An Evaluation of Nutrient Trading Options in Virginia: A Role for Agriculture?

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Water quality trading, particularly for nutrients, is increasingly being advocated and proposed by professional economists and regulatory agencies as a means for achieving pollutant control requirements for point sources under the Clean Water Act. As commonly conceived and designed, agriculture plays an integral role in most nutrient trading program proposals by allowing point source dischargers to purchase verifiable nutrient reductions (called "offsets" or "credits") from agricultural nonpoint sources. Such "point-nonpoint" trading has been hailed by federal agencies such as USDA, NRCS, and EPA as a significant new potential source of revenue for agriculture (USDA/EPA 2006; Knight 2003; Conservation Technology Information Center 2006).

Yet, the potential of nutrient trading programs to generate revenue for agricultural nonpoint sources is still speculative. Despite more than 10 years of state and federal agency promotion, demonstration projects, and research, the total volume and value of voluntary trades involving regulated point source dischargers and agricultural nonpoint sources is minimal (Stephenson and Shabman 2008). Yet, trading advocates often assume, and some empirical research supports, the notion that agricultural nonpoint sources will be the favored and most economical (low cost) trading partner for point sources (Faeth 2000; EPA 2004; Ribaudo, Heimlich, and M. Peters 2005; Hanson and McConnell 2008). The objective of this paper is to compare and evaluate agricultural nonpoint source offsets against a wide variety of other offset options under a regional nutrient trading program in Virginia.

Nutrient Trading in Virginia

The state of Virginia is implementing one of the largest scale nutrient trading programs in the United States. The aim of the trading program is to establish a cap on nutrients from point sources that drain into the Chesapeake Bay. Unlike other regional trading programs (e.g., Connecticut, North Carolina), the Virginia program is the first in the country to be explicitly authorized and described in detail by state statute (§62.1-44.19:12 - 19).

The Virginia program establishes strict annual mass load limits (called wasteload allocation or WLA) on nitrogen and phosphorus discharge for all municipally owned waste water treatment plants (WWTP) and industrial point source dischargers.[1] The mass load limits are calculated by multiplying near limits of technology concentration standards by the dischargers' permitted design flow. Compliance is scheduled for 2011 (9 VAC 25-820-70C).

Trading options are allowed for existing and new/expanding sources and conducted under a general permit (9 VAC 25-820-10 et seq). An existing source is a source that has received a WLA by 2005 (9 VAC 25-720). These sources must file a plan for attainment with their individual WLA, and are expected to make additional nutrient control investments to achieve their wasteload allocation. In the event that discharger exceeds WLA, a point source discharger must seek point source credits from another point source within the same river basin.[2] A point source credit is the difference between the WLA and total pounds discharged for a given year (when WLA > total pounds discharged).[3] The transfer of point source credits would typically occur or be facilitated by an association of point source dischargers.[4] In the event that no point source credits are available, a point source may then pay a per pound discharge fee to the Virginia Water Quality Improvement Fund (WQIF) (§62.1-44.19:18.A). Fee revenue from this fund, administered by state agencies, would then used to sponsor nonpoint source reductions. It appears unlikely most point sources will need to achieve compliance through the WQIF. The setting of the WLA based on technically achievable (but costly) concentration standards and plant design flow broadly ensures that existing sources will be able to achieve collective point source compliance with a tributary point source cap. Compliance is aided by a significant capital grants program for WWTPs and most existing sources will eventually be able to meet individual load limits internally. Finally, a point source cannot include purchase of nonpoint source credits from WQIF as part of a long term compliance plan (§62.1-44.19:14.C.3).

Compliance becomes a more difficult issue for new sources or for sources that expand (growth in discharge flows grow).[5] By statute, a new or expanding point source can only acquire WLA from an existing source, implying the state cannot issue new WLA (§62.1-44.19:14). Rather, new and expanding sources must acquire WLA from either: 1) existing point source, or

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[1] Mass load limits apply to all but the smallest point source dischargers. Generally see, 9 VAC 25-720.
[2] Generally, trading is allowed within major watershed (tributaries) in Virginia, including the Potomac/Shenandoah, Rappahannock, York, and James River watersheds.
[3] No banking of credits is allowed. All unsold point source credits expire the year the credits are created.
[4] The point source discharger association assists in the coordination between dischargers and assists in the negotiating credit prices between association members. General provisions of the point source association are described in §62.1-44.19:17.
[5] New and expanding sources are generally those sources that have new or expanded NPDES permitted flows after July 1, 2005 (§62.1-44.19:15A).

2) by funding nutrient reducing best management practices (BMPs) from nonpoint sources, or 3) by other means approved by the Virginia Department of Environmental Quality (DEQ)(§62.1-44.19:15.B.1). WLA acquired from nonpoint source BMPs or other approved measures must achieve 2 pounds of reduction for every one pound of point source WLA (2:1 trading ratio).[6] New WLA for new/expanding sources are called offsets (since it "offsets" new load) and the offset must be maintained as long as the new nutrient loads occur.

The statute also outlines nonpoint source baseline requirements that must be achieved before granting nonpoint source offsets. Specifically, nonpoint source offsets are reductions in nutrient loads above and beyond reductions required by state law or by reductions identified a state nutrient planning process, called the "tributary strategies" (§62.1-44.19:15.B.1b).[7]

Offset Evaluative Criteria

Conceptually, a large variety of possible nutrient offset options might be available to secure offsets under the Virginia nutrient trading program. Nutrient offsets could be obtained from three general categories of sources: 1) agricultural nonpoint sources, 2) urban nonpoint sources, and 3) nutrient assimilation services. Each broad category contains a variety of different practices or control technologies by which to reduce nutrient loads to the Chesapeake Bay.

The aim of this analysis is to evaluate specific nutrient reductions options in each category against four general criteria that reflect the public and private appeal of that option as a nutrient offset. The evaluative criteria consist of cost, administrative and technical feasibility, certainty in achieving claimed reductions, and administrative risk.

First, achieving offsets for new point source loads at a low cost would be desirable from both a private discharger and societal perspective. The analysis will provide estimates of the marginal cost of nutrient control for each offset option. Second, offset options must be reasonably achievable from an administrative and technical perspective. The indicator used to measure administrative and technical feasibility will be the level of activity needed to obtain an offset for a typical point source. The level of activity will be measured by the number of contracts, practices, or acres necessary to offset (in perpetuity) a one million gallon per day

[6] Depending on geographic location, attenuation ratios may also apply to account for fate and transport.
[7] This process identified general classes of actions that must occur to meet nutrient reduction targets within each major tributary to the Chesapeake Bay.

(mgd) expansion for a wastewater treatment plant operation (approximately 9,000 lbs/yr of total nitrogen).[8]

The third criterion is a qualitative assessment of the certainty in achieving reductions of each offset. Different nutrient control options will each have different degrees of uncertainty in measuring total nutrient reductions. In some cases nutrient reductions can be measured and monitored directly, while in other cases changes in load must be estimated/modeled. Furthermore, scientific and modeling uncertainty varies across control options. In general, offset options would be more appealing from a water quality management perspective the higher degree of certainty in achieving the claimed reductions. Each offset option will also be qualitatively evaluated against the certainty of achieving the required offset.

Finally, point sources would prefer, ceteris paribus, that offsets carry low administrative/regulatory risks. Unlike many environmental trading programs, a regulated discharger cannot transfer legal responsibility for achieving reductions to a nonpoint source. Under the Virginia trading program, for example, all offsets become part of a point source discharger's NPDES [National Pollution Discharge Elimination System] discharge permit. Thus, a failure of an offset to provide the claimed nutrient reduction would constitute a permit violation for the point source buyer. Hence, a point source discharger may prefer to obtain offsets from sources or activities that are directly under their management control rather than relying on a third party for offsets. One indicator for regulatory risk would be legal and management control over the offset.

Nutrient Offset Alternatives

Agricultural Nonpoint Source Offsets

The Virginia DEQ has recently approved a number of best management practices eligible to generate nutrient credits from agricultural nonpoint offsets (VDEQ 2008). These practices include continuous no-till, 15% yield reserve (applying 85% of recommended nitrogen application rate), and early cover crops. Nutrient offsets can also be secured by converting land to less nutrient intensive uses (e.g. converting agricultural land to forest or converting cropland to pastureland). Nutrient load reductions for each practice or land use change are estimated and explicitly listed in the DEQ guidance document (VDEQ 2008). The agricultural offset options

[8] Assumes new sources will achieve the required new source concentration standard of 3mg/l of total nitrogen.

and a sample of assigned nitrogen reductions are shown in Table 1. These reductions are then subject to the 2:1 trading ratio.

Table 1: DEQ Approved Agricultural BMPs and Assigned Nitrogen Removal Rates

	Per Acre Removal Rates (pounds)*							
Offset Options	Shenandoah/ Potomac		Rappahannock		York		James	
	West	East	West	East	West	East	West	East
Early Cover Crops	1.05	1.10	0.28	0.68	0.04	0.87	0.54	0.91
15% N Reduction	2.60	4.21	2.07	2.70	1.11	4.15	1.75	3.70
Continuous No-till	1.79	1.32	0.93	0.86	0.71	1.08	1.05	1.13
15% N Reduction+Cont No-till	4.01	5.01	2.69	3.28	1.65	4.78	2.53	4.46
Crop to Forest Land Conversion	10.91	11.58	4.24	6.51	3.71	8.75	5.48	9.34

To meet statutory baseline requirements, DEQ also requires that five minimum best management agricultural practices be installed before agricultural sources are eligible to generate offsets. These minimum control measures include implementing an approved nutrient management plan, soil conservation plan, cover crops, livestock exclusion from streams, and riparian buffers (35 ft minimum).

Urban Nonpoint Source Offsets

Virginia law also allows for other offsetting options if approved by DEQ. While other options have yet to formally approved, a variety of potential options exist. This analysis considers two general sources of urban nonpoint source offsets, nutrient reductions from treatment and control of urban stormwater runoff and the reduction/treatment of on-site (ex. septic) nutrient discharge sources.

Conceptually, urban nonpoint source offsets may be achieved by implementing a number of treatment practices and strategies to reduce nutrient loads in urban stormwater runoff. A wide variety of control options exist, but this analysis will focus on the more commonly employed practices, wetponds, constructed stormwater wetlands, bioretention areas, and sand filters.

Urban nonpoint source offset could be generated by reducing/eliminating/treating small urban nutrient discharges. On-site systems, or septic systems, are an acknowledged source of nutrients to the Chesapeake Bay. The Chesapeake Bay Program estimates that septic systems in the Shenandoah-Potomac River basin were responsible for 1,000,000 pounds of delivered nitrogen into the Chesapeake Bay in 2005 (Chesapeake Bay Program 2007). While wellfunctioning on-site disposal systems may not discharge nutrients directly into surface waters, nutrients can enter surface water indirectly through groundwater or subsurface flows. Failing septic systems, on the other hand, discharge nutrients and harmful bacteria into surface waters. Municipal wastewater treatment plants with advanced biological nutrient removal may have a greater ability to remove nutrients from wastewater than do septic systems because of their longer retention times and more consistent operation conditions designed to maximize the effectiveness of nitrogen removing bacteria (CH2MHill 2007). The EPA has granted (NPDES) permit holders in Colorado and New Mexico additional nutrient wasteload allocations (1 lbs of phosphorous and 23.5 lbs of nitrogen respectively) for retiring existing septic systems (Aultman 2007). Also, a study by CH2MHill of septic retirement in Maryland produced a median nitrogen reduction estimate of 17.85 pounds of nitrogen per home per year (CH2MHill 2007).

An unresolved issue for urban nonpoint offsets in Virginia is identification of acceptable baselines. Offsets from urban stormwater runoff must exceed state/federal requirements and tributary strategy reductions. A number of state and federal requirements will likely apply. Currently, Virginia is revising its state stormwater regulations. The proposed regulations establish stringent nutrient control requirements for any runoff associated with a new development. Any new development (land disturbing activity) will likely need to implement multiple stormwater control practices to achieve compliance. These reductions cannot be claimed as offsets. In addition to state requirements, the federal Clean Water Act also requires municipalities above a certain size to limit stormwater discharge (MS4 program). While the federal program does not contain numerical limits or specific mandates to install particular practices, it does instruct permit holders to undertake effort to limit dischargers to the “maximum extent practical”. How such language would apply to defining baselines is uncertain.

Any reductions that could feasibly be claimed as offsets could only occur on existing developed lands that face no numerical control requirement. For this situation, the state has yet to define baselines relative to the “tributary strategies. For example, the Shenandoah-Potomac tributary outlines a goal that 74% of suburban and urban developed lands will have urban stormwater BMPs. One baseline definition suggested by VDEQ would allow only 26% of nutrient reductions from urban stormwater BMPs on developed lands to be counted as an offset (VDEQ 2006). This baseline proposal is called the strategies allocation reduction factor, SARF. This means that for every physical pound of nitrogen reduction achieved from installing a BMP on a residential development that, after accounting for the 2:1 trading ratio and the tributary strategies requirements, only 0.13 pounds of that reduction can be counted toward new WLA.

Nutrient Assimilation Offsets

Finally, another class of offsets could be realized by directly removing nutrients from ambient waters (Shabman and Stephenson 2007). Increasing the capacity of the aquatic environment to remove nutrients is called a nutrient assimilation offset. These reductions can be achieved in the target water body independent of any changes in point and nonpoint source loads. At least three nutrient assimilation offsets will be evaluated in this analysis including nutrient reductions from increasing oyster populations, algal biomass harvest, and floodplain wetland restoration.

The water filtering capacity of the native Chesapeake Bay oyster is widely acknowledged. Investments in oyster aquaculture can provide additional water filtration services to the Bay above and beyond what is achieved through unmanaged production. Filter feeding oysters could remove nutrients from Bay waters in at least two ways. First, nutrients embodied in the phytoplankton will be sequestered in the biomass of oyster shell and meat. When oysters are harvested, nutrients are permanently removed from the system. In addition, oysters may remove nutrients by accelerating a denitrification processes. When oysters feed, they expel relatively large quantities of partially digested phytoplankton (called pseudo feces). When reaching the underlying sediment, these biodeposits, rich in organic nitrogen, may partially undergo a nitrification and denitrification process (Newell 2004; Newell et al 2005). Such a process will eventually transform a portion of the nitrogen compounds into N_2 gas, which is biologically unavailable for primary production. The use of shellfish aquaculture as a water quality management option as been piloted in other areas (Lindahl et al 2005).

Plant biomass harvest is another way to provide nutrient assimilation services (Sano, Hodges, and Degner 2005; Adey, Luckett, and Jensen 1993). While a variety of approaches exist, a basic strategy involves pumping ambient waster (or post-treatment wastewater) into an algal growout facility. One such technology spreads water out over prepared flat surfaces covered with an engineered geomembrane. Periphytic algae grow on the prepared surface and consume and sequester nutrients during growth. The algal biomass is then periodically harvested, thus removing nutrients from the ambient system. The filtered water is then discharged back into the water body with lower nutrient concentrations. Such systems are used to remove phosphorus from lakes in Florida and are currently being piloted to remove nitrogen and phosphorus in the Chesapeake Bay watershed (Hydromentia 2005).

Finally, restoring former floodplain wetlands can increase the nutrient assimilative capacity of the aquatic ecosystem. Wetlands are a well recognized nutrient sink. Wetlands trap nutrient rich water and sediment during flood events. Nutrients are sequestered in plant material and some nitrogen converted to unavailable forms. Large scale wetland restoration is being piloted explicitly for a nutrient removal practice in other areas of the country.

As a potential offset option, nutrient assimilation services face no apparent baseline requirements since no private entities are required to remove nutrients through this approach. Any additional investment in nutrient removal through these activities could conceivably be counted as an offset.

Applying Evaluation Criteria to Offset Alternatives

This section evaluates the various offset alternatives just described against the four evaluative criteria: cost, administrative and technical feasibility, certainty in achieving claimed reductions, and administrative risk.

Agricultural Nonpoint Source Offsets

Despite the significant literature on agricultural BMP effectiveness and water quality trading, remarkably little rigorous economic analysis of BMP implementation costs has been done. Many cost estimates are based on financial outlays of direct costs (labor, capital, material inputs, etc). Cost estimates for the same agricultural BMP can vary widely, adding to the uncertainty about actual costs.

The Chesapeake Bay Program estimates per acre costs for early cover crops range between $13.80 to $56.50 (2007 dollars) and recent analysis in Delaware estimates costs are $30 to $40ac (Chesapeake Bay Program 2003; DDNREC 2008). Hanson and McConnell (2008) assume incentives payments of both $20 and $30 per acre to induce farm operators into trading offsets with point sources using early cover crops. Less cost information is available on the cost of 15% N reduction. Metcalfe et. al. (2007) estimated a range of per acre costs (adjusted for 2007 prices) ranged between $8.15 and $16.75. The low cost of $8.15 was the estimate of the expected lost revenue from decreased yield minus increased savings from lowered fertilizer costs, incurred by farmers of the program. The $16.75 estimate includes the cost of insurance for profit lost associate with yield reductions. These costs, however, may underestimate the compensation necessary for farmers to adopt this practice. Currently, some farmers receive $30 per acre to implement reduced N applications. For continuous no-till, some studies found an increase in farm profits, implying a negative cost (Diaz-Zorita 2004, Pendell 2006). Given that no-till involves higher upfront, out-of-pocket costs from an increase in herbicide usage and equipment purchase/rental but cost reductions from reduced labor, fuel, and repair costs, farmers may need financial incentive to adopt this practice (Massey 1997). Furthermore, it is uncertain how farmers value the loss of production flexibility that is implied by continuous no-till. Finally the cost of converting crop to forest was estimated given assumptions of land costs ($5,000 to $15,000/ac) and land conversion costs (Aultman 2007).

The above cost estimates were used to calculate per pound costs of providing a nitrogen offset. Using the nitrogen reduction rates specified by VDEQ were used to convert per acre costs to pounds removed. Nitrogen offsets were then calculated under the condition that two pounds of nonpoint source reduction is required to generate one pound of offset (new WLA). The annual nonpoint offset costs are reported in Table 2. Acquiring offsets using early cover crops would cost a minimum of $26/offset but with high end estimates exceeding $1,000. The estimated cost of reducing fertilizer applications ranges between $8 to $54/pound of offset (assuming costs between $16.75 and $30/ac). The cost to converting cropland to forest land ranges from $66 to $550 per pound of offset.

Table 2: Nonpoint Source Offset Cost Estimates

Offset Options	Annual Cost of Nitrogen Offset			
	Shenandoah/ Potomac	Rappahannock	York	James
Early Cover Crops	$26 to $107	$40 to $404	$31 to $2,800	$30 to $210
15% N Reduction	$8 to $23	$12 to $29	$8 to $54	$9 to $34
Continuous No-till	NA	NA	NA	NA
15% N Reduction+Cont No-till	NA	NA	NA	NA
Crop to Forest Conversion	$66 to $189	$117 to $487	$87 to $556	$82 to $376

It should be pointed out these are likely to be minimum costs necessary for an agricultural operator to provide offsets because these costs do not include any incremental costs incurred to implement the five minimum baseline practices. According to anecdotal evidence, very few farmers have fully reached baseline conditions. Furthermore, these costs do not include any transaction costs necessary to certify and register offsets.

The technical and administrative feasibility of the agricultural nonpoint offsets is measured here as the amount of acres necessary to offset a 1 mgd expansion in wastewater flows for each agricultural nonpoint source offset option (See Table 3). For example, the early cover crop BMP would require between 16,000 and 64,000 acres to offset a 1 mgd of wastewater flows (assuming 2:1 trading ratio and 3mg/l N concentration standard). Combining both reduce fertilizer application and continuous no till would requires between 3,500 and 11,000 treated acres. Even converting the most N intensive agricultural land use to forest would require between 1,500 to 4,000 acres (2.3 to 6.4 square miles).

To put these totals into perspective the total number of corn acres (3 year average) in each river basin is reported at the bottom of Table 3. In most instances, the total number of acres required for a 1 mgd equivalent offset represents a significant portion of the entire region. For example, there is barely enough corn grown in the entire Rappahannock River basin to generate a 1 mgd equivalent offset using early cover crops. A one mgd offset using continuous no-till would require approximately 10%, 26%, 24%, and 20% of all cornland in the Shenandoah/Potomac, Rappahannock, York, and James River basins respectively. These percentages appear more daunting considering very few farms are currently thought to be meeting baseline requirements.

Table 3: Crop Acres Necessary to Generate Offset for 1 mgd Point Source Expansion

Offset Options	Acres Required for a 1 MGD Offset							
	Shenandoah/ Potomac		Rappahannock		York		James	
	West	East	West	East	West	East	West	East
Early Cover Crops	17,143	16,364	64,286	26,741	450,000	20,690	33,333	19,780
15% N Reduction	6,923	4,276	8,696	6,667	16,216	4,369	10,286	4,865
Continuous No-till	10,056	13,636	19,355	20,930	25,352	16,667	17,143	15,929
15% N Reduct+Cont No-till	4,489	3,529	6,691	5,488	10,909	3,766	5,488	7,115
Crop to Forest Conversion	1,650	1,554	4,245	2,765	4,852	2,057	3,284	1,927
Total Corn Acres Available in Each Region	*126,870*		*74,920*		*82,170*		*79,935*	

The individual land owner contracts necessary to generate such offsets might present an administrative challenge. Farms in many regions of the state tend to be small. Average county farm size ranges between 100 and 400 acres across the entire four Virginia river basins, with the most typical farm sizes ranging between 150 to 200 acres. Even accounting for the variation between commercial and part-time farms, a one mgd offset could likely involve a minimum of 30 to 70 farm operations.

In addition to transaction costs associated with multiple small contracts, agricultural nonpoint source offsets carry some regulatory risks associated with noncompliance given the relatively large number of contracts with sources outside the control of the permitted discharger. Finally, under the Virginia program no agricultural nonpoint source load reductions would be measured. In some cases, even field verification of practices such as reduce fertilizer application would be challenging.

Urban Nonpoint Source Offsets

Stormwater BMPs fair poorly on all evaluation criteria except administrative risk. Achieving offsets by retiring existing septic systems rank slightly higher on most criteria (see Table 4).

The cost of generating offsets from stormwater BMPs was calculated using the approach described in Aultman (2007). The cost of constructing BMPs of varying sizes were calculated using cost equations from Wossink and Hunt (2003).[9] Stormwater BMP nutrient removal efficiencies were taken from the Chesapeake Bay Program (2006). Generalizing the cost of an stormwater offsets is difficult because cost and effectiveness can vary widely from site to site. We present the cost estimates for installing stormwater BMPs on two hypothetical sites in the northern Virginia area to provide an idea of the range in costs. The first scenario installs stormwater BMPs on a hypothetical 25 acre residential development and the second installs BMPs on a 5 acre parking lot.

After applying a 2:1 trading ratio, the cost per pound of nitrogen offset is reported in Table 4. Annual nitrogen offset costs for the residential development range from$377.88 per pound for offsets from bio-retention areas with sandy soils to $ 13,370 per pound using sand filters. Of the stormwater BMPs considered bio retention in areas with sandy soil and constructed wetlands produced the lowest cost offset. For the parking lot, the annual nitrogen offset costs range from $230 per pound for offsets from bio-retention areas with sandy soils to $3,518 per

[9] Capital costs are annualized at 5% over 20 years.

pound using sand filters. It is important to note that these are cost estimates for constructing BMPs for new developments. As explained above, any urban offsets would likely come from retrofitting existing development with stormwater controls. Because retrofitting existing developments with BMPs is more expensive than building BMPs for new developments the reported cost estimates should be considered a lower bound (NRC 2008). In addition, these cost estimates exclude the potential application of the SARF.

In additional to these high control costs, there are considerable technical challenges to using stormwater BMPs as a control practice. To offset 9,000 pounds of nitrogen load from a 1 mgd plant expansion would require reducing nitrogen in stormwater discharges by 18,000 pounds. For the residential development example used above, 0.55 pounds of nitrogen were removed per acre treated with bio retention areas (assumes 2.5 mg/l concentration of nitrogen in the runoff). To create an 18,000 pound reduction in nitrogen would require retrofitting approximately 32,730 acres or 51 square miles of urban residential land. In terms of the number of BMPs, if bio-retention areas and sand filters treated sites that were 5 acres on average and wetlands and wet ponds treated sites that were 50 acres on average then to offset a 1 MGD plant expansion would require 6,546 bio-retention areas, 8,372 sand filters, or 1,092 constructed wetlands or wetponds. For the parking lot example, 2.75 pounds of nitrogen were removed per acre treated with bio-retention areas. Thus to create an 18,000 pound reduction in nitrogen would require retrofitting approximately 6,550 acres or 10 square miles of parking lots. In terms of the number of BMPs, to offset a 1 MGD plant expansion would require 1,310 bio-retention areas, 1,638 sand filters, or 218 constructed wetlands or wetponds treating sites similar to this hypothetical parking lot. These large number of practices required is due to a significant degree to the relatively low concentration of nutrient in urban stormwater runoff and the relatively low amount of water detained and treated per practice.

Connecting existing septic system to a centralized treatment system is also a fairly expensive method of acquiring offset. Aultman (2007) estimated the piping and installation costs of connecting residential septic systems to an existing sewer system. The costs exclude road demolition, pumping, and incremental wastewater treatment costs. Estimated nitrogen load reductions in septic loads were assumed to range from 12 to 24 pounds per home. Using these assumptions, the annual cost of generating nitrogen offsets is estimated to be a minimum of

$60/lb/yr. Assuming a 2:1 trading ratio, between 750 to 1,500 homes would need to be connected to generate sufficient offsets for 1 mgd plant expansion.

In all cases of urban offsets, the nutrient reductions would likely be modeled or default estimates. Direct measurement is likely to be cost prohibitive.   On the other hand, many urban sources are under the control of municipal or county governments. Thus, such offsets could avoid legal requirements and risk associated with securing third party provision of a permit requirement. As advantage of sewer connection is that municipally owned water treatment plants would have direct control over the offset process.

Nutrient Assimilation Offsets

A bioeconomic model of commercial aquaculture was used to estimate the cost of providing a nitrogen offset from commercial oyster aquaculture (Miller 2009). The model estimates cost by calculating the supplemental compensation necessary for a commercial aquaculture operation to produce additional oysters. The total nitrogen removed from ambient waters was calculated based on total nitrogen sequestered in oyster tissue and shell at harvest (biomass sequestration) and nitrogen removed through denitrification of oyster biodeposits (assuming 0 to 30% of total N in biodeposits removed) (Miller 2009).

Estimated cost to generate one pound of offset range from $0 to $150/lb/yr (see Table 4). Cost estimates vary depending on assumptions about oyster prices, input costs, growth and mortality rates (Miller 2009).[10] Estimated total nitrogen removed for every 1 million oysters harvested ranges between 260 to 840/lbs per year (depending on assumptions of denitrification rates). Furthermore, a portion of these estimates can be directly measured and verified through observable oyster harvest.

To achieve a 9,000 pound nitrogen offset (& applying the 2:1 ratio) 21 and 69 million oysters would need to be produced annually by Virginia oyster aquaculture operations. Only 16 million oysters, however, were produced from oyster aquaculture operations in 2008 (Bosch et al 2008). Thus, at the current scale of aquaculture in the Bay oyster aquaculture does not appear to be able to feasibly produce offsets on this scale of a 1 mgd point source expansion.

[10] Conceptually, costs may be zero because in some economic circumstances oyster growers would be willing to expand production without any compensation for nutrient removal services.

The algal turf scrubber is in use in some areas of Florida as a P removal strategy rather than nitrogen. The estimated removal cost for phosphorus is $24/lb/yr of the Florida system (Sano, Hodges, Degner 2005). While most systems have been designed for phosphorus, it is estimated that a square meter of ATS surface area can produce 35g/m^2 of dry matter per day with 3% total nitrogen.[11] At this algal production, a one acre biomass production area would remove about 3,400 pounds of nitrogen per year. Thus to secure a 9,000 pound nitrogen offset (18,000 pound of reduction) for a point source with a 2:1 offset would require little more than a 5 acre (biomass growing area) algal turf scrubber facility. Due to insufficient data, the cost to achieve these reductions could not be estimated at this time.

Algal biomass harvest offer several advantages over nonpoint source offsets. The N removed from biomass harvest can be directly measured by through harvested biomass weight or by differences in nitrogen content of water flows in and out of the growout facility. Furthermore, such facilities can be operated internally by point source permit holders, thereby eliminating exposure to legal risks of noncompliance of third party offset providers.

Nitrogen removal from restored wetlands is highly variable but Mitsch et al (2000) reports that sustainable nitrogen retention rates range from 100 to 400 kg/ha/yr in the Eastern U.S.. These rates translate into 89 to 365 lbs/yr of nitrogen. Large variation in nitrogen removal rates have been observed across wetland types, with large connected floodplain wetlands showing the greatest nutrient removal potential (Jordan, Simpson, and Weammert 2007). Assuming rates from Mitsch et al, between 50 and 200 acres of wetlands would need to be restored to produce enough nitrogen reductions to offset a 1 mgd plant expansion.

Like removal rates, wetland restoration costs vary. The North Carolina Ecosystem Enhancement Program charges $22,000 to $146,000 per acre under its wetland in lieu fee program (NCEEP 2009). Program fees are established to cover the entire cost of wetland restoration. Assuming the NCEEP wetland restoration fees are a reasonable approximation of wetland restoration costs in the Chesapeake Bay area, the total annual offset cost for an offset would be between $57 and $377 for nitrogen removal rates of 100 kg/ha/hr.[12] Under higher removal rates (400 kg/ha/yr), restored wetland offsets range between $14 and $94 per pound of offset.

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[11] http://www.algalturfscrubber.com/ and personal conversation with Walter Adey, October 2007.
[12] Costs annualized over 30 years at 5%.

Discussion and Conclusions

Discussions of trading programs begin with the premise that regulated point sources will find attractive trades with agricultural nonpoint sources. Evidence from the Virginia nutrient trading program suggests that this assumption may be erroneous. Agricultural nonpoint offsets do not appear particularly attractive on a strictly cost of control basis. Furthermore, the application of stringent baselines and relatively small per acre reductions assigned to accepted nonpoint source practices may make it physically difficult to find enough reductions to offset even modest increases in wastewater flows. Finally, potentially high contracting costs and legal risks of permit violations in the event of nonpoint source noncompliance further reduce the appeal of agricultural nonpoint source offsets (with the possible exception of the land conversion option).

Unfortunately for regulated sources, many other types of offsets do not offer few improvements over agricultural nonpoint offset options. Urban nonpoint source offsets, particularly from stormwater, appear prohibitively expensive in addition to failing to generate offsets on the scale necessary for most wastewater treatment plants. The one class of sources examined here that offer cost effective reductions in quantities sufficient to cover WWTP needs are nutrient assimilation offsets. Yet, the regulatory approval to use nutrient assimilative offsets options is uncertain. As population growth continues to increase point source flows, the state will likely be forced to expand their compliance options or change the rules for nonpoint source offsets.

Given the limited number of financially attractive and feasible trading options, strong incentives for point sources exist to seek and develop other offset options. Given in-house expertise in effluent treatment and the appeal to manage offsets under their regulatory control, point source dischargers may look to assume responsibility for small, but still unregulated sources of discharge. For instance, at least one WWTP in Virginia is negotiating with VDEQ to acquire WLA by assuming the treatment of a neighboring counties septic pump-out waste and the treating the waste from municipal landfill lagoons. In essence, incentives are being created for point sources to voluntarily treat more nutrient sources in exchange for an expanded cap. Given that the marginal cost of point source nitrogen control is in the $10 to $15 per pound range (Aultman 2007), such options are also cost effective. Similarly, additional room under a point source cap could be created by expanding the use of post-treatment wastewater (ex. gray water reuse). These incentives for expansion of point source treatment and control, along with the results presented on the cost and feasibility of many types of offsets, cast significant doubts as to whether trading will generate any significant revenues for the agricultural sector in Virginia.

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Table 4: Summary of Offset Compliance Options in Virginia

Offset Options	**Evaluative Criteria and Indicators**			
	Annual Cost of N Offset ($/lb)*	Technical/Admin Feasibility (Activity required to offset 1 mgd expansion)*	Certainty in Achieving Reductions (Modeled Estimate or Direct Measurement)	Administrative Risk (Permittee Control of Offset Activity)
Agricultural Nonpoint Offsets				
Early Cover Crops	$26 to $400	16,300 to 64,300 acres	Modeled/Estimated	No
15% N Reduction	$8 to $56	4,370 to 16,215 acres	Modeled/Estimated	No
Continuous No-till	TBD	10,055 to 20,930 acres	Modeled/Estimated	No
15% N Reduction + Contin No-till	TBD	3,530 to 10,910 acres	Modeled/Estimated	No
Crop to Forest Land Conversion	$66 to $556	1,555 to 4,850 acres	Modeled/Estimated	Yes
Urban Nonpoint Offsets				
Stormwater wetponds	$1,294 - $3,131	10,900 to 54,600 acres	Modeled/Estimated	To some degree
Stormwater wetlands	$437 - $749	10,900 to 54,600 acres	Modeled/Estimated	To some degree
Bioretention areas	$230 – $378	6,550 to 32,730 acres	Modeled/Estimated	To some degree
Sand Filters	$3,518 – $13,370	8,190 to 41,860 acres	Modeled/Estimated	To some degree
Septic Retirement	min $60/lb	750 to 1,500 houses	Modeled/Estimated	Yes
Nutrient Assimilation Offsets				
Oyster Aquaculture	$0-$150	21 to 69 million oysters	Measured + Modeled	Unlikely
Algal Biomass Harvest	TBD	6 acres	Direct Measurement	Yes
Restored Floodplain Wetlands	$14-$377	50 to 200 acres	Modeled/Estimated	Possible

* Includes application of the 2:1 trading ratio.