The Use of Nutrient Assimilation Services in Water Quality Credit Trading Programs

By

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Introduction

In many watersheds (particularly freshwater reservoirs, lakes and estuaries), water quality managers and regulatory officials have identified nutrients as a primary cause of failure to meet water quality standards. Regulatory officials respond by placing legally enforceable individual nutrient discharge limits on those sources over which they have permitting authority. In addition, programs have been implemented around the country to provide these regulated discharge sources varying degrees of flexibility in complying with these discharge limits. These programs, sometimes referred to as water quality trading, may allow regulated sources to obtain compliance by sponsoring nutrient reductions (called credits or offsets) offsite at another regulated source (point to point) or at an unregulated source (point-to-nonpoint).

Another means to secure water quality standards is to implement a variety of technologies and processes that can increase the nutrient assimilative capacity of the ambient environment. By increasing the nutrient assimilation capacity, water quality can be improved without additional point or nonpoint source load reductions; or, water quality can be maintained in the face of growth in point or nonpoint source loads. Regulatory officials' acceptance of an enhancement to nutrient assimilation services of the ambient environment as an offset to permitted loads from regulated sources will be called nutrient assimilation credits.

The immediate goal of this paper is to discuss the possible use of nutrient assimilation credit offsets within a water quality management program. The paper starts with the recognition that nutrient credit offsets are being developed as an element of Chesapeake Bay state's trading programs. For this reason we will evaluate the efficacy of using nutrient assimilation credits in such programs. While discussed in this paper as an option to offset loads in the context of a nutrient trading program, investments in nutrient assimilation services in Chesapeake Bay might also be an important option for state and local governments to meet the water quality standards that underlie the Bay TMDL (total maximum daily load). The paper is divided into four sections. The first section briefly outlines the actions that might be taken to increase nutrient assimilation services. The second section describes how nutrient assimilation credits can be included in a nutrient trading program. The third section provides a comparative evaluation of nutrient assimilation credits with nonpoint source reduction credits. This section introduces a variety of criteria to evaluate the extent to which equivalent water quality outcomes are achieved during trading. Finally, the last section introduces how buyers and sellers of such services could establish contracts that would assure them and the public that the credits were being provided, before a payment for the services was made.

I. Nutrient Assimilation Processes

Nutrient assimilation services are the result of actions to enhance and accelerate the ability of the ambient environment to accept nutrients (phosphorus and nitrogen) and still meet water quality standards. In general, nutrient assimilation services can be created or enhanced by managing one or more of the following processes: chemical transformation, nutrient harvest, and nutrient storage. Chemical transformation refers to the conversion of nitrogen compounds into biologically unavailable forms. The most common example of chemical transformation is the nitrification/denitrification process that converts organic and inorganic nitrogen compounds in ambient waters into forms unavailable for primary production (e.g., N2 gas). Nutrient harvest occurs when nutrients present in ambient waters foster the growth of aquatic plant or animal biomass, so that the nutrients are sequestered in biomass and then removed from the aquatic system as the organisms are harvested (Rose et al 2010). Finally, nutrients may be removed from ambient waters by enhancing the sequestering nutrients in soil or aquatic sediments (e.g. via burial/storage processes).

These processes are present in four strategies for creating or enhancing nutrient assimilation services: managed wetland systems, shellfish aquaculture, algal production facilities, and stream restoration.

Managed Wetlands

Wetlands have long been recognized for the nutrient cycling functions they provide. Wetlands provide these nutrient storage and chemical reduction processes naturally, but active human management can create and enhance these services. Constructed treatment wetlands are a common method to treat stormwater runoff. Wetlands have also been constructed to treat effluent wastewater. Unlike some constructed wetland systems designed to treat wastewater flows, nutrient assimilation wetlands remove nutrients from ambient source water. The type of source water is an essential difference between “load treatment wetlands” and wetlands that provide assimilation services. Nutrient assimilation in managed or constructed wetland systems could be further enhanced by active management of the water flow through the wetland (timing, duration, magnitudes) and by the selection and management of wetland vegetation (Wetlands Initiative 2010).

Substantial literature exists summarizing the nutrient removal efficiencies of various types of wetlands, without regard to the water inflow source (Cherry et al., 2007; Kadlec and Knight, 1996; Mitsch and Gosselink, 2000; Fisher and Acreman, 2004). Nutrient removal efficiency of emergent stormwater treatment wetlands ranges between 0 and 55% for total nitrogen and 15 to 75% of total phosphorus. Nutrient removal efficiencies, particularly for phosphorus, would be expected to decrease over time as the nutrient storage capacity of the wetland is used (unless the wetland is actively managed to remove accumulated plant mass and nutrient saturated sediment) (Cappiella et al., 2008). Mitsch et al (2000) found that Midwestern wetlands remove between 90 and 350 pounds of nitrogen annually (10 to 40 $g\text{-}N/m^2$), but nitrogen removal rates in constructed wetlands in similar geographic regions can be higher (Mitsch et al. 2001). Nutrient assimilation wetlands have been estimated to remove 274 pounds of nitrogen and 24 pounds of phosphorus per acre from large Midwestern wetland systems with high nutrient inflows (Hey et al., 2005).

Shellfish Aquaculture Enhancement

Oysters are productive filter feeders that graze on phytoplankton suspended in the water column. Nutrients in the water column are the primary source of energy in phytoplankton production. When oysters feed, a portion of the nutrients contained in the phytoplankton are converted into oyster tissue and shell (biosequestration). For this reason, enhanced oyster aquaculture operations, adding to the wild stock and current aquaculture production, can be a new source of nutrient removal from ambient waters. Aquaculture oysters (shellfish in general) require no feed inputs (no importation of nutrients into the system). Further, aquaculture oysters are exclusively the product of human intervention and the associated water quality improvements would not occur in the absence of that investment. Aquaculture oysters are spawned in hatcheries, reared in upwellers, and then grown out in designated areas that do not displace wild oyster populations. Although not often described as oyster aquaculture, nutrient assimilation services may also be created through human investments in establishment and maintenance of artificial oyster reefs, even if the oysters are not harvested for sale.

Nutrients sequestered in oyster biomass are removed when harvested. Higgins et al. (2011) found that one million aquaculture Bay oysters contain between 92 and 657 pounds of nitrogen in oyster shell and tissue (range depends on the size class of the oysters). Other researchers have quantified the nutrients sequestered in other species of aquaculture shellfish and similar analysis could be applied to clam aquaculture in the Chesapeake Bay. The use of aquaculture shellfish production as a nutrient removal strategy has been piloted in several locations (Landry, 2002; Gifford et al., 2005; Lindahl et al., 2005).

Oyster researchers also hypothesize that oysters may improve water quality by accelerating the storage of nutrients and chemical transformation of nitrogen. Unlike many other shellfish, oysters filter constantly, even after the oyster has satisfied energy needs for maintenance and growth. Oysters process phytoplankton and other suspended particles and deposit the digested and partially digested material (biodeposits in the form of feces and pseudofeces) onto aquatic sediments. A portion of the nutrients in the oyster biodeposits might be buried and stored in aquatic sediments. Some researchers also estimate that a portion of the oyster biodeposits undergo a nitrification-denitrification process, thus removing organic and inorganic nitrogen from ambient waters by releasing N_2 gas into the atmosphere (Newell, 2004; Newell et al., 2005).

Aquaculture oysters add to these filtering services, thus potentially removing additional nutrients from the aquatic system (biomass harvesting, nitrogen processing and nutrient burial). In addition, human investments to create and manage artificial oyster reefs (habitat) can add to these filtering and nutrient removal services. Wild oysters need hard substrates in order to thrive and private investments can create viable oyster reefs that could increase oyster populations above current levels. Regulations in both Virginia and Maryland prevent placement of aquaculture equipment or other manmade structures from displacing current wild productive shellfish growing areas, thus any oysters added to the Chesapeake Bay represent new nutrient removal services.

Aquatic Plant Biomass Harvest

The active cultivation and management of aquatic plants is a long recognized means to improve water quality through the removal of nutrients from ambient waters. Managed aquatic plant systems (MAPS) have been the subject of considerable research. In the case of MAPS, all nutrient removal is achieved largely through sequestration in soils and harvest of plant material.

A variety of aquatic plant species, including multiple species of microalgae, macro algae (“seaweed”), and aquatic plants (e.g. water hyacinths), have been investigated as potential ways to harvest nutrients from ambient waters. MAPS production areas can be developed in either an offline or in-situ (inline) configuration. Offline systems convey nutrient rich ambient water into an adjacent grow-out areas or production facilities. Nutrients present in the ambient source water are used for plant growth but the vegetative treatment area does not occupy space within the source waterbody. After plant uptake of nutrients, water is returned to receiving water. In-situ systems designate specific vegetation production/harvest areas in the ambient aquatic environment for MAPS cultivation.

Research and interest in algae production facilities is expanding rapidly. One type of algal production technology involves pumping ambient water into a production area that includes prepared flat surfaces covered with an engineered geomembrane (called algal turf scrubbers). Periphytic algae grow on the prepared surface and sequester nutrients during growth. The algal biomass is then periodically harvested. The water is then discharged back into the water body with lower nutrient concentrations (Adey et al., 1993; Adey et al., 1996; Hydromentia, 2005). Large-scale pilot projects in Florida found that up to 1,300 kg/ha of nitrogen and 330 kg/ha of phosphorus can be removed by such facilities (Hydromentia, 2005). Mulbry et al. (2010) removed an equivalent of 330 and 70 kg/ha/yr of nitrogen and phosphorus, respectively, from small-scale experimental scrubbers in the Chesapeake Bay.

In addition, a variety of seaweed can be actively cultivated and harvested and has been actively used as a means to mitigate the impact of nutrient-intensive finfish aquaculture (Neori et al., 2004). Thousands of metric tons of nitrogen are estimated to be removed from ambient waters from the harvest of seaweed grown for food (Troell et al., 2003). Floating aquatic plants (e.g., water hyacinth) have higher growth than submerged plants and may sequester more than 1,500 pounds of nitrogen per hectare annually (Reddy and DeBusk, 1985). Others have explored the potential of adding aquatic plants to accelerate and enhance the nutrient removal in stormwater treatment ponds (Fox et al., 2008).

Harvested biomass may then in turn be put to other beneficial uses such as compost, animal feed, human food, and biofuel. Financial returns on these beneficial uses are often insufficient on a stand-alone basis to simulate investment in aquatic plant harvesting. Payments for nutrient assimilative services would provide an additional, potentially primary, financial incentive to stimulate investment in MAPS efforts in the mid-Atlantic region, but appropriate beneficial uses of biomass harvest can reduce the cost of providing the nutrient removal services.

Stream Restoration

Recently more attention has been given to the possibility that stream restoration can also facilitate and enhance nitrogen removal from ambient waters (Bukaveckas, 2007; Kaushal et al., 2008). Researchers hypothesize that the hydrologic features characteristic of modified stream channels and streams altered by urban environments diminish riparian denitrification rates. Stream stabilization and restoration activities that restore more naturally occurring stream features such as river bends and pool/riffle structures slow water velocities and stabilize stream channels/banks which may, in turn, enhance instream nitrogen processing (Kaushal et al., 2008). Reduced velocities may also reduce channel and bank erosion, reducing sediment and nutrients contributions to the stream. Alterations to stream hydrology often result in significant erosion of stream bed and bank materials, resulting in downcutting, mass wasting of stream banks, and significant sediment and nutrient export. Restorative approaches that reduce erosion and improve instream nutrient processing holds potential to solve urban drainage issues and generate nutrient reductions.

II. Illustration of Use of Nutrient Assimilation Service Credits in a Nutrient Trading Program

All the technologies and processes described above can increase the nutrient assimilative capacity of ambient waters; we term that increase an assimilation service. Regulatory program acknowledgement, quantification, and certification of nutrients removed from ambient waters are called nutrient assimilation credits. Thus it is the recognition and certification of these services that makes the provision of assimilation services an offset within a trading program.

The Chesapeake Bay states are developing programs to provide regulated sources options to remain in compliance with their individual nutrient wasteload allocations (WLA), permit requirements, or aggregate mass load caps, frequently called nutrient trading. Most states allow varying types of trade options between these regulated sources. Under certain specified conditions, for example, point source dischargers may trade with unregulated nonpoint sources. The use of nutrient assimilation service credits (e.g., via wetlands, stream restoration, biomass harvest) have been proposed or explored in the literature (Heberling, Thurston. and Mikota. 2007; Cherry et al., 2007; Stephenson and Shabman 2007; Newell 2004). Nutrient assimilation projects for the purpose of generating credits for use in a trading program have been piloted for wetlands (Hey et al., 2005), aquaculture shellfish harvest (Lindahl et al., 2005), and algal harvest (Pizarro et al., 2006). Some programs, particularly for stormwater, have approved offsets that involve stream restoration (Henrico County, Virginia fee in lieu program) and removal of nutrients through temporary retention (Hanover County, Virginia).

A Virginia example illustrates how nutrient assimilation credits could be used in a watershed-based trading program. In Virginia *existing* point sources must make specified cash payments to the state Water Quality Improvement Fund (WQIF) in the event that a permitted point source (over a specific size) cannot meet their WLA within their own facility ("on-site") and if no point source credits are available for trade from other point sources. The regulatory agencies would then use the payments to the WQIF to pay for nonpoint source reductions that are predicted to reduce nutrient loads from unregulated sources in amounts equivalent to the point sources. *New/expanding* sources must offset new loads by either 1) purchasing WLA from existing point source (buying down loads from another point source) or 2) sponsoring nutrient load reductions, called offsets, from unregulated sources who agree to implement certain BMPs, or 3) or by other means approved by the Department of Environmental Quality. All trades must occur within the major tributaries and trades are subject to delivery ratios (e.g. trades denominated in "delivered pounds"). By statute, nonpoint source trades are subject to a 2:1 trading ratio to account for uncertainty in nonpoint source loadings.

To illustrate the mechanics of trading and how nutrient assimilation credits might be applied, consider a hypothetical new point source discharge in the upper Rappahannock River basin (see **Figure 1**).[1] Assume a new discharger enters the watershed and will be discharging 0.5 mgd of wastewater flow. The source would be required to operate with advanced wastewater

[1] A similar illustration of the spatial distribution of trades could be provided for any type of regulated discharge, including offsets for stormwater discharge.

treatment technology (3 mg/l TN), but would still contribute 4,000 pounds of new nitrogen annually to the system. Due to attenuation that occurs between the discharge point and the Chesapeake Bay, 2,440 pounds would be delivered to the Chesapeake Bay (delivery factor of 0.61). Virginia law requires that the point source offset this new delivered load.

Figure 1. Hypothetical trading scenario between new/expanding discharge source and offset project within Rappahannock Basin

Consider three potential ways the new point source load could be offset: purchase of point source WLA/point source credits, nonpoint source credit offset, and nutrient assimilation credit offset.

- Trade with existing point source - First, the new source can acquire WLA allocation from any existing point source within the basin. For instance, the source may negotiate a WLA purchase from an existing source below the fall line (see Figure 1). Given that the point source seller (existing source) discharges into estuary waters, the new source would need to purchase 2,440 pounds of nitrogen WLA from the existing source to fully offset the new load to the Chesapeake Bay. As a result of the trade, the nutrient loads in the river between the new and existing have increases, but the nitrogen load delivered to the Chesapeake Bay does not. Such trades are allowed if there are no localized nutrient related water quality impairments between the new and existing source.

- Nonpoint Source Credit Offset - Virginia law also allows the point source to offset new loads by securing nonpoint source credits from agricultural sources. For example, the new source may elect to purchase nonpoint offsets anywhere in the Rappahannock basin. In concept, the new point source above the fall line can purchase credits from a nonpoint source below the fall line (same general location as previous example, noted by the green arrow in Figure 1). Given the 2:1 trading ratio, the new point source would be required to purchase 4,880 nitrogen credits to fully offset the nitrogen loads delivered to the Bay by the new point source (2440 pounds of new nitrogen load delivered to the Bay times 2). The total number of credits generated by agricultural BMP practices is described in a guidance document (DEQ 2008). Nonpoint source offsets could be generated by reducing fertilizer applications 15% below agronomic rates annually on 1,807 acres of land or by converting 749 acres of cropland into forest (2.7 lbs of total nitrogen removed per acre from reduced fertilizer applications and 6.51 lbs of TN removed per acre from land conversion) (DEQ 2008).

- Nutrient Assimilation Credit Offset – Most trading programs in the Bay region, including Virginia, allow other offset options contingent on regulatory approval. One potential way to offset the new point source load is through the use of nutrient assimilation service credits. In the same vicinity of the lower Rappahannock (green arrow, Figure 1), viable nutrient assimilation enhancement activities would include managed wetland systems, expanded oyster aquaculture production, algal biomass production and harvest, or aquatic plant production/harvest, and local stream restoration. The total pounds of nitrogen removal needed to offset the new upstream load would be dependent upon the trading ratio established by the regulatory agency. The total nitrogen removal required from nutrient assimilation service efforts would range between 2,440 and 4,880 pounds per year. After accounting for uncertainty, the total pounds of nitrogen reaching the Chesapeake Bay and the spatial distribution of the nitrogen loads within the watershed are identical across nutrient assimilation, agricultural nonpoint source, and point source credit options. Whether, and to what extent, nutrient assimilation credits provide the same level of public assurances as other offset options that claimed nutrient control actually occurs is the subject of the Section III.

Legal Status of Nutrient Assimilation Credit Offsets

Conceptually, nutrient assimilation service credits can yield the same water quality outcomes as other point and nonpoint credit trades. A question remains, however, as to whether nutrient assimilation credit offsets are allowable for meeting water quality standards under some interpretations of the Clean Water Act (CWA). The CWA requires regulated (NPDES permitted) point sources to implement technology based effluent limits (TBEL) before granting a permit to discharge. TBEL are established for specific industries and pollutants and are based on specific reduction technologies at the load source. If water quality standards are not met, water quality-based effluent limits (WQBEL) are to be imposed. Early during the implementation of the CWA, EPA determined that instream treatment measures (ex. instream aerators, etc) could not be implemented in lieu of implementing end-of-pipe controls (TBEL or WQBEL) even if equivalent water quality outcomes (DO levels, for example) could be achieved (ex: EPA Memo from Deputy Assistant Administrator for Water Enforcement May 2, 1977).

It is argued here that nutrient assimilation services should not be considered instream treatment *in the context of nutrient control programs being implemented in the Chesapeake Bay region*. The key difference between instream treatment as proposed in the 1970s and nutrient assimilation credits as described here rests on the fact that nutrient assimilation credits are not being proposed as a substitute for end-of-pipe treatment at NPDES regulated sources. Most nutrient management programs within the Chesapeake Bay do not allow regulated point sources to avoid advanced (“on-site”) nutrient treatment. Both Virginia and Maryland require regulated dischargers to follow a well-defined sequencing logic that prioritizes the minimization of source nutrient discharge before trading is allowed. As the example in Section II illustrates, Virginia requires a new permitted point source to implement advanced nutrient treatment before being granted the authority to discharge. These stringent treatment requirements cannot be avoided through purchase of offsets.[2] Regulatory programs only allow point-nonpoint source offsets to address growth in (uncontrollable) point wastewater flows and in instances where additional source reduction is technically difficult to achieve. Offsets are not a substitute for treatment. In addition to the point source program, developers also face minimum on-site nutrient standards for stormwater runoff that cannot be avoided through trading. In that same sense the purpose and use of nutrient assimilation service credits is not a substitute for treatment and so their justification is fundamentally different than the proposed use of instream technologies in the 1970s. Instead, the recognition of nutrient assimilation service credits as part of these regulatory programs is consistent with the U.S. Environmental Protection Agency's (EPA's) watershed approach that promotes multiple means to achieve water quality standards.

III. Public Assurances of Water Quality Protection: An Evaluation of Nutrient Assimilation Service Credits

Trading programs must be able to translate source heterogeneity of pollutant loads into equivalent water quality results, generally called equivalence. Ensuring equivalence in water quality outcomes as a result of a trade requires addressing a number of issues in defining the commodity to be traded, in this case a nutrient credit. In terms of water quality outcomes, nutrient assimilation credits are conceptually identical to a nonpoint source nutrient credit. Therefore, a critical element in evaluating the possible role of nutrient assimilation credits in a trading program is comparing nonpoint source load reduction credits with nutrient assimilation credits according to water quality outcomes.

A number of criteria can be used to evaluate and compare nutrient credit alternatives and procedures, including measurement certainty, performance verification, baseline/additionality, and leakage (Stephenson et al., 2009). This discussion will not evaluate nutrient credit alternatives based on economic criteria (for example credit costs -- a discussion of comparative costs can be found elsewhere. See Stephenson et al., 2010).

The following discussion will briefly describe general water quality evaluative criteria and then compare nonpoint source nutrient credits against nutrient assimilation credits. Furthermore, all nutrient trading programs in the Bay region already incorporate nonpoint source credits, thus providing a given policy benchmark for comparison. The overall question being considered is: "Can nutrient assimilation credits provide the public with levels of water quality assurances equal to or greater than nonpoint source credits?"

Measurement of Results

Determining the credits expected from an action requires a prediction of either the reduction in nutrient discharge from a particular load reduction action and then delivered to the

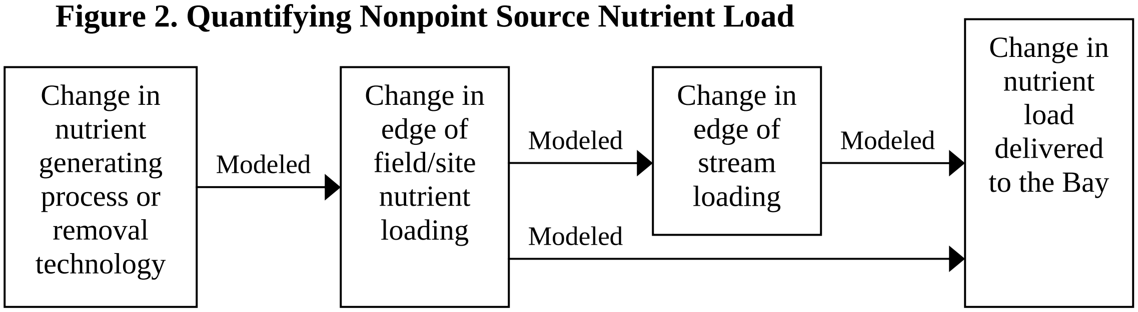
[2] Developers also face minimum on-site treatment standards for nutrients from stormwater runoff that cannot be avoided through trading.

receiving water, or the expected removal of nutrients from receiving water. The effects on water quality in the receiving water are equivalent. Once the action is taken, it is necessary to quantify the realized change in nutrient reduction or removal from ambient waters to be certain that the expected offset is being realized. The realized change in nutrient reduction or removal can be estimated using the same models that were used to predict the effect of the action measured directly, or combinations of both. Other factors held constant, direct measurement (quantification) of nutrient reduction or removal would provide greater certainty and public assurances that expected nutrient changes are actually being achieved.

All Chesapeake Bay states estimate the realized change in nonpoint source loads from credit generating practices with models, and at most check to see if the practice has been implemented (see next section on Verification) Pennsylvania and Maryland both use a model to estimate field level changes (edge of stream) in nutrient loads from the implementation of specific agricultural best management practices (BMPs). Virginia calculates nutrient load changes for a more limited set of agricultural BMPs and publishes the changes in the form of “look-up” tables. Emerging urban stormwater management programs also quantify load changes from modeled load estimates. Virginia, for example, is developing a spreadsheet model that estimates phosphorus and nitrogen loads given the application of stormwater control practices on three general categories of land cover (impervious surface, urban turf, and forest). In all cases actual nutrient removal performance is assumed to reflect modeled outcomes. Changes in nutrient loads, effluent flow, or nutrient concentrations are not directly observed or measured.

Quantifying realized changes in nonpoint source load produced by a particular nutrient reducing action involves a number of steps (see Figure 2). Starting with the adoption of some technology or behavioral change (ex BMP implementation), models are used to calculate the change in flow and concentration of runoff from a field or site. Runoff may then travel some distance before entering a stream channel, necessitating the need to estimate changes in transport and loss of nutrients in the process. If the area is not adjacent to the Bay itself, additional modeling is needed to estimate the portion of nutrients transported through miles of streams that reach the Chesapeake Bay (attenuation rates). Given these changes are not, or cannot, be measured directly, uncertainty about the actual load changes occurs at each stage in **Figure 2**. Given this performance uncertainty, Virginia imposes a 2 to 1 trading ratio on all point-nonpoint trades. Maryland and Pennsylvania require a 1.1 to 1 trading ratio (not justified on measurement uncertainty but on the risk of a project not being adequately implemented, Box 1 in **Figure 2**).

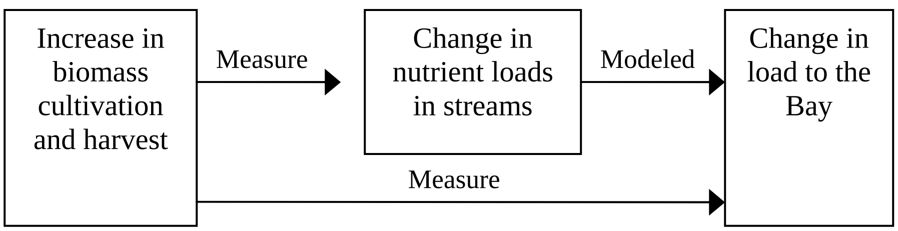
Figure 2. Quantifying Nonpoint Source Nutrient Load



Finally, weather has obvious impacts on the timing of the reductions achieved. The timing and magnitude of rainfall can influence the actual load reductions achieved in a given year. Within the Bay region, modeled changes in nonpoint source loads are calculated based on average rainfall patterns and quantified reductions do not vary across years.

In contrast to assuming practices are in place and their effectiveness, realized nutrient assimilation activities and projects can, in many instances, more easily quantify by direct measurement the amount of nutrients removed from receiving waters. For instance, nutrient removal via cultivated biomass harvest (e.g., algal, seaweed, aquaculture oysters) can be directly quantified by recording total harvested cultivated biomass (e.g., dry weight) and sampling the percent TN and TP composition of that biomass. If this biomass cultivation activity occurs in the estuary (or off-stream using estuary water), no further quantification is needed to measure the removal of nutrients from the Bay (see **Figure 3**). If the biomass harvest occurs within freshwater systems, model estimates (via delivery or attenuation ratios) would still be needed to translate how the removal nutrients upstream of the Bay translate into nutrient loads delivered to the Bay.

Figure 3. Quantifying Nutrient Removal via Cultivated Biomass Harvest



Measurement costs can be reduced if field results demonstrate that elements of the nutrient calculation procedure exhibit minimal variance over time. For instance, the TN and TP content of macroalgae (expressed in nutrients per unit of algal mass) has been found to be relatively stable across samples, time and location (Mulbry et al., 2010). If this is the case, then biomass harvesters might only need to measure the mass quantity harvested in order to generate accurate estimates of nutrients removed. In the case of aquaculture oysters in the Chesapeake Bay, nitrogen and phosphorus sequestered in harvested aquaculture oysters is directly and closely related to oyster size (measured by shell length) (Higgins et al., 2011). In this case quantifying nitrogen and phosphorus removal can be measured by the harvest of different size classes of aquaculture oysters.

Other nutrient assimilation processes may also be directly observed and measured. For instance, the nutrient concentrations of water moving through the inlets and outlets of nutrient assimilation wetland can be regularly sampled and the total volume of water measured in much the same way point source loads are monitored (Hey et al., 2005; Cherry et al., 2007). Nutrient removal of the wetland can be measured as the difference in calculated reductions in nutrient load between inflow and outflows. Some nutrient assimilation processes, however, may be either too technically difficult or costly to measure directly. Measuring changes in nutrient load from stream restoration may be technically difficult to isolate, prompting one recent study to conclude that there is insufficient evidence that stream restoration can lead to sustained higher levels of nutrient cycling (Bernhardt et al., 2008). Yet, some local stormwater programs now use stream restoration as an offset mechanism for increased nutrient loads from development activity. Measured changes in outcomes were based on the predicted removal derived from existing literature rather than measured, observed changes in ambient stream conditions. Multiple methods exist to quantify nutrient loads from stream restoration (Beisch 2011). Of course, this measurement practice is equivalent to how BMP load reductions are now measured. Similarly, the nutrient removal of nutrients from ambient water from the *in situ* water filtering of aquaculture oysters (via nutrient burial and denitrification of oyster biodeposits) is difficult to measure directly. The timing and duration of nutrient burial in sediments is also uncertain. Nutrient removal estimates would need to be developed through scientifically defensible modeled estimates.

Like nonpoint source credits, weather and other natural variability can impact the timing of the reductions achieved. For example weather can influence the growing conditions for biomass harvest projects and the timing and magnitude of flows through nutrient assimilation wetlands. Furthermore, all biological systems may be influenced by unanticipated chemical and ecological interactions. A variety of approaches can be used to address this natural variability, including developing expected annual averages (like nonpoint sources) and risk management mechanisms (e.g. insurance).

Verification of Implementation, Operation and Maintenance of Actions

Protocols may also be necessary to verify that the modeled or measured load changes were produced from credit-generating activities. The type and certainty of verification will differ between various nonpoint source and nutrient assimilation credit technologies/processes.

As illustrated in Figure 2, nonpoint source credit reduction projects begin with landowner application of BMPs. Agricultural nonpoint source credit-generating activities can include long term land conversion (ex. cropland to hay or forest) or annual activities such as planting of early cover crops, conservation tillage, or reduced fertilizer applications. Since changes in loads from such activities are not measured directly, verification of credit-generating performance occurs by documenting and confirming the implementation and operation of practices. If verified to be installed and operated correctly, performance (as predicted by model estimates) is assumed to occur. The cost and certainty of verification of behavioral change differs across practices. While it might be relatively easy to verify land conversion activities through visual inspection and satellite imaging, verification of the timing of cover crop planting or the changes in fertilizer application rates must be accomplished indirectly through self-reporting.

Verification of performance for nutrient assimilation credits will differ across various nutrient assimilation approaches. While biomass harvest might be straightforward to quantify, some types of nutrient harvest might also require biomass source verification. Cultivated biomass harvest represents new nutrient assimilation services to the aquatic ecosystem that do not diminish naturally occurring processes. Verification may be necessary to verify that the biomass harvested is the product of managed cultivation and from the diminishment of wild, beneficial biomass. For instance, oysters grown in an aquaculture operation may not be easily distinguishable by sight inspection from wild caught oysters. In such cases, verification protocols beyond simple biomass measurement might be required. Such verification could be provided by documentation of the use of inputs necessary to produce aquaculture oysters (e.g., oyster seed purchases, private leases, grow-out permits, grow-out structures deployed). This type of verification is analogous to the approach needed to verify some nonpoint source BMP implementation (e.g., reduced fertilizer inputs, cover crop timing). Conversely, the provision of other nutrient assimilation services may need no additional verification beyond the nutrient quantification. Verification of the harvest of algal biomass in an algae production facility could be accomplished by the measurement of algal biomass produced since there is no concern about the harvest of "wild" algae.

Baselines and Additionality

An important consideration in the evaluation of nutrient credits are two closely related concepts, baseline and additionality. Baseline is the identification of a reference point from which to begin to measure credit generation. Conceptually, additionality is the provision of new nutrient reduction or removal services that occur as a result of a trade. Assurance that credits represent an additional nutrient reduction/removal ensures that net pollutant loading do not increase as a result of a trade. Additionality arises because of the challenges in quantifying changes in effluent loads from sources without an explicit load requirement (Stephenson et al., 2009).

Defining baselines for nonpoint source credit activities requires defining what level of pollution control responsibility is required for the trading party before credits can be generated. While nonpoint source baseline requirements differ across Bay states, all require some minimum level of nutrient control before credits can be generated. Virginia requires the installation of five agricultural best management practices before an agricultural operation can begin generating credits (DEQ 2008). Regulatory authorities selected the baseline BMPs based on levels of implementation needed to meet tributary nonpoint source targets. Maryland establishes specific per acre nutrient loading rates based on per acre loading consistent with meeting the TMDL. Credits are then defined as the reductions in nonpoint source loads beyond the baseline load. The US EPA has issued guidelines that state baselines should be established that are consistent with sector load allocations in the Chesapeake Bay TMDL (see Appendix S).

For nonpoint sources, the selection of a specific baseline has no precise analytical solution. Baseline definition involves issues of equity (fairness related to what levels of pollutant control responsibility assigned to different source sectors) and the level of public assurance that equivalent water quality results will be achieved when trading occurs (additionality). If minimal baselines are established, nonpoint sources may generate credits without achieving additional reductions. For example, an agricultural operation may have undertaken a number of nutrient reduction practices unrelated to trading activity (cost share programs, profitable BMPs). In such cases the agricultural operation generates transferable credits without additional reductions. If these credits are sold to a regulated point source that will increase loads, the net load to the receiving water increases as a result of a trade.

Baselines may also require a time-referenced benchmark for when credits can be calculated. Trading rules may stipulate a specific date from which all nutrient-reducing activities can be counted as credit-generating activities. For example, most Bay states allow nonpoint source reduction credits to be created with different types of land conversion (cropland-hayland-forestland conversion or naturalizing riparian areas). Since land use change is continuous and ongoing, the question arises as to when land conversion (or other nonpoint source BMPs) can be counted as credit-generating activity. Most programs will not allow land conversion that occurred before trading program development to be counted as a credit because of additionality concerns.[3]

In some respects, nutrient assimilation credit suppliers do not face as many baseline/additionality challenges as nonpoint source reduction activities. For example, regulatory and water quality management programs in the Bay region do not establish minimum levels of nutrient assimilation investments. Nutrient assimilation credit suppliers face no nutrient removal expectations or requirements. Any new private investments to remove nutrients through the provisioning of nutrient assimilation services are above and beyond state and federal requirements or expectations.

Similar to nonpoint source credits, some nutrient assimilation credits would require the establishment of baseline dates. For instance, wetland banking and oyster aquaculture firms are companies currently providing some nutrient removal services. The opportunity to participate in a trading program would provide incentives to expand operations in order to provide new nutrient removal services. However, a time referenced benchmark would appear necessary in order to prevent an existing firm to claim credits for past investments. Once such time referenced baselines are established, expansions of nutrient credit services (new nutrient farm wetlands, expanded oyster aquaculture production, etc. beyond the referenced date) could be counted new (additional) services and credited.

Leakage

A related accounting problem, called leakage, occurs from incomplete load accounting of nutrient reducing/removal activities. Leakage is the induced, but unaccounted for, increase in pollutant loadings that result from trade activity. Leakage is a potential concern for both nonpoint source and nutrient assimilation credit projects.

For nonpoint source reduction projects, an agricultural operation could generate nonpoint credits by installing BMPs such as riparian buffers on a portion of its land. Holding all other farming activities constant, the riparian buffer would reduce nutrient loads leaving the farm and nonpoint source credits could be generated (assuming baselines are met). The installation of forested buffers may take highly productive bottomland out of production, prompting the farmer to bring additional upland acres under active cultivation. If the intensified upland land use increases unaccounted nutrient loads, leakage occurs. Research suggests that farm operations do have such incentives and leakage is a potential concern with agricultural BMPs (Bonham et al., 2006).

The type of leakage just described occurs when the credit generator undertakes other actions that increase unaccounted for loads, called primary leakage. Another type of leakage, called secondary leakage, can occur when credit-generating activities create changes in market conditions that tend to increase pollutant discharges (Aukland et al., 2003). For instance, if land conversion (for nutrient reduction) reduces local vegetable production, the price of local produce may increase. Higher produce prices may then induce additional intensive vegetable cultivation

[3] Within nascent U.S. carbon markets, agricultural operations face minimal baselines and time benchmarks. For instance, the Chicago Climate Exchange protocols allow farmers to claim carbon sequestration credits from the implementation of conservation tillage regardless of when the farmer switched to conservation tillage.

elsewhere. Thus new sources of nutrient loads are created indirectly through trade activity but are unaccounted for in the trading system.[4]

Leakage is also a potential issue for certain types of nutrient assimilation credit-generating activities. For instance, biomass harvesting activities may be shifted from location to location. Oyster aquaculture facilities may be expanded in one area in order to generate credits. The increase, however, could stimulate a reduction in cultivation activities elsewhere in the watershed. Leakage issues may be less likely for noncommercial bioharvest and creation of nutrient removal wetlands.

Primary leakage can be reduced for both nonpoint source reduction and nutrient assimilation services by relatively straight-forward policies. For instance, expanding nutrient accounting from the project level (e.g. project operation) to the entity level (e.g., entire farm, firm) would help avoid unanticipated load increases from activity shifting.

Summary of Public Assurances of Realized Water Quality Outcomes

When considering all evaluative criteria, nutrient assimilation credits provide strong public assurance that expected water quality outcomes are in fact being realized, when compared to the level of assurance provided by nonpoint source credits (see **Table 1** for a summary of the discussion above). Many types of nutrient assimilation projects offer more certainty in quantifying changes in nutrient loads compared to nonpoint reduction projects. Some types of nutrient assimilation credit-generating activities will require efforts to verify nutrient load reductions, ensure achievement of additional reductions, and prevent leakage, but these issues are not unique to nutrient assimilation credits. As the discussion above illustrates, similar issues confront the definition of nonpoint source credits. Credit definition protocols can be devised to address verification, additionality, and leakage issues for both nutrient assimilation credits and nonpoint source credits.

IV. Contracting for Water Quality Performance

The creation of assimilation credits would be sponsored by a regulated party or by third party intermediaries when they buy credits and then resell them to a source in need of load reduction offsets. These sponsoring sources are “buyers” of assimilation credits. The “providers” of assimilation credits are any entity willing and able to implement the actions described earlier, and that has met the regulatory requirements that define the conditions for documenting and verifying the quantity of nutrient assimilation credits provided. These entities can be called “certified sellers.”

Assimilation credits only will be produced when buyers and certified sellers can reach an agreement on the amount of credits to be provided to the buyer, how it will be documented that the credits were provided to the seller’s satisfaction, and the payment terms for the provision. These agreements will be described in a contract between the buyer and the certified seller. As noted, the contract also will assure the buyer that the conditions set by the regulatory authorities

[4] Leakage, it should be noted, is not a challenge unique to nonpoint or nutrient assimilation credit trading. Leakage can occur when the imposition of a point source cap causes a growth in unregulated sources (example a shift of new housing away from centralized sewer to on-site septic systems)

are being met by the seller so that the assimilation credits can be used as offsets in the trading program.

The terms of the contracts between buyers and certified sellers will differ according to the way the assimilation credits are produced: wetlands creation, stream restoration, shellfish and aquatic plant propagation/harvest. However, there is one fundamental requirement of any assimilation credits contract: payments will be made annually, but only after there has been documentation of contract compliance in order to assure credits were provided during each year of the contract. Nutrient assimilation offsets lend themselves to measurement and verification, as discussed above, making assimilation credits especially amenable to a contracting process where payment is contingent on demonstrated results.

A prediction of expected assimilation credits will establish the quantity of assimilation credits expected under the contract. That prediction will be made using estimates developed for each of the different assimilation credit production approaches and using input data specific to the location of the proposed strategy. The predictions at any site will need to recognize analytical uncertainty and natural variability over the life of the contract. Some of the strategies will be less subject to analytical prediction error than others, but all can be subject to natural variability (i.e. weather, variable biological growth rates). Both prediction error and the expected natural variability in assimilation services mean that some "average annual" level of assimilation services could be certified by the regulatory authority as the quantity of offsets provided for each year of the contract. Documentation that assimilation services were provided in any year, as condition for receiving annual payment, would need to recognize and address annual variability and uncertainty when defining what range of measured service would constitute contract compliance. Other elements of the contracting process also would need to be tailored to the way the credits are produced, including such matters as the financial responsibility for initial investment costs, contract length and penalties if the terms of the contract are broken by either party.

There are numerous examples of how to tailor contract elements that can be taken from and adapted to the design of assimilation credit contracts. These include operating programs in the areas of wetlands mitigation banking and Payment for Environmental Services Programs (www.fresp.net). Of course there will be contract elements from load reduction based offset programs that also would be transferable.

V. Conclusions

The Chesapeake Bay states and the federal government have committed to an ambitious and comprehensive program to meet water quality goals established for the Bay. Achieving these goals will be challenging, but achieving and maintaining those goals in the face of population and economic growth will require a level of innovation and commitment far greater than what has so far been achieved.

Recognition and incentivizing investment in nutrient assimilation services may offer regulated parties and water quality managers new ways to control costs and achieve additional water quality improvements. This discussion points out that nutrient assimilation credits can be used in similar ways as source reductions in a trading program. Compared to nonpoint source credits, nutrient assimilation credits may provide the public equal or additional certainty that trades will achieve equivalent water quality results. The challenge will be to create trading program rules and flexibility that allow participants the discretion to explore and develop multiple credit-generating alternatives in order to achieve water quality objectives, control costs, and allow continued economic growth.

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Table 1. Summary of Public Assurances of Realized Equivalent Water Quality Outcomes

	Measurement of Results	Verification of Implementation, Operation and Maintenance of Actions	Baselines and Additionality	Leakage
Nonpoint Source Credits				
Annual Ag BMPs	Model	Behavioral/practice change	Minimum Baselines Time Benchmarks	Some leakage potential
Land Conversion	Model	Behavioral/practice change	Baselines, Maybe Time Benchmarks	Some leakage potential
Nutrient Assimilation Credits				
Nutrient Assimilation Wetlands	Measure or Model Estimate	None beyond measurement, or performance indicators	Maybe Time Benchmarks	Minimal
Oyster Aquaculture	Biomass Harvest: Measure Burial/denitrification: Model	Source verification protocols	Maybe Time Benchmarks	Some leakage potential
Oyster Reef Enhancement	Model	Verification of animal condition	Maybe Time Benchmarks	Some leakage potential
Algal Harvest	Measure	None beyond measurement	None needed	Minimal
Seaweed/Aquatic Plant Harvest	Measure	None beyond measurement. Perhaps source verification	None needed	Minimal
Stream Restoration	Model	Behavioral/practice change	Maybe Time Benchmarks	Minimal