Water Quality Trading Without Trades: An Analysis into the Lack of Agricultural Nonpoint Source Credit Demand in Virginia

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INTRODUCTION

Governmental agencies, researchers, and agricultural organizations promote water quality trading programs as an innovative policy to engage agricultural producers in conservation activities. The U.S. Environmental Protection Agency (EPA) and the United States Department of Agriculture (USDA) have issued policy statements, guidance documents, and grant funding to support the development of water quality trading programs (Logue and Fewell 2015; Jones and Selman 2015; USEPA 1996, 2004, 2007; Willamette Partnership et al 2015). These agencies promote a form of water quality trading that grants regulated dischargers (called point sources) varying degrees of compliance flexibility to meet pollutant control requirements by allowing the purchase of off-site pollutant load reductions, defined as a reduction credits, from another source. The credit seller may be another regulated effluent source, but frequently trading advocates argue that credits could be created and sold by unregulated diffuse runoff from agricultural sources (so called “point-nonpoint” trading). The attraction for USDA and many agricultural organizations is that the creation and sale of nonpoint source credits provides a new revenue source for farmers. They also argue that the prospect of a payment through a trading program creates a financial incentive for an agricultural operator to take pollutant load reducing actions while still keeping land in agricultural production (working lands), in effect supporting the farm economy.

The demand for reduction credits is expected to materialize when regulated dischargers facing high marginal pollutant control costs can lower their compliance costs by purchasing credits from dischargers with lower pollutant control costs. Numerous studies report that agricultural nonpoint sources are the low cost provider of pollutant reduction, fueling expectations that agricultural operators will be active sellers of credits in trading programs. Because multiple agricultural sources often are the largest single contributor of pollutants to a watershed, potential point source buyers are expected to have ample opportunities to buy low cost agricultural nonpoint source credits.

In practice regulated sources seeking to comply with permit conditions have purchased few nonpoint source reduction credits from agricultural land owners. The gap between *ex ante* expectations and *ex post* experience continues to puzzle trading advocates and researchers. Investigations into this issue tend to focus on supply side constraints. In this paper we assess the demand for agricultural nonpoint sources in nutrient trading programs in Virginia. The reason the Virginia experience offers lessons for the nation is because the state has: 1) implemented three trading programs with aggressive regulatory requirements ("drivers"), 2) actively developed the technical and legal support for nonpoint source credit supply, and 3) created the legal authority to support trades for regulatory compliance rather than pilot or demonstration trades. We describe Virginia's regulatory conditions and nutrient trading rules for industrial and municipal wastewater treatment plants (WWTPs), municipal stormwater programs, and land developers. In analyzing the well-developed Virginia programs, we find little existing and future demand for agricultural credits generated from working agricultural lands. We argue that the lack of demand in the Virginia's nutrient trading programs can be attributed to a substantial degree to the design features and incentives present in multiple regulatory programs. Virginia regulated dischargers will not buy significant quantities of agricultural nonpoint source credits in the foreseeable future. We believe that the lessons learned in Virginia are broadly representative of the challenges facing the demand for agricultural nonpoint source credits elsewhere in the country.

WATER QUALITY TRADING IN THE UNITED STATES

Water quality trading programs must be implemented within the legal context of the federal Clean Water Act (CWA). Under the CWA, states delegated water quality management and permitting responsibility by the federal government typically identify water quality standards for lakes, streams and estuaries. Water quality standards consists of defining designated uses of a waterbody (recreational fishing, swimming, aquatic life support, etc.) and then identifying quantitative and qualitative criteria (water quality criteria) to evaluate whether the designated uses are being achieved. When a waterbody does not meet water quality criteria, regulatory authorities identify the waterbody as an impaired and undertake a process, called a TMDL (total maximum daily load), to identify the cause of the impairment and what must be done to achieve the designated uses for the waterbody.

In this context, water quality trading programs are most often used in regulatory efforts to address eutrophication issues associated with nutrients (nitrogen and phosphorus). Elevated nutrient concentrations in ambient waters have been identified as one of the primary factors contributing to violations of water quality standards in many lakes, streams and estuaries (NRC 2000; Howarth et al. 2002; USEPA Science Advisory Board 2011). Furthermore, nutrient impairments tend to be regional in scope, affecting relatively large waterbodies from multiple regulated (point) and unregulated (non-point) sources. Nutrients do not typically produce acute localized impacts, allowing for the possibility that nutrient loads can be reallocated across multiples sources within the watershed.

When a waterbody is found to be impaired by nutrients, regulators then assign specific nutrient control requirements, called wasteload allocation (WLA), for regulated dischargers. For nutrients, wasteload allocations are defined as the total allowable mass load (kg or lbs and calculated as the product of wastewater flow and pollutant concentration in wastewater) of nutrients that can be discharged over specific time period (typically a season or year). Permits may also include nutrient concentration limits that specify to maximum allowable nutrients in each unit of wastewater (mg/l). Regulators issue permits that specify mass load and concentration limits for each regulated source, most typically municipal and industrial wastewater treatment facilities. In addition, permit programs increasingly apply to construction sites and existing municipal stormwater systems. Unlike industrial wastewater permits, permit programs covering urban stormwater runoff typically do not include numeric effluent limits, but contain requirements to implement runoff control practices and management programs.

Regulators also assign overall nutrient control targets, called “load allocation”, to classes of unregulated sources. Most agricultural operators face no mandatory requirements to limit nutrient mass load because the federal Clean Water Act explicitly exempts runoff from agricultural fields from federal permitting. The exemption presents challenges in meeting TMDLs whenever agricultural nonpoint sources contribute a relatively large share of nutrient loads to the waterbody. To encourage control of nonpoint source loadings water quality management agencies generally rely on public education programs (technical assistance) and public subsidies, relying on voluntary adoption agricultural conservation practices, called best management practices or BMPs to reduce nutrient loads.

Within this regulatory context, trading advocates envision markets developing for agricultural nonpoint source credits. An agricultural nonpoint source credit is defined as the estimated mass load reduction in agricultural pollutant load per unit of time (e.g. kg/yr) below a reference level (called a baseline). The demand for nonpoint source credits originates with the regulated sources. Conceptually, regulated sources should be willing to pay for agricultural nonpoint sources credits if credit prices are lower than other compliance alternatives, including the cost of reducing nutrients "on-site" using the regulated source's control technologies. Agricultural operators will supply these credits if the price the point sources are willing to pay is greater than credit production costs. The cost of producing nonpoint source credits includes the costs incurred to implement agricultural BMPs and the administrative costs (transaction costs) to certify/verify the creation of the credits by the regulatory agency.

Researchers cite a substantial body of research reports showing regulated sources can significantly reduce regulatory compliance costs by purchasing agricultural nonpoint nutrient reduction credits (Faeth 2000; Ribaudo et al. 2005; Mehan 2008; Hansen and McConnell 2008; Jones et al 2010; Fang et al 2005; Van Houtven et al. 2012; Wainger et al 2013; Perez et al 2013; Shortle et al 2014). Costs typically include the financial costs of capital and operation and maintenance associated with pollutant control technologies and practices. These studies regularly report that the marginal nutrient control costs are higher for industrial and municipal WWTPs than agricultural BMPs. Jones et al (2010) report that the annual cost to remove a pound of nitrogen for the Chesapeake Bay range from $92 to over $200 for urban stormwater practices and average $15.80 for WWTPs (with highs approaching $50 per pound). In contrast, the cost to reduce nitrogen from agricultural sources using BMPS such as grass buffers, cover crops, and conservation tillage is reported to be $10/lb/yr or less (Jones et al 2010). Furthermore, some researchers claim that the differences in marginal control costs may grow over time with economic and population growth. Regulated point source control costs will tend to rise as the limits of wastewater treatment technology are reached and the volume of wastewater in need of treatment continues to grow (Wainger and Shortle 2013).

Analysts report even larger nutrient control cost disparities between municipal stormwater systems and agricultural BMPs (Van Houtven et al 2012; Weimar et al. 2015). Van Houtven et al (2012) report that the cost to remove nitrogen and phosphorus using conventional stormwater management practices generally exceed $300 and $5,000 lb/yr respectively, compared to less than $100 and $600/lb/yr for agriculture in the Chesapeake Bay watershed.

Federal and state agencies actively encourage point-nonpoint trading by supporting the development of agricultural nonpoint source credit supply. Government agencies finance the development of computer models and tools needed to estimate the agricultural load reductions and credits generated from the application of agricultural practices (USDA 2015). USDA and EPA also fund the development of technical resources and guidebooks for the certification, verification, and trade of nonpoint source credits (Willamette Partnership et al 2015; Willamette Partnership 2013, 2012; Sanneman et al 2013). Government agencies and nonprofit organizations provide grant funding to support the development of pilot nutrient trading programs that encourage the production of agricultural nonpoint source credits (USDA 2015; EPRI 2015). These pilot projects also provide funding to demonstrate nonpoint source credit trades. However, to date the reported agricultural nonpoint source credit trades are often purchased with donated or grant funds rather than payments from regulated sources seeking to achieve regulatory compliance (Stephenson and Shabman 2011).

THE LACK OF NONPOINT SOURCE TRADES

Despite the estimates of significant cost savings from point-nonpoint trading and public investment in agricultural nonpoint source credit guidelines and demonstration programs, nutrient trading programs have produced a notable lack of purchases by regulated sources from unregulated agriculture (Breetz et al. 2004; Shortle 2013; Fisher-Vaden and Omstead 2013). A number of possible reasons for what some see as a puzzling lack of trades have been offered, with most professional attention focused on the cost of generating agricultural credits.

Supply side research investigates factors other than calculated BMP implementation costs that can increase the costs of nonpoint source credits. First, “point-nonpoint trading ratios” raise the cost of nonpoint source credits. Regulatory authorities typically impose point-nonpoint trading ratios to account for uncertainty in nonpoint source loads estimates. A 2:1 trading ratio that requires a nonpoint source to generate two pounds of reduction for every one pound the buyer can use for compliance effectively doubles the cost to the regulated source of a nonpoint source credit. Second, credit quantification rules surrounding “baselines” may add to the costs of producing credit. Quantifying a nonpoint source credit requires defining a starting point from which to begin counting load reductions, called a baseline. Setting a baseline below current loads would require the nonpoint source to undertake nutrient reduction actions just to meet baseline, adding costs to generating a credit (Ribaudo et al. 2014; Stephenson et al 2010). Third, the costs of certifying and verifying the implementation of a nonpoint source control practice adds credit production costs. The transaction costs to quantify nonpoint source load changes, certify these changes as credits, and then monitor credit generating practices, can represent a substantial portion of the costs to supply agricultural nonpoint source credits (Rees and Stephenson 2016). Finally, some speculate that agricultural producers may be leery about entering into contracts with regulated sources. The result is a premium above control costs that agricultural producers require before supplying credits (Wainger and Shortle 2013; Ghosh et al 2005; King and Kuch 2003; Breetz et al. 2005).

The limits on regulated source demand for agricultural nonpoint source credits receive less attention. The nutrient trading modeling efforts of regulated sources' willingness to pay for nonpoint source credits are organized around a straightforward concept: as long as a regulated source's pollutant control costs for the marginal pound of discharge are higher than nonpoint source credit alternatives, the regulated source will have an incentive to buy credits. Several possible explanations for the lack of nonpoint source credit purchases have been put forward. Some ascribe the lack of nonpoint credit purchases to the unwillingness of regulators to impose stringent enough load reduction requirements that would drive up point source control costs, frequently referred to as regulatory "drivers" (King 2005). Other researchers investigate whether the lack of demand may be attributed to trading areas that are too small or too thinly populated with regulated sources to generate a sufficient number of potential buyers (Ribaudo and Nickerson 2009; Greenhalgh and Selman 2012).

We argue that the lack of demand for nonpoint sources credits from regulated sources stems from other reasons. Weak demand for agricultural nonpoint credits is deeply tied to the institutional structure of the CWA and derivative regulations that limit and influence choices of regulated sources. The disincentives and conditions emerging from a complex permitting structure and multiple regulatory conditions can radically dampen the willingness and ability of regulated sources to pay for nonpoint source credits (Stephenson and Shabman 2011).

DEMAND FOR NONPOINT SOURCE CREDITS IN VIRGINIA

Virginia explicitly promotes agricultural nonpoint sources credit purchase as a compliance option for regulated sources. The Virginia General Assembly directed the Virginia Department of Environmental Quality (VDEQ) to establish rules and programs to quantify nutrient credits (including defining baselines), certify credits, register and track credits, and to develop compliance monitoring (§62.1-44.19:20.B.b). In response VDEQ published guidelines on how to quantify agricultural nonpoint source credits (VDEQ 2008).

The VDEQ has also implement three trading programs that are expected to create the demand for these credits. These programs offer nutrient trading compliance options to municipal and industrial wastewater dischargers, land developers with stormwater control obligations, and municipal stormwater systems. As we have noted earlier, these Virginia trading programs include what trading advocates would agree are the essential elements for a creating the demand for nonpoint source credits. Despite these efforts Virginia has not produced a single nonpoint source credit trade from installation of BMPs on working agricultural lands. The few nonpoint credit purchases that have occurred involve projects that permanently take land out of agricultural production.

This section describes the structure of rules that limit demand for such agricultural nutrient credits in the three categories of potential buyers of nutrient credits. For each of the three regulatory programs, the observed outcomes and regulatory compliance behavior of regulated permittees is summarized. We also assess the potential for future nonpoint source credit trades in each program.

Virginia Stormwater Management Program, General permit for Construction Activities

Urban development generally converts permeable land surfaces (forest, pasture, cropland, etc) into impervious surfaces (roads, buildings, parking lots, sidewalks, etc). The resulting post construction land use generally increases the volume of stormwater runoff and often increases the quantity of pollutants in that runoff. In 2012 Virginia substantially revised regulatory requirements for the control and management of both the quality (9VAC25-870-63) and quantity (runoff volume) (9VAC25-870-66) of urban runoff from urban land development projects. These regulatory requirements apply to most land disturbing activities associated with residential, commercial and industrial building construction and road construction. The state administers these regulatory requirements through the Virginia Stormwater Management Program (VSMP) general permit for construction activities.

The water quality control requirements require that post-construction runoff from a greenfield development meet a phosphorus load limit of 0.41 lbs/ac/yr. Separate water quality limits exist for development on existing urban lands (called redevelopment). Permittees (land developer) can implement a variety of stormwater control practices to achieve the phosphorus limit. In general, stormwater control practices reduce phosphorus losses by either reducing the total volume of runoff (via infiltration practices) or by treating the nutrients and sediments in the runoff (stormwater treatment practices such as retention ponds and constructed wetlands). The permittee is expected to implement post development controls to achieve and maintain that limit indefinitely.

Permittees have the option to meet a portion of their phosphorus control requirements offsite of the construction site through the purchase of phosphorus credits.[1] The permittee can purchase credits from a third party provider or by over complying with the phosphorus limit at another site that they manage. Phosphorus credits can be provided by any party that demonstrates permanent offsetting phosphorus reductions elsewhere in the watershed.

The demand for these phosphorus credits, however, is constrained by the program design rules. First, program rules limit the extent to which permittees can purchase credits for compliance. For development sites that disturb 5 acres or more, the permittee is required to achieve at least 75% of the required amount of phosphorus control requirements on-site. When less than 5 acres are disturbed (or required post-construction phosphorus reductions are less than 10 lbs/yr), the permittee has the option to offset all phosphorus loads offsite (9VAC25-870-69).

Phosphorus credit demand is also limited by other regulatory requirements. Stormwater *quantity* control requirements limit the volume of stormwater for development site and these requirements are not transferable. All water quantity control requirements must be met onsite. Compliance with water quantity limits, however, jointly provides some phosphorous reduction. For instance, runoff reducing stormwater control practices (infiltration practices) help permittees achieve both water quantity and nutrient reduction requirements (Battiata et al 2010). Thus, complying with the water *quantity* standards can reduce the demand for phosphorus credits.

Finally, permittees are limited by the type of nonpoint source credits that can be used for compliance. Since the land development activity involves long-term conversion of land to urban uses, regulatory authorities require permittees to secure equivalent long-term off-site phosphorus

[1] The credit trading ratio between onsite loads and offsite phosphorus credits is 1:1.

reductions. If trading is used for compliance, developers must secure "perpetual" credits that produce a stream of permanent annual phosphorus reductions. The permanent offset requirement limits the ways to generate credits. Perpetual credits can be created by installing long-term "off-site" structural stormwater practices (e.g. regional stormwater treatment structures/ponds with a permeant maintenance obligation). Agricultural landowners can generate perpetual nutrient credits by permanently retiring land from agricultural production. Land retirement typically involves reconverting cropland and pasture to forest and providing legal assurances (ex. easement) that the land will remain in that lower nutrient-intensity use in perpetuity.

Through June 2016, VDEQ has certified 31 nutrient credit projects (VDEQ 2016) for use under this regulatory program. Every nutrient nonpoint source credit project except one generates perpetual phosphorus credits through permanent agricultural land use conversion. The other project involved reconstruction of a regional scale stormwater wetpond. These projects have generated 2,843 perpetual phosphorus credits and 16,383 nitrogen credits.[2] To date, a total of 1,058 perpetual phosphorus credits have been purchased (see Figure 1). While credit trades do indicate cost savings for VSMP permittees, phosphorus credits are expensive. Although no systematic price information is published, anecdotal evidence indicates phosphorus credits sell for $10,000 to $18,000 per pound (Frances 2014). Expressed in annualized nutrient reduction terms ($500 to $900/lb/yr), the observed prices of nutrient credits achieved through land retirement are considerably higher than the estimated nutrient removal costs associated with short term agricultural management practices (cover crops, enhanced nutrient management, etc).

[2] Under the VSMP program, nitrogen credits are automatically retired whenever a phosphorus credit is sold for VSMP compliance.

The EPA has held up these credit sales as evidence of a successful program (EPA 2014), but the nonpoint nutrient credits are not generated by the application of agricultural BMPs on working agricultural lands. A common purported advantage of agricultural nonpoint source trading is that nutrient credit sales will help keep land in agricultural production and benefit farm income. Since the majority of farmland is rented in the state, farm operators themselves may not directly benefit from these nutrient credit sales and some farmers may actually see their income fall by having rented land removed from production.

Virginia Point Source Nutrient Credit Exchange

Virginia is a long standing participant in the regional effort to reduce nitrogen and phosphorus loads to the Chesapeake Bay. During the 1980s and 1990s, the Bay states pursued voluntary nutrient reduction efforts. Beginning in 2000, lawsuits required the development and implementation of a Bay-wide TMDL should voluntary efforts fail to achieve target water quality outcomes by 2010. In anticipation for the impending TMDL, the Virginia General Assembly passed the Virginia Nutrient Credit Exchange Program in 2005 (§ 62.1-44.19:12 through 19). The legislation created a comprehensive program to limit the total mass load of nitrogen and phosphorus from municipal and industrial WWTPs discharging to the Chesapeake Bay watershed. Echoing nonpoint source trading advocates elsewhere, the legislation claims to establish “market-based incentives to help achieve the Chesapeake Bay Program's nonpoint source reduction goals” (§ 62.1-44.19:12) by allowing point-nonpoint trading. Yet the design of the legislation itself and the supporting implementation programs have all worked to limit the ability and incentive of regulated WWTPs to achieve compliance through nonpoint source credit purchases.

The program assigns annual nitrogen and phosphorus WLAs (lbs/yr) to all existing municipal and industrial WWTPs above a minimum size. WWTPs are initially assigned WLA based on multiplying stringent nutrient concentration standards by the wastewater design flow of the permitted facility. The level of stringency varies slightly across the four major Virginia tributaries to the Chesapeake Bay (Shenandoah-Potomac, Rappahannock, York, and James. Wastewater sources were required to meet WLA requirement by 2011 (9VAC 25-820-70C). In addition, the state will not issue any WLA to new and expanding WWTPs, effectively establishing a long-term aggregate nutrient limit or "cap" for wastewater discharges within each major tributary. Any new loads must be offset by nutrient reductions elsewhere in the tributary.

Existing point sources can comply with the WLA by either upgrading treatment processes on site or by purchasing annual point source credits. Point source credits are the difference between the WLA and total pounds discharged for a given calendar year (when WLA > total pounds discharged).[3] In the event that a discharger's nutrient load exceeds its WLA, a point source discharger must seek credits from another *point* source within the same river basin (James, York, Rappahannock, and Potomac River basins). If no point source credits are available, a point source may then pay a per pound fee to a state administered fund (Virginia Water Quality Improvement Fund or WQIF, see §62.1-44.19:18.A). Fees are currently $6.04 and $15.08 per pound of nitrogen and phosphorus respectively (9VAC 25-820-70J). Fee revenue from this fund, administered by state agencies, would then be used to sponsor point or nonpoint source reductions elsewhere in the watershed. By law, existing point sources must first use all

[3] Credits are defined as pounds of nutrients delivered to the Chesapeake Bay. "Delivered load" is defined by multiplying load measured at the discharge point ("end of pipe") by the attenuation factor (a ratio of the portion of load that reaches the Chesapeake Bay).

available point source credits before exercising the WQIF option regardless of any cost advantage of using the WQIF.

Separate trading rules apply for new and expanding WWTPs (WWTPs that add new wastewater flow after the enactment of the program). By statute, a new or expanding WWTP must offset all new nutrient loads by buying annual credits or securing WLA from an existing WWTP. Like existing sources, regulatory sequencing preferences apply to the offset of new loads. Nutrient offset priorities are: 1) purchase WLA or credits from an existing point source, or 2) fund nutrient reducing best management practices (BMPs) from nonpoint sources, 3) fund reductions by other means approved by the Virginia Department of Environmental Quality (VDEQ), or 4) purchase credits from the WQIF (§62.1-44.19:15.B.1). New and expanding sources must also limit total nitrogen discharge to 3 mg/l and total phosphorus discharge to 0.3 mg/l, regardless of the cost effectiveness of any nutrient offsets (§ 62.1-44.19:15).

To facilitate the preference for point-point source compliance, Virginia law authorizes the formation of a discharger association, called the Virginia Nutrient Credit Exchange Association (§62.1-44.19:17). The Association coordinates point source compliance plans within each tributary under a 5-year general permit. To facilitate the use of trading as a compliance option, the Association facilitates point source credit trading. Association trading rules are designed to provide certainty and confidence in point-point trades. Since credits are calculated only at the end of calendar year after counting all discharges, buyers have limited assurance that a specific quantity of credits would be available over the five-year compliance period. In an effort to provide more certainty, the Association defines two classes of credits: “Class A” and “Class B”. Class A credits represent pledges by individual point sources to provide a specified number of credits for a 5-year period. The Association sets Class A credit prices for five years based on estimated operational costs. Class B credits are the residual surplus (WLA load - Class A credits) left over at the end of the year. Class B credit prices vary year-to-year. All point-to-point trades are subject to a 1:1 trading ratio. Operators of multiple wastewater treatment facilities in the same tributary may also combine individual WLA under single ownership, called a "bubble". Bubbling allows a single owner to manage multiple facilities as a single discharge.

Other trading rules diminish WWTP demand for nonpoint source credits. WWTP trades with a nonpoint source BMPs must secure 2 pounds of nonpoint source reduction for every one pound of point source discharge (2:1 trading ratio). The 2:1 trading ratio is implemented to account for the higher uncertainty associated with quantifying nonpoint source loads (VDEQ 2014).

Several ancillary programs and rules further dampen WWTP need for nonpoint source nutrient credits. In addition to mass load limits, VDEQ also imposes nutrient concentration limits in all point source permits consistent with the nutrient control technology installed at the wastewater facility (§62.1-44.19:16). While trading may be used to meet annual mass load limits (WLA), a point source discharger's numeric concentration limits cannot be modified, amended, or traded, regardless if it is more cost effective undertake less control onsite. Compliance with the concentration standard effectively eliminates any demand for compliance credits from existing point sources.

Mandatory nutrient concentration limits also generate substantial quantities of excess point source credits. For example, a one million gallon per day (MGD) municipal wastewater treatment plant with advanced nitrogen removal technology typically faces a 4 mg/l concentration limit. Such a plant would receive a nitrogen wasteload allocation of 12,180 lbs/yr (4 mg/l x 1 mgd design flow). Since WLA is based on a concentration standard multiplied by the plant's *design flow,* a plant required to meet a 4 mg/l concentration limit will almost always be discharging below the WLA because wastewater treatment plants typically operate at 60 to 70% of design flows. Thus, a one MGD plant operating at 65% capacity and meeting the required 4 mg/l concentration limit would discharge approximately 7,980 lbs of nitrogen per year and generate 4,260 credits annually (12,180 – 7,980).

Under the nutrient point source control program, WWTPs have successfully reduced tributary discharges far below the total WLA issued in each tributary. Total nitrogen and phosphorus discharge is 31% and 49%, respectively, below the total allowable discharge (tributary caps). In 2014 point sources generated nearly 5.8 million nitrogen credits and 770,000 phosphorus credits (Virginia DEQ 2015b). Point sources produced relatively large quantities of credits across every tributary. The total cap, discharge levels, and point source credit supply for 2014 is shown in Figures 2 and 3. Given the surplus of credits, point sources currently have no need for nonpoint source credits (even in absence of sequencing requirements found in state law).

In addition, Virginia also employs a substantial capital grant subsidy program to help fund nutrient removal technology upgrades at municipal WWTPs. Municipal wastewater represents almost 80 percent of all point source discharge capacity in Virginia's Chesapeake Bay watershed. Municipal WWTPs may upgrade to enhanced nutrient removal (ENR) technologies (target nitrogen concentration of 3 to 5 mg/l and 0.3 mg/l for phosphorus) or to biological nutrient removal (BNR) technologies (target nitrogen concentration of 8 mg/l). The state pays for

30 to 90% of the capital costs of nutrient-related plant upgrades. State grant subsidies lowers point source compliance costs and the incentive to trade with other sources.

The point source control program is producing credits at a price that would be cost competitive with nonpoint source credits. The Association sets Class A credits for buyers at or below $4.00/lb/yr for nitrogen and $6/lb/yr for phosphorus (Nutrient Credit Exchange Association 2015). On-site capital upgrades are also relatively low cost. The annualized capital costs for advanced nitrogen removal and municipal WWTPs in Virginia are shown in Figure 4. The weighted average of annualized capital costs for nitrogen removal is less than $10/lb/yr. The portion of the costs borne by the municipality, after inclusion of state grants, is less than $4/lb/yr.

Furthermore, point source compliance behavior suggests a general discharger preference for on-site upgrades over credit compliance trading. Over 80% of all point source dischargers were able to comply with their individual WLA without purchasing any point source credits. A substantial portion of the remaining plants were able maintain compliance by pooling WLA under the common ownership bubble, effectively avoiding trades with other permittees. Point source investment behavior suggests that many plants prefer to implement capital upgrades even if *point* source nutrient credit trades would cost less and despite the Association's efforts to provide certainty in the supply of point source credits (Dowd 2015). Such behavior indicates that some permittees are willing to pay some price premium to control and manage their own nutrient discharges to maintain permit compliance.

Point sources are expected to continue to produce large surpluses of credits for the foreseeable future. Virginia's population is expected to grow by about 1% annually over the next 30 years (Weldon Cooper 2012). Even assuming no technological improvement in reducing nutrient concentrations at wastewater treatment facilities and no additional capital upgrades, existing nutrient treatment capacity is expected to adequately meet regulatory requirements (WLA) over the next few decades. Furthermore, existing municipal wastewater treatment facilities still have some capacity for further nutrient reductions. Roughly one quarter of all municipal wastewater treatment capacity has yet to be equipped with the most advanced nutrient removal treatment processes (enhanced nutrient removal or ENR).

In addition, some point sources are beginning to implement wastewater reuse projects that can reduce nutrient loads to the Chesapeake Bay by reducing the volume of wastewater discharged (Stephenson et al 2010). Recently, the Hampton Roads Sanitation District (HRSD) proposed a large scale reuse project that would treat up to 120 million of gallons a day of municipal wastewater to drinking water standards (Henifin et al 2015). The treated water would then be injected into the coastal aquifer to remediate a regional aquifer overdraft problem. If implemented, the project would reduce nutrient loads discharged to the lower Chesapeake Bay by more than a million pounds a year.

Municipal storm sewer program

Municipal separate storm sewer systems (or MS4s) represent the third possible buyer of agricultural nonpoint source credits in Virginia. Urban areas above a certain population are required to obtain a permit for infrastructure systems that collect, transport, and discharge stormwater runoff in systems (those separate from sewer wastewater pipes). In the Chesapeake Bay watershed, MS4s contribute a relatively small, but growing, share of nutrient loads to the Bay. The EPA Chesapeake Bay Program estimates that Virginia's MS4s contributed approximately 11%, 9%, and 10% of the total state nitrogen, phosphorus, and sediment loads to the Chesapeake Bay. Given these pollutant loads, VDEQ has recently established new regulatory requirements for all MS4s in the Chesapeake Bay watershed.

Typically, MS4 permits do not include numeric limits on the amount of pollutants released from their stormwater systems. Rather, MS4 permits required education programs, illicit discharge detection, administration of construction runoff requirements, and management of post-construction stormwater practices. The CWA also directs regulators to require MS4s to implement stormwater pollutant controls to the "maximum extent practicable" (MEP), while leaving the definition of the term vague. However, VDEQ recently established special new permit conditions that set numeric nutrient and sediment load limits for all MS4s permittees within the Chesapeake Bay watershed (VDEQ 2014). The new permit conditions impose specific percent reductions in nitrogen, phosphorus, and sediment loads from 2009 levels.[4] These nutrient and sediment goals will be phased in over three 5 year permit cycles.

The VDEQ published technical guidance outlining methods for quantifying nutrient and sediment loads and the required load reductions from stormwater systems (VDEQ 2014). The guidance document also outlines methods for achieving compliance with these numeric load limits. MS4s can achieve compliance within their jurisdiction by installing structural urban stormwater treatment practices, making land use changes (ex. increasing forest cover), implementing urban stream restoration, and increasing street sweeping. In addition to a large number of "on-site" (within the boundaries of the MS4) nutrient reduction practices, Virginia

[4] Nitrogen, phosphorus, and sediment loads shall be reduced 6%, 7.25%, and 8.75% respectively on pervious areas and 9%, 16%, and 20% respectively on impervious areas.

law authorizes MS4s to purchase either point or nonpoint source credits to comply with nutrient and sediment reduction requirements.

Unlike other nutrient trading programs, the state places no statutory or regulatory constraints or conditions on the use of nutrient credits by MS4s. Specifically, Virginia allows MS4s to purchase nonpoint reduction credits from agricultural sources or other urban sources without any sequencing requirements. Virginia also allows MS4s to purchase credits from nutrient assimilative service providers (such as algal or shellfish harvest) (§ 62.1-44.19:21.A). MS4s must purchase credits within the same tributary (subject to 1:1 trading ratio). MS4s may also combine their nutrient control requirements with other MS4s within the same tributary in order to meet a single nutrient and sediment requirement. While MS4's appear to have flexibility in complying with the Bay nutrient requirements, several factors will limit MS4 use of agricultural nonpoint source credits as a compliance mechanism.

At this time MS4 compliance plans remain unclear, but to date no nonpoint source credits from working lands have been purchased by MS4s. Given that VDEQ only requires MS4s to achieve relatively small reductions in the first 5-year permit cycle (generally ending around 2018), MS4s can achieve these initial permit conditions by implementing modest enhancements to their existing stormwater management activities. In the first 5-year permit cycle common compliance strategies include street sweeping and urban stream restoration. Stream restoration also offers local governments multiple and highly visual local benefits besides nutrient reduction. Some MS4s are also pooling reduction requirements, allowing them to achieve compliance over a larger geographic area.

Existing and future MS4 demand for agricultural nonpoint source credits may be limited by permitting and regulatory conditions other than those imposed by the Chesapeake Bay TMDL. The CWA requires MS4 permits to contain requirements to implement stormwater practices independent of any Chesapeake Bay requirements, and these practices also reduce nutrient and sediment loads (Cappiella et al 2014). In addition, many MS4s have local water quality impairments and TMDLs within their jurisdictions. While urban streams are often impaired by pollutants other than nutrients, the stormwater control measures used to address these impairments also reduce nutrient loads (Cappiella et al 2014). Practices implemented to meet other regulatory requirements produce incidental nutrient and sediment reductions would also count toward Chesapeake Bay TMDL compliance.

Yet, the high cost of reducing nutrients in urban stormwater provides MS4s with financial incentives to investigate other compliance options. Agricultural nonpoint source credits must compete with other potential credit providers, including point source credits. Overall, point source credits appear to be a feasible and cost effective credit purchase option for MS4s. Point source nitrogen credits are generally less than $6/lb/yr. Furthermore, point sources generate large quantities of credits relative to MS4 compliance needs. Figures 5 and 6 show the estimated nutrient reductions needed by MS4s to meet the final 2025 Chesapeake Bay nutrient goals (e.g. the difference between estimated 2014 loads and 2025 goal, Chesapeake Bay Program, TMDL Tracking Database). The figures also show the total point source credit supply in 2014 (derived from Figures 2 and 3). For nitrogen, point source credits are 3 to 6 times larger than the maximum MS4 compliance needs in the Potomac, York, and Rappahannock basins.[5] Point

[5] WLA is still uncertain in the lower James due to a localized water quality impairment.

source phosphorus credits exceed MS4 load reduction needs by 6 to 28 times in each of the three basins. Given that municipal wastewater treatment plants and MS4s are both local government enterprises, local governments would have both the administrative means, and financial incentives, to effectively combine MS4 and WWTP nutrient and sediment requirements to achieve municipal reductions in a cost effective way.

THEMES FROM VIRGINIA: REGULATED SOURCE DEMAND FOR AGRICULTURAL NONPOINT SOURCE CREDITS

The review of three nutrient trading programs in Virginia offers substantial evidence that the demand for agricultural nonpoint source credits is limited by factors unrelated to the relative cost differences between the regulated source and nonpoint sources. These factors often are related to CWA regulatory programs and include a) direct regulatory requirements that limit trade opportunities with nonpoint sources; b) complex overlapping regulatory requirements and water quality program opportunities that diminish the incentive to trade, and c) regulatory compliance preferences of dischargers. Each is discussed in turn.

Regulatory Requirements and Trade Restrictions

The explicit goal of the Clean Water Act is the elimination of pollutant discharge into the waters of the U.S and regulatory permitting programs express this intent by imposing regulatory "sequencing" preferences to first reduce the impacts on-site of the permitted activity (Stephenson and Shabman 2011; Hodge and Cutter 2012). For example, the Obama administration (2015) recently issued a memorandum asserting support of regulatory credit trading programs *after* the "avoidance and minimization" of impacts. Strict adherence to such sequencing logic reduces the demand for nonpoint source credits by design.

Virginia's regulatory programs reflect this sequencing logic. The Virginia nutrient point source program require permittees to operate any installed capital equipment to operational design capability by imposing mandatory concentration limits in permits, regardless of the cost advantages of having another source do equivalent levels of control. New and expanding sources must meet even more restrictive nutrient control requirements on-site. The state also prioritizes point-point trading over other trading options. The VSMP permit for land development activity requires three quarters of all phosphorus control to occur on site and MS4s are expected to maximize the installation of stormwater controls at MS4s to the "maximum extent practicable".

Overlapping Regulatory Requirements

Regulated dischargers face a suite of regulatory obligations, and compliance with some of these obligations reduces the need for incremental nutrient controls. Every Virginia regulatory program demonstrated overlapping regulatory requirements that diminish a regulated party's demand for nonpoint source nutrient credits. The VSMP permit program establishes nontransferable requirements for the total volume of stormwater runoff from a site. Meeting the water quantity requirements can also contribute to meeting phosphorus control requirements that could have otherwise been met through credit purchases. For MS4s, the implementation of local stormwater control practices can help meet regulatory requirements associated with local (non-nutrient) related water quality impairments, contribute to MS4 permit compliance, and reduce nutrients for Chesapeake Bay TMDL compliance.

HRSD's proposed wastewater reuse and aquifer recharge project is an example of how other regulatory requirements can drive nutrient reductions at point sources. HRSD willingness to make a billion-dollar investment in a wastewater reuse project is not driven solely by nutrient regulatory requirements or by water supply benefits (Henifin et al 2015). The aquifer recharge project may allow HRSD to postpone a *multi*-billion dollar effort to address another regulatory issue. HRSD is currently operating under an EPA consent decree to reduce overflows that sometimes occur during large rain events from their combined sewer and stormwater conveyance system. EPA allows municipalities some regulatory flexibility to reschedule large scale capital projects based on availability of capital funding and regulatory priorities. HRSD's proposal would prioritize the aquifer recharge project over the sewer overflow issue, effectively postponing the upgrades to the combined sewer/stormwater infrastructure in exchange for investing in a project that yields larger economic and environmental benefits. By treating wastewater to drinking water standards, HRSD could also comply with future anticipated regulatory requirements for other constituents (e.g. virus, pharmaceuticals, etc). While addressing these multiple regulatory concerns, the proposed aquifer recharge project would dramatically reduce nutrient discharge to the James River watershed.

Finally, state programs to assist municipal governments in meeting new regulatory requirements significantly reduce the costs faced by regulated dischargers. The Virginia Water Quality Improvement Fund provides capital grants that cover 30 to 90% of the cost of nutrient capital upgrades at municipal point sources, significantly lowering meeting mandatory mass load limits with onsite technological improvements. With these capital subsidies, discharger nutrient control costs are low and on par with even the lowest cost nonpoint source reductions.

Compliance preferences of regulated dischargers

The outcomes observed in Virginia also provide some evidence that regulated dischargers prefer to achieve compliance with technologies and control practices under their direct control and are willing to pay a premium for that control. In the Virginia point source program, point sources will typically elect to install and operate technologies under their control rather than rely on point-point trading as a compliance mechanism. Pooling regulatory requirements from multiple sources under the management of a single entity is popular. This general preference is observed under the most favorable trading conditions, such as low credit prices and low transaction costs trades with other point sources.

A number of potential explanations could explain these compliance preferences. One potential explanation involves the risk of noncompliance under CWA permitting. Under CWA five year permits (NPDES permits for industrial and municipal wastewater dischargers and MS4s), the pollutant control responsibility cannot be transferred to another party (Stephenson, Shabman and Geyer 1999). If a federal CWA permittee buys credits, the permittee is still responsible for the reduction being undertaken by the credit seller. Thus, the permittee gives up some control over permit compliance when engaging in a trade because a default by a credit provider would produce a permit violation for the regulated party. Note, however, this risk does not apply to Virginia VSMP permittees. The permit for construction activities is a one time, temporary permit and when a phosphorus credit is purchased, the responsibility for maintaining that phosphorus reduction is transferred from the developer to the landowner. Unlike other programs, the purchase of a nutrient credit immediately absolves the VSMP permittee of any future regulatory obligations from that discharge. The fact VSMP permittees buy nonpoint phosphorus credits may be partly attributed to this design feature.

Noncompliance risks also may increase due to frequent and multiple credit contracting. MS4s and wastewater point sources on-site compliance choices typically involve one time, long term structural investments. The useful life of pollution control equipment and structural urban stormwater practices typically spans between 20 to 30 years. Agricultural nonpoint source credits from working lands typically have much shorter durations. A decision to pursue on-site and long term capital controls avoids the regulatory risks and administration costs of repeated short-lived nonpoint source credit projects. For example, a 1 mgd point source expansion would require offsetting 9,000 pounds of nitrogen discharge (1 mgd at 3mg/l standard for expanding sources). Most agricultural BMPs in Virginia require 0.5 to 2 acres to generate a single nutrient credit (VDEQ 2008; Stephenson et al 2010). Thus, to achieve permit compliance through agricultural nonpoint source credits, the permittee would require multiple contracts with farmers/landowners covering thousands of acres with multiple renewals. VSMP phosphorus point-nonpoint trades may be more popular to permittees because the scale of the permit requirements matches the scale of the credit project, reducing contracting risks and transaction costs. Typically, a developer requires a small number of credits (less than 10) in a one-time deal with a single credit provider.

CONCLUSION

Cost analyses concluded that, similar to many other watersheds throughout the United States, Virginia offers favorable conditions for the emergence of point-nonpoint source trading. Multiple regulated parties face some of the most stringent, and therefore potentially costly, nutrient control requirements in the United States. Furthermore, cost studies consistently report that regulated parties can lower costs by purchasing credits generated by agricultural nonpoint BMPs (Van Houtven et al 2012; Wainger et al 2013; Jones et al. 2010). However, like nutrient trading programs across the United States, the number of credits created by BMPs on working agricultural lands that in turn have been purchased by regulated entities is negligible. The only nonpoint source trades to occur in Virginia are from land conversion projects that require the permanent removal of land out of agricultural production.

In current forms nutrient trading in Virginia will not create a demand for agricultural nonpoint source credits from working agricultural lands. A detailed analysis of Virginia nutrient trading programs highlights how trading program designs and institutional context reduces the demand for agricultural nonpoint source credits. While every nutrient trading program contains its own unique set of rules, many of the themes identified in Virginia are not unique to the state. Regulatory risks, sequencing logic, and overlapping regulatory requirements are derivative from federal statutory directives and regulatory programs.

The identification of the regulatory conditions that reduce the demand for nonpoint source credits raises the question, can the conditions be changed to encourage more point-nonpoint source trades? While some changes could make marginal improvements in trading program design, overall we conclude that there is little optimism for substantial improvements. Many regulatory conditions are deeply ingrained into the overall pollution control policy philosophy in the United States (e.g. sequencing). The litigious nature of environmental policy reinforces a conservative compliance strategy by permitted parties regarding trading (Corrigan

2015)[6]. In addition, regulated parties will still need to devise overall compliance strategies that respond to multiple and overlapping regulatory conditions.

In assessing the potential of nutrient trading to reduce compliance costs, we found the Virginia experience illustrates the importance of investigating the details and complexity of this regulatory environment. This complexity is difficult to fully capture in cost models based on capital and operation and maintenance costs. Regulated discharger preferences for on-site compliance may be influenced by multiple factors and are incompletely understood. More attention to understanding the complex institutional setting under which regulated sources make decisions is critical for setting realistic expectations for the potential for point-nonpoint trading to lower costs and to improve farm incomes.

Supporters of trading may claim that agricultural nonpoint source may still overcome these barriers when technological limits of control are finally reached. To achieve and maintain water quality goals over time, the regulatory program still needs to find ways to accommodate the growth in regulated source nutrient loads caused by economic and population growth. While demand for nonpoint source credits in Virginia appears quite limited in the foreseeable future, in the longer term economic and population growth could become sufficiently large to induce an increase in nonpoint source credit demand.

Our analysis focused on regulatory conditions that limit demand, but induced technological innovation in point source control will also continue to reduce demand for nonpoint source credits. Ample evidence indicates that performance-based environmental regulations can stimulate improvements in regulated source control technology, lowering costs,

[6] For instance Food and Water Watch and Friends of the Earth sued EPA for authorizing state nutrient trading programs in the Chesapeake Bay in 2010.

and reducing the need to trade (Burtraw 2000; Porter 2001; Shabman and Stephenson 2007). Similar evidence can be found in Virginia. Some point sources in Virginia are implementing wastewater reuse projects to reduce nutrient loads, an unanticipated outcome. Virginia wastewater treatments plant operators are creatively moving to lower nutrient removal costs of enhanced nitrogen removal processes. For instance, advanced removal of nitrogen in municipal wastewater requires a carbon source to accelerate the denitrification process. Conventional nitrogen removal requires the purchase of supplemental carbon sources. Several plants in Virginia aim to reduce costs by utilizing more carbon already present in the municipal wastewater (Bott 2013). These developments reduce nutrient control costs, increase the availability of point source credits, and lower the demand for nonpoint source credits.

The belief that regulated parties will stimulate investments in agricultural conservation, boost farm incomes, and significantly reduce agricultural nonpoint source loads is misplaced. To achieve such outcomes, development of another "buyer" of nonpoint nutrient credits is needed. Water quality trading program advocates assume regulated sources would buy nonpoint source credits to offset increase in loads, but the biggest "buyer" of nonpoint source reductions are federal and state governments. For decades, federal and state programs have provided farmers with financial assistance ("cost-share") to implement specific agricultural practices to reduce pollutant loads. These programs pay farmers to implement practices, rather than to pay directly for pollutant load reductions. Recent efforts to boost the supply of nonpoint source load reduction credits for trading demonstrates that nonpoint source practices can be quantified and certified into estimated load reductions. If governments would apply these nonpoint source crediting tools and methods along with competitive bid processes to identify low cost nonpoint source options with public nonpoint source funding, the demand for nonpoint source credits could dwarf any future demand from trading programs.

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Literature Cited

Battiata, J., K. Collins, D. Hirschman, and G. Hoffman. 2010. "The Runoff Reduction Method". *Journal of Contemporary Water Research and Education*. 146: 11-21.

Bott, C. 2013. "Update on Technology Developments and Research Needs in Point Source Nutrient Removal". Presentation to the Scientific and Technical Advisory Committee, Chesapeake Bay Program.

Breetz, H., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, R. Terry. 2004. Water Quality Trading and Offset Initiatives in the U.S.: A Comprehensive Survey. Dartmouth College, Hanover, New Hampshire.

Breetz, H., K. Fisher-Vanden, H. Jacobs, C. Schary. 2005. "Trust and Communication: Mechanism for Increasing Farmers' Participation in Water Quality Trading." *Land Economics*. 81 (2): 170-190.

Burtraw, D. 2000. "Innovation under the Tradable Sulfur Dioxide Emissions Permits Program in the U.S. Electricity Sector." Resources for the Future Discussion Paper 00-38. Washington DC.

Cappiella, K., B. Stack, J. Battiata, D. Nees, and L. Farley-McNeal. 2014. "Potential Application of Stormwater Banking in the Chesapeake Bay Watershed Using Two Case Studies." Center for Watershed Protection, Maryland.

Conservation Technology Information Center (CTIC). 2006. *Getting Paid for Stewardship: An Agricultural Community Water Quality Trading Guide*. West Lafayette Indiana.

Corrigan, Z. 2015. “The Case Against Water Quality Trading.” *Natural Resources and Environment* 30(2):1-4.

EPRI. 2015. “EPRI Awarded $2 Million for Water Quality Trading Project” Electric Power Research Institute Press Release. October 27th.

Economist, “Blooming Horrible” June 23 2012, print edition.

Faeth, Paul. 2000. *Fertile Ground: Nutrient Trading’s Potential to Cost-Effectively Improve Water Quality*, World Resources Institute, Washington D.C.

Fang, F., W. Easter, P. L. Brezonik. 2005. “Point-nonpoint Source Water Quality Trading: A Case Study in the Minnesota River Basin” *Journal of the American Water Resources Association* June: 645-658.

Fisher-Vanden, K. and S. Olmstead. 2013. “Moving Pollution Trading from Air to Water: Potential, Problems, and Prognosis.” *Journal of Economic Perspectives*. 27 (1): 147-172.

Ghosh, G., M. Ribaudo, and J. Shortle. 2011. “Baseline Requirements Can Hinder Trades in Water Quality Trading Programs: Evidence from the Conestoga Watershed. *Journal of Environmental Management*. 92(8): 2076:2084.

Greenhalgh, S., and M. Selman. 2012. “Comparing Water Quality Trading Programs: What Lessons Are There to Learn?” *Journal of Regional Analysis and Policy*. 42(2): 104-125.

Hanson James C. and K.E. McConnell. 2008. “Simulated Trading for Maryland’s Nitrogen Loadings in the Chesapeake Bay” *Agricultural and Resource Economics Review* 37:211-226.

Henifin, T., J. Mitchell, J. Bernas, and C. Bott. 2015. “Sustainable Water Recycling: Aquifer Replenishment System”. Hampton Roads Sanitation District. October 1.

Hodge, C., and W. Bowman Cutter. 2012. "In lieu Fees: Steps Toward Stormwater Treatment Cost-Effectiveness." In *Economic Incentives for Stormwater Control*. Ed. Hale W. Thurston. CRC Press, Boca Raton, Florida.

Howarth, R.W., A. Sharpley, and D. Walker. 2002. Sources of Nutrient Pollution to Coastal Waters in the United States: Implications for Achieving Coastal Water Quality Goals. *Estuaries*. 25(4): 656-676.

King, Dennis M. 2005. "Crunch Time for Water Quality Trading" *Choices* 20(1): 71-74.

King, Dennis M., and Peter J. Kuch. 2003. "Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles." *Environmental Law Reporter* 33(5): 10352– 68.

Logue, C. and B. Fewell. 2015. "Elements Affecting the Water Sector of Water Quality Trading-Point and Nonpoint Sources" in *Advances in Water Quality Trading as a Flexible Compliance Tool*. Water Environment Federation, Alexandria Virginia.

Mehan, G. Tracy. 2008. "Establishing Markets for Ecological Services: Beyond Water Quality to a Complete Portfolio" *New York University Environmental Law Journal* 17 (1): 638-645.

Jones, Cy., Evan Branosky, Mindy Selman, and Michelle Perez. 2010. "How Nutrient Trading Could Help Restore the Chesapeake Bay" World Resources Institute Working Paper. Washington, DC

Jones, C. and M. Selman. 2015. "Current Policy Directions" in *Advances in Water quality Trading as a Flexible Compliance Tool*. Water Environment Federation, Alexandria Virginia.

Obama, B. 2015. “Presidential Memorandum: Mitigating Impacts on Natural Resources from Development and Encouraging Related Private Sector Investment.” November 3. Office of the President, Washington DC.

Rees, G. and K. Stephenson. 2016. “Transaction Costs of Expanding Nutrient Trading to Agricultural Working Lands: A Virginia Case Study” *Ecological Economics.* Forthcoming.

Perez, M., S. Walker, and C. Jones. 2013. *Nutrient Trading in the MRB: A Feasibility Study Using Large-Scale Interstate Nutrient Trading in the Mississippi River Basin to Help Address Hypoxia in the Gulf of Mexico.* World Resources Institute. Washington DC.

Ribaudo, M.O., R. Heimlich, and M. Peters. 2005. Nitrogen Sources and Gulf Hypoxia: Potential for Environmental Credit Trading. *Ecological Economics* 52: 159-168.

Ribaudo, M.O. and C.J. Nickerson. 2009. “Agriculture and Water Quality Trading: Exploring the Possibilities” *Journal of Soil and Water Conservation*. 64 (1): 1-7.

Ribaudo, M.O., J. Savage, and J. Talberth. 2014. “Encouraging Reductions in Nonpoint Source Pollution through Point-nonpoint Trading: The Roles of Baseline Choice and Practice Subsidies.” *Applied Economic Perspectives and Policy*. 1-17

Sanneman, C., S. Culliney, and B. Cochran. 2014. “Verification in Markets for Water Quality and Habitat.” October, Willamette Partnership, Portland Oregon

Schary, Claire and Karen Fisher-Vanden. 2004. “A New Approach to Water Quality Trading: Applying Lessons from the Acid Rain Program to the Lower Boise River Watershed, *Environmental Practice* 6 (December): 281- 295.

Shabman, L. and K. Stephenson. 2007. Achieving Nutrient Water Quality Goals: Bringing Market-Like Principles to Water Quality Management. *Journal of American Water Resources Association* 43(4):1076-1089.

Shortle, J. 2013. Economics and Environmental Markets: Lessons from Water-Quality Trading. *Agricultural and Resource Economics Review* 42 (1): 57-74.

Shortle, J., Kaufman, Z., Abler, D., Harper, J., Hamlett, J. and Royer, M., 2014. The Costs to Agriculture of the Chesapeake Bay TMDL. Environment and Natural Resources Institute, Penn State University.

Stephenson, K., L. Shabman, and L.L. Geyer, 1999. Watershed-Like Effluent Allowance Trading: Identifying the Statutory and Regulatory Barriers to Implementation. *The Environmental Lawyer* 5(3):775-815.

Stephenson, K. and B. Beamer. 2008. *Economic Impact Analysis of Revisions to the Virginia Stormwater Regulation.* Virginia Department of Conservation and Recreation, Richmond Virginia.

Stephenson, K., S. Aultman, T. Metcalf, and A. Miller. 2010. "An Evaluation of Nutrient Nonpoint Offset Trading in Virginia: A Role for Agricultural Nonpoint Sources?" *Water Resources Research* 46, April 29, 2010.

Stephenson, K. and L. Shabman. 2011. "Rhetoric and Reality of Water Quality Trading and the Potential for Market-like Reform" Journal of the American Water Resources Association. 47(1): 15-28.

Suter, J.F., J.M. Spraggon, and G.L. Poe. 2013. "Thin and Lumpy: An Experimental Investigation of Water Quality Trading." *Water Resources and Economics*. 1: 36-60.

United States Department of Agriculture. 2015. "USDA Partners with EPA, Offers New Resources to Support Water Quality Trading" September 17, News Release No. 0260.15

United States EPA. Watershed Tracking, Assessment and Environmental Results. http://ofmpub.epa.gov/waters10/attains_nation_cy.control

United States Environmental Protection Agency. 1996. *Draft Framework for Watershed-based Trading.* Office of Water, Washington DC.

United States EPA. 2004. *Water Quality Trading Assessment Handbook: Can Water Quality Trading Advance Your Watershed Goals*. EPA 841-B-04-001. Washington DC.

United States EPA. 2007. *Water Quality Trading Toolkit for Permit Writers.* Office of Wastewater Management, EPA. EPA 833-R-07-004. Washington DC.

United States EPA. Nonpoint Source Pollution: The Nation's Largest Water Quality Problem EPA factsheet. EPA841-F-96-004A http://water.epa.gov/polwaste/nps/outreach/point1.cfm

United States Environmental Protection Agency. 2014. "Federal Agencies Support Virginia's Innovative Market-based Approach to Improving Water Quality in the Chesapeake Bay" December 16 Press Release. Accessed September 2015 at http://yosemite.epa.gov/opa/admpress.nsf/0/AB495CFDDE332C2B85257DB0004FD789

United States Environmental Protection Agency Science Advisory Board. 2011. *Reactive Nitrogen in the United States: Analysis of Inputs, Flows, Consequences, and Management Options.* Office of the Administrator. EPA-SAB-11-013. Washington DC

Van Houtven, G., R. Loomis, J. Baker, R. Beach, and S. Casey. 2012. *Nutrient Credit Trading for the Chesapeake Bay: An Economic Study*. Chesapeake Bay Commission, Annapolis MD.

Virginia Department of Environmental Quality. 2008. *Trading Nutrient Reduction from Nonpoint Source Best Management Practices in the Chesapeake Bay Watershed: Guidance for Agricultural Landowners and Your Potential Trading Partners*. Richmond Virginia.

Virginia Department of Environmental Quality. 2014. "Nutrient Credit Trading Ratio Study Report." Dec 23, Richmond Virginia.

Wainger, L. and J. Shortle. 2013. "Local Innovations in Water Protection: Experiments with Economic Incentives. *Choices.* 28(3): 1-6.

Wainger, L., G. Van Houtven, R. Loomis, J. Messer, R. Beach, and M. Deerhake. 2013. "Tradeoffs among Ecosystem Services, Performance Certainty, and Cost-efficiency in Implementation of the Chesapeake Bay Total Maximum Daily Load." *Agricultural and Resource Economics Review*. 42 (April) 1: 196-224.

Willamette Partnership, World Resources Institute, and the National Network on Water Quality Trading. 2015. *Building a Water Quality Trading Program: Options and Considerations, June 2015: Point-Nonpoint Trades* http://willamettepartnership.org/wp-content/uploads/2015/06/BuildingaWQTProgram-NNWQT.pdf.

Willamette Partnership 2012. *In It Together: A How-To Reference for Building Point-Nonpoint Water Quality Trading Programs* Hillsboro Oregon.

Willamette Partnership. 2013. *General Crediting Protocol 2.0.* November. Portland Oregon.

Willamette Partnership, World Resources Institute, and the National Network on Water Quality Trading, 2015. Building a Water Quality Trading Program: Options and Considerations (Point-nonpoint). http://willamettepartnership.org/wp-content/uploads/2015/06/BuildingaWQTProgram-NNWQT.pdf.

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Figure 1: Phosphorus Credits (Perpetual) in Virginia, May 2016

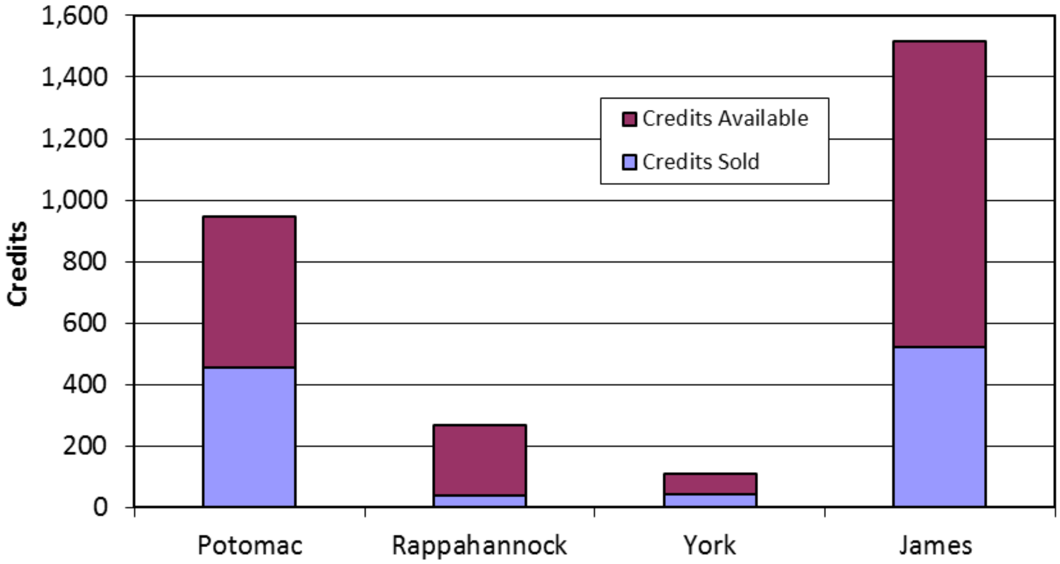


Figure 2: Point Source Nitrogen Caps, Discharge, and Credits, 2014

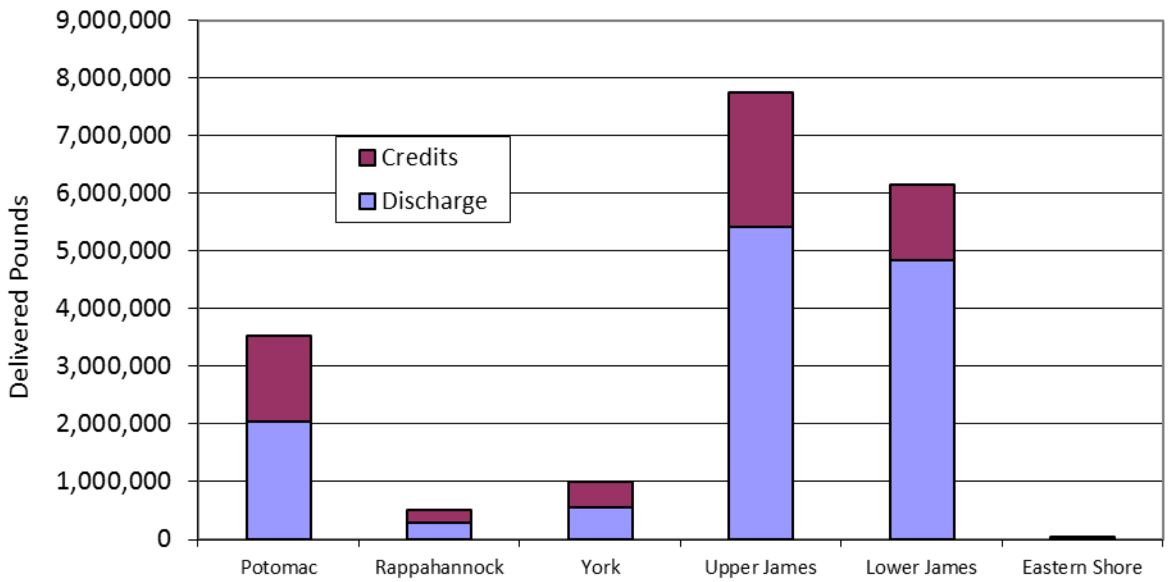
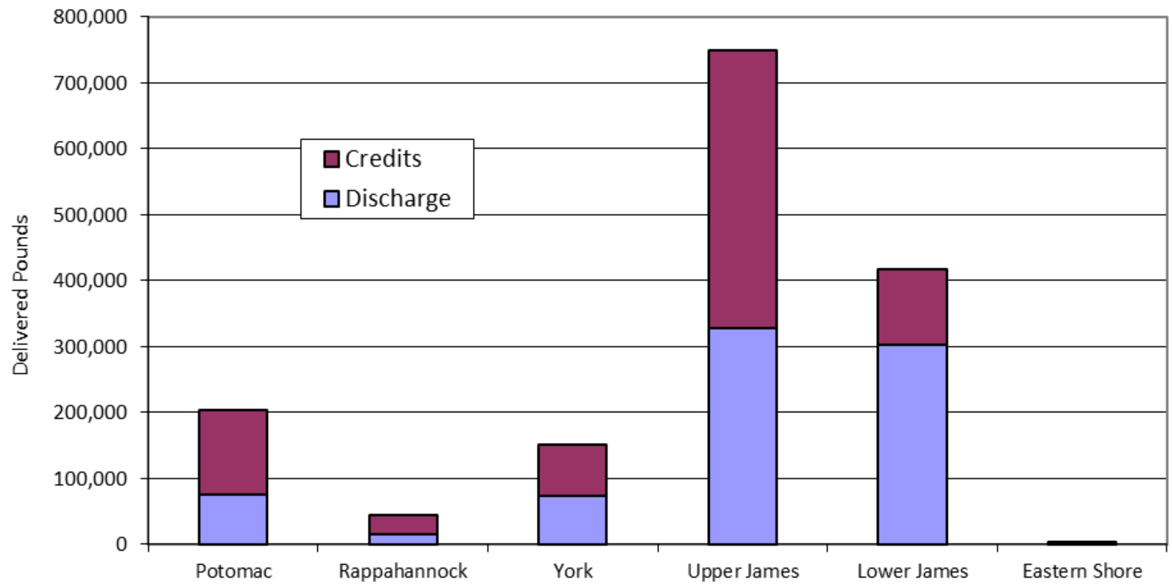


Figure 3: Point Source Phosphorus Caps, Discharge, and Credits, 2014



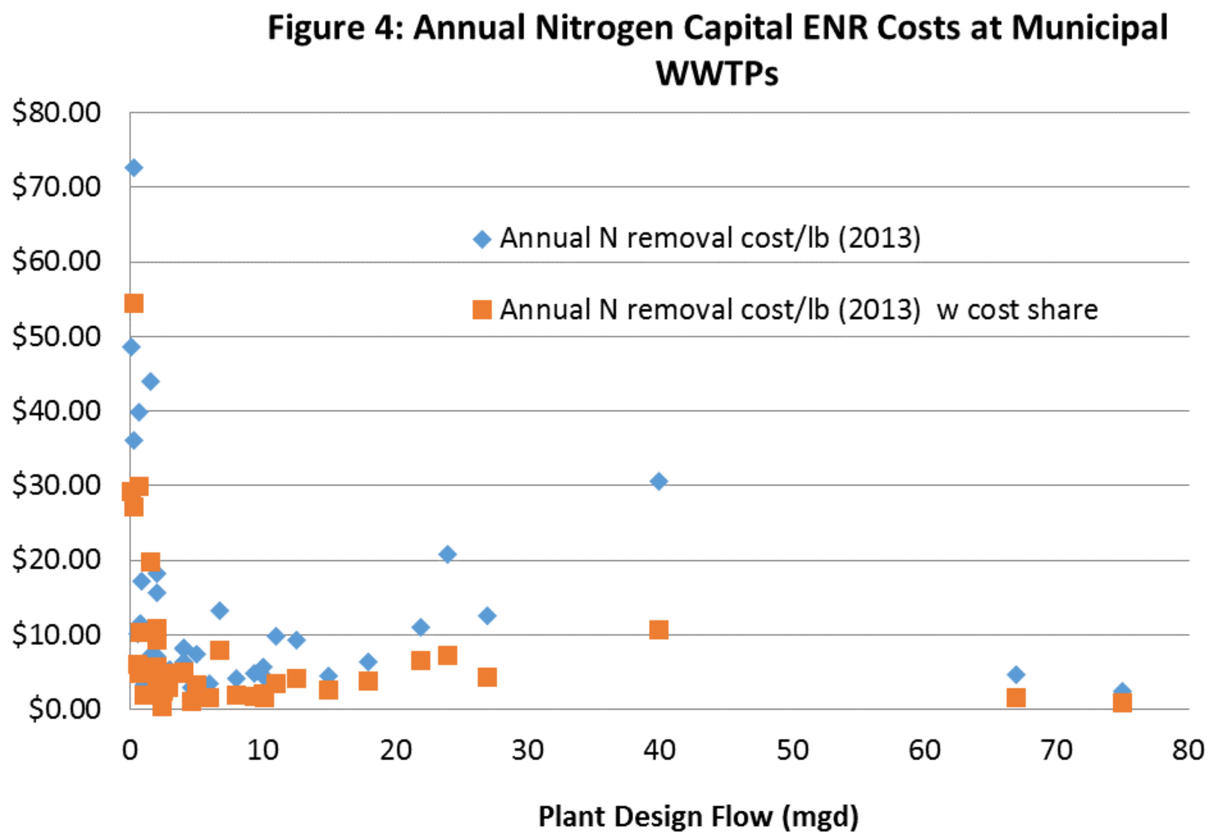
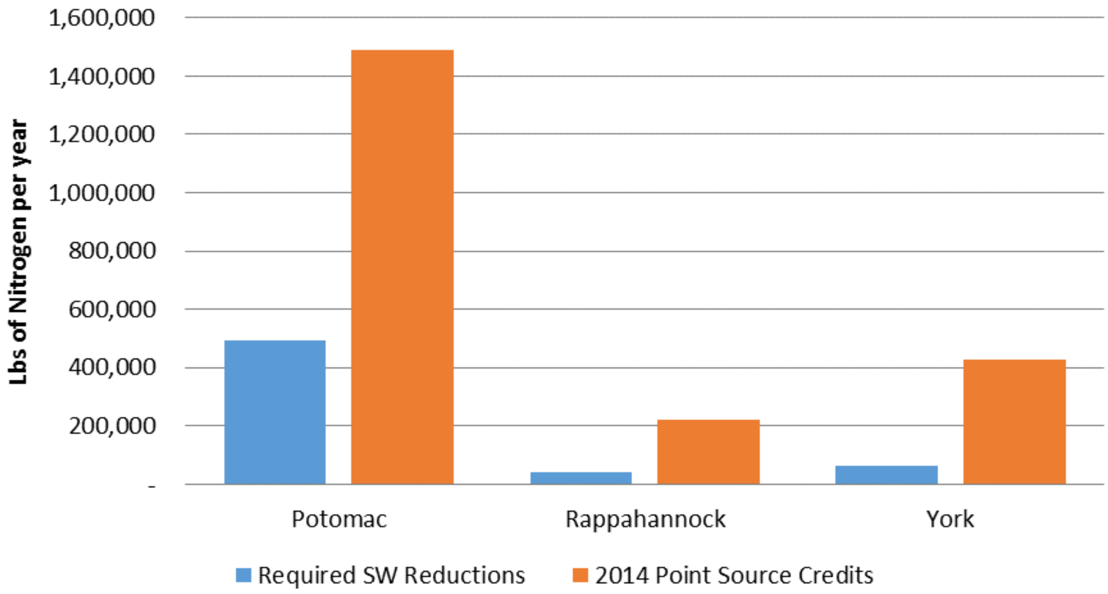


Figure 4: Annual Nitrogen Capital ENR Costs at Municipal WWTPs
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
0
10
20
30
40
50
60
70
80
Annual N removal cost/lb (2013)
Annual N removal cost/lb (2013) w cost share
Plant Design Flow (mgd)

Figure 5: Required Nitrogen Reductions from Regulated Stormwater and Point Source Credits



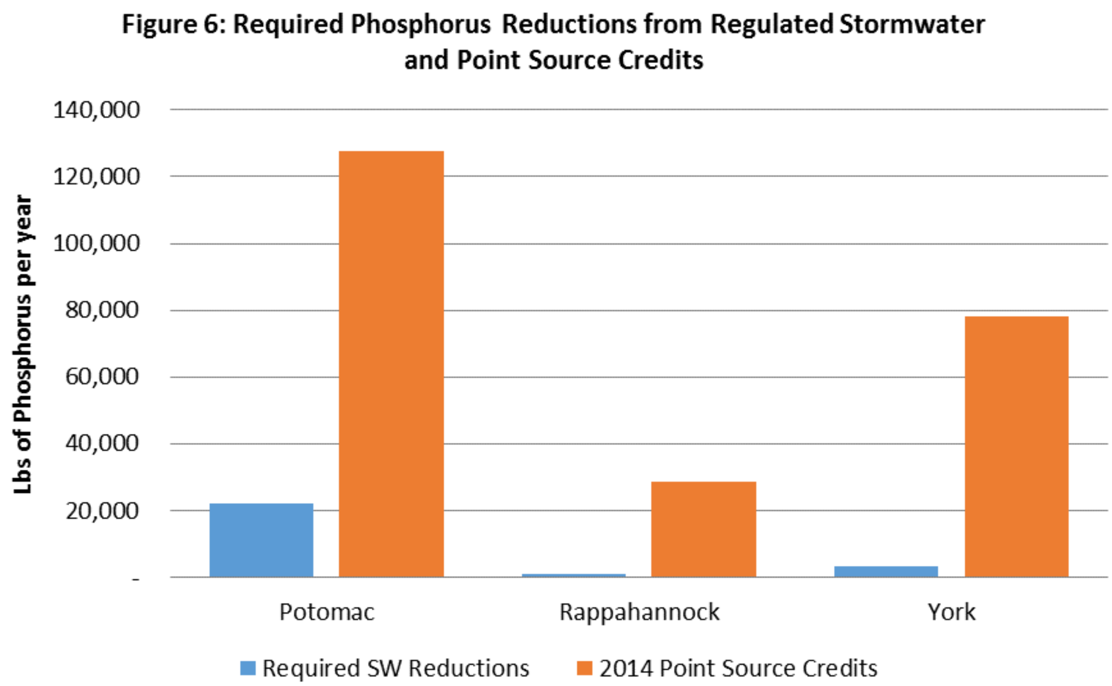


Figure 6: Required Phosphorus Reductions from Regulated Stormwater and Point Source Credits
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
Lbs of Phosphorus per year
Potomac
Rappahannock
York
Required SW Reductions
2014 Point Source Credits