Re-plumbing the Chesapeake Watershed: Improving Roadside Ditch Management to Meet TMDL Water Quality Goals

STAC Workshop Report

October 9-10, 2014

Easton, MD

STAC Publication 16-001

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

Publication Date: March, 2016

Publication Number: 16-001

Suggested Citation: Schneider, R. and K. Boomer. 2016. Re-plumbing the Chesapeake Watershed: Improving roadside ditch management to meet TMDL water quality goals. STAC Publication Number 16-001, Edgewater, MD. 43 pp.

Cover graphic from: James Houghton for the Cornell Roadside Ditch Program.

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Funding:

In addition to support from STAC and CRC, funds were provided through a grant from the U.S. Department of Agriculture Research, Education, and Economics Agricultural Research Service (Beltsville, MD) and through contributions from the Cornell Local Roads Program, Cornell University, The Chesapeake Bay Foundation, and The Nature Conservancy.

Table of Contents

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EXECUTIVE SUMMARY

A workshop entitled "Re-plumbing the Chesapeake Watershed: Improving roadside ditch management to meet TMDL goals" was held in October 2014, in Easton, Maryland, to discuss impacts from roadside ditches and associated opportunities to meet Chesapeake Bay Program goals. Roadside ditches are common landscape features, paralleling both sides of almost every mile of road and highway. Cumulatively, ditch networks intercept approximately 20 percent of the runoff and shallow interflow generated in adjacent land areas. Captured water is shunted rapidly to nearest streams, thereby causing upstream dry-outs, and contributing to downstream flooding, water pollution, in-stream erosion, altered streambeds, and degraded habitats. As such, roadside ditches have had a significant but previously unrecognized impact on the Chesapeake Bay for almost a century. The workshop audience of 71 water resource professionals, highway practitioners, scientists, and policy-makers unanimously agreed that roadside ditch management represents a critical but overlooked opportunity to help meet total maximum daily load (TMDL) and habitat goals. Additionally, improved ditch management provides a strategy for buffering the impacts of high intensity rainfalls and other extremes expected with climate change.

Workshop presentations in the session on "state of the science" highlighted multiple threats posed to regional waterways by poorly managed roadside ditches. A strong body of research has consistently documented that ditches are contributing to flooding in streams, increasing peak stream heights by as much as 300 percent. Roadside ditches also play significant roles in water pollution; first acting as very rapid conduits of sediment, nutrients, fecal coliforms, and other pollutants moving from farm fields and other land surfaces to streams. Equally important, ditches directly provide a major source of sediment when cleaned/scraped and left exposed to erosion during storms. Highway maintenance crews reported that scraping without re-vegetation was a common practice throughout thousands of road miles in New York and Pennsylvania. Further, ditches can transform contaminants, either acting as a filter, (e.g., a dense grass matrix helps remove sediment and nutrients) or alternatively as a contaminant source, (e.g., the greenhouse gas nitrous oxide (N_2O) can be generated if conditions exist for incomplete denitrification). In association with such hydrologic and chemical impacts, early research indicates that chronic outputs from the vast expanse of roadside ditches have degraded in-stream aquatic habitats - altering flow regimes, encouraging chronic stream bank erosion, and degrading habitat quality and food web structures far downstream from the ditch outfalls. Finally, the state of the science session also highlighted key knowledge gaps and uncertainties that likely limit our ability to manage impacts from roadside ditches. Priority research areas include (a) understanding how low- or zero-flow conditions influence nutrient dynamics and contaminant transport, and how high-flow discharge events influence downstream conditions particularly through effects on channel morphology; (b) developing reliable models to identify which stream reaches are most vulnerable to roadside ditch impacts, where improved management practices can advance water quality and habitat goals most significantly, and how much capacity improved roadside management can provide toward achieving Bay water quality and habitat goals; (c) refining our understanding of roadside ditch impacts on habitat conditions, including effects on temperature and salinity regimes, invasive species establishment, and physical effects on downstream habitat; and (d) understanding socio-economic and political factors that most critically influence management decisions. Field studies indicate that these micro-topographic features strongly influence regional waterways, but few broad scaled assessments have been developed to evaluate the cumulative effects in different physiographic provinces of the Chesapeake Bay watershed.

The second workshop session explored a diverse set of design strategies, which range in cost and required maintenance to mitigate roadside impacts. The least expensive strategies essentially modernize traditional maintenance procedures. For example, shaping ditch excavations to shallow, trapezoidal or rounded profiles rather than V-cuts reduces concentrated, incisive flow and sediment erosion. This practice adjustment also facilitates routine mowing and minimizes the potential for storm flow to undercut and destabilize roadbeds. More highly engineered strategies can be considered for ditches that carry extreme excess or contaminated waters. Some practices modify road design to diffuse runoff along adjacent areas– for example, installing multiple cross-road subsurface drainpipes. Other practices focus on reestablishing natural filters (e.g., bio-swales, compound or "two-stage" channels, and level lip spreaders) to enhance groundwater recharge and "treat" contaminants. Where ditches carry excessive contaminant loads or where space is limited, highly engineered practices may provide the best remediation option. These practices generally consist of enlarging a ditch to accommodate a filter medium. Proper best management practice (BMP) design and implementation, tailored to the specific location, is essential for managing water volume and quality, as well as habitat condition.

Participant feedback during the break-out sessions, as well as speaker presentations on the State of Roadside Ditch Management, clearly indicated that overall roadside ditch management across the Chesapeake Bay is fair to poor and that most of the BMPs presented are not being adopted. Scraping ditches is a pervasive means of nominally "cleaning" ditches and deepening of ditches is actually capturing more subsurface flow and worsening the erosion problems. Five major factors contributing to poor management included: (1) insufficient guidance and a critical need for better design and maintenance guidelines on when and how to apply the diverse BMPs; (2) mapping and inventories of the ditch networks have never been conducted by many municipalities; (3) a pervasive lack of awareness of ditch impacts among all stakeholders, including private landowners who control road right-of-ways; (4) a broad and conflicting array of practices and policies in use across local municipalities and among states, which has complicated efforts to effectively mitigate impacts; and (5) inadequate funding -- highway staff unanimously reported that constraints on manpower, time, and equipment limited capacity to adopt modern ditch management strategies as much as BMP costs.

The STAC workshop identified a set of eight recommendations for improving roadside ditch management across the Chesapeake Bay to help meet the Bay Program's TMDL goals. These recommendations incorporated lessons learned from several case studies of successful ditch management, including the importance of inventory and assessment of ditch networks as a first step, education of all stakeholders, interagency cooperation and partnership, and strong leadership. The recommendations can be summarized broadly into three categories

- Ensure that the CBP emphasizes water quality and habitat impacts associated with these micro-topographic features and the opportunity to help meet CBP goals by promoting ditch management, including funding and regulatory incentives to ensure implementation.

- Explicitly recognize the critical roles that roadside ditch networks have on water pollution, flooding, and wildlife habitat by developing a comprehensive, watershed-wide program with cross-jurisdiction team-based leadership and consistent policy and guidelines to promote "re-plumbing" roadside ditch networks across towns, counties, and states in the Chesapeake Bay watershed.

- Create targeted, funded research programs focused both on improving our understanding of ditch impacts and better management practices to address these impacts.

WHY A WORKSHOP ON DITCHES?

Although roadside ditches have long been used to enhance road drainage and safety, traditional management practices have been a significant, but unrecognized contributor to flooding and water pollution in the Mid-Atlantic and Northeastern U.S. Since the post-WWII building boom, ditch management practices have changed little. The primary objective is to move water away from local road surfaces as quickly as possible, without evaluating local and downstream impacts. For example, town highway staff routinely "clean" or scrape ditches to facilitate direct drainage or remove aggraded sediments. As a consequence, miles of exposed soil enhance potential to transport excess nutrients, deicers, and other road contaminants into streams during storm events. Continued widespread use of outdated road maintenance practices reflects a break-down in communications among scientists, highway managers, and other relevant stakeholders, as well as tightening budgets and local pressures to maintain traditional road management services.

Thousands of miles of roadside ditches crisscross the Chesapeake Bay watershed, each providing a high velocity sluiceway that rapidly shunts water, debris, and contaminants to downstream waterways. These micro-topographic hydrologic features capture approximately 20 percent of runoff from road surfaces and adjacent hillslopes. As a result, elevated discharges increase peak stream flows and exacerbate downstream flooding. The rapid, high volumes of flow also carry nutrient-laden sediment, salt and other road contaminants, and even elevated bacteria counts, thus contributing significantly to regional water quality concerns. Finally, increased flow strengthens stream power enough to alter natural geomorphic processes controlling the distribution of tributary deltas and gravel deposits, thus causing significant changes to downstream channel structure and habitat condition. All of these impacts will be exacerbated by the increased frequency of high intensity storms associated with climate change.

Impacts from rural-suburban roadside ditch networks consistently have been overlooked and remain largely unaccounted in the current Chesapeake Bay TMDL framework. Yet modern BMPs can provide tremendous capacity to meet TMDL requirements and simultaneously help road managers to meet expectations for safe, pleasing, sustainable road infrastructure. Strategies range from simple hydroseeding and channel reconfiguration to more resource-intensive green infrastructure such as bioswales, biofilter bags, permeable asphalt, and under-road drain tubes. In short, **improved road ditch management provides an often overlooked, cost-effective set of strategies to reduce water pollution and improve aquatic habitat conditions.**

WORKSHOP OVERVIEW

To address the challenges and opportunities associated with roadside ditch management, the Chesapeake Bay Program's (CBP) Science and Technical Advisory Committee (STAC) and the United States Department of Agriculture (USDA) sponsored a two-day workshop, "Re-plumbing the Chesapeake" held on October 9-10, 2014, at the Tidewater Inn in Easton, Maryland. The forum allowed a broad array of stakeholders, including federal, state, and local level policy makers, watershed planners, public works and highway staff, and restoration specialists to share information at a critical time, when the CBP is developing its 2017 Midpoint Assessment. This mid-course check provides an opportunity to adjust BMP strategy recommendations and to ensure that the Partnership can achieve its 2025 goals to restore the Bay ecosystem.

A strong welcome address by MD Secretary of the Environment, Dr. Robert Summers, emphasized the importance of this issue to the diverse audience of 71 attendees. The format for the two-day workshop included three sessions of presentations by 15 speakers covering the state of the science, management, and policy issues surrounding roadside ditches, followed by a breakout discussion session to get audience perspectives and feedback specific to the workshop goals.

WORKSHOP GOALS

- Increase awareness of the critical impacts of roadside ditches and BMPs to reduce these impacts.
- Inventory the current status of ditch management across the Chesapeake Watershed.
- Develop recommendations for how best to improve roadside ditch management to meet TMDL goals, reduce flooding, and buffer impacts of climate change.

STATE OF THE SCIENCE

Workshop speakers consistently demonstrated that roadside ditches are negatively impacting stream and river ecosystem health in a multitude of ways. Speakers also presented convincing evidence that adoption of better practices can provide a suite of new opportunities for meeting TMDL goals. This section briefly describes the main overall impacts and regional differences across the Chesapeake Bay watershed, and summarizes key areas for additional research.

The interwoven complexity of roadside ditches provides a highly efficient network of artificial flow channels directly connected to regional waterways. The length of these artificial flow channels often exceeds natural stream length, doubling (or more) stream channel density and thereby increasing the overall connectedness between land and water (Buchanan et al. 2013b; Graf 1977; Ogden et al. 2011 Schneider 2014; Wemple et al. 1996). Across much of the Chesapeake Bay area, the enhanced drainage networks have shifted our watersheds from groundwater-driven systems to more of a surface water-driven system. As a result we see a greater frequency of high volume downstream floods, increased turbidity, and "storm-driven" geomorphology, all of which adversely affects humans as well as native flora and fauna (Arnold et al. 1982; Schneider 2014).

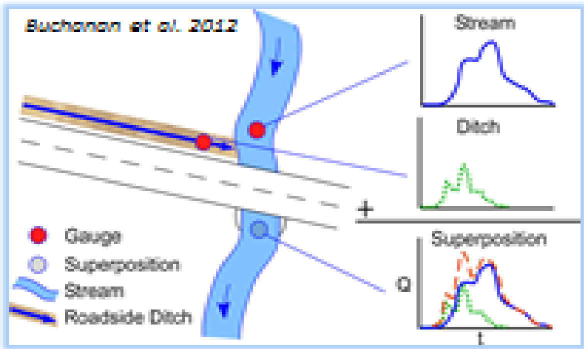
MAIN OVERALL IMPACTS

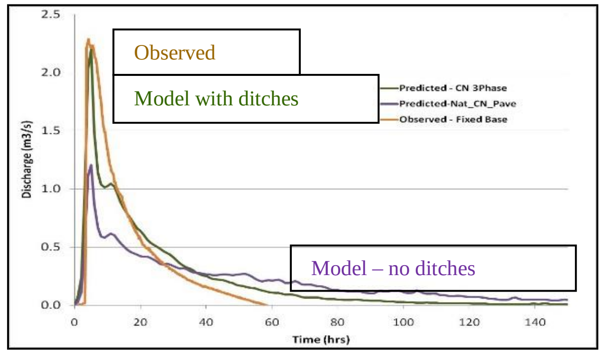
The following three main areas of roadside ditch impacts were highlighted throughout the workshop:

- Hydrologic impacts, including increased storm runoff peak flows, flashier stream discharge and more frequent downstream flooding;
- Water quality impacts, including enhanced delivery of nutrients, sediment, and other contaminants of concern; and
- Biological impacts, acting directly on biota, and indirectly through impacts to aquatic habitat.

Impact #1 - Increased Downstream Flooding

Networks of ditches effectively intercept approximately 20 percent of the surface runoff in each watershed, divert shallow interflow, and rapidly shunt these combined waters to nearby streams to increase peak flows and flooding (Buchanan et al. 2012a; Buchanan et al. 2013b; Diaz-Robles 2007). Studies in central New York documented that ditch networks capture not just road-top runoff, but as much as 50 percent of a rainfall event in the associated drainage basins (Diaz-Robles 2007). As a result, a greater proportion of runoff no longer moves downslope as slow diffuse flow. Instead it is concentrated and rapidly shunted past wetlands, thereby increasing peak flow by as much as 300 percent and magnifying downstream flooding (Buchanan et al. 2012a; Carluer and Demarsily 2004; Diaz-Robles 2007; Meierdiercks et al. 2010; Wemple and Jones 2003). More efficient surface runoff also reduces groundwater recharge and reduces water supplied to headwater streams, thus increasing the frequency of dried headwater streambeds.





Increased stream peak heights due to ditch inputs (Buchanan et al. 2012a)

Impact #2 - Water Pollution

Interconnected ditch networks play multiple roles in pollution, acting variously as a conduit, a source, or a transformer of contaminants traveling to downstream waters.

- Most visibly, ditches provide highly efficient conduits transferring sediment and nutrients eroded from upland landscapes to waterways (Buchanan et al. 2013b; Diaz-Robles 2007; Fablo et al. 2013; Hatt et al. 2004; Wemple et al. 2001). Agricultural fields, ditches, and tile drains often are managed deliberately to discharge into roadside drainage systems. As a result, fecal coliforms from manure spreading and other agricultural pollutants can be conveyed to downstream drinking water supplies, sometimes tens of miles away (Falbo et al. 2013). Further, sediment contributions to streams increase exponentially where ditches adjoin dirt and gravel roads (Sheridan and Noske 2007; Susquehanna River Basin Commission 2002). New York, Pennsylvania, and Vermont have identified 10,000s of miles of unpaved roads which account for 10 to 30 percent of stream sediment loads (Susquehanna River Basin Commission 2002).

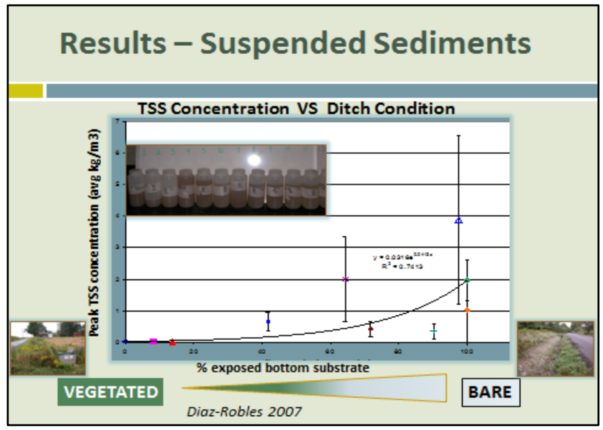
- Somewhat surprising, roadside ditches also provide a major source of sediment and associated phosphorus, especially where more traditional cleaning and scraping maintenance strategies leave soils exposed to erosion (Diaz-Robles 2007; Falbo et al. 2013). In New York, such scraping occurs approximately once every 2 to 4 years, and half of the highway staff do not consider revegetation a priority. Thus thousands of miles of ditch are left exposed to erosion every year.

(Left) Exposed rock and gravel in ditch due to high velocity runoff and severe scouring. (Right) Installation of tile drain in farm field with outflow location in the roadside ditch (Schneider 2014).

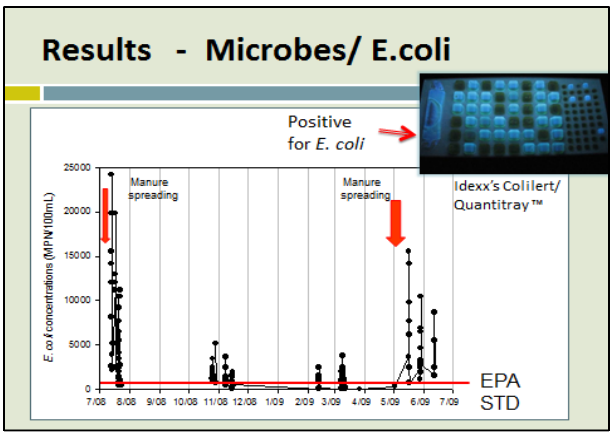
- Roadside ditches also can act as transformers of nutrients, especially in ditches that hold standing water (Kroger et al. 2012). For example, ditch substrates can enhance denitrification, perhaps reducing excess nitrate and possibly improving water quality. However, incomplete conversion will produce N_2O, a potent greenhouse gas, so the net impacts are unclear. Further, stagnant, deoxygenated waters can lead to increased phosphorus bioavailability as well as other redox-sensitive contaminants of concern. Transforming processes in ditches deserve further research.

(Left) Typical method for cleaning ditches in New York. (Right) Heavy sediment load transported to stream from scraped and eroding ditch during storm event (Schneider 2014).

Local landscape features strongly influence water quality impacts from a given roadside ditch. In particular, the slope of the road surface and its orientation relative to channel flow direction can exacerbate or reduce impacts of roadside ditches. A study in the Lake Champlain basin showed that mean suspended sediment production increased by more than 100 percent along roads with grades steeper than 2 percent, from less than 1 to nearly 10 metric tons per km road length per year (Wemple 2014). Further, observed sediment and total phosphorus fluxes increased directly with the extent of impervious road area. Enhanced stream bank erosion and degraded habitat conditions were observed more frequently where roadside ditches discharged to streams that flowed perpendicular to the adjacent road (Wemple 2014). In general, the healthiest streams, in terms of geomorphic condition, were those located more than 150 m away from adjacent roads. These factors should be considered in developing a targeting framework.



Scraping of ditches, and the extent of exposed substrate, was directly related to the amount of sediment transported to streams (Diaz-Robles 2007).



Manure spreading in headwater farms results in repeated transport of fecal coliforms into ditches and downstream to drinking water supplies (Falbo et al. 2013).

Impact #3 - Aquatic Habitat Degradation

The shunting by ditches of both runoff and contaminants into the stream network at numerous locations degrades aquatic habitat, drives regional stream systems toward disequilibrium, and encourages invasive species. Preliminary studies suggest that geomorphological processes shift throughout the entire drainage network due to roadside ditch impacts (Arnold et al. 1982; Florsheim et al 2001; Schneider 2014). On low-order streams, incised ditches often bypass riparian buffers or other natural filters, and discharge as high velocity "faucets" directly to streams. Increased storm discharge shifts the natural pattern of stream flow, leading to increased stream bank erosion, and channel widening and/or deepening. Stream flow is also redirected around the deltas of bedload gravel deposited at many channel-stream junctions (Carluer and DeMarsily 2004). Post-storm, over-sized channels and reduced base flow lead to frequently dry streambeds. Overall, chronic deposition and enhanced erosion alters the texture of the stream bed and adversely affects aquatic habitat far downstream of ditch outlets.

Samples of bedload gravel and rocks transported in a small rain event (top left) and the 3ft deep pile of bedload rock deposited in a single ditch during the 2006 flood in the Susquehanna River Basin (top right). Delta of bedload gravel deposited at bottom of ditch (lower) (Schneider 2014).

Shifts in natural flow regimes, including increased peak flow and reduced base flow, pose serious threats to amphibian and invertebrate species, for example, by limiting reproductive success in headwater streams and wetlands (Blasius and Merritt 2009; Collins and Russell 2009; Coffin 2007). While some studies suggest that amphibians may be attracted to artificial waterways as breeding habitat, offspring survivorship is greatly reduced compared to natural habitats (Van Meter 2014). Altered stream flow regimes, changes in bed substrate, and loss of hydrologic connectivity to headwaters also causes sweeping impacts to downstream aquatic food chains.

Pollution presents another challenge adversely affecting survivorship of aquatic species. Elevated salts are of particular concern (Kaushal et al. 2005). Within the Chesapeake Bay watershed, road managers apply more than 20 tons of road salt to each mile of four-lane highway during an average winter; or about 2.5 million tons across the entire watershed (Center for Watershed Protection 2003). Runoff concentrations are high enough to shift food web structures in small ponds and channels from freshwater to marine conditions, thus creating toxic conditions to native species. Particularly vulnerable are those freshwater species that utilize roadside areas for egg-laying in late winter months when episodic salt pulses flood the habitat. The overview of habitat concerns led workshop participants to question whether ditch networks should themselves be viewed as habitat as well as being managed to improve habitat quality downstream.

Roadside ditches provide ideal conditions for establishment and expansion of invasive species. Vigorous growth is especially favored since ditch soils are disturbed and excess nutrient and salt inputs favor non-natives (Albert et al. 2013). Japanese stilt grass (Microstegium vimineum (Trin.) A. Camus), Japanese knotweed (Polygonum cuspidatum), and Phragmites australis have been particularly problematic in roadside ditches and near culverts (Mortensen et al 2009; Lelong et al. 2007). It is likely that networks of ditches also provide corridors of movement for some invasive species.

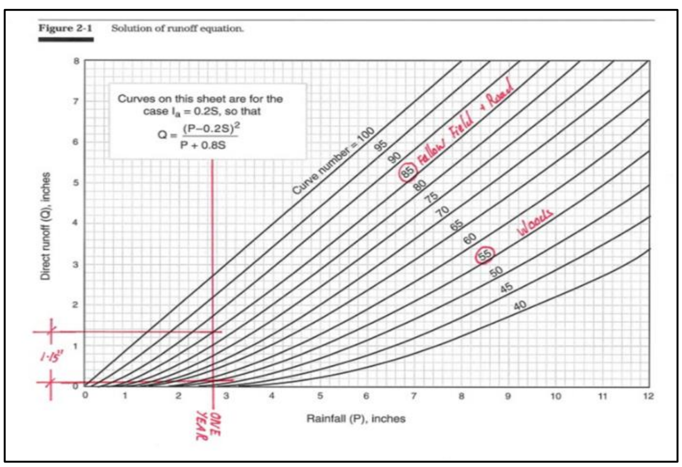
REGIONAL DIFFERENCES ACROSS THE CHESAPEAKE WATERSHED

The workshop explored how the impacts of roadside ditches vary regionally across the watershed, due to differences in topography, soils, land use, and management approaches.

- In Ridge and Valley regions, steep slopes and thin soil depths often lead to greater runoff and rainfall capture by the intercepting ditches, regardless of land cover conditions (i.e., in forested, rural, and developed landscapes). Even in "healthy" forested watersheds, roadside ditches along low-volume rural roads create an efficient water-capturing network in an otherwise pervious landscape, resulting in significant concentrations of overland flow, interception of shallow groundwater flow, and water degradation. These alterations lead to a greater frequency and intensity of gully erosion, debris slides, and excess sediment delivery.

- In comparison, the deeper soils of the Piedmont Region provide a greater supply of erodible sediments, thereby magnifying pollution and degradation of downstream water quality. Further, the agriculture, and the interconnectedness of agricultural ditches and tile drains with roadside ditches exacerbate rapid transfer of irrigation waters and contaminants (Herzon and Helenius 2008; Moussa et al. 2002; Needelman et al. 2007).

In the flat lowlands of the Atlantic Coastal Plain, erosion risks are considerably reduced due to both slower surface water flow gradients and widespread occurrence of estuarine sandy deposits which enhance infiltration. However, vast networks of artificial channels were constructed to expand agricultural acres and to reduce flooding in developed areas including along transportation networks. On the Delmarva Peninsula alone, thousands of miles of artificial drainage channels have caused expansive wetland loss and lowered regional water table conditions. As a result, stream hydrology has shifted similarly to that in other physiographic provinces of the Chesapeake Bay watershed; that is, expansive artificial drainage networks have resulted in flashier river systems with increased storm flow and reduced base flow. These findings are consistent with feedback from tax ditch managers who report that road runoff shunted to regional ditch networks has increased downstream flooding (Boomer 2014). Enhanced surface water runoff is especially problematic where elevated soil phosphorus conditions occur, such as on the Eastern Shore (Easton et al. 2010; Keppler 2014; Kleinman et al. 2007).



Runoff equations prescribed by the TR55 Method emphasize the influence of on-site land cover conditions, topographic slope, and soil type, together with event rainfall amount – factors which differ regionally across the watershed (Ryall 2014).

Additional physical and socio-economic factors drive differences in ditch management across the Bay watershed. For example, roadside maintenance practitioners recognized that climatic variation across the region results in greater application of de-icers to road surfaces, particularly in the Appalachian Plateau and Ridge and Valley regions of the Bay watershed (Kelly et al. 2008). Further, more frequent freeze-thaw cycles in the colder climates increase surface runoff and erosion. Social factors of governance and management, attitudes and cultures, also vary regionally and thus superimpose additional factors affecting impacts from roadside ditches. (See Management section below.)

Regardless of terrain, the interconnected system of tile drains, ditches, and streams truncates terrestrial hydrologic pathways and shortens water residence time needed for effective filtering of chemical and microbial contaminants. Water degradation has been linked strongly with the density of drainage ditches and also the orientation and distance of roadside ditches from streams (Jones et al. 2000; Wemple 2014).

Roadside ditch in upstate hills of New York, on the Appalachian Plateau (left), and in Maryland, on the Delmarva Peninsula of the Outer Coastal Plain (right) (Schneider 2014).

IDENTIFIED RESEARCH GAPS AND KEY UNCERTAINTIES

- Improve understanding of how ditch outflows, including the quantity of water and associated contaminants, influence in-stream geomorphological processes and aquatic ecosystem health.

- Refine understanding of contaminant transport, storage, and particularly transformation processes in ditches, especially in relation to maintenance practices and cycles.

- Assess how physical, socio-economic, and political factors influence resource allocation and decision-making in roadside ditch management across the Chesapeake Bay watershed.

MITIGATION STRATEGIES TO REDUCE IMPACTS

Workshop speakers presented a diverse array of management practices to reduce flow velocities and contaminant transport and to mitigate impacts from roadside ditches while accommodating road safety concerns. These strategies can be divided into three broad, but overlapping categories: (1) practices designed to hold or redirect stormwater runoff, thereby minimizing contributions to downstream flooding, and (2) practices designed to slow down outflow and filter out contaminants, and (3) practices to improve habitat. Whereas traditional stormwater management focused on scraping or armoring ditches to collect and rapidly transport water downstream, modern strategies focus on diffusing runoff to enhance sheet flow, slowing velocities, and increasing infiltration and groundwater recharge 44. This approach reduces the rapid transfer of rainwater out of catchments and helps to restore natural hydrologic conditions and to reduce pollution.

#1 Practices to Reduce Stormwater Discharges

- Disconnect ditches from streams and redirect the discharges to infiltration or detention ponds.

- Restore or establish an intervening wetland between the ditch and the stream to capture and slow down ditch discharges. Wetlands are well documented as natural filters which enhance sedimentation, facilitate nitrogen removal via denitrification, and allow time for infiltration and ground water recharge, and also potentially provide high quality habitat.

- Level lip spreader systems divert concentrated flow into manmade depressions oriented perpendicular to flow (Newbold et al. 2010). The structures are designed to store water temporarily and diffuse flow across the land surface, ideally as sheet flow or shallow ground water through a riparian buffer. A properly constructed "lip" or shallow levee between the diversion channel and the riparian wetland prevents unintended formation of additional concentrated flowpaths that can short-circuit riparian buffer functions.

- More highly engineered strategies can be considered for roadside ditches that carry excessive volumes of water. Some of these practices modify the road design to diffuse runoff along a ditch, rather than encouraging concentrated outflow. For example, crowning the road surface so that centerlines are at the highest elevations and runoff diffuses along the entire length of the road to adjacent natural areas significantly reduces concentrated flow and can even eliminate the need for roadside ditches. The "divide and conquer drainage" approach of installing multiple under-road pipes/culverts at frequent intervals also minimizes the capture and concentration of storm water runoff, and allows more diffuse natural flow to the stream.

Under-road pipes (left) and level lip spreaders (right) are two strategies to diffuse stormwater discharges and reduce concentrated ditch outflows (Bloser 2014; Sweeney 2014).

#2 Practices to Slow Outflow and Filter Contaminants

Although less effective during larger storms, simple adjustments to traditional management practices can reduce roadside impacts significantly. Traditional V-shaped channels are problematic because they concentrate surface flow and lead to incision and erosion. Over time, chronic "over-ditching" and deepened roadside channels can capture greater amounts of groundwater, further destabilizing channel banks. Deep, incised ditches also present dangerous hazards to pedestrians and cars. The least expensive modern technologies to reduce roadside ditch impacts include simple modifications to traditional ditch maintenance strategies.

(Left) Deeply scraped, V-shaped ditch with exposed substrates (Schneider 2014). (Right) Erosion and undercutting of road surface due to erosive flows in ditch (Bloser 2014).

- Reshaping ditches to shallow, trapezoidal or rounded profiles reduces concentrated, incisive flow and the potential for erosion. This practice adjustment facilitates establishment of grasses which filter out contaminants and can be maintained by routine mowing. Shallower ditches also minimize the potential for storm flow to undercut and destabilize roadbeds. In addition, channel slope should be graded to allow gradual but continuous outflow, thereby minimizing opportunities for standing water conditions likely to elevate contaminant concentrations, support mosquito populations, or create other nuisances.

- Optimizing vegetative cover, including hydroseeding and a regular mowing program, should be substituted for mechanical scraping. When necessary, mechanical scraping should be scheduled to accommodate seasonal weather patterns and growing season so as to reduce elevated risks of contaminant transport. When scraping occurs in autumn, outside of the growing season, ditch substrates remain exposed throughout spring snowmelt, thereby sustaining high risks for erosion and elevated suspended sediment loads. Alternatively, during summer, warm standing water in contact with exposed soils also can degrade water quality by enabling biogeochemical processes that release soil-bound nutrients and metals. Accordingly, where scraping is necessary, managers should schedule roadside ditch maintenance during late spring or early summer when hydroseeding will be more successful.

- Building check dams, or a series of riprap bars oriented across the channel perpendicular to flow, can reduce channel flow rates and induce sediment deposition while enhancing ground water recharge. Where necessary, erosion risks from steeply sloping ditches can be minimized with riprap along the entire ditch. Rocks, however, act as thermal reservoirs and can transfer detrimental heat loads to downstream aquatic species, especially during summer rainfall events. Therefore careful consideration to the full suite of management impacts must be considered.


Check dams (left) and hydroseeding to establish vegetation (right) are two strategies that slow down flow velocities and help capture sediment (Schneider 2014).

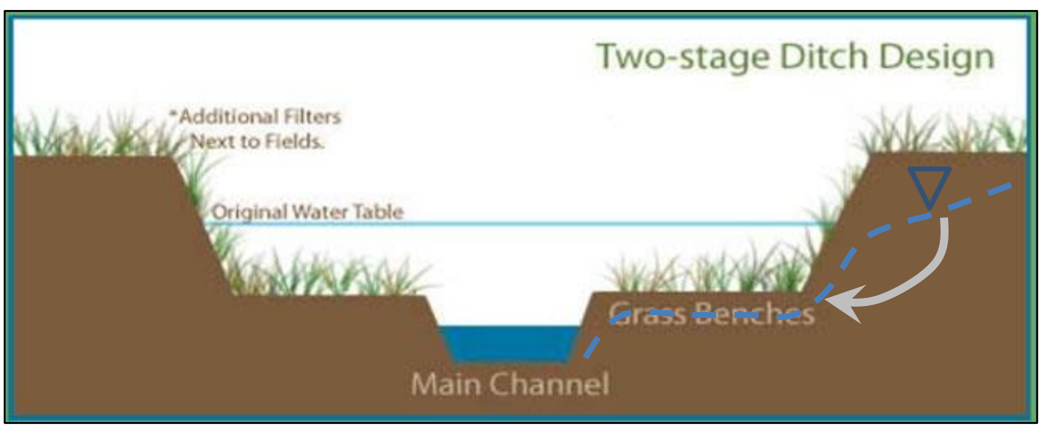
- Water quality can be protected further by using quality aggregate road materials developed specifically to reduce fine sediments and the associated water quality impacts on adjacent habitats. Rainfall simulation experiments indicated that quality aggregate can reduce sediment loss compared to unimproved or tar and chip gravel roads by 90 percent over several years (Bloser et al. 2012).

More sophisticated but moderately more expensive practices focus on reestablishing natural filters, such as bio-swales, compound or “two-stage” channels, and level lip spreaders.

- Bio-swales are designed to hold and filter runoff using natural substrate and vegetation (Ryall 2014), usually underlain by porous material and pipes. The broad array of attractive designs has increased the appeal and adoption of this practice more recently.

Example of a bio-swale (State Highway Administration 2015).

- Compound "two-stage" ditches have been used successfully in Midwestern agricultural ditches and, when downscaled, show great promise for roadside ditches. The channel is engineered to transport low flow through a sinuous channel that increases water residence time and allows natural filter processes to occur; however, during high flow the channel allows adequate water drainage. Normal flows can be confined to a meandering channel 'thalweg' while the larger, flat, and straighter channel can transmit excess storm flow to reduce local flooding risks. Pocket wetlands located in the channel meanders provide additional filter capacity. Equally important, two-stage ditches constructed to intercept shallow groundwater will filter lateral discharge along the length of the ditch. A properly designed two-stage ditch design replicates the form and function of a natural floodplain system.



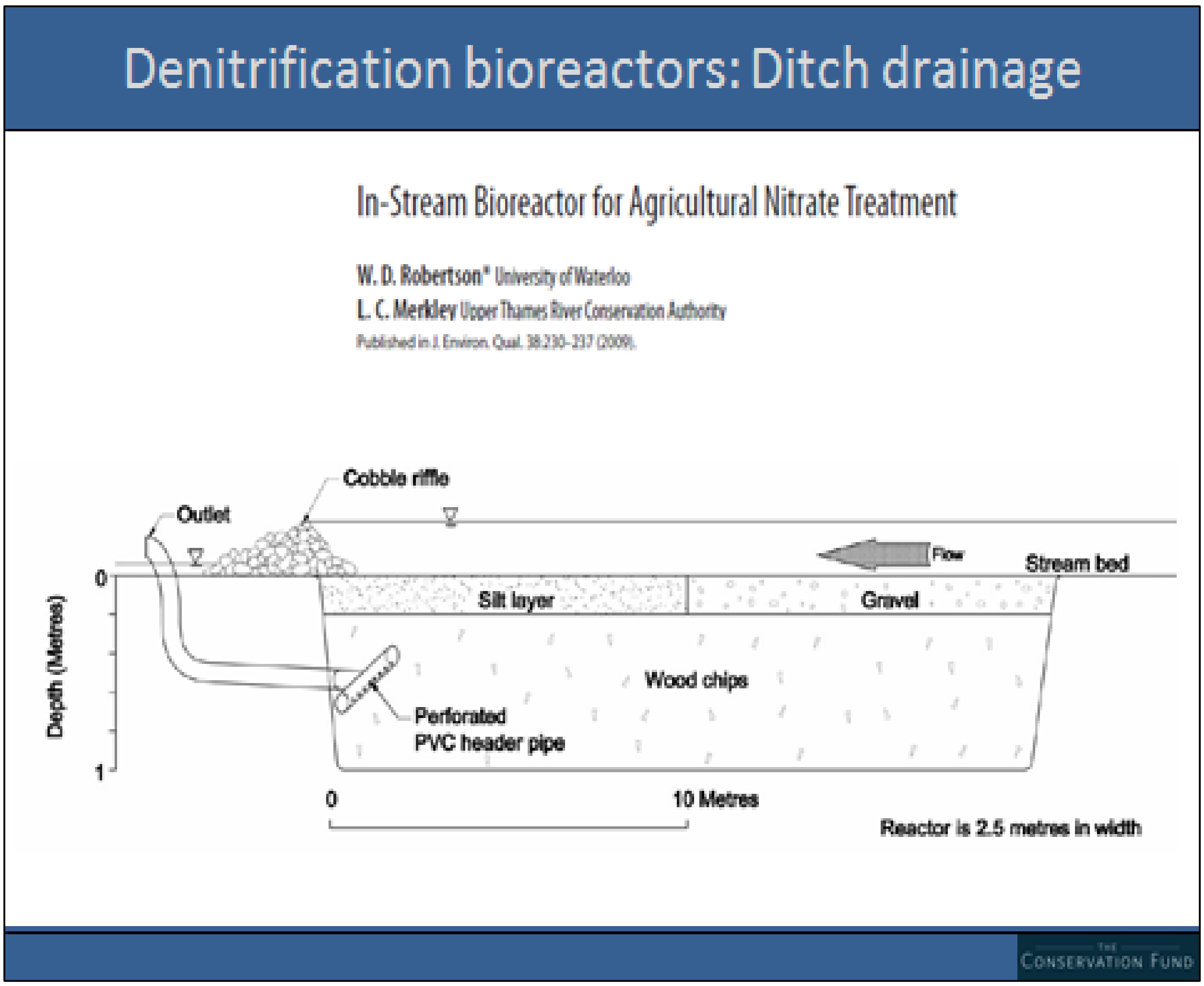
Graphic representation of a two-stage ditch design (The Nature Conservancy 2015).

- Where space is limited, highly engineered filter practices may provide the most suitable option to reduce roadside impacts, especially for ditches that transport high volumes of contaminated water. These practices generally consist of enlarging a ditch to accommodate a filter medium selected for targeted constituents. Promising technologies reviewed during the workshop included the following:

a) Iron- and aluminum-rich acid mine treatment residuals can be used as a filter medium to enhance ion exchange capacity and sorb phosphorus to reactive particle surfaces. Additional filter medium alternatives include fly ash, drinking water treatment residuals, alum, and bauxite mining or steel slag waste (Table 1).

b) Organic, carbon-enriched substrates (e.g., woodchips or woodchips/biochar) enhance denitrification and also appear to reduce orthophosphate concentrations (Lassiter and Easton 2013; Christianson et al. 2012; Table 2).

c) Inorganic substrates can sorb contaminants to particle surfaces or enhance co-precipitation. For example, subsurface gypsum "curtains" constructed with residue or by-product of flue-gas desulfurization can reduce bioavailable phosphorus from inflowing waters by enhancing calcium phosphate mineral precipitation (Buda et al. 2012; Bryant et al. 2012).



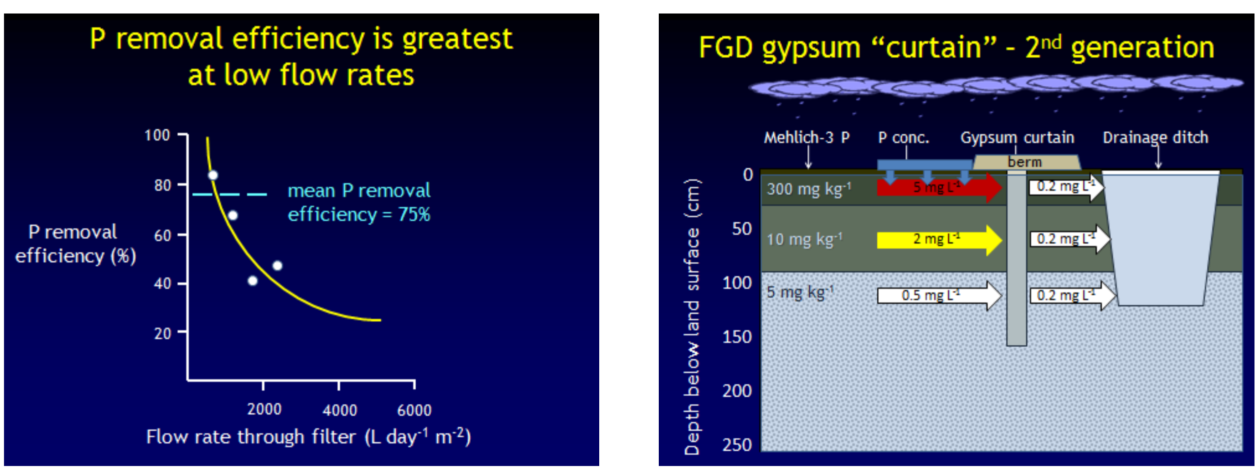
Conceptual design of a woodchip bioreactor to reduce excess nitrogen (Christianson 2014)

Table 1: Comparison of alternative filter media for dissolved phosphorus removal.

Filter Material	Advantages	Disadvantages
• Flue gas desulfurization gypsum ○ Silt size	• Low toxicity or concentration of contaminants • Widely available • Easy handling	• Precipitation reaction and P removal relatively slow • High rate of Ca release • Potential hardening when mixed with soil at high rates

• Coal Combustion Fly Ash
  ○ Sand to gravel size
  ○ Generates insoluble Fe and Al precipitates
	• Easy handling
	• Relatively fast reaction
		• Heavy metal contamination
		• Potential hardening when mixed with soil at high rates

• Drinking Water Treatment Residuals ○ Ground to gravel size aluminum sulfate	• Low contaminant level • Rapid sorption reaction	• Raw material must be dried and ground • Generates alum
• Acid Mine Treatment Residuals ○ Silt to gravel size Fe and Al oxides	• Handles easily • Rapid sorption reaction	• Heavy metal contamination
• Bauxite Mining Waste ○ Silt to gravel sized aluminum ore, carbonate, Fe oxides, and clays	• Rapid sorption reaction	• Heavy metal contamination • Transported from Jamaica mines
• Steel Slag Waste ○ Gravel size Fe and Al oxides and Ca minerals	• Widely available • Easy handling • Rapid sorption reaction and Ca precipitation	• Heavy metal contamination



Filters for use in removing phosphorus (Bryant et al 2012).

Table 2: Summary table of effectiveness of bioreactors to remove nitrogen.

Source	Site	Influent NO_3^--N Conc.	Percent Reduction	Nitrate-N Removal Rate
van Driel et al., 2006	Ontario, Canada	11.8 mg/L	--	2.5 g $N/m^2/d$
Jaynes et al., 2008	Central Iowa	19.1 to 25.3 mg/L	40% - 65%	0.62 g $N/m^3/d$
Woli et al., 2010	East-Central Illinois	2.8 to 18.9 mg/L	23% - 50%	6.4 g $N/m^3/d$
Christianson et al., 2012	Central Iowa	1.2 to 8.5 mg/L	22% - 74%	0.4-3.8 g $N/m^3/d$
Christianson et al., 2012	Northeast Iowa	9.9 to 13.2 mg/L	12% - 14%	0.9-1.6 g $N/m^3/d$
Christianson et al., 2012	Central Iowa	7.7 to 15.2 mg/L	27% - 33%	0.4-7.8 g $N/m^3/d$
Christianson et al., 2012	Central Iowa	7.7 to 9.6 mg/L	49% - 57%	0.4-5.0 g $N/m^3/d$

#3 Strategies to Improve Wildlife Habitat

Most of the discussion on best management practices for reducing impacts by roadside ditches focused on water quality and quantity. However, practices should be able to simultaneously improve wildlife habitat. Constructed wetlands have the greatest potential to expand habitat, if properly located, designed, and managed. Currently, however, there is limited guidance regarding target species of concern and specific design criteria to promote enhanced wetland habitat restoration. Developing such recommendations has been difficult because of the variation in habitat requirements across potential candidate species. Life stage requirements pertaining to moisture conditions, vegetation and canopy cover, and connectivity to adjacent habitat, all need consideration. Managing invasive species establishment in created, restored, or enhanced natural filter projects also was noted as a significant challenge and limitation to optimizing habitat conditions.

Constructed wetland for stormwater runoff provides water quality improvements, flood reduction, and wildlife benefits (Schneider 2014).

<u>WHAT'S WORKING AND WHAT'S NOT? - STATE OF DITCH MANAGEMENT AND POLICY</u>

Workshop participants unanimously agreed about the overall "fair-to-poor" condition and mounting challenges associated with managing roadside ditch networks throughout the Bay watershed. Of noticeable concern, highway department managers reported that increased frequency of heavy, intense rainfall events underscores their concerns for better design and maintenance guidelines (see call-out box). The following is the list of barriers identified by all workshop participants. A potential solution is listed for each challenge followed by a summary of successful programmatic approaches which were presented by the speakers.

CHALLENGES AND BARRIERS TO IMPROVING ROADSIDE DITCH MANAGEMENT

#1 - Unclear tools, guidance, and associated communication: For a variety of legitimate reasons, many modern, best-road-management practices currently are not being adopted or implemented. Workshop participants recognized the impacts and opportunities associated with roadside ditches, but reported the following factors contributing to their lack of adoption:

- A frustrating lack of guidance and organized decision-making tools to help highway staff choose which strategy best addresses site-specific situations/opportunities.
- Educational resources are available on the Web, but not in any coordinated framework.
- Serious knowledge (science) gaps remain in our collective understanding of how best to tailor management practices to a specific setting.
- Coordinated monitoring to measure and compare outcomes among different landscape locations, with consideration to design, is severely lacking and is thus limiting our capacity to update policies and recommendations.

This overarching challenge is reinforced by lack of an efficient communications network across the hundreds of independently operating jurisdictions throughout the Chesapeake Bay watershed. Providing local information across a regional scale and also linking decision tools to the regulatory water quality framework presents major challenges to modelers/tool developers. Watershed model applications tend to focus on comparing cumulative impacts of land cover and land use conditions in different land-river segments, at an annual timescale. Results, often estimated or communicated as average annual nutrient and sediment loads, may help direct regional funding but do not indicate specific roads or ditches where retrofits or other BMPs can mitigate impacts most effectively. In contrast, design engineers evaluate BMP outcomes based on water storage capacity in relation to the intensity and magnitude of a rainfall event. Similarly, field monitoring programs generally provide capacity to capture or evaluate local responses to short-term weather events.

Solution: Based on these shared realities, workshop participants emphasized an urgent need for science-based decision tools designed to identify roads, fields, or properties where additional investments can advance water quality and habitat goals most significantly.

#2 - Un-mapped ditch networks: Few municipalities have mapped their ditch networks, and fewer still have assessed the volume of water and materials moving throughout their entire systems. The extensiveness of management areas combined with the high density of roads and drainage ditches present major challenges to developing a reliable inventory or assessment of field conditions.

Existing roadside ditch assessments, often based on estimated volume of inflow and local land use conditions, suggest that only 20 to 35 percent of a network significantly affects downstream water quality, thus indicating a critical need for targeting BMPs. To date, ground- or field-mapped data derived from high resolution global positioning systems (GPS) have provided the most reliable strategy for inventorying roadside ditches, but because of cost and time, municipalities seldom have access to such high precision data. While remote sensing products continue to improve, the size of ditches, often less than two meters wide and one meter deep, generally are not discernable from regional spatial datasets. Recent advances in remote sensing, including high-resolution light detection and ranging (LiDAR) derived topography data, show promise of improving our ability to map ditches, detect stream connectivity, and determine flow direction, but the quality of these data vary widely and interpretation requires strong expertise in geospatial analyses (Duke et al. 2003). Incorporating the high-resolution data in watershed models such as the Variable Source Area application of the Soil Water Assessment Tool may provide additional capacity to identify which roadside ditches impose the greatest impacts on downstream conditions (Buchanan et al. 2012a).

Solution: A comprehensive inventory of roadside ditch networks presents a critical first step toward prioritizing practices and maximizing management efficiency (Bloser 2014; Mills et al. 2007; Wick 2014).

#3 - Engaging unaware public stakeholders: A critical obstacle to adopting more effective roadside maintenance strategies is pervasive public unawareness concerning the serious impacts that poor ditch management is having on our local waterways and the Chesapeake Bay. In particular, managing right-of-ways (ROWs) effectively is key to modernizing roadside practices. Ditches usually occur on private land and highway staff have access only for management. Landowners often perceive widening ditches as a reduction of their lawn space and they generally are unwilling to accommodate changes to ditch management practices. Highway personnel are unwilling to try new practices without landowner support, especially in regions where highway superintendents are elected officials.

Outreach and training to highway staff at roadside ditch demonstration sites in an effective tool for improving ditch management (Schneider 2014).

Overview of New York State Roadside Ditch Management

A survey of 932 Town and 57 County Highway Superintendents, conducted in 2014, provided a valuable snapshot of the current status of roadside ditches and ditch management across New York State. Cumulative responses from 408 highway officials in 56 counties suggest that current management approaches to roadside ditches are less than ideal.

- Ditch maintenance consumes a large portion of highway staff's effort. 52 percent (n=389) of the Highway Superintendents reported that the most common method of ditch maintenance was cleaning/scraping all or part of the ditch. Just under half (49 percent) report this scraping occurs no less than once every 4 years.

- 51 percent do not hydroseed any ditches immediately after scraping. While just over half (52.2 percent) responded that maintaining vegetative soil cover was a priority, the other half (47.4 percent) reported that it was not!

- Highway departments reported facing two broad types of challenges which prevent their improving ditch management:
  - Insufficient resources in time, manpower, equipment or money; and
  - Conflicts with landowners over what can be done within the right-of-way (ROW) along the highway or road.

"With the increase of the amount of rainfall per storm in recent years, it is hard to manage the amount of water entering the ditches which contributes to larger ditches, etc…"
Highway Superintendent comment regarding current challenges.

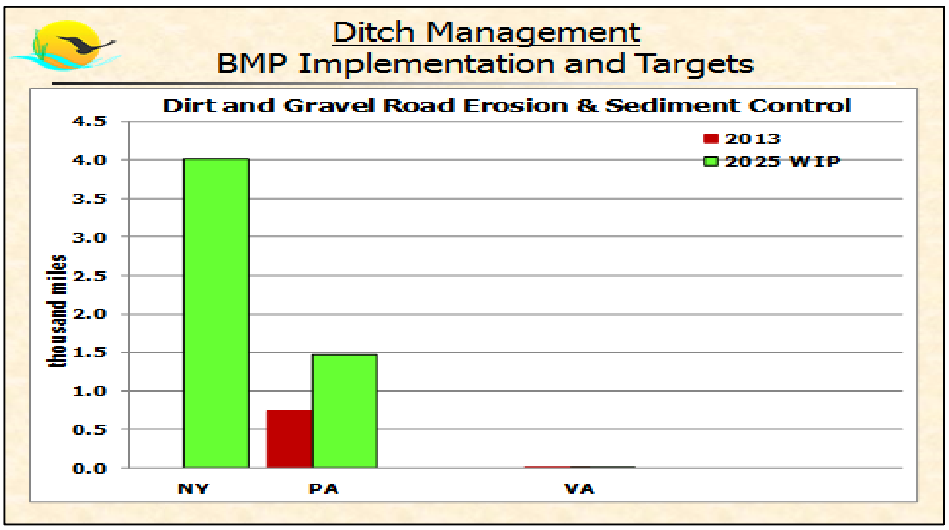
The Cornell University Department of Natural Resources and the Cornell Local Roads Program are currently performing additional analyses of these survey data to determine the next steps to help highway agencies in rural New York State improve their management of roadside ditches and ascertain where future research may be best applied.

Johnson, A. 2015. Assessing condition of New York's roadside ditches and their management. MPS - thesis. Dept. Natural Resources. Cornell University.

Solution: A comprehensive public education campaign targeting stakeholders of all demographics and addressing neighbor attitudes is needed to complement outreach to officials and highway maintenance crews.

#4 - Problematic policies: Lack of roadside BMP adoption is symptomatic of a much bigger problem: the lack of recognition of the major impacts imposed by these micro-scale features translates to their low priority ranking by decision-makers. For example, in both New York and Maryland, town highway departments have lead responsibility for the majority of roads, but town highway superintendents are locally elected officials elected often serving short terms. Road maintenance is further complicated in Maryland, where town commissioners, who often have limited knowledge of roadside BMPs, drive maintenance priorities and decision-making. As a result, although road managers are committed to addressing roadside impacts, they have limited capacity and few incentives to adopt new, potentially expensive practices. In Pennsylvania, a different bureaucratic challenge impedes adoption of roadside maintenance strategies: county highway departments are responsible for road maintenance, but unionized state agency workers are under contractual obligation to scrape all vegetation. Across the Bay states, there is little or no coordinated engagement by state and federal agencies on stormwater in general or education transfer among agencies. Thus there is limited guidance and oversight provided to road maintenance crews (Balascio and Lucas 2009). The lack of guidance and priority filters all the way down to the town level is complicated due to the lack of communication. Finally, roadside managers in more progressive locations recognize roadside ditches as opportunities to meet water quality mandates, but are challenged by the current TMDL framework. In particular, town and county officials cite a lack of clarity and inequity regarding crediting for BMP practices and concern about the regulatory model's changing source attributions and BMP efficiencies. Officials also expressed frustration about the lack of opportunity or disincentives for cross-sector (urban vs. agricultural) collaboration and crediting.

Solution: Build on current capacity in the Chesapeake Bay Program to address ditch management and advance innovative practices (Sweeney 2014).



Current and planned roadside BMPs to reduce excess nutrients and sediment among the Bay states (MD, WV, DC, and DE did not report any roadside BMPs to meet TMDL goals; Sweeney 2014)

#5 - Limited resources: Limited access to resources and funding is inhibiting adoption of more effective roadside ditch management strategies across the Bay watershed. Top priorities for highway staff are ensuring efficient traffic flow, enhancing road safety, and limiting liability issues (Schreeve 2014). Environmental concerns are of very minor or nonexistent priority and therefore are often ignored under tight budgets. In New York, for example, townships juggle austere local budgets to pay for staff, trucks, deicers, snowplowing, and filling potholes, in addition to major road improvements. Improving ditch management requires additional, unavailable funding for labor, equipment, and materials, along with annual maintenance costs.

Solution: Recognition of the cost savings of improving water quality at the highest government levels should translate into funding to assist town and county highway departments in their adoption of better ditch management practices. As evidence, the Pennsylvania Roads Program highlights the cost-effective water quality and habitat benefits of modern roadside practices. After ten years of success and 2,600 projects, Pennsylvania's Center for Dirt and Gravel Roads has been recognized as so successful in meeting multiple goals, that Pennsylvania Department of Transportation (PADOT) quadrupled the "Better Roads, Cleaner Streams" program budget and set plans for more than 10,000 projects along unimproved and paved roads throughout the State.

#6 - Climate extremes: Workshop participants consistently acknowledged the exacerbation of ditch impacts due to climate extremes. Already, highway department staffs perceive a need for more frequent ditch maintenance, which they associate with more severe weather patterns. The increase in the amount of rainfall per storm event has made it challenging to manage the volume of water entering the ditches.

Solution: Participants also enthusiastically recognized that updating ditch management practices has strong potential to enhance the resiliency of transportation infrastructure, local communities, and the environment to climate extremes. Whether the Mid-Atlantic climate shifts to warmer and drier seasonal patterns or to a wetter climate with more frequent, intense storms, advanced management of roadside ditches designed to enhance infiltration and water storage may provide significant protection to our natural resources by enhancing groundwater recharge and reducing downstream flooding.

SUCCESSFUL STATEWIDE PROGRAMS AND LESSONS LEARNED

Presentations by PA's Dirt and Gravel Roads, Cornell Local Roads, NYS Soil and Water Conservation Districts, as well as the Lake Champlain Basin TMDL program overviewed statewide programs which had demonstrated successes in this arena and shared key lessons on what it takes for success. Common themes arose from the presentations:

Assessment and modeling are critical first steps. Regardless of scale, highway staffs would benefit by having an inventory and assessment of the condition of the roadside ditch systems. Ditches should be viewed as part of an overall asset management strategy. Mapping should be done via GPS and geographic information system (GIS) computerized programs. These inventories can help prioritize and target management efforts, using criteria of soil type, slope, cost, and impacts to receiving water bodies. Photographs are critical aids with which to seek funding from legislators (Buchanan et al. 2012b; Duke et al. 2003).

Cooperation and partnerships are essential for success. Cross-agency collaboration, including local municipalities and state and federal agencies, is required to promote stakeholder buy-in and to access necessary resources. Forming a coalition of districts and towns can further empower and leverage resources (Dolan 2014; Schreeve 2014).

Education is critical, as evidenced by both New York and Pennsylvania programs. Education includes training on how to implement BMPs, and also to provide outreach to landowners to influence perceptions. Engagement via citizen monitoring programs can provide critical support to enhance outreach programs. Education of government officials is also needed to convince them why and how to better manage ditches to achieve water quality and other environmental goals.

Leadership is key. Given the demonstrated importance of roadside ditches, leadership from the CBP Partnership is needed to address impacts. Guidance from the Partnership will enable local champions to promote and fund modern practices at the local scale.

Vermont's Lake Champlain Basin Leads the Way: Advances in water quality management outside of the Chesapeake Bay demonstrate the value of improved inter-agency collaboration. Vermont has explicitly identified ditch management as a key component of the newly mandated TMDL for Lake Champlain (Dolan 2014). The associated watershed provides a model for the Chesapeake Bay but in miniature, as Lake Champlain managers also deal with problems of excess phosphorus and sediment loading from the watershed. In addition, Vermont has invested significantly in re-framing the discussion about water quality and marketing management strategies to emphasize "we are all in this together". Officials argue convincingly that tourism, agriculture, and all industries will be hurt by pollution of the Lake and conversely, everybody working together can streamline the problem solving. As an example of effective inter-agency cooperation, Vermont's Department of Conservation provides technical and financial assistance to town highway staff through programs such as the "Better Back Roads" and have created a general stormwater permit for town highway staff to facilitate projects.

SUMMARY OF WORKSHOP RECOMMENDATIONS

Presentations by speakers, complemented by break-out group discussions with all participants, identified a suite of eight recommendations concerning how to comprehensively improve roadside ditch management across the Chesapeake Bay Watershed. The good news is that we have a comprehensive portfolio of modern BMPs available to reduce ditch impacts on our water resources, mitigate flood risk, and address safety concerns, while accommodating budget constraints (Orr 2014). There are also successful programs that can provide examples and leadership. Increased guidance, communication, cooperation, and use of modern BMPs concerning roadside ditch management can help address the TMDL needs, create a win-win for roads and waters, and increase resiliency of our Bay communities.

1. **Develop recommendations to promote "re-plumbing" roadside ditch networks throughout the Chesapeake Bay watershed**. An overarching, science-based program could streamline access to education materials, equipment, and other resources, and also facilitate knowledge transfer. The roadside ditch program needs to be geographically comprehensive because roadside ditch networks, like streams, ignore political boundaries. Workshop participants shared numerous accounts of different, even conflicting ditch management practices between adjacent townships, across counties, and among states. For example, participants reported poor practices in upstream municipalities that contribute to flooding in downstream areas, despite use of BMPs by the downstream community. This policy should address the diversity of government structures, highway maintenance needs, and landscape settings, throughout the region.

2. To ensure success**, a watershed wide program must employ a full suite of strategies to incentivize better road management**, including voluntary and regulated components. A state-coordinated, comprehensive program should include education and awareness campaigns specifically tailored to multiple stakeholder groups, guidance on BMPs, a carefully selected set of regulatory incentives and deterrents, increased access to equipment and other resources, and funding for targeted research. The absence of any one of these key elements will likely be a key barrier preventing improvement.

3. **Develop a broad-based education and outreach program to increase awareness and provide guidance to key stakeholder groups.** It can take advantage of the successes of existing programs and the nation-wide Local Technical Assistance Programs (LTAP) training centers. Components must be tailored to each of a diverse set of stakeholders, including:

    - <u>Highway staff</u> who make daily decisions as the on-the-ground ditch practitioners.
    - <u>Policy-makers</u> who play a critical role in developing and enforcing regulations concerning ditch management and also are responsible for funding allocations.

- Agency staff of USDA's Soil and Water Conservation District Staff and Natural Resource Conservation Service - these staff members currently play key roles providing technical guidance, site-specific ditch designs, and assist in actual implementation of hydroseeding and other practices.
- Environmental non-governmental organization (NGOs) that build partnerships to secure funds (often through grants for targeted projects), spearhead outreach, and coordinate BMP implementation.
- Private landowners own the land adjacent to roads, but need education on the importance of ditch improvements which may impact their own activities.

4. **As a core component of the education resources and outreach, develop BMP implementation guidelines that include a full inventory of BMPs categorized based on when and where a practice is appropriate. Guidance on where to target BMPs based on performance- and cost-effectiveness also is essential.** For the Chesapeake Bay watershed, recommendations should be tied to the TMDL regulatory framework. A potential outreach strategy identified by workshop participants could consist of a well-organized website where the BMPs are listed, the associated decision-making tool is available, and successful projects and strategies can be reviewed.

5. **Create a Roadside Ditch Management Executive Team, including representatives from all relevant agencies at federal to town levels, along with other stakeholders including scientists and non-profit organizations (NPOs), in order to build a collaborative, working framework.** This team will share knowledge, avoid redundancy or conflicting requirements among agencies, and develop recommendations that work across political boundaries. It will take advantage and leverage existing programs, such as the EPA Phase II stormwater regulations, that can enhance efforts to establish Bay watershed-wide guidelines.

   - As a first step, the Urban Stormwater Workgroup, the Watershed Technical Workgroup, and Agriculture Workgroup of the CBP should develop ditch management recommendations collaboratively. As a result, the Trading and Offsets Workgroup also may benefit from discussion of local opportunities for cross-sector trading.

6. **Support funding for roadside ditch improvement and maintenance practices.** Highway staff charged with maintaining roadside environments unanimously report limited manpower, time, and equipment. Current pools of related funding for green infrastructure, stormwater management, or conservation may be relevant but grant writing support may be valuable, especially given the numerous other responsibilities of highway staff.

7. **Prioritize applied research that addresses key knowledge gaps limiting the reliability of decision tools and guidelines.** Specifically, promote modeling and field research needed to refine our understanding of how roadside BMPs influence water quality and habitat outcomes based on the location and design of the practice. Inevitably, this information will depend on understanding how local hydrologic and biogeochemical processes vary across the landscape, in relation to seasonal and climatic conditions. Identified topics of key concern include: 1) evaluating chemical contaminant transformations in roadside ditches, particularly for nitrogen and phosphorus, as well as other, potentially more serious contaminants, 2) exploring impacts of altered hydrology on wetland and aquatic habitat, and 3) determining if additional contaminants of concern warrant increased attention, possibly including bacteria, carbon, salt, heavy metals, and other contaminants associated with vehicular traffic.

8. **Support efforts to link science and management, by linking research modeling efforts to the development of targeting tools or guidelines and by promoting monitoring programs to evaluate the outcomes of implemented practices, in relation to predicted outcomes.** It is essential that these decision-making tools be accessible and credible with local agencies, targeting tools should be developed in close partnership with relevant agencies, from town-level up through the state-level.

    - As a first step, the CBP Land Use Workgroup should consider whether current land use/land cover inventories and the CBP hydrologic modeling framework adequately capture impacts from roadside ditches and other artificial concentrated flow channels.

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APPENDIX A: WORKSHOP AGENDA

Re-plumbing the Chesapeake Watershed:

Improving roadside ditch management to meet TMDL water quality goals

The Tidewater Inn
Easton, Maryland
October 9-10, 2014

Overall Workshop Goals

- Increase awareness of the critical impacts of roadside ditches and best management practices to reduce these impacts
- Inventory the current status of ditch management across the Chesapeake Bay watershed
- Develop recommendations for how best to improve roadside ditch management to meet TMDL goals, reduce flooding, and buffer impacts of climate change

AGENDA – DAY 1

9:30 **Welcome -** Mr. Dirck Bartlett, Talbot County Council, MD

9:35 **Welcome Address -** Dr. Robert Summers, Secretary of Maryland's Department of Environment

9:50 **Dr. Kathy Boomer** (TNC) - Overview and Goals of the Workshop

State of the Science: Sizing Up the Problem

10:00 **Dr. Rebecca Schneider** (Cornell) **-** Overview of the contribution of roadside ditches in rural and suburban settings: floods, pollution, and sediment

10:35 **Coffee Break**

10:45 **Dr. Beverley Wemple** (Vermont) **-** Understanding the effects of roads in upland settings on hydrology, geomorphology and water quality

11:15 **Dr. Zach Easton** (Virginia Tech) **-** Lessons from agricultural ditches: modeling and management of agricultural drainage

11:45 **Dr. Robin Van Meter** (Washington College) - Road impacts on aquatic ecosystems

12:15 **LUNCH (1 hour)**

Mitigating Ditch Impacts: Strategies for "Re-plumbing" our Watersheds

1:15 **Mr. Steve Bloser** (PA Center for Dirt and Gravel Roads) **-** Successful BMPs - 2,500 projects and counting

1:45 **Mr. David Wick** (Exec Director, Lake George Park Commission) **-** NYS storm water management case studies – success stories and challenges

2:15 **Dr. Ray Bryant** (USDA- Agricultural Research Service) - Filtering mediums for treating stormwater runoff

2:45 **Dr. Bernard Sweeney** (Stroud Water Research Center) – Level-lip spreaders

3:15 **Afternoon Break**

3:30 **Dr. Laura Christianson** (the Conservation Fund) **-** Woodchip bioreactors: Design modifications to "ditch" nitrogen

4:00 **Mr. Jason Keppler** (MD Department of Agriculture) **-** Agricultural ditch management of Maryland's Eastern Shore

4:30 **William Ryall** (Environmental Concern, MD) - Swale design considerations

5:00 **Dr. Rebecca Schneider/Dr. Kathy Boomer -** Day 1 Wrap-Up
Ms. Donnelle Keech - Day 2 Preview

5:30 **"DOWN IN THE DITCHES" HAPPY HOUR – cocktails and appetizers -** Hosted by the **Chesapeake Bay Foundation** (102 E. Dover Street, Easton) with additional sponsorship by **Cornell University and the Cornell Local Roads Program**

AGENDA – DAY 2

Linking Ditch Management Science and Policies, Across Multiple Spatial Scales

8:30 **Welcome Back and Overview of Days 1 and 2**

8:45 **Mr. Jeff Sweeney** (Chesapeake Bay Program) **-** Roadside ditches and the current CBP Model: Opportunities for future CBP model development

9:15 **Ms. Kari Dolan** (Vermont DEC) **-** Case Study **-** Vermont Lake Champlain TMDL Program

9:45 **Dr. David Orr** (Cornell Local Roads) **-** Overcoming Barriers to Change: Training and Technical Assistance

10:15 **Mr. Robert Shreeve** (Deputy Director, Office of Environmental Design - Maryland State Highway Administration) **-** Understanding road maintenance concerns in managing water quality improvements

10:45 **Coffee Break**

11:00 **Breakout Group Discussions - Donnelle Keech,** Facilitator

- How do roadside ditch impacts and practices vary across the Chesapeake Bay Watershed?
- What is needed to improve roadside ditch management watershed-wide?

12:30 **Lunch**

1:30 **Group Discussion and Recommendations**

- Report from Breakout Groups
- Group Discussion - areas of consensus, areas of divergence, gaps in knowledge
- Key recommendations

3:15 **Rebecca Schneider and Kathy Boomer -** Workshop Wrap-Up

APPENDIX B: WORKSHOP PARTICIPANTS

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APPENDIX C: WORKSHOP PRESENTATION ABSTRACTS

SESSION II: Mitigating Ditch Impacts: Strategies for "Re-plumbing" our Watersheds

Mr. Steve Bloser (PA Center for Dirt and Gravel Roads) - Successful BMPs - 2,500 projects and counting. Pennsylvania's Dirt and Gravel Road Maintenance Program has been implementing Environmentally Sensitive Road Maintenance practices since it began in 1997. Over 2,500 projects have been completed statewide to date. This presentation begins with a brief program overview, followed by a focus on three individual projects as examples of the practices being employed, and finishes with a "big picture" overview of projects and a discussion of future direction.

Mr. David Wick (Executive Director, Lake George Park Commission) – New York State stormwater management case studies – success stories and challenges. Protecting water quality on a watershed scale requires cooperation and commitment from a vast array of constituencies. As highway drainage and ditch practices have been found to be a significant contributor to water quality degradation in the Chesapeake Bay watershed, the solutions to these problems requires the full understanding and commitment from our highway professionals. To begin to tackle this issue in upstate New York, many Soil and Water Conservation Districts have developed very strong working relationships with local and state highway departments. Using the technical and grant generation strengths of Districts, numerous county-based roadside erosion control programs have been developed in the past decade. Thanks to a wide array of grants, more than half of the Conservation Districts in New York now have active roadside hydroseeding programs to address this significant issue. Successful regional coalitions of Conservation Districts and partners have been created to work together on broader regional issues, and have found great success at generating the funding and partnerships needed to more aggressively forward to tackle nonpoint source pollution issues. As an example, in the Lake Champlain Basin of upstate New York, a comprehensive roadside erosion control inventory was conducted by one of the regional coalitions. Every mile of road in this vast watershed was inventoried for roadside erosion control problems, and a comprehensive inventory and report was developed highlighting the issues and solutions. Out of this effort, significant grant funding has been generated within the New York side of the Champlain Basin to stabilize these areas, and greatly reduce water quality impairments of Champlain tributaries and the main lake. Partnerships, planning, and ultimately local action can make significant strides in protecting and ultimately improving the quality of our precious water resources, in Chesapeake Bay and throughout the Northeast.

Dr. Laura Christianson (The Conservation Fund) - Woodchip bioreactors: Design modifications to "ditch" nitrogen. Growing alarm about the negative cascading effects of reactive nitrogen in the environment has led to global efforts to address elevated nitrate-nitrogen levels in water bodies worldwide. While nitrogen is an essential element for life on this planet, excess nitrate transported in agricultural ditches demands a thoughtful approach that facilitates continued highly-efficient food production in tandem with protection of water resources. The best way to mitigate negative N-related impacts is to convert nitrate to stable, non-reactive dinitrogen gas through the natural process of denitrification. Woodchip bioreactors are a novel, fairly low-tech option capable of enhancing this natural N-conversion process via addition of a solid carbon source (e.g., woodchips) and through designs that allow the development of anoxic conditions required for denitrification. Most simply, a woodchip bioreactor consists of woodchip-filled trench through which nitrate-laden waters are routed. The fact that bioreactors typically require no (or very little) land removed from production means this targeted practice is extremely compatible with producers' existing management and yield goals. This presentation provided a background on the technology and highlights potential design modifications to allow this approach to fit easily within the Chesapeake Bay's agricultural ditches and ground waters. Wood-based enhanced denitrification practices hold great potential to be recognized as “approved” Chesapeake Bay agricultural BMPs, but more regional research and performance data are required.

SESSION III: Linking Ditch Management Science and Policies Across Multiple Spatial Scales

Dr. David Orr (Cornell Local Roads Program) - Overcoming Barriers to Change: Training and Technical Assistance. Even when there is an understanding of technical solutions to a problem, there are many barriers, both real and perceived, that can keep change from occurring. Orr examined some of the barriers that are not monetary or regulatory. These barriers may be specific to ditches such as digging the ditches too deep; or they may be communication and personal barriers such as fear of exposure. He reviewed these barriers and then gave a couple of possible ways to overcome these challenges including: collaboration and modification of the 4E’s from highway safety: engineering, education, enforcement, and environment.