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Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles

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Despite the compelling economic logic of nutrient credit trading, widespread support for it, years of research into how it should work, and about 37 on-the-ground prototype trading programs in the United States, very few nutrient credit trades have actually taken place. This Article addresses questions about whether the obstacles preventing nutrient credit trading seem to be supply-related, demand-related, or the result of institutional problems that inhibit buyers and sellers from consummating trades. We conclude that institutional obstacles are significant, but of secondary importance and capable of being overcome. The problems related to inadequate supply and demand are more important, more difficult to overcome, and largely outside the control of regional groups attempting to develop and manage nutrient trading systems at the watershed level.

Changes in state and federal water and agricultural policies that would be required to stimulate the supply and demand for regional nutrient credits are unpopular, often considered inequitable, and not likely to take place any time soon. Therefore, we recommend that market-style nutrient credit trading be promoted only in areas where favorable supply and demand conditions can be demonstrated. Since such areas are not widespread, we also recommend that enthusiasm about the concept of market-style nutrient trading not be allowed to divert attention away from other incentive-based solutions to "overnutrification" problems.

The Problem

The "overnutrification" of the nation's rivers, streams, and coastal oceans is recognized as a serious and growing problem.[1] In most parts of the United States, nutrient discharges from point sources, e.g., wastewater treatment facilities, have already been significantly reduced, leaving agricultural nutrient discharges, e.g., farm runoff, as the major remaining cause of nutrient-related problems.[2]

Point/nonpoint source nutrient credit trading programs are being proposed as a potential solution to agricultural nutrient discharge problems. In such trading programs a point source discharger, e.g., a factory or waste treatment facility, is allowed to meet an established discharge restriction (a cap) by further treating its wastes, or by purchasing offset "credits" from other nutrient dischargers who reduce their discharges to levels below their required "caps." Although it is assumed that point sources could buy credits from other point sources, the significant cost savings associated with such trading are assumed to result from high-cost point sources, such as municipal wastewater treatment facilities, buying offset credits from low-cost nonpoint sources, in particular farmers. Because such trading is expected to reduce the cost of meeting point source discharge restrictions it is presumed that it will allow tighter caps to be imposed on point source dischargers, and thereby improve water quality. The use of "trading ratios" (rules of exchange that require point sources to purchase credits associated with more than one pound of nonpoint discharge reductions to offset each pound of point source discharge allowed) is also expected to reduce net discharges and improve water quality.[3]

However, despite widespread support for point source/nonpoint source nutrient credit trading, years of research and discussion regarding how to design and administer nutrient credit trading programs, and the establishment of many prototype nutrient trading programs in the United States, very few nutrient trades appear to have actually taken place. Figure 1 summarizes the level of activity associated with the 37 U.S.-based nutrient trading programs we identified, and provides a contact for each of them. As Figure 1 indicates, the information that we examined about these trading programs revealed that only three have actually experienced any trading activity. Moreover, the few trades that have taken place have been primarily regulator-approved bilateral agreements negotiated between point source dischargers. They have not been the "market-style" trading of standardized credits by independent buyers and sellers envi-

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1. "Overnutrification" is used to refer to levels of nutrient that are known to have adverse environmental and/or economic impacts. For an overview of national "overnutrification" problems, see U.S. Environmental Protection Agency (EPA), The Quality of the Nation's Waters, A Summary of the National Water Quality Inventory: 1998 Report to Congress (2000).
2. In the Chesapeake Bay watershed, for example, recent studies show that agriculture contributes 40.8% of nitrogen and 47.0% of phosphorus inputs, while point sources contribute 22.1% of nitrogen and 22.3% of phosphorus. *See* Chesapeake Bay Program, Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines (2002), *available at* http://www.chesapeakebay.net.trading.htm.
3. These two sources of potential discharge reductions from trading, tighter emission caps made possible because of lower compliance costs and trading ratios, work against one another. Higher trading ratios increase the cost of achieving regulatory compliance through trading and, in turn, reduce opportunities to lower emission "caps." In some cases, high trading ratios may eliminate cost saving from trading, or prevent trading altogether and result in no trade-related benefits. This is a real possibility when trading ratios are used not only to achieve net environmental gains from trade, but also to account for the inherent risks, that is to equalize the expected (risk-adjusted) increases and decreases in nutrient discharges.

sioned by most nutrient trading proponents. Furthermore, only one of the trades that we examined involved nonpoint dischargers. Although these few negotiated emission offset agreements may be called trades, they teach us little about market-style point/nonpoint source trading per se. On the other hand, we can learn quite a bit about the limits and opportunities of market-style trading by delving into the reasons for the general lack of trading activity, even in situations where such trading is popular and is being promoted by regulators.

The theoretical reasons why the trading of pollution rights should be superior to direct regulation, and the mechanics of how trading programs should operate, are well known. In this Article we address a few questions that have not been given very much attention. What obstacles are preventing nutrient trading programs from developing and attracting the two ingredients they need to succeed: willing buyers and willing sellers? What policy options, if any, are available to remove these obstacles? Are these policy options within the control of the regional organizations that are trying to develop, and are hoping to administer regional point/nonpoint nutrient trading programs? The answers to these questions will determine how we should view proposals by nutrient trading advocates to make credit-based trading the centerpiece of our national strategy to deal with overnutrification problems.

Analytical Approach

To answer these questions we examined whether the obstacles preventing nutrient trading seem to be *supply-related* or *demand-related*, or the result of *institutional failures* that prevent buyers and sellers from coming together or otherwise inhibit them from consummating trades. Since most factors affecting supply and demand in these types of markets are determined by regulatory decisions, all problems related to these markets could be classified as being institutional. For our purposes, however, we define institutional obstacles as those associated with trading institutions per se, such as problems establishing acceptable rules and units of exchange, methods of assigning trade risks, or monitoring or enforcement capabilities. Obstacles created by government programs that limit the willingness of buyers or sellers to participate in nutrient credit trading are treated separately and are referred to as supply- and demand-related obstacles.

Organization of the Article

The remainder of this Article is divided into four sections. The first section, *The Basics of Nutrient Credit Trading*, describes the necessary conditions for nutrient credit trading programs to succeed, and describes the economic forces and policy decisions that will determine when and where these conditions will exist. In *A Brief History of Nutrient Credit Trading*, we summarize the effort that has gone into establishing nutrient trading in the United States, and describe the status of 37 "active" trading programs. The third section, *Determinants of Supply and Demand*, explains why "contrived" (regulation-driven) environmental markets do not behave the same way as "natural" (consumer-driven) markets, and compares the supply and demand conditions that one would expect in these markets based on economic theory with the conditions that are being observed on the ground. The final section, *Conclusions and Recommendations*, summarizes the obstacles that are inhibiting nutrient credit trading, and suggests what policy choices would be required to remove them.

The Basics of Nutrient Credit Trading

Environmental Versus Conventional Markets

Aside from some basic rules regarding property rights, fraud, safety, and the liability of trading partners, conventional markets for goods and services need only two things to succeed: willing buyers and willing sellers. They also tend to be self-governing as buyers and sellers compete and negotiate with one another about price and quality. Buyers base their quality decisions on how well products fulfill their personal needs (consumer demand) or needs that derive from their quest for profits (business demand). Trade regulators are rarely needed to impose quality control in conventional markets because buyers are concerned about quality, and are usually knowledgeable about quality differences.[4]

Environmental credit markets are very different. Buyers here are not knowledgeable about, and outside of a regulatory context are not particularly concerned about, the underlying quality, e.g., environmental equivalency, of what is being traded. Demand is determined by regulatory requirements that create "credit seekers," e.g., caps on point source dischargers, and supply is determined by the terms and conditions that regulators put on what can be exchanged, e.g., the "creditworthiness" of on-farm nutrient management practices. In general, buyers in these markets want to minimize the price of purchasing an offset credit, and sellers want to minimize the cost of producing them. Both are only as "quality conscious" as third-party trade regulators require them to be.

To understand the economic forces at work in environmental trades it is important to view trades as three-party transactions involving active participation among buyers, sellers, and trade regulators.[5] This is particularly important because the role of the trade regulator in these three-way trades is to protect the public interest, e.g., prevent declines in water quality goals or achieve no net loss of wetlands.[6] These unusual conditions often result in extraordinary competitive strategies and exhibitions of "gaming behavior"

4. Quality uncertainty is a growing problem in modern markets. Research into this problem, and related problems associated with what is called "asymmetric information," won the 2001 Nobel Prize in economics. Special problems that result because of widespread quality uncertainty in environmental markets are described in Dennis M. King, *Managing Environmental Trades: Lessons From Hollywood, Stockholm, and Houston*, 32 ELR 11317 (Nov. 2002).

5. In situations in which there is a requirement for public participation in the permitting process, some observers refer to four-way trades involving environmental groups, as well as buyers, sellers, and trade regulators.

6. For a description of why the role of trade regulators in land-based trading systems actually involves competing with buyers and sellers, rather than merely regulating trades, see King, *supra* note 4, at 11317. For details about how they play this role in other land-based environmental markets, see James Boyd et al., *Compensation for Lost Ecosystem Services: The Need for Benefit-Based Transfer Ratios and Restoration Criteria*, 20 Stan. Envtl. L.J. 393 (2001); Lisa Wainger et al., *Wetland Value Indicators for Scoring Mitigation Trades*, 20 Stan. Envtl. L.J. 413 (2001).

that are almost never encountered in conventional markets.[7] In environmental markets, for example, it is common for the economic interests of credit buyers and sellers to be aligned with, not against, one another. Their common economic interests in low cost/low price credits are often aligned against the trade regulator whose role is to impose quality control on behalf of everyone else.

Illustrations in Nutrient Credit Trading

In the case of nutrient credit trading, for example, point source credit buyers can save more money and nonpoint credit sellers can earn more money if trade regulators employ relatively lax trade "scoring" criteria. Such criteria, for example, may allow a point source to offset nutrient discharges that would be costly to reduce by purchasing credits generated by low-cost land use changes, e.g., the planting of forested riparian buffers, regardless of whether they are taking place in a location where they are likely to be effective. They might involve granting credit for land use changes for which the landowner has already been paid or would be undertaking anyway, or are already required by law or established by a total maximum daily load (TMDL) agreement. They might involve not assigning liability to either buyer or seller for agreed-upon land use changes that are either not undertaken, or do not prove to be effective. By default, of course, trade risks that are not assigned to buyers or sellers fall on the general public.[8]

Types of Trading

For purposes of this Article, an environmental trade involves one party meeting all or part of its obligation to reduce nutrient discharges by arranging for another party to reduce its discharges, or undertake other activities, in a way that relieves the first party of its obligation. Using the conventional approach for categorizing the criteria used to evaluate the effectiveness of environmental incentives we assume that these *credits* may be established using *performance-based* criteria, e.g., actual measures of nutrient discharges, or *activity-based* criteria, e.g., changes in practices that have an expected effect on nutrient discharges.[9] Depending on the underlying regulatory structure, in other words, the baseline for measuring *credit*s may be a discharge limit (cap) or some other standard of treatment (percent discharge reduction).[10]

Types of Market Structures

The structures of markets that support trading in conventional goods and services take many different forms, e.g., food stores, auctions, Wall Street, eBay®. Similarly, there are many different market structures that could be used to facilitate nutrient credit trading. The terms used to describe environmental markets are still evolving, and are very confusing. One recent study attempted to clarify the terminology used to describe "water quality trading" by defining four general market structures, including *exchanges, clearinghouses, bilateral negotiations*, and *sole-source offsets*.[11] Although not widely used, this taxonomy does reflect a basic difference between what we might call market-style trading that is based on standardized units of exchange and large numbers of buyers and sellers, e.g., clearinghouses and exchanges, and other more ad hoc types of trades that are based on bilateral negotiations and specialized arrangements that take place outside of any structured market. In this regard, environmental trading is similar to trading in conventional goods and services; in both cases, trading can and does take place in the absence of any structured markets and often without any strict rules or units of exchange. In fact, most of the actual nutrient trades described in subsequent sections involved bilateral regulator-approved arrangements that took place without the benefit of any organized markets.

The appropriate structure for an environmental market depends on two of the same factors that determine the appropriate structures of conventional markets: (1) the comparability, or more precisely the "fungibility," of what is being

7. A description of the unusual "gaming behavior" exhibited by buyers and sellers in emerging environmental markets for wetland mitigation and carbon sequestration, and the strategies that trade regulators must use to control them are presented in Dennis M. King, *Anatomy of "Early" Carbon Sequestration Trading: Common Sense Can Prevent Costly and Embarrassing Mistakes*, Electronic J. of the F. for Envtl. L., Sci., Engineering & Fin., Spring 2002, *available at* http://www.felsef.org/summer02/htm (last visited Feb. 19, 2003).

8. Trade risk in this context does not involve financial risks to buyers or sellers, but rather the likelihood that the trades will not result in gains in environmental functions and values that are equal to losses. A recent review of wetland mitigation trading in the United States, for example, concludes that the inherent riskiness of wetland mitigation trades and trade terms that do not assign liability to trading partners have resulted in a significant loss in wetland functions and values, and, possibly, a net loss in wetland acres. *See* National Research Council, Committee on Mitigating Wetland Losses, Compensating for Wetland Losses Under the Clean Water Act (2001).

9. These two approaches to targeting incentives based on either actual measures of performance or activity-based standards are described in M. Ribaudo et al. Economics of Water Quality Protection From Nonpoint Sources (1999) (U.S. Department of Agriculture, Economic Research Serv., Agricultural Economics Report No. 782). As a practical matter, the transactions costs associated with "scoring" point/nonpoint trades on the basis of direct measurements of changes in nutrient discharges will probably be prohibitive. If they take place at all, therefore, such trades will probably involve presumed default values based on specific activities undertaken at specific locations. This would make the distinction between performance-based and activity-based credits relatively unimportant.

10. Although it is generally understood that a tradable environmental credit may be "scored" in many different ways, the term *allowance* is often used to refer to a tradable unit that is produced by achieving emission reduction levels below an established discharge "cap," and the term *credit* is used to refer to a tradable unit that is based on undertaking activities that may not be taking place under an established cap, or may not result in overall discharges falling below an established cap. The distinction between performance-based and activity-based trade scoring criteria is very important, especially when considering incentives for innovative treatment technologies. *See* Leonard Shabman et al., *Trading Programs for Environmental Management: Reflections on the Air and Water Experiences*, 4 Envtl. Prac. 153 (2002). We use the term *credit* to refer to a unit of exchange in a nutrient trading program that may be either performance-based or activity-based.

11. The literature on this topic is confusing and contains references to credit trading, allowance trading, offset trading, emission trading, pollution trading, etc. It also refers to different types of trading systems using terms such as clearinghouses or market style or commodity-type trading as opposed to bilateral trades or centrally managed allowance offset contracts or sole-source agreements. The taxonomy used here was presented in a recent paper by Richard T. Woodward & Ronald Kaiser, *Market Structures for U.S. Water Quality Trading*, 24 Rev. of Agric. Econ. 373 (2002), which does a good job of explaining critical differences in these market structures.

traded[12]; and (2) the number of buyers and sellers who are expected to participate. However, there is a third factor that one needs to consider when evaluating structures for environmental markets that can be ignored when designing markets for conventional goods and services, and that is the purpose of the trading system. Does the trading system focus exclusively on nutrients or water quality in general? Does it have secondary or ancillary environmental and economic goals? Is it meant to supplement or replace other nutrient management strategies, e.g., legal requirements, green payments, allocated TMDLs? The nature of nutrient problems and the economic and institutional opportunities and constraints to trading also differ from region to region, and even within watersheds within a given region. These differences will also influence the goals of the trading system and the appropriate market structure. There is no reason to assume that any particular market structure will or should dominate the national nutrient trading picture. Evidence will be presented in subsequent sections, however, that the most popular market-style trading structure with private interests exchanging nutrient discharge or water pollution rights with minimal government interference may only be possible in a few parts of the country.[13]

Lessons From Air Emission Credit Trading

The characteristics of successful air emission credit trading programs provide a few useful insights for designing successful nutrient credit trading programs. However, the similarities between the two types of trading systems are superficial, and very easy to overemphasize. Air emission credit trading involves highly fungible units of exchange, e.g., tons of carbon or sulfur dioxide, that are relatively easy to measure using "end-of-pipe" technologies.[14] With point/nonpoint source nutrient trading what is being exchanged is not directly comparable and often too costly to measure directly, e.g., nutrient content of "edge-of-farm" runoff, the portion of the runoff that reaches the water body. Trade regulators in nutrient credit markets must use fairly complex "scoring" criteria to convert nutrient-related gains and losses from different land use changes, e.g., farm management practices, undertaken at different locations, e.g., proximity to receiving waters, into commensurate units, e.g., tradable credits. Where they begin and end their assessments of trades has some obvious short-term and long-term implications on the viability of trading. If they employ scoring criteria that are too lax and allow too many trades that are later shown to result in a net decline in water quality, the resulting skepticism will undermine public support for nutrient trading.[15] Conversely, they may overshoot the mark and, in their efforts to protect the public interest, establish units and rules of exchange and monitoring and validation requirements that are so strict that they prevent trading from taking place, even where opportunities for water quality gains and cost savings are significant. The role of trade regulators in emerging nutrient credit markets, in other words, is far more complex and important than the role of trade regulators in established air emission offset credit markets.

Nutrient Trading Guidance

In 1996, the U.S. Environmental Protection Agency (EPA) published *Framework for Watershed-Based Trading*, which provided general guidelines for establishing effluent trading programs.[16] However, a 1999 EPA review of effluent trading in the United States indicated that very few programs complied with the 1996 guidelines. In 2002, therefore, EPA prepared a follow-up water quality trading policy statement to address "issues left open by and limitations encountered implementing projects and programs under EPA's 1996 Effluent Trading in Watersheds Policy."[17] In early 2003, EPA released a Final Water Quality Trading Policy statement recommending that "in addition to including provisions to be consistent with the Clean Water Act [(CWA)], trading programs should include the following general elements to be *credible* and *successful*"[18]:

1. Legal authorities and mechanisms for trading to occur.
2. Clearly defined units of trade.
3. Creation and duration of credits.
4. Quantifying credits and addressing uncertainty.
5. Compliance and enforcement provisions.
6. Public participation and access to information.
7. Periodic program evaluations.

These elements of a trading program reflect the necessary conditions for them to be *credible*, and therefore institutionally and politically acceptable. However, they do not address the necessary conditions for them to be *successful* in terms of attracting willing buyers and sellers. In fact, if success is measured in terms of trading activity, there are important trade offs to consider when designing trading programs to achieve credibility and success; and, leaning too far in either direction will result in failure. Establishing trading rules to achieve the elements listed above, for example, may make the administration of the trading program prohibitively costly, or impose risks on buyers or sellers that are bound to scare them off. On the other hand, striving to establish rules and units of exchange that will attract buyers and

12. Fungibility is a term widely used in trading. According to the 2003 Merriam-Webster online dictionary *at* http://www.m-w.com (last visited Feb. 19, 2003), "fungible" means "being of such a nature that one part or quantity may be replaced by another equal part or quantity in the satisfaction of an obligation." Highly fungible products include No. 2 heating fuel, pork hocks, Midwest winter feed corn, and lawyers trained at Yale; commodities that are barely fungible include dogs, Italian meals, and economists trained anywhere besides Yale.

13. Woodward & Kaiser, *supra* note 11, provide an excellent discussion of the factors that need to be considered when establishing water pollution trading systems, and why they differ from region to region.

14. Many papers that describe how air emission trading programs were carried out to deal with acid rain, nitrogen oxides, and sulfur oxides can be downloaded from the EPA air trading website at http://www.epa.gov/airmarkets (last visited Feb. 19, 2003).

15. The effects of early bad experiences with wetland trading experiences on the willingness of environmental groups and wetland regulators to endorse wetland trading are described in Dennis M. King & Lisa Wainger, Wetland Value Indicators for Scoring Mitigation Trades With Illustrations Based on Actual Mitigation Bank Trades (2000) (unpublished manuscript, on file with authors).

16. U.S. EPA, Office of Water, Effluent Trading in Watersheds Policy Statement (1996), *available at* http://www.epa.gov/OWOW/watershed/hotlink.htm (last visited Feb. 19, 2003).

17. U.S. EPA, Proposed Water Quality Trading Policy 1 (2002).

18. U.S. EPA, Office of Water, Final Water Quality Trading Policy (2003), *available at* http://www.epa.gov/owow/watershed/trading/finalpolicy2003.html (last visited Feb. 19, 2003).

sellers, a popular short-term strategy, may jeopardize the credibility and long-term viability of the trading program. However, looking beyond the elements listed above focuses attention on other, perhaps more important obstacles to credible and successful trading. Supply and demand conditions that will allow successful trading do not exist in many regions, are determined by factors beyond the control of those attempting to design regional trading systems, and will persist regardless of whether the right or wrong methods are used to achieve the elements listed in the EPA guidelines. In the early stages of water pollution credit trading, therefore, it is important to focus investments to achieve the necessary institutional elements of a credible and successful trading on regions, e.g., watersheds, where supply and demand conditions favor success.

The Equivalency of Credits

Figure 2 provides a list of typical on-farm best management practices (BMPs) that reduce "edge-of-farm" nutrient discharges, and are potential sources of nonpoint nutrient offset credits. Consider the challenge of "scoring" such practices in terms of the equivalent number of point source discharge offset credits they are worth. The first challenge is to estimate the effectiveness of these practices in reducing "edge-of-farm" nutrient discharges. These are site-dependent, and affected by soil type, hydrology, historical land use patterns, previous crop rotations, how the site is irrigated and fertilized, and so on. Within any trading period the effectiveness of these practices will also be affected, to a large extent, by the weather.[19]

However, "edge-of-farm" nutrient discharges are not the only consideration when comparing the gains and losses from a point/nonpoint trade. How spatially removed the farm is from an adjacent water body and other factors related to its landscape context significantly affect the portion of nutrient discharges that will actually reach the adjacent water body. Still other factors related to the conditions in adjacent receiving water, e.g., preexisting pollution, proximity to fish habitat, flushing rates, residence time, determine how much reducing nutrient deliveries at a particular farm site will affect water quality and related habitat values.[20]

The difficulty of determining when and where a one-pound nutrient discharge reduction by a nonpoint source is equivalent to a one-pound increase in point source discharges somewhere else is a significant institutional obstacle to point/nonpoint trading. This "scoring" problem is obviously more significant when attempting to regulate trades using standardized credits than when each trade can be evaluated on its individual merits. The situation, therefore, tends to favor "regulator-approved" bilateral trades based on case-by-case assessments over "commodity-style" credit-market trading. Of course, addressing and "scoring" trades on a case-by-case basis can be expected to impose significant transactions costs on regulator-approved trading that may prevent trading.[21]

The trade offs between reducing environmental risks by increasing trade auditing and verification and the associated increase in transaction costs are extremely important in evaluating the potential of nutrient credit trading. Nutrient trading proponents who base their support primarily on theoretical justifications tend to envision decentralized "cap-and-trade" schemes with many buyers and sellers exchanging standardized units, e.g., pounds of N or P, subject to third-party verification and enforcement.[22] Such trading systems would have relatively low transactions costs. However, it seems that those proponents who are attempting to make these trading systems work on the ground are being forced to deal with "regulator-approved" trading that involves contracts that address specific circumstances.

For example, based on our review, a typical regulator-approved trade involves a point source who is seeking a permit for new waste treatment capacity, attempting to round up commitments for an appropriate number of offset credits from other point or nonpoint sources, and then seeking approval of the accumulated portfolio of offsetting activities from the permitting authority. If the point source is successful, the commitment to achieve the offsets is usually incorporated into new permit requirements with the liability for nonperformance resting with the point source. Since the point source usually faces the cost of performing additional waste treatment at the plant site if the nonpoint sources do not perform as expected, these ad hoc transactions can put the point source at significant risk. Since point source operators are generally not knowledgeable about agriculture and land management practices, they must frequently rely on outside expertise and possibly a brokering agent to develop trades with nonpoint sources. This can add significantly to transactions costs. Transactions costs and trade risks can be especially high in situations where regulatory authorities have few ex ante criteria for establishing "tradable" credits, or where there is potential for political pressure to discourage permitting authorities from approving trades that "allow businesses to buy their way out of their responsibilities to reduce pollution."

Under existing circumstances, in other words, attempting to engage in trades with nonpoint sources can be risky and expensive to point sources. The full cost of realizing offsets through such trades includes not only the amount that must be paid to the nonpoint source to undertake activities that reduce nutrient discharges, but also the costs of developing and exercising the trade, verifying outcomes, accepting risks, and so on. These are often higher to the point source than the cost of meeting permitting requirements by on-site discharge reductions. The effective cost of achieving nutrient discharge offsets by purchasing credits is also adversely affected by the widespread use of trading ratios that increase

19. Information about how controllable and uncontrollable site and landscape conditions affect pasture, rangeland, and grazing operations BMPs is available at EPA's agriculture compliance assistance website *at* http://www.epa.gov/agriculture/anprgbmp.html (last visited Feb. 19, 2003).

20. The effects of landscape and "waterscape" characteristics on the downstream environmental consequences of nutrient discharges are discussed, and related references are provided, at EPA's ecoregional nutrient criteria website *at* http://www.epa.gov/waterscience/criteria/nutrient/ecoregions (last visited Feb. 19, 2003).

21. If these transactions costs are borne by taxpayers in general rather than the parties involved in the offset contracts they may not inhibit trading. However, these transactions costs reduce the economic gains from trade regardless of who pays them and they will affect the acceptability of trading.

22. The economic gains that most market advocates associate with market-based trading rely on competition among many buyers and sellers. In some watersheds there may be too few buyers or too few sellers to have competition. The existence of a few bilateral offset agreements in such watersheds, although they may reduce costs to one party and generate net income to the other, is not evidence that market-based trading is viable in those watersheds or anywhere else.

the number of credits a point source must purchase to offset discharges.

The Use of Trading Ratios

In many ways point source/nonpoint source trading is like trading a product for a service. A pound of N emissions per year is allowed by a point source (the product) in return for a commitment by a land owner to adopt and maintain one or more land management practices that are expected to reduce N emissions by an equivalent one pound of N per year (the service). It has not escaped the notice of those who are concerned about water quality that such trades, although they may result in cost savings to point sources and help nonpoint sources recoup treatment costs, do not actually result in any net change in overall nutrient discharges. Moreover, since the potential for a land management changes to reduce "edge-of-farm" nutrient emissions is far less certain than the "end-of-pipe" nutrient emissions from a point source, the expected (risk-adjusted) outcome of such trades, if they are allowed on a pound-for-pound basis, is an expected decline in water quality. In order to have trading systems that result in net reductions in expected nutrient discharges, and to take account of risks, most existing nutrient trading programs employ "trading ratios." These ratios require the "uncertain value" of the nutrient discharge reductions from the nonpoint source to be greater than the "certain value" of the point source discharge they are intended to offset.

Typical trading ratios are in the range of 3:1 or 4:1, reflecting trade rules that require point sources to buy credits associated with expected nonpoint discharge reductions of three or four pounds of N for each pound of N they are allowed to discharge.[23] Although these trading ratios may be a useful way to account for the inherent riskiness of these trades they provide yet another economic disincentive for point source dischargers to engage in point/nonpoint trading. Trading ratios of 3:1 or 4:1, in effect, increase the cost of purchasing credits to offset a unit of point source discharge by 300% or 400% over the cost of achieving an offset on a one-for-one basis. Some observers claim that higher trading ratios increase the demand for credits by increasing the number credits that must be purchased to offset a given level of discharge. As the following section illustrates, however, the opposite is usually the case. Higher trading ratios reduce the economic value of a credit (the treatment costs it displaces) and, all other things equal, make it more cost-effective for point sources to treat waste on-site rather than purchasing credits.

Early Indicators of Trading Problems

We initially focused our research on the institutional problems that trade regulators can be expected to face as they attempt to score and manage trades.[24] However, as we reviewed experiences with actual trading programs we had one clear indication that the obstacles inhibiting nutrient credit trading in the United States were probably related to supply-side or demand-side problems, more than institutional problems. The clue was that so few buyers and sellers have tried to take advantage of early opportunities to even experiment with trading. In the early stages of other types of environmental trading, such as wetland mitigation trading and carbon sequestration trading, the most common problem has been too many buyers and sellers attempting too many "wildcat"[25] trades before regulatory institutions were in place to validate them.[26]

In the case of nutrient trading the situation is reversed. Buyers and sellers have not been willing to enter into trades even in situations where trade regulators seem to have been extremely flexible and supportive of "demonstration" or "prototype" trades. Based on the observation that buyers and sellers were not choosing to participate in early trading regardless of the institutional setting, even for purposes of public relations, we decided to focus our attention less on the institutional and technical issues related to managing trades, and more on the underlying forces affecting the supply and demand for nutrient offset credits. The following section describes the factors that affect the supply and demand for nutrient credits and how they can be expected to influence the future of nutrient credit markets.

A Brief History of Nutrient Credit Trading

The U.S. Policy Context

Regional trading systems that allow point source nutrient dischargers to meet nutrient reduction targets by purchasing "credits" from nonpoint nutrient dischargers have been promoted by economists for almost 20 years.[27] The environmental community has been talking seriously about using such trading systems to deal with agricultural water pollution problems for at least 10 years.[28] Recent advocates of nutrient credit trading suggest that it should be the centerpiece of regional strategies to improve water quality,[29] that it has potential to help reduce incidence of "hypoxia" in coastal

23. Trading ratios are also referred to in some cases as "compensation ratios" or "mitigation ratios." They are used routinely in wetland mitigation to account for differences in the timing, level, and riskiness of expected gains and losses from trades. *See* King & Wainger, *supra* note 15.

24. This focus on institutional problems was intended to draw lessons from wetland mitigation and "early" carbon sequestration credit trading which involved "scoring" and verification problems and risk issues that are similar to those expected to be encountered with nutrient credit trading.

25. "Wildcat trades," is a term borrowed from the oil industry ("wildcat rigs") and was used in the early years of wetland mitigation trading to refer to speculative trades that were not sanctioned by regulatory authorities. They were undertaken in most cases to increase political pressure on regulatory authorities to grant permit approval.

26. In the absence of any "official" trade scoring criteria, for example, early "unofficial" carbon sequestration credit trades can be based on whatever criteria are agreeable to buyers and sellers. Buyers and sellers in these markets are in a position to "brand" themselves in emerging environmental markets by becoming involved in these trades. As a result they have a natural tendency to use criteria that make their trades look highly favorable.

27. Any environmental economic text from as far back as the 1980s includes sections that describe the benefits of trading. *See especially* W.J. Baumol & W.E. Oates, The Theory of Environmental Policy (2d ed. 1988); D.W. Pierce & R.K. Turner, Economics of Natural Resources and the Environment (1990).

28. Paul Faeth, Fertile Ground: Nutrient Trading's Potential to Cost Effectively Improve Water Quality (World Resources Inst. 2000), *available at* http://www.nutrientnet.org (last visited Feb. 19, 2003).

29. *See* Environmental Defense Fund, Proposal for Nitrogen Trading in Long Island Sound (1998); World Resources Institute, Market-Based Incentives and Water Quality (1999), *available at* http://www.igc.org/wri/incentives/feath.html (last visited Feb. 19, 2003); Faeth, *supra* note 28.

waters,[30] could help eliminate the huge "dead zone" in the Gulf of Mexico,[31] and could be an effective market-based approach to restoring the health of the Chesapeake Bay.[32]

By now, most interested parties are convinced that nutrient credit trading (if it can be made to work) would be more politically acceptable than nutrient taxes, more effective than education and exhortation, and less costly and more sparing of public funds than increasing the "green payments" to farmers for improving their nutrient management practices. Of course, these trading systems do, in effect, result in increased "green payments" to farmers, except that the payments are made by point source dischargers and their customers, rather than by taxpayers at large.

In recent years, EPA has published a series of policy papers offering institutional and technical guidelines to help state and regional government agencies and nongovernmental organizations develop nutrient trading systems.[33] Many states have working groups, some in place for many years, developing prototype nutrient credit trading systems.[34] Some environmental groups such as the World Resources Institute (WRI) and Environmental Defense (ED) have been aggressively promoting nutrient trading between point and nonpoint sources, and WRI has initiated a pilot online nutrient trading system to facilitate trading around the country.[35]

To appreciate the challenges and opportunities related to nutrient credit trading it is useful to understand how interest in this approach evolved. The CWA was enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[36] The initial focus of the CWA was the control of point source pollution. By 1990, over 87% of major municipal facilities and 93% of major industrial facilities were in compliance with technology-based water pollution reduction standards that were established as part of the national pollution discharge elimination system (NPDES). Nonetheless, by 1998, water quality in 39% of the nation's assessed river and stream miles, 45% of its assessed lake and pond acreage, and 51% of its assessed estuarine areas was still below the levels required to support their "designated uses," e.g., drinking, fishing, or swimming.[37] The CWA requires that where technology-based permitting of point sources, e.g., treatment requirements, fails to achieve water quality standards, states must shift to water quality-based permitting. This often takes the form of emission standards on point source dischargers and aggregate load limits based on a TMDL for particular water bodies, e.g., lakes, tributaries, etc.[38]

Annual point source water quality control costs in the United States during 1997 were estimated to be $14 billion for the private sector and about $34 billion for the public sector.[39] It is generally accepted that point source dischargers, e.g., municipal wastewater facilities, are already employing whatever low-cost options are available to them to reduce nutrient discharges into the nation's waters. For most of them, making additional reductions in nutrient discharges would be extremely costly. In many watersheds it is also generally accepted that nonpoint sources, e.g., farms, are responsible for most remaining nutrient problems, and that the costs to farmers of reducing nutrient discharges are substantially lower than the cost of additional point source nutrient discharge reductions.[40]

There are stark political and economic trade offs associated with regulatory decisions aimed at achieving further nutrient discharge reductions by targeting either point or nonpoint dischargers. On the one hand, further restricting nutrient discharges by point sources will be costly to them, and to their residential and industrial customers, mostly in urban and suburban areas. This is also unlikely to achieve water quality standards in the many watersheds where nonpoint source discharges are the primary source of the problem. On the other hand, further restricting discharges by nonpoint sources, in particular by farmers, is politically unpopular and can be difficult to enforce. As a result of these problems the EPA, some states, a few environmental groups, and many economic and policy think tanks have been promoting a third option: point/nonpoint nutrient credit trading.[41] This is expected to reduce the cost of additional reductions by point sources and to provide additional incentives for nonpoint sources to engage in better nutrient management practices without imposing any unpopular new restrictions on them. It is generally recognized that opportunities to engage in this type of trading would have little or no impact in watersheds where the vast bulk of nutrient impairment results from agriculture sources and point sources are few and small.

Most of the nutrient trading schemes being proposed and developed in the United States are modeled after regional air emission credit trading programs that are generally viewed as having been successful at reducing air pollution control costs and allowing the attainment of more stringent regional air pollution control targets.[42] Most recently, nutrient credit

30. *See* Otto Doering et al., Evaluation of the Economic Costs and Benefits of Methods for Reducing Nutrient Loads to the Gulf of Mexico (Purdue Univ., Dep't of Agric. Econ. 1999).

31. *Id.*

32. *See* E. Bacon & C.N. Pearson Jr., Nitrogen Credit Trading in Maryland: A Market Analysis for Establishing a Statewide Framework (2002).

33. U.S. EPA, Effluent Trading in Watershed Policy (1966) [hereinafter U.S. EPA, Effluent Trading]; U.S. EPA, Proposed Water Quality Trading Policy (2002) [hereinafter U.S. EPA, Proposed Policy]. *See also* U.S. EPA, Wetlands, Oceans & Watersheds, *Total Maximum Daily Loads*, *at* http://www.epa.gov/owow/tmdl/policy.html (last visited Feb. 19, 2003).

34. For information about the status of specific nutrient trading efforts, contact the individuals listed in Figure 1.

35. *See generally* Faeth, *supra* note 28.

36. 33 U.S.C. §1251(a), ELR Stat. FWPCA §101(a).

37. U.S. EPA, National Water Quality Inventory Report to Congress (2002), *available at* http://www.epa.gov/owow/oceans/305b.html (last visited Feb. 19, 2003).

38. A thorough discussion of the economic aspects of proposed TMDL rules under the CWA is provided in James Boyd, *The New Face of the Clean Water Act: A Critical Review of the EPA's New TMDL Rules*, 11 Duke Envtl. L. & Pol'y F. 39 (2000).

39. *See* U.S. EPA, Proposed Policy, *supra* note 33.

40. In the Chesapeake Bay watershed, for example, recent results show that agriculture contributes 40.8% of nitrogen and 47.0% of phosphorus inputs. *See* Chesapeake Bay Program, *supra* note 2. A recent study of nutrient discharge reduction costs in the Chesapeake region shows that "average cost per pound to reduce nitrogen ranges from $5 to $110." Bacon & Pearson, *supra* note 32, at 2-15.

41. U.S. EPA, Effluent Trading, *supra* note 33; U.S. EPA, Proposed Policy, *supra* note 33; Faeth, *supra* note 28; T. Young & C. Congdon, Plowing New Ground: Using Economic Incentives to Control Water Pollution From Agriculture (Environmental Defense Fund 1994); Bacon & Pearson, *supra* note 32.

42. Information about the success of U.S.-based air pollution trading and banking is available at the U.S. EPA air trading website, http://www.epa.gov/airmarkets/tmdl/policy.html (last visited Feb. 19, 2003).

trading is being promoted within the context of TMDLs that are being established to limit discharges into water bodies across the nation.[43] However, such trading could also occur in cases where persistent water quality problems force regulators to reissue discharge permits with restrictions that require point sources to achieve discharge reductions beyond what they could achieve with commonly available technologies. Allowing these plants to meet more stringent permit requirements by purchasing offset credits may be the only way to allow them to remain operating until they can upgrade or replace their facilities.

A recent study undertaken by EPA estimates that the annual national cost of TMDLs that would allow water bodies to meet their designated use standards, e.g., fishable, swimmable, drinkable, would be $900 million less with pollution credit trading than without pollution credit trading.[44] However, the economic payoff from trading depends, to a significant extent, on the limits that are imposed on dischargers. For example, it has been estimated that if dischargers in the Mississippi River drainage were required to reduce waste sufficiently to ameliorate the Gulf of Mexico's "Dead Zone," the opportunity to engage in point/nonpoint source nutrient trading would save point sources approximately $14 billion.[45] A study of how nitrogen credit trading in Maryland would affect the cost of reducing nitrogen discharges 62.5% below 1985 levels estimated savings of between $9 million and $12 million annually, with differences depending on the type of trading schemes being simulated.[46]

In the majority of conceptual studies and quantitative simulations of prospective U.S.-based nutrient trading systems, most of the cost savings result from assuming that point sources with high incremental nutrient reduction costs will buy credits from nonpoint sources with lower nutrient reduction costs. However, this assumption relies on two underlying assumptions that are made, either implicitly or explicitly, in most of these studies and may not be valid. The first is that nutrient credit markets will operate efficiently with relatively low transactions costs that allow buyers and sellers to share most of the potential economic gains from trading. The second is that those buyers and sellers who could potentially gain from trading will participate in trading.

The evidence presented in the previous section suggests that despite a proliferation of "active" trading programs, very few potentially eligible buyers and sellers have elected to participate, and also that the few trades that have taken place, because they were designed to meet specific circumstances, entailed inordinately high transactions costs.[47] To understand why these conditions may represent long-term obstacles to trading, and not just temporary growing pains, it is useful to consider the very significant differences between pollution credit markets that result from policy decisions by governments and conventional markets for goods and services that result from the self-interested decisions of independent buyers and sellers.

In 1998, the Great Lakes Trading Network was established to provide a forum for the exchange of information about water quality trading programs in Canada and the United States; it lists 13 affiliated programs and projects.[48] However, in 1999, an EPA review of what is actually happening on the ground identified approximately 37 "active" nutrient trading systems in the United States, including some that have been operating for over 10 years.[49]

Water pollution trading was also introduced as an "alternative management measure" to reduce the effects of nonpoint source pollution on coastal waters as part of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990.[50] From what we can determine, no trading has occurred in the implementation of state nonpoint source programs under the CZARA. The states of Maryland and Virginia are developing "tributary strategies" for the Chesapeake Bay that will establish nitrogen discharge allocations for point sources, and are involved in a baywide effort to develop a trading system that will involve both point sources and nonpoint sources.[51] The current plan is to have teams of scientists establish an allowable discharge level for each tributary, and then have tributary strategy teams allocate discharge rights to point sources based on those limits. Trading will presumably allow point sources to meet their assigned limits, at least in part, by purchasing offset credits. There have been significant delays in establishing the overall levels of allowable discharge for each tributary; they are now scheduled to be established in the spring of 2003. Because of this delay the tributary strategy teams have not attempted to assign the initial endowments of discharge rights to point source dischargers in any tributary. Despite considerable interest in nutrient trading in the Chesapeake Bay area, the institutional conditions necessary for nutrient trading between point and nonpoint sources in the area is likely to be years away.[52]

Reports About Actual Nutrient Trading

A report issued by WRI indicates that there are three point/nonpoint source trading programs currently operating in the United States—Lake Dillon, the Cherry Creek Basin, and the Tar Pamlico Basin.[53] In the case of Lake Dillon, in Colorado, a few trades have occurred that involve nonpoint measures to contain phosphorus runoff from town and ski

43. Federal and state programs to implement TMDLs are changing constantly. One convenient way to determine the status of voluntary and regulatory activities to achieve TMDL goals in various watersheds is to consult the U.S. EPA, Wetlands, Oceans & Watersheds, *Total Maximum Daily Loads*, *at* http://www.epa.gov/owow/tmdl/policy.html (last visited Feb. 19, 2003).

44. *See* U.S. EPA, Proposed Policy, *supra* note 33.

45. Doering et al., *supra* note 30, at 43.

46. Bacon & Pearson, *supra* note 32, at vi.

47. Transactions costs will decline as scoring methods improve, and as numbers of trades increase. However, the transactions costs associated with regulator-approved bilateral trades that are approved based on ad hoc criteria are always likely to be higher than those associated with market-style trading of standardized credits.

48. Information about these programs and projects is available at http://www.kieser-associates.com (last visited Feb. 19, 2003).

49. U.S. EPA, A Summary of U.S. Effluent Trading and Offsets Projects (1999).

50. 16 U.S.C. §1455b(g), ELR Stat. CZMA §306b(g).

51. Bacon & Pearson, *supra* note 32, at 1-2.

52. Reports describing the principles being developed to guide the Chesapeake Bay nutrient credit trading and the results of meetings with various stakeholder groups on this topic can be downloaded from the Chesapeake Bay Program website at http://www.chesapeakebay.net/trading.htm (last visited Feb. 19, 2003).

53. Faeth, *supra* note 28, at 15.

areas.[54] In Colorado's Cherry Creek Basin, there have been a few small phosphorus trades involving practices for controlling runoff from construction and site development but, as of 2000, this small level of trading has resulted in no prices being established for the exchange of credits in the basin, and no additional trades.[55] North Carolina's Tar Pamlico Basin is probably the most often cited example of an established point/nonpoint source trading program. In that case an association of point sources was expected to be the major source of demand for nonpoint credits supplied by hog farmers. So far, however, the point sources have chosen to treat their own waste rather than purchase credits and, to our knowledge, no trades have taken place between point sources and nonpoint sources as part of that program.[56]

The only identified instance of trading in the United States between a point source and agricultural sources occurred in Minnesota in 1997.[57] That trade, which took place before the establishment of any official trading system, involved the Rahr Malting Company obtaining a permit to build a wastewater treatment facility on the lower Minnesota River in exchange for financing upstream agricultural practices to reduce farm runoff. These practices included soil erosion controls, livestock fencing, rotational grazing, critical-area set-asides, and creating/restoring wetland systems.[58]

A new point/nonpoint source trading program that is closer to the type of credit-based trading programs most observers have been expecting to evolve in the United States has surfaced in Canada on the South Nation River.[59] In that situation any new point source faces a zero phosphorus discharge limit that they can meet by totally eliminating their phosphorus discharges, or by purchasing phosphorus credits from farmers at a 4:1 ratio (four pounds of reduction in farm discharges for each pound of point discharge allowed). The credits are generated by landowners undertaking such practices as manure and wastewater management, conservation tillage, constructing buffer strips, or implementing on-farm nutrient management plans. A community-based nonprofit organization called the South Nation Conservation (SNC) is acting as a broker between the point sources and landowners in the watershed, and is assisting landowners by providing "grants" to help farmers finance the implementation of credit-producing practices. Presumably SNC receives funding for its grants from new point source dischargers who are seeking permits.

54. C. Paulson et al., Phosphorus Credit Trading in the Cherry Creek Basin: An Innovative Approach to Achieving Water Quality Benefits (2000).

55. *Id.* at 6-10.

56. An economic analysis that examines the theory of pollution credit trading and its application in the Tar-Pamlico nutrient-trading program in North Carolina appears in D. Hoag & J. Hughes-Popp, *Theory and Practice of Pollution Credit*, 19 Rev. Agric. Econ. 252 (1997).

57. Recently, the Great Lakes Trading Network reported that "contrary to popular belief" the Tar-Pamlico nutrient trading system has experienced point/nonpoint trades. Whether these trades were meaningful or merely undertaken to provide evidence that this long-established trading system is not a complete failure remains to be determined.

58. Faeth, *supra* note 28, at 21.

59. Dennis O'Grady & Mary Ann Wilson, Phosphorus Trading in the South Nation River Watershed, Ontario, Canada (2002) (unpublished manuscript, on file with authors).

Determinants of Supply and Demand

Necessary Conditions for Trading

The three necessary conditions for nutrient credit trading are illustrated in Figure 3; they include willing buyers, willing sellers, and trade regulators willing to approve the validity of the trade. These conditions can and do exist outside of any formal market for nutrient credits. In the illustration of the typical trade described in the previous section, for example, a point source negotiates many bilateral agreements with other point and nonpoint sources without participating in any established credit market. Such agreements constitute nutrient offset trading, but they do not establish that the basis exists for market-based nutrient credit trading.

Necessary Conditions for Market-Based Trading

The conditions necessary for nutrient offset trading to take place through formal credit markets, and thereby result in the many benefits associated with market-based trading, are depicted in Figure 4. Markets require that units of exchange be standardized, in this case in terms of offset equivalency, and that the supply and demand curves for those standardized units intersect. It may be within the power of regional organizations attempting to develop and manage a nutrient credit trading program to achieve the first goal, standardized credits. However, the factors influencing the behavior of buyers and sellers and overall supply and demand conditions, as shown in Figure 4, are largely outside of their control. The lower three graphs in Figure 4 illustrate three sets of credit market conditions that could exist in a region: the *ideal market*, in which supply and demand curves intersect at a level of trading that results in significant aggregate cost savings, the *marginal market*, in which supply and demand curves intersect at a low level of trading that result in little aggregate cost savings, and the *nonexistent market*, in which the supply and demand curves do not intersect and no trading takes place. Experience so far suggests that inherent supply and demand conditions in most locations where attempts have been made to develop credit markets fall into the last category. Supply and demand conditions have not been adequate to support any trading at all.

Bilateral Trading Versus Market-Based Trading

So far we have evidence of a few regulator-approved nutrient offset contracts in a few regions. The existence of these contracts should not be interpreted as any indication that the necessary conditions exist for market-based point/nonpoint nutrient credit trading. For example, the agreements that form the portfolio of approved nutrient discharge offsets in those cases may include all of the available low-cost offsets that are available in the region. Similarly, the point source discharger entering into those agreements may be the only entity in the watershed in need of offsets, and may have all offset needs satisfied by this one agreement. Far from establishing that further trading is possible, in other words, these contracts may have resulted in the depletion of the supply of potential credits and/or the depletion of any potential demand for credits, making future market-based trading in the region less likely. We have not examined overall supply and demand conditions in the regions that have experienced one or more nutrient discharge offset trades. However, the fact that so few subsequent trades have occurred in those regions suggests that these few early trades may, in fact, have exhausted either the potential supply or the potential demand for nutrient discharge rights in those regions.

Determinants of Credit Supply

The *supply* of nutrient credits by nonpoint sources (how many credits they will offer at any given credit price) depends on their nutrient management costs, and also on how the baseline for producing valid nonpoint credits is established, as shown in Figure 5. Baseline conditions can be expected to exclude the selling of credits based on discharge reductions that result from changes in practices for which the landowner has already been paid or would be undertaking anyway, or are already required by law or established by a TMDL. As more nutrient management practices are required by state regulations,[60] or to meet Farm Bill Conservation Compliance requirements[61] or have been "paid for" under other voluntary "green payment" programs,[62] fewer additional activities are available for land managers to use for generating tradable credits. As Figure 5 illustrates, legal requirements and requirements of other government programs are usually met using the least cost nutrient-reduction practices. This makes "additional" nutrient reductions, those above the baseline, relatively expensive, and means that such credits will only be supplied by nonpoint sources at relatively high credit prices.

The point here is not to suggest that state laws restricting nonpoint nutrient discharges (particularly from animal feeding operations) and the expansion of "green payment" programs that pay farmers to undertake on-farm practices that reduce nutrient discharges should be changed to improve prospects for nutrient credit trading. However, because they change the baseline for producing credits, these programs, in effect, compete with emerging nutrient credit markets for supplies of low-cost nonpoint source nutrient reductions, resulting in a lower supply and higher price of credits in these emerging markets. Expanding government programs always result in farmers implementing the easiest and most well-known practices for reducing nutrient management practices first. This also means that those practices that become eligible for producing tradable credits tend to be more difficult to document and validate, and often more risky, which further drives up the cost of providing them. Trading such credits frequently involves more risks, which often means more political resistance and higher trading ratios. These conditions increase transactions costs and discourage many nonpoint sources from being credit suppliers.

Some farmers also believe that engaging in such trading poses additional risks to them by establishing a justification for the government to reduce or eliminate "green payments" and by requiring that someone establish the effectiveness of on-farm nutrient management practices that could later be required by law. Note also that engaging in such trades requires farmers and other potential credit suppliers to admit to being "nutrient polluters" and that the money they can earn by supplying credits is directly related to the amount of nutrients they can prove they would discharge under "without trade" conditions. The risks of drawing this much attention to the level of nutrient discharges and the low cost of reducing them provide another disincentive for nonpoint sources to engage in this type of trading.

Figure 5 summarizes the effects of some of these factors on expected credit supplies from nonpoint sources. Because of baseline restrictions the supply of credits from nonpoint sources reflected in S does not begin until N_2. Because of transaction costs S reflects a smaller expected supply of credits at any given price than one would expect based purely on treatment costs.

Determinants of Credit Demand

Demand for nutrient credits by a point source discharger depends on the difference between the cost of further on-site waste treatment and the cost of buying enough nonpoint source credits to offset further discharges. However, while further treatment costs may be relatively high the cost savings from purchasing credits will depend, in large measure, on the prescribed trading ratio (how many credits must be purchased to offset a discharge) and the transactions costs involved in recruiting trading partners, gaining regulatory approval, and so on. Because point sources may be liable to reduce on-site discharges if the nonpoint credit provider does not perform as expected, the costs of entering into a point/nonpoint contract also need to reflect a significant amount of trade risk.

Figure 6 illustrates the demand for credits at various credit prices by point source dischargers who face a particular set of nutrient discharge restrictions (caps). The most significant factors affecting demand for emission offsets, of course, is the level of those caps and how they are enforced. However, converting the initial derived demand for an emission offset at a given cost to the demand for offset credits offered at a given price requires at least three adjustments.

First, the buyer must adjust the economic value of the credit (how much the buyer is willing to pay) to account for transactions costs; these include the costs of finding and negotiating with potential credit suppliers, and perhaps monitoring credit producing activities, and validating results. Second, the buyer must factor in the costs associated with accepting liability for trade risks if the nonpoint source does not perform an activity, or if that activity does not result in the expected level of offsets. Third, the buyer must factor in the effects of the trading ratio. A trading ratio of 2:1 or 3:1, for example, requires point sources to purchase two or three credits to offset one pound of point N or P discharge. This reduces the price point sources are willing to pay for a credit by 50% or 66.6% below the price they would pay with a 1:1 trading ratio.

60. For example, the state of Maryland's laws restricting the discharge of nutrients from nonpoint sources, including agricultural lands, are described at http://www.dnr.state.md.us/bay/czm/nps (last visited Feb. 19, 2003).

61. The Farm Bill requires farmers on highly erodible land to implement erosion control practices in order to participate in most federal agricultural programs. See the conservation provisions of the 2002 Farm Bill at http://www.usda.gov/farmbill/conservation_fb.html (last visited Feb. 19, 2003).

62. Through the U.S. Department of Agriculture-operated Conservation Reserve Program (CRP), Conservation Reserve Enhancement Programs (CREP), and the Environmental Quality Improvement Program (EQUIP), farmers receive payments for undertaking land use and land management practices that improve nutrient management and achieve other environmental goals. For information about these programs, see http://www.nrcs.usda.gov/partners/for_farmers.html (last visited Feb. 19, 2003).

Another factor limiting demand for nutrient offset credits is the sentiment among many powerful environmental groups that nutrient regulations should require nutrient discharge reductions by point sources and not allow them to "buy their way out of their responsibilities." Although this may not make economic sense it raises problems and potential risks for point sources who choose to make the purchasing of offset credits a part of the regulatory compliance strategy. This is especially true in the case of early credit trading where the validity of credits purchased now may face mounting political challenges later.

Conclusions and Recommendations

Lessons Learned

Experience so far with water pollution trading in the United States is very limited and involves primarily point source polluters, e.g., municipal wastewater facilities, trading pollution allowances with one another. The *units of exchange* in these trades are relatively easy and inexpensive to measure in physical terms, e.g., pounds of nitrogen or phosphorus. Because these early trades were viewed as learning experiences by traders and trade regulators, the *rules of exchange* that governed them were intentionally flexible and were based primarily on ad hoc criteria and direct negotiations. Achieving water quality goals was only one goal of these early trades; they were also being used as trials to test trading protocols.

Unfortunately, these early experiences with regulator-approved water pollution trading do not provide many insights to help guide the development of the kind of market-based trading systems that will be needed to significantly reduce the cost of achieving water quality goals in most parts of the country. To have any significant effect on costs, these trading systems will need to involve many more traders (credit seekers and credit producers) and many more individual trades. They will also need to involve participants with significantly different nutrient discharge reduction costs. Such trading systems will need to cope with an extraordinary amount of uncertainty about the number of credits associated with activities as diverse as restoring wetlands, constructing forest buffers, building manure sheds, and even planting oyster reefs. The system for scoring trades will also need to take account of differences in the impacts of nutrient reduction activities based on how the activities are managed and on-site characteristics and landscape context. In addition, the trade scoring criteria will need to take account of differences in the effects of pollution loadings and reductions in pollution loadings on water quality and the effects of water quality on fish and other natural resources that are determined by where the discharge allowances and reductions take place in the watershed. Attempting to manage large numbers of such trades using a standard credit scoring method will be difficult. On the other hand, attempting to manage such trades using ad hoc criteria and direct negotiations is likely to be administratively difficult, prone to political abuse, and add significantly to transactions costs.

However, our conclusions are that these institutional obstacles to nutrient trading are largely within the control of those who are designing nutrient credit trading. Because it may make sense to have the taxpayers rather than individual trading partners pay the costs of addressing these institutional obstacles they may not be as formidable as the problems associated with weak supply and demand. We summarize these obstacles as follows:

> *Supply-side obstacles* to nutrient credit trading are significant and are associated with factors that are largely outside the control of those attempting to develop and manage these trading systems. The most significant of these obstacles are expanding federal and state regulatory and subsidy programs that require and/or pay farmers to implement nutrient management practices. Although these programs may be worthwhile and well managed they do affect the viability of credit trading by raising the baseline for scoring nonpoint source credits and thereby reducing the scope of activities that farmers can use to generate nutrient credits.

It may be possible to alleviate this problem by allowing point sources to help pay for more "expensive" on-farm practices in return for credits, or by excluding some required activities from the baseline, if they are not otherwise subsidized. For example, animal feeding operations are becoming subject to increasing regulatory pressure, and large animal feeding operations (defined as concentrated animal feeding operations (CAFOs)) are treated as point sources for regulatory purposes.[63] Waste containment beyond that required in EPA's new regulations (beyond the 25-year/24-hour storm events for beef and dairy and beyond the 100-year/24-hour storm event for poultry, swine, and veal) could be eligible for credit creation. Likewise, elements of required waste management plans, particularly for off-site land application of wastes, could be made eligible for credit creation when they are not fully subsidized by federal or state programs. This could encourage credit earnings via the creation of more extensive buffer systems, or the cessation of local land application of manure, or the processing and shipping the wastes outside of the local area.

Although state nutrient-management requirements and federal cost-sharing and incentive payments for nutrient management practices are potentially worthwhile in terms of overall nutrient abatement, these two types of government programs, in effect, compete with credit markets and greatly reduce the opportunities for farmers to generate credits they can sell in regional nutrient credit markets. Other things equal, farmers are likely to prefer earning income by supplying nutrient credits in relatively permanent markets to earning money through "green payment" programs of uncertain duration that are subject to payment limitations. However, supplying credits requires farmers to admit to being "nutrient polluters" and focuses a great deal of attention on levels of farm nutrient discharges and the cost and effectiveness of control measures. This exposes farmers to risks they do not experience when they accept government "green payments" and may provide justification for re-

63. On December 15, 2002, EPA and the U.S. Department of Agriculture announced a new rule governing nutrient discharges by 15,500 CAFOs. Under the regulations, all large CAFOs will be required to apply for a permit, submit an annual report, and develop and follow a plan for handling manure and wastewater. The rule also requires controls on land application of manure and wastewater, covering all major animal agriculture sectors. For more information, see EPA's CAFO web page at http://www.epa.gov/npdes/caforule (last visited Feb. 19, 2003).

ducing future "green payments" or tightening on-farm nutrient management restrictions.

Demand-side obstacles to nutrient credit trading are the most significant, but are subtler than supply-side obstacles and occur at several levels. All trading systems involve the exchange of rights that in one way or another need to be assigned prior to trading. Although most point source dischargers favor nutrient credit trading in principle, most also oppose (and some claim they will refuse to participate in) point/nonpoint trading that is based on what they believe is an inequitable allocation of pollution rights to nonsource dischargers. They understand that promoters of point/nonpoint trading expect to generate credit demand by tightening discharge restrictions on them and allowing them to "bribe" their way out of these restrictions by buying credits from agricultural interests. Given the contributions they have already made to reduce nutrient discharges, and recognizing that agriculture, not their industry, is frequently the major source of nutrient impairment and receives significant government subsidies to manage their nutrients, such trading strikes them as unfair. Some point out that it is also a violation of the "polluter-pays principle." Their customers, many political and business leaders and some environmental groups, agree with them.

Most point sources are already reducing nutrient discharges to the point that the cost of achieving stricter nutrient discharge reduction targets are significant and, all other things equal, should make them interested in purchasing relatively low-cost credits from nonpoint sources. However, regulatory requirements for them to meet additional nutrient discharge reduction targets do not currently exist, or are not being implemented. Moreover, the political will to support credit trading by further restricting discharges by point sources and allowing them to buy their way out of these restrictions by paying farmers is not politically popular. The expansion of voluntary "green payment" programs inhibits the expansion of credit markets by reducing the potential supply of credits as mentioned above. However, our research suggests that these programs are also adversely affecting the potential demand for credits. There is a widespread sense that creating demand for credits by further restricting point source nutrient dischargers at the same time that nonpoint dischargers face fewer nutrient discharge restrictions and have subsidies available to undertake nutrient management, is unfair. For now, at least, these demand-side issues significantly limit the willingness of point source dischargers to engage in point/nonpoint credit trading and make it unlikely that political leaders will attempt to force them into credit trading by approving further restrictions on them without imposing similar restrictions on nonpoint sources. The implementation of TMDLs in ways that result in what is considered an equitable restrictive load allocation for point sources and nonpoint sources, including agriculture, could help the situation. Of course, it is reasonable to expect that if and when institutional and supply-side obstacles to nutrient credit trading are overcome and opportunities exist for point sources to save money by purchasing credits they will do so regardless of their feelings about the initial endowment of nutrient discharge allowances.

Our conclusion, therefore, is that despite earnest federal, state, and regional efforts to overcome technical and institutional problems, point/nonpoint nutrient credit trading cannot succeed in the United States unless two conditions change. First, there would have to be a substantial increase in federal and state regulatory pressure on point sources to stimulate credit demand. Second, there would have to be a shift in emphasis away from federal and state subsidies of on-farm nutrient management, to stimulate supply. Others can decide whether or not the payoff from taking these steps, in terms of market-driven cost savings or water quality improvements, would be worth the costs. The fact, however, is that such unpopular changes in government policies are not likely to take place any time soon, and certainly not soon enough for nutrient credit trading to contribute in any meaningful way to near-term water quality problems.

For this reason, efforts to make this kind of trading work should be confined to local situations where the gains from trading are large and obvious to potential participants, and should not inhibit policymakers at all levels of government from implementing more promising regulatory and economic-incentive options. It should also be recognized that point source/nonpoint source trading cannot achieve water quality standards in watersheds where nonpoint sources are responsible for the bulk of nutrient discharges and where very large reductions in nutrient loading must be achieved. In such situations point sources are an inadequate lever for achieving water quality standards. To that extent, point/nonpoint nutrient trading cannot and should not be the main component of our national strategy for dealing with regional "overnutrification" problems.

Figure 1
U.S. Current and Pending Nutrient Trading and Offset Projects*
Page 1 Activities

			Focus on Trading	Number of Trades to Date	Allow Point/ Nonpoint
Ref #	Title	Location	N/P/Both		
1	Bear Creek Trading Program	CO	P		Y
2	Blue Plains WWTP Credit Creation	DC & VA	N		N
3	Boone Reservoir	TN	Nutrients		Y
4	Boulder Creek	CO	Ammonia		Y
5	Chatfield Reservoir Study and Trading Program	CO	P		Y
6	Chehalis River Basin	WA	TBD		Y
7	Cherry Creek Basin Trading Program	CO	P	3	Y
8	Chesapeake Bay Nutrient Trading Program	MD	B		Y
9	Clear Creek	CO	TBD		Y
10	Clermont County Project	OH	P		Y
11	Delaware River Basin Trading Simulation	PA	B		Y
12	Fox-Wolf Basin Watershed Pilot Trading Program	WI	P		Y
13	Kalamazoo River Water Quality Trading Demonstration	MI	P		Y
14	Laguna de Santa Rosa	CA	Nutrients		Y
15	Lake Dillon Trading Program	CO	P	2	Y
16	Little Deep Fork	OK	P		TBD
17	Long Island Sound Trading Program	CT	N		Y
18	Lower Boise River Effluent Trading Demonstration Project	ID	P		Y
19	Maryland Nutrient Trading Policy	MD	B		Y
20	Michigan Water Quality Trading Rule Development	MI	B		Y
21	Minnesota River Nutrient Trading Study	MN	P		Y
22	Neuse River Nutrient Sensitive Water Management Strategy	NC	N		Y
23	New York City Watershed Phosphorus Offset Pilot Programs	NY	P		Y
24	Rahr Malting Permit	MN	P	1	Y
25	Red Cedar River Pilot Trading Program	WI	P		Y
26	Rock River Basin Pilot Trading Program	WI	P		Y
27	Sacramento River	CA	TBD		TBD
28	Southern Minnesota Beet Sugar Cooperative Plant Permit	MN	P		Y
29	Tampa Bay Cooperative Nitrogen Management	FL	N		Y
30	Tar-Pamlico Nutrient Reduction Trading Program	NC	B		Y
31	Town of Acton POTW	MA	P		Y
32	Truckee River Water Rights and Offset Program	NV	B		Y
33	Virginia Water Quality Improvement Act and Tributary Strategy	VA	B		Y
34	Wayland Business Center Treatment Plan Permit	MA	P		Y
35	Wicomico River	MD	P		Y
36	Wisconsin Effluent Trading Rule Development	WI	P		Y
37	Yakima River Basin	WA	TBD		TBD

* Source: Compiled from EPA documents (especially Environomics, 1999 and EPA, 1996) and phone surveys and web searches.

Figure 1 (cont.)
U.S. Current and Pending Nutrient Trading and Offset Projects*
Page 2 Contacts

Ref #/Title	Contact	Phone/e-mail	Website
1 Bear Creek Trading Program	Dick Parachini, CO Dept. of Public Health and Environment	(303) 692-3500dick.parachini@state.co.us	www.epa.gov/surf2/hucs/11040005
2 Blue Plains WWTP Credit Creation www.epa.gov/surf2/states/DC	Walter Bailey, DC Water & Sewer Authority		(202) 645-6299
3 Boone Reservoir	EPA Office of Policy, Planning & Evaluation		(202) 260-5363
4 Boulder Creek	Denver Regional Council of Governments	(303) 455-1000	
5 Chatfield Reservoir Study and Trading Program	Dick Parachini, CO Dept. of Public Health and Environment	(303) 692-3500dick.parachini@state.co.us	www.epa.gov/surf2/hucs/10190002
6 Chehalis River Basin	Washington Dept. of Ecology	(360) 407-3600	
7 Cherry Creek Basin Trading Program	Dick Parachini, CO Dept. of Public Health and Environment	(303) 692-3500dick.parachini@state.co.us	www.epa.gov/surf2/hucs/10190003
8 Chesapeake Bay Nutrient Trading Program	Allison Wiedeman, U.S. EPA Chesapeake Bay Program Office	(410) 267-5733wiedeman.allison@epa.gov	www.chesapeake.net
9 Clear Creek	Clear Creek Watershed Forum	(303) 692-3513	
10 Clermont County Project	Wayne Gorski, EPA Region 5	(312) 886-0140gorski.wayne@epamail.gov	www.epa.gov/surf2/hucs/05090202
11 Delaware River Basin Trading Simulation	Charles Marshall, Philip Services Corp.	(215) 643-5466cmarshall@philipinc.com	www.epa.gov/surf2/hucs/02040104
12 Fox-Wolf Basin Watershed Pilot Trading Program	Mary Anne Lowndes, WI Dept. of Natural Resources	(608) 261-6420lowndm@dnr.state.wi.us	www.epa.gov/surf2/ahr/14
13 Kalamazoo River Water Quality Trading Demonstration www.epa.gov/surf2/ahr/75	David Batchelor, MI Dept. of Envtl. Quality		(517) 373-2677batcheld@state.mi.us
14 Laguna de Santa Rosa	Dave Smith, EPA Region 9	(415) 744-2012	
15 Lake Dillon Trading Program	Bill McKee, CO Dept. of Public Health and Environment	(303) 692-3500bill.mckee@state.co.us	www.epa.gov/surf2/hucs/14010002
16 Little Deep Fork	Richard Smith, Indian Nations Council of Governments	(918) 584-7526	
17 Long Island Sound Trading Program	Mark Tedesco, EPA L.I. Sound Office	(203) 977-1541tedesco.mark@epamail.epa.gov	www.dep.state.ct.us/wtr
18 Lower Boise River Effluent Trading Demonstration Project www.epa.gov/surf2/hucs/17050114		Clair Schary, EPA Region 10	(206) 553-8514schary.claire@epamail.epa.gov
19 Maryland Nutrient Trading Policy	Virginia Kearney, MD Dept. of the Envt.	(410) 631-3574vkearney@mde.state.md.us	www.epa.gov/surf2/states/MD
20 Michigan Water Quality Trading Rule Development http://www.deq.state.mi.us/swq/	David Batchelor, MI Dept. of Environmental Quality		(517) 373-2677batcheld@state.mi.us trading/temp5x.htm
21 Minnesota River Nutrient Trading Study	Paul Faeth, World Resources Institute	(202) 729-7688Paul@wri.org	www.epa.gov/surf2/ahr/30
22 Neuse River Nutrient Sensitive Water Mgmt. Strategy	Dave Goodrich, NC DENR	(919) 733-5083dave.goodrich@ncmail.net	www.h2o.enr.state.nc.us/wqhome.html
23 NYC Watershed Phosphorus Offset Pilot Programs www.epa.gov/surf2/hucs/02030101	James Benson, NYC Dept. of Environmental Protection		(914) 742-2034Jbenson@valgis.dep.nyc.ny.us
24 Rahr Malting Permit www.epa.gov/surf2/ahr/30	Wayne Anderson, Minn. Pollution Control Agency	(651) 296-7323wayne.p.anderson@pca.state.mn.us	
25 Red Cedar River Pilot Trading Program	Mary Anne Lowndes, WI Dept. of Natural Resources	(608) 261-6420lowndm@dnr.state.wi.us	www.epa.gov/surf2/hucs/07050007
26 Rock River Basin Pilot Trading Program	Mary Anne Lowndes, WI Dept. of Natural Resources	(608) 261-6420lowndm@dnr.state.wi.us	www.epa.gov/surf2/hucs/07050002

Figure 1 (cont.)

U.S. Current and Pending Nutrient Trading and Offset Projects*
Page 2 Contacts

Ref #/Title	Contact	Phone/e-mail	Website
30 Tar-Pamlico Nutrient Reduction Trading Program	Rich Gannon, NC DENR	(919) 733-5083rich_gannon@h2o.enr.state.nc.us	www.h2o.enr.state.nc.us/nps/tarp.htm
31 Town of Acton POTW	Jane Downing, EPA Region 1	(617) 918-1571downing.jane@epa.gov	www.epa.gov/surf2/hucs/01070005
32 Truckee River Water Rights and Offset Program	Pyramid-Winnemucca Lakes		www.epa.gov/surf2/hucs/16050103
33 Va. Water Quality Improvement Act and Tributary Strategy	John Kennedy, VA Dept. of Envtl. Quality	(804) 698-4312jmkennedy@deq.state.va.us	www.epa.gov/surf2/states/VA
34 Wayland Business Center Treatment Plan Permit	Jane Downing, EPA Region 1	(617) 918-1571downing.jane@epa.gov	www.epa.gov/surf2/hucs/01070005
35 Wicomico River	EPA Off. of Policy, Planning, and Evaluation	(202) 260-5363	
36 Wisconsin Effluent Trading Rule Development	Mary Anne Lowndes, WI Dept. of Natural Resources	(608) 261-6420lowndm@dnr.state.wi.us	www.epa.gov/surf2/states/WI
37 Yakima River Basin	Battelle's Pacific Northwest Laboratory	(509) 372-4342	

*Source: Compiled from EPA documents (especially Environomics, 1999 and EPA, 1996) and phone surveys and web searches.

Figure 2
Farm Management Practices That May Result in Tradable Nonpoint Source Nutrient Credits*

Animal Waste Management (e.g., ponds, lagoons, tanks)
Conservation Tillage (e.g., no till, low till)
Cover Crops (e.g., small grains planted in fall)
Nutrient Management (amount, placement, timing, and application of fertilizer, sludge)
Retirement of Highly Erodible Land
Runoff Control
Erosion Control
Stream Protection With Fencing
Stream Protection Without Fencing (e.g., troughs away from streams)
Forest Conservation
Forest Harvesting Practices
Forested Buffers
Grassed Buffers
Nonstructural Shore Erosion Control (e.g., grass)
Structural Shore Erosion Control (e.g., riprap)
Tree Planting (e.g., away from rivers and streams)
Enhanced Stormwater Management
Erosion and Sediment Control (e.g., regulatory)
Stormwater Management Conversion
Stormwater Management Retrofits

* These on-farm best management practices (BMPs) were identified for a tributary of the Patuxent River basin in the Chesapeake Bay.

Figure 4

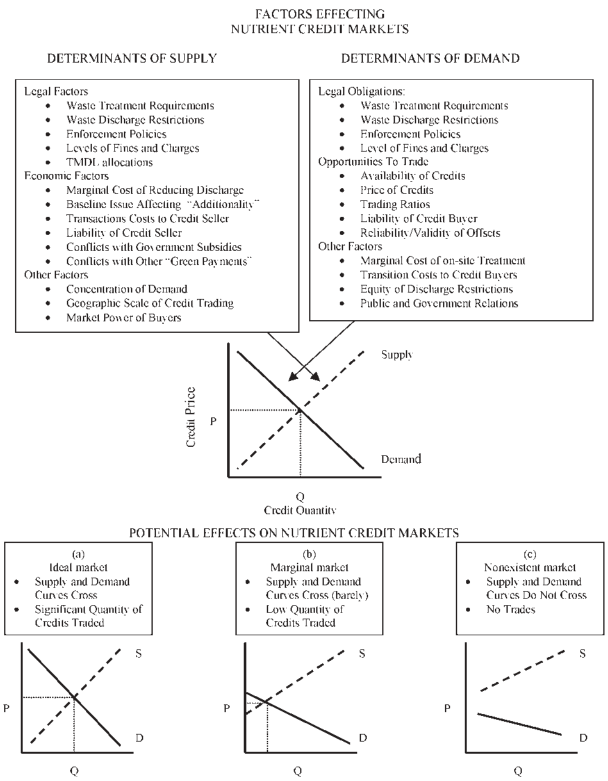


Figure 3
NECESSARY CONDITIONS FOR A POINT/NONPOINT NUTRIENT CREDIT TRADE

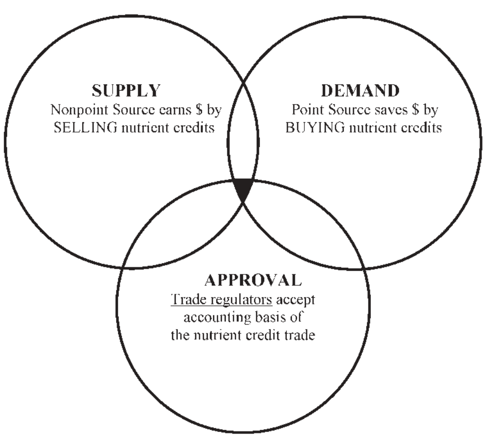


Figure 5
NECESSARY CONDITIONS
FOR
NONPOINT CREDIT SUPPLY

Overview

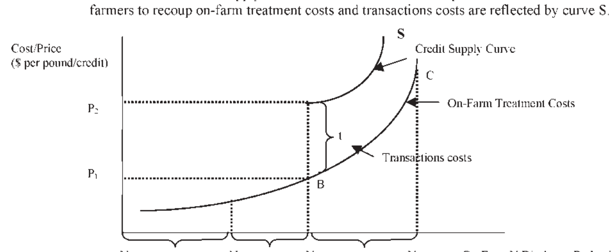
(1) The cost per pound of reducing "edge of farm" nutrient discharge increases as more discharges are withheld. Therefore increasing marginal treatment costs along ABC.

(2) Farmers can only generate tradable credits by reducing N discharges beyond the level required by law (N_1) and beyond levels associated with on-farm conservation practices for which they are receiving subsidies (up to N_2).

(3) In the absence of N discharge requirements and subsidies mentioned in (2) available credit supplies would be from N_0 to N_{max} and the cost of producing credits would start at P_1.

(4) However, legal requirements and subsidies are built into the credit supply baseline so the available credit supplies start at N_2 and the cost of N discharge reductions that form the basis of credits start at P_2.

(5) The cost of producing a marketable credit include transactions costs (t) as well as treatment costs, so the supply curve for credits that reflect the price that will allow farmers to recoup on-farm treatment costs and transactions costs are reflected by curve S.



N_1 = Nonpoint N discharge reductions required by law
$N_2 - N_1$ = Nonpoint N discharge reductions associated with subsidies
N_2 – "Baseline" level of N discharge reduction used for "scoring" credits
$N_{max} - N_2$ = Nonpoint N discharge reductions that result in potential credits
t = Transactions cost per credit paid by the seller
$\mathbf{P_1}$ = Credit price required to attract supply with no transactions costs
$\mathbf{P_2}$ = Credit price required to attract supply with transactions costs of t per credit.

Figure 6
NECESSARY CONDITIONS
FOR
POINT SOURCE CREDIT DEMAND

Overview

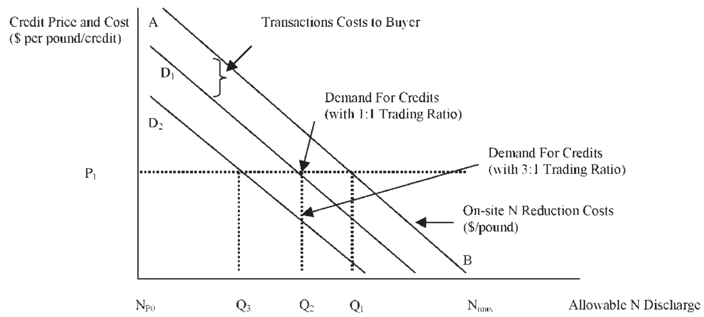
(1) Marginal cost of treating waste increases as the level of allowable level of N discharge decreases from the maximum of N_{max}, as depicted in AB.

(2) Point sources gain from buying nonpoint credit offsets as long as the cost of buying credit offsets is less than the cost of on-site treatment.

(3) However, the effective cost of buying a credit is determined by:
- (a) the point source's share of transactions costs (t).
- (b) the trading ratio (e.g. 1:1 or 3:1)
- (c) the liability for trade risks assigned to the credit buyer

(4) The point source's "willingness to pay" for a credit is inversely related to the trading ratio that determines how many credits are required to offset one pound of N discharge by the point source. High trading ratios "dilute" the economic value of credits to point source discharges and under many circumstances result in them purchasing fewer credits.

(5) The combination of transactions costs and trading ratios result in point sources being willing to buy at credit prices that are significantly lower than their per unit treatment costs.



Nmax = Status quo discharge level
AB = Marginal Treatment Cost Per Unit ($/pound)
D_1 = Theoretical Demand For Credits with 1:1 Trading Ratio (after transactions costs)
D2 = Theoretical Demand For Credits with 3:1 Trading Ratio (after transactions costs)