable soils into water-holding rocks that provide underground storage (i.e., aquifers).

Habitat: the place where a population (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and non-living.

Homeowners' Association: a group that governs a subdivision, condominium, or planned community. The association collects monthly fees from all owners to pay for common area maintenance, handle legal and safety issues, and enforce the covenants, conditions, and restrictions set by the developer. It operates under authority of state laws.

Hydrocarbons (HC): chemical compounds that consist entirely of carbon and hydrogen.

Hydrodynamics: that part of the science of mechanics which deals with the dynamics of water and of the effects of the motion of water past bodies on its surface or immersed in it.

Hydrogeomorphic Classification: emphasizes the hydrologic and geomorphic controls that influence many wetland functions. The HGM Approach focuses on the location of a wetland in a watershed (its geomorphic setting), its sources of water, and its hydrodynamics. The HGM approach first classifies wetlands based on their differences in functioning, second it defines functions that each class of wetland performs, and third it uses reference to establish the range of functioning of the wetland. A series of geographically based models or "functional profiles" for various wetland types are being created for use in functional assessments. The classification is designed for onsite application and requires considerable field effort for model development. The HGM models could help broaden our understanding of the range in performance of selected functions by different wetland types.

Impervious: not capable of being passed through, damaged, or disturbed. Water is not able to flow through impervious surfaces, such as asphalt roads and concrete sidewalks.

Impervious Surface: a hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development; and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam, or other surfaces which similarly impede the natural infiltration of surface and stormwater runoff. Open, uncovered flow control or water quality treatment facilities shall not be considered impervious surfaces for determinations of thresholds. For the purpose of modeling though, onsite flow control and water quality ponds are modeled as impervious surface per Chapter 3 of the King County Surface Water Design Manual.

Infiltration: 1) the penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls. 2) the technique of applying large volumes of waste water to land to penetrate the surface and percolate through the underlying soil.

Infiltration basin: the holding of runoff in a basin without release except by means of evaporation, infiltration, or emergency bypass.

Integrated Mosquito Management Methods: an effective and environmentally sensitive approach used to manage mosquitoes, relying upon a combination of scientific knowledge and common sense. The practice of an integrated mosquito control program requires that a number of parameters must be included in the decision making process, including: current, comprehensive information about the life cycles of the numerous mosquito species inhabiting a given area, and the interaction of those mosquitoes with people, other animals and the surrounding environment; a knowledge of mosquito BMPs, including but not limited to source reduction, mosquito habitat modification and the use of biological and/or chemical products to control larval and adult mosquitoes; mosquito control decisions based upon surveillance results, habitat inspections and a rigorous sanitation program; and a strong educational component for staff members and the community at large that emphasizes the elimination of potential sources of public health nuisances and possible disease transmission.

Integrated Pest Management (IPM): based on ecological, economic and social criteria and integrates these multidisciplinary methodologies to develop pest management strategies that are practical and effective to protect public health and the environment.

Interstices: spaces, especially small or narrow ones, between things or parts (e.g., the tiny spaces within streambed sediments).

Invasive Species: introduced by human action to a location, area, or region where it did not previously occur naturally (i.e., is not native). These species become capable of establishing a breeding population in the new location without further intervention by humans, and become pests in the new location, threatening local biodiversity.

Invertebrate: an animal without a backbone. Invertebrates include insects, arachnids (spiders & ticks), gastropods (snails & slugs), crustaceans (crayfish & isopods), centipedes, worms, and others.

Land Use: the way land is developed and used in terms of the types of activities allowed (agriculture, residences, industries, etc.) and the size of buildings and structures permitted. Certain types of pollution problems are often associated with particular land uses, such as sedimentation from construction activities.

Landform: any feature of Earth's surface having a distinct shape and origin. Landforms include major features (such as continents, ocean basins, plains, plateaus, and mountain ranges) and minor features (such as hills, valleys, slopes, drumlins, floodplains, and dunes). Collectively, the landforms of Earth constitute the entire surface configuration of the planet.

Landscape Connectivity: the degree to which the structure of a landscape helps or hinders the movement of wildlife species. A landscape is considered "well connected" when organisms (or natural processes) can readily move among habitat patches over the long term.

Larvae: immature, often wormlike stage of insect development, after the egg and before the pupa (cocoon) and adult. Larvae is the plural; larva is the singular.

Larvicide: a class of pesticides used to kill insect larvae and other immature forms (nymphs). Usually refers to insecticides used for controlling mosquito larvae, but also to chemicals for controlling caterpillars on crops.

Life Cycle: the natural process of stages that an organism goes through as it ages. For example, human stages are birth, infant, toddler, kid, pre-teen, teenager, young adult, adult and death. Insects go through a life cycle that begin with the egg and eventually result in the adult form. Mosquitoes, butterflies, and moths go through complete metamorphosis, with four different life stages: the egg, larva (caterpillar), pupa, and adult. Other insects undergo incomplete metamorphosis, where the juvenile (the nymph) is not very different from the adult form.

Localized: confined or restricted to a particular location.

Low Impact Development (LID): has emerged as a highly effective and attractive approach to controlling stormwater pollution and protecting developing watersheds and already urbanized communities throughout the country. Instead of large investments in complex and costly engineering strategies for stormwater management, LID strategies integrate green space, native landscaping, natural hydrologic functions, and various other techniques to generate less runoff from developed land. LID is different from conventional engineering. While most engineering plans pipes water to low spots as quickly as possible, LID uses micro-scale techniques to manage precipitation as close to where it hits the ground as possible. This involves strategic placement of linked lot-level controls that are "customized" to address specific pollutant load and stormwater timing, flow rate, and volume issues. One of the primary goals of LID design is to reduce runoff volume by infiltrating rainfall water to groundwater, evaporating rain water back to the atmosphere after a storm, and finding beneficial uses for water rather than exporting it as a waste product down storm sewers. The result is a landscape functionally equivalent to pre-development hydrologic conditions, which means less surface runoff and less pollution damage to lakes, streams, and coastal waters.

***Ludwigia* species (water primrose, primrose willow):** a perennial herb that can be found creeping along the shoreline, floating on the water surface, or growing upright. It is a robust plant with bright yellow, showy flowers and willow-like leaves. It is a non-native species originally from South America and the southern U.S. and has been introduced into Europe and northern North America. It favors the margins of lakes, ponds, ditches, and streams. These plants are very invasive and aggressive and will form very dense mats of vegetation.

Marsh: a type of wetland, featuring grasses, rushes, reeds, cattails, sedges, and other herbaceous plants (possibly with low-growing woody plants or shrubs) in a context of shallow water. A marsh is different from a swamp, which is dominated by trees rather than grasses and low herbs. The water of a marsh can be fresh, brackish, or saline. Coastal marshes may be associated with estuaries and along waterways between coastal barrier islands and the inner coast.

Media: specific environments—air, water, soil—which are the subject of regulatory concern and activities.

Metals: an element that readily forms ions (cations) and has metallic bonds. Metals are sometimes described as a lattice of positive ions (cations) in a cloud of electrons. The metals are one of the three groups of elements as distinguished by their ionization and bonding properties, along with the metalloids and nonmetals. On the periodic table, a diagonal line drawn from boron (B) to polonium (Po) separates the metals from the nonmetals.

Methoprene: an insecticide that inhibits the growth of certain insects in their immature or larval and pupal stages. When mosquito larvae are exposed to methoprene, they do not immediately die. The effect of the product usually shows in the pupal stage. In this stage, without exposure to methoprene, the immature mosquitoes normally develop into adult insects and immerge to start their biting, reproducing life cycle. However, the young insects that have come in contact with methropene will not survive past the pupal stage and never become adult biting pests.

Metropolitan Area: a large population nucleus, together with adjacent communities having a high degree of social and economic integration with that core. Metropolitan areas comprise one or more entire counties.

Micropool: a smaller permanent pool used in a stormwater pond due to extenuating circumstances, i.e., concern over the thermal impacts of larger ponds, impacts on existing marshes, or lack of topographic relief.

Mid-Atlantic States: the Mid-Atlantic region of the U.S., located in the northeastern section of the country, includes the following states and district: Delaware, Maryland, New Jersey, Pennsylvania, Virginia, and Washington, D.C. Sometimes on the northern end, New York is added to this region, sometimes on the western end, West Virginia is added, and sometimes on the southern end, North Carolina is added.

Mitigation: measures taken to reduce adverse impacts on the environment. These measures might involve taking actions to avoid adverse impacts, or taking steps to reduce adverse impacts, or taking actions to help compensate for any adverse impacts that could not be avoided or lessened.

Mosquito Abundance: the number of mosquitoes relative to a particular area.

Mosquitoes: members of the family Culicidae in the order Diptera (true flies). Adult mosquitoes are distinguished from other flies by the presence of a long proboscis and scales on the margins and veins of the wing. Males differ from females by having feathery antennae and mouthparts not suited for piercing skin. Mosquitoes are the most prominent bloodsucking insects that as a group, annoy humans and other warm-blooded animals. Not only are their bites (and subsequent itching welts) annoying, but mosquitoes can transmit several serious diseases to humans and animals, including malaria, yellow fever, dengue fever, filariasis, several types of encephalitis viruses and canine heartworm.

Naiad: the immature, or nymph, stage of some aquatic insects, such as dragonflies, that undergo incomplete metamorphosis; these organisms have three life stages: egg, naiad, adult; the naiad looks entirely different from the adult.

National Pollutant Discharge Elimination System (NPDES): a provision of the Clean Water Act which prohibits discharge of pollutants into waters of the U.S. unless a special permit is issued by EPA, a state, or, where delegated, a tribal government on an Indian reservation.

National Wetlands Inventory (NWI): produces information on the characteristics, extent, and status of the Nation's wetlands and deepwater habitats.

Nutrient: any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements.

***Ochlerotatus japonicus*:** an invasive mosquito species that has been found with WNV and is capable of transmitting the virus. It is difficult to sample and does not appear to be particularly aggressive. Its importance, or lack thereof, as a vector is not yet understood. It is not known to be an EEE vector. *Ochlerotatus japonicus* are found in rock pools, tree holes and containers. They over winter in the larval stage and could be among first larvae collected in spring. The adults are active during the day and will bite humans. They are attracted to carbon dioxide, and have a flight range up to 600 feet.

Offline: a type of pond design where the design treatment volume is diverted offline to a treatment pond by a control structure. When the offline pond becomes full, the remaining runoff bypasses the pond. This approach allows for the segregation of the "first flush" of runoff, which may contain the majority of pollutants.

Online: a type of design where all of the runoff from a storm routes through a pond. This method may have a lower pollutant removal efficiency than offline ponds if the pond volume is not large enough to hold all the runoff from a significant rain event. This is because the most polluted volume is mixed with the remainder storm volume, and excess flows dilute the concentrations and leave the pond with the mixed polluted water. If the online pond is sized properly, it can treat the entire runoff volume.

Open Space: a portion of a site which is permanently set aside for public or private use and will not be developed. The space may be used for passive or active recreation, or may be reserved to protect or buffer natural areas.

Organic: 1) referring to or derived from living organisms. 2) in chemistry, any compound containing carbon.

Orthophosphate: a commonly used corrosion inhibitor that is added to finished drinking water. Orthophosphate works by forming a protective coating inside of pipes in the distribution system and in customer homes to prevent lead from leaching into drinking water.

Outfall: the place where effluent is discharged into receiving waters.

Outlet: the point at which water discharges from such things as a stream, river, lake, tidal basin, or pipe.

Pavers: bricks in numerous sizes and shapes that are used for constructing sidewalks, patios, and driveways.

Peat: an accumulation of partially decayed vegetable matter. Peat forms in wetlands.

Percolate: to drain or seep through a porous substance (e.g., when water passes through the grains of soil).

Peri-urban: low density housing and road development on the periphery of urban areas, still retaining small areas of rural land within networks of suburban building.

Permit: an authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Pesticide: substances or mixture there of intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture intended for use as a plant regulator, defoliant, or desiccant.

Phosphorus: an essential chemical food element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of phosphorus-containing materials into surface waters.

***Phragmites*:** a tall invasive reed that colonizes the edges of salt marshes and can replace low-lying salt-tolerant grass species.

Pollutant: Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.

Polymeric Materials: materials composed of large molecules, generally based on carbon, that have been formed from the chemical bonding of smaller units (monomers). Commonly known as plastics.

Pond Inlet: an opening through which stormwater enters a pond.

Pond: a still body of water smaller than a lake, often shallow enough for rooted plants to grow throughout.

Porous pavement: an alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground tone reservoir. The stored runoff then gradually infiltrates into the subsoil. Porous pavement is not recommended for use in areas with high water table conditions.

Predation: predation is an interaction between organisms (animals) in which one organism captures and feeds upon another called the prey.

Public Health: one of the efforts organized by society to protect, promote, and restore the people’s health, involving a combination of sciences, skills, and beliefs directed to the maintenance and improvement of health through collective or social actions. A social institution, a discipline, and a practice with the goal to reduce the amount of disease, premature death, and disease-produced discomfort and disability in the population.

Putative: commonly put forth or accepted as true on inconclusive grounds; “the foundling’s putative father”; “the reputed (or purported) author of the book”; “the supposed date of birth”.

Rats: small nearly omnivorous rodents of the genus *Rattus*, which comprises 56 different species of what are commonly known as the Old World Rats or true rats originating in Asia. Rats are bigger than their relatives the mice, but seldom weigh over 500 grams.

Real Time: events that happen in real time are happening virtually at that particular moment. When you chat in a chat room or send an instant message, you are interacting in real time since it is immediate.

Recovery Time: the length of time required for the design treatment volume in a pond to subside to the normal water level or bottom of the pond. This time should normally be between 24 and 72 hours. This recovery may be accomplished by either infiltration or controlled release through an outfall structure.

Reeds: tall grass with hollow stems, often found in or near water.

Residential: land use that is primarily for houses, townhouses, apartments or other dwelling types.

Resmethrin: a type of pyrethroid insecticide. Pyrethroids are synthetic versions of a natural insecticide produced by chrysanthemum flowers. Resmethrin is not very toxic to mammals, but it is highly toxic to bees and fish.

Retention: onsite storage of stormwater with subsequent disposal by infiltration into the ground or evaporation to prevent direct discharge of stormwater runoff into receiving waters. They usually contain some water permanently.

Riparian Habitat: areas adjacent to rivers and streams with a differing density, diversity, and productivity of plant and animal species relative to nearby uplands.

Riprap: broken stone, cut stone blocks, or rubble that is placed on slopes to protect them from erosion or scour caused by flood waters or wave action.

Run-off: that part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface-water. It can carry pollutants from the air and land into receiving waters.

Rushes: grass-like plants growing in wet places and having cylindrical often hollow stems.

Salamander: the common name applied to approximately 500 amphibian vertebrates with slender bodies, short legs, and long tails (order Caudata or Urodela). The moist skin of the amphibians limits them to habitats either near water or under some protection on moist ground, usually in a forest. Some species are aquatic throughout life, some take to the water intermittently, and some are entirely terrestrial as adults.

Salt Marsh: a low coastal grassland that is regularly or irregularly covered by tidal water. Salt marshes are found on the edges of estuaries; places where a river flows into the ocean. In the marsh, the water flows very slowly so sediments are dropped from the water and build up a muddy environment where plants can grow and small animals can live.

Sand: a soil particle between 0.05 and 2.0 millimeters in diameter.

Sedges: a group of grass-like, herbaceous plants that, unlike grasses, have unjointed stems. Stems are usually solid and often triangular in cross section.

Sediment: topsoil, sand, and minerals washed from the land into water, usually after rain or snow melt.

Sedimentation Chamber: where the heavy pollutant particles settle out of stormwater.

Silt: sedimentary materials composed of fine or intermediate-sized mineral particles.

Soil Horizon: a layer of soil that can be distinguished from the surrounding soil by such features as chemical composition, color, and texture.

Source Reduction: reducing the amount of materials entering the waste stream from a specific source by redesigning products or patterns of production or consumption (e.g., using returnable beverage containers). Synonymous with waste reduction.

Species: 1) a reproductively isolated aggregate of interbreeding organisms having common attributes and usually designated by a common name. 2) an organism belonging to belonging to such a category.

Spillway: an open or closed channel, or both, used to convey excess water from a reservoir.

Stabilization: providing vegetative and/or structural measures that will reduce or prevent erosion.

Stabilized: made stable or firm.

Stagnant: a body of water which is motionless or ceases to flow.

Storm Drain: an opening leading to an under-ground pipe or open ditch for carrying surface runoff, separate from the sanitary sewer or wastewater system.

Stormceptor® Oil and Sediment Separator for Stormwater Runoff and Spill Control: an engineered stormwater treatment structure that removes oil and sediment from storm runoff. Comprised of a round precast concrete tank and fiberglass partition, the patented Stormceptor replaces a maintenance hole in the storm sewer. By capturing oil spills and suspended solids, the system prevents non-point source pollution from entering downstream lakes and rivers. In the stormwater management industry it is commonly referred to as an: Oil-grit separator or Oil and grit separator (OGS), or Oil-sediment separator, or Oil and sediment separator (OSS).

Stormwater: precipitation that accumulates in natural and/or constructed storage and stormwater systems during and immediately following a storm event.

Stream Channel: the bed where a natural stream of water runs or may run; the long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

Submergent: a wetland plant that has adapted to grow underwater.

Substrate: the surface or medium (e.g., rock, sand, mud, pilings, shells) that serves as a base for something.

Suburban: relating to, characteristic of, or situated in suburbs. Suburbs are inhabited districts located either on the outer rim of a city or outside the official limits of a city.

Sumithrin (Anvil): a pyrethroid-based pesticide registered for use in mosquito control by EPA. It is effective against adult mosquitoes, including the *Culex* species, which transmitted West Nile virus. Anvil is registered for use against mosquitoes in swamps, marshes, outdoor residential and recreational areas. It has low toxicity to humans, mammals, and the environment.

Sump: a pit or tank that catches liquid runoff for drainage or disposal.

Surveillance: the systematic collection, analysis, interpretation, and dissemination of data.

Suspended Solids: small particles of solid pollutants that float on the surface of, or are suspended in, sewage or other liquids. They resist removal by conventional means.

Swale: an elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels, may provide some groundwater recharge, and may be a source of mosquitoes.

Swallows: Tree Swallows (*Tachycineta bicolor*) are charming little birds that are found over most of North America and Canada. They can be voracious mosquito eaters. They have a strong preference for mating near water such as lakes, marshes, or wet meadows. All of these places are also great places for mosquito breeding. They also feed on midges, gnats, horseflies, moths, grasshoppers, dragonflies, and mayflies.

Swamp: low, spongy land generally saturated with water and covered with trees and aquatic vegetation. A deepwater swamp, such as the cypress tupelo, has standing water all or part of the growing season. Bottomland hardwood forest swamps are only flooded periodically.

Temephos: an organophosphorus insecticide of slight toxicity which is used largely as a mosquito larvicide.

Terraces: dikes built along the contour of sloping farm land that hold runoff and sediment to reduce erosion.

Tidal: the periodic rise and fall of the ocean water masses, produced by gravitational effects of the moon and sun on the Earth.

TMDL (Total Maximum Daily Load): a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

Topographic Position within a Watershed: streams are assigned a stream order number (1-3) with respect to the topographic position within the watershed drainage system. Tributary or headwater streams are low-order streams (1 or 2) located at higher elevations within the watershed.

Total Suspended Solids (TSS): a measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids."

Toxic Pollutants: materials that cause death, disease, or birth defects in organisms that ingest or absorb them. The quantities and exposures necessary to cause these effects can vary widely.

Upland: dry land located at an elevation above wetlands or waterways.

Urban: relating to or concerned with a city or densely populated area. The "urban" category includes those areas classified as being urbanized (having a population density of at least 1,000 persons per square mile and a total population of at least 50,000) as well as cities, villages, boroughs (except in Alaska and New York), towns (except in the six New England states, New York, and Wisconsin), and other designated census areas having 2,500 or more persons.

Vector: an organism, often an insect or rodent that carries a disease agent.

Vortex: a revolving mass of water which forms a whirlpool. This whirlpool is caused by water flowing out of a small opening in the bottom of a basin or reservoir. A funnel shaped opening is created downward from the water surface.

Wastewater Treatment: the process that removes the majority of the contaminants from wastewater or sewage and produces both a liquid effluent suitable for disposal to the natural environment and a sludge. To be effective, sewage must be conveyed to a treatment plant by appropriate pipes and infrastructure, and the process itself must be subject to regulation and controls. Other wastewaters require often different and sometimes specialized treatment methods.

Water Boatmen: aquatic bugs (Order Hemiptera) that paddle along the water surface with oarlike hind legs. Water boatmen occur in fresh or brackish water throughout the world. In certain ponds or lakes they may be extremely abundant. About 525 species are known worldwide, 132 in North America. Water boatmen occur most commonly in ponds and along the edges of lakes, although a few species inhabit the brackish waters of estuaries. Most water boatmen eat algae and minute aquatic organisms. Some are predaceous and feed on mosquito larvae and other small aquatic animals; in this way, they help to control aquatic pests. In turn, they are important prey for many larger aquatic animals.

Water Striders: a water bug (Order Hemiptera) that looks a lot like a big mosquito walking on the surface of the water. Water striders live on the surface of ponds, slow streams, marshes, and other quiet waters. Common water striders eat living and dead insects on the surface of the water. Some prey are aquatic insects, such as mosquito larvae coming up from the bottom, and others are terrestrial (land) insects, such as butterflies or beetles that accidentally land on the surface.

Waterfowl: any bird that spends a large portion of their lives in wetlands, in or at the edge of lakes, rivers, or streams.

West Nile Virus (WNV): emerged in 1937 from its origins in Africa (Uganda) into Europe, the Middle East, west and central Asia and associated islands. It is a flavivirus (family Flaviviridae) with more than 70 identified viruses. Serologically, it is within the Japanese encephalitis virus antigenic complex similar to St. Louis, Japanese and Murray Valley encephalitis viruses. Similar to other encephalitises, it is cycled between birds and mosquitoes by certain types of mosquitoes, and transmitted to mammals (including horses) and man by other types of infected mosquitoes known as "bridge vectors". WNV might be described in one of four illnesses: the least severe manifestations known as West Nile Fever, is characterized by fever, headache, tiredness and aches or a rash, which may last a few days or several weeks. The other manifestations are more severe and are grouped as "neuroinvasive disease" which affects the nervous system; West Nile encephalitis affects the brain, and West Nile meningitis (meningoencephalitis) is an inflammation of the brain and membrane around it.

Western Equine Encephalitis: an avian disease that is spread to horses and humans by infected mosquitoes. It is one of a group of mosquito-borne virus diseases that can affect the central nervous system and cause severe complications and even death. Other similar encephalitis diseases are eastern equine encephalitis, St. Louis encephalitis, and LaCrosse encephalitis. Western equine encephalitis is found in North, Central, and South America, but most cases have been reported from the plains regions of the western and central United States.

Wetlands: an area that is saturated by surface or ground water with vegetation adapted for life under wet soil conditions, including swamps, bogs, fens, marshes, and estuaries.

Wildlife: living organisms that are not in any way artificial or domesticated and which exist in natural habitats. Wildlife can refer to flora (plants) but more commonly refers to fauna (animals). Wildlife is a very general term for life in various ecosystems. Deserts, rainforests, plains, and other areas—including the most built-up urban sites—all have distinct forms of wildlife.

Woodland: a vegetation community that includes widely spaced large trees. The tree crowns are typically more spreading in form than those of forest trees and do not form a closed canopy. Grass, heath, or scrub may develop between the trees.

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