Water Quality Trading in Agriculture
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Water Quality Trading in Agriculture

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Note

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The other background reports (also available at [www.oecd.org/agriculture/water](http://www.oecd.org/agriculture/water)) are:

*AgroViva and Water Quality: Monetary Costs and Benefits across OECD Countries*
Andrew Moxey, Pareto Consulting, Edinburgh, Scotland, United Kingdom, assisted by Eva Panagiotopoulou, Department of Agricultural Economics and Rural Development, Agricultural University of Athens, Greece;

*Emerging Water Pollution arising from Agriculture*
Alistair Boxall, Environment Department, University of York, United Kingdom;

*Agriculture’s Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters*
Robert Díaz, Institute of Marine Sciences, United States; Nancy N. Rabalais, Louisiana Universities Marine Consortium, United States and Denise L. Breitburg, Smithsonian Environmental Research Center, United States. This paper has also been published in OECD (2010) *Advancing the Aquaculture Agenda: Workshop Proceedings*. 
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EXECUTIVE SUMMARY

Water quality trading (WQT) refers to the application of emissions trading to water pollution control. Applications of emissions trading to date have largely occurred in the domain of air pollution. There is now substantial interest in extending the method to water pollution, including to water pollution from agriculture. WQT Initiatives have been implemented in Australia, Canada, New Zealand, and the US, and are being studied elsewhere, including by Finland, Sweden, and other countries surrounding the Baltic Sea to address nutrient pollution in the Baltic Sea.

Canada and New Zealand each have one WQT program, both involving agricultural sources, with additional programs under consideration. The Canadian program, initiated in 2000, involves phosphorus trading between industrial and municipal point sources and agricultural nonpoint sources in the Ontario South Nation River watershed. The program has produced pollution reductions and pollution cost savings in the 10 years that it has been in operation. The New Zealand program, initiated in 2010, is limited to nitrogen trading between agricultural sources in the Lake Taupo watershed on the North Island. The program is too new to assess. Australia has a couple of successful trading programs for industrial point sources but none at the present for agriculture. A nutrient trading program that would include agricultural sources is being considered for Moreton Bay.

WQT experiments began in the US in the early 1980s, mostly in the form of pilot or demonstration projects. Early initiatives were disappointing, producing little or no trading activity. Despite this experience, interest in WQT increased beginning in the mid-1990s with water quality policy developments requiring caps on pollution from point and nonpoint sources in impaired waters, and evidence of the success of air emission trading programs. State water quality managers have been the innovators with support and encouragement from the US Environmental Protection Agency, including the creation of national policy guidelines for WQT in 2003, technical assistance, and funding for WQT projects. The technical assistance addresses issues of legal compliance with national law but also presents guidelines for the creation of successful trading models based on lessons learned from ex post evaluations of early initiatives. These lessons include:

- Binding regulatory limits on pollution levels are essential for trading activity to occur. Such limits are essential to create the incentives for polluters to seek out options for pollution control cost savings.
- Trading activity requires sufficiently large differences in pollution control costs between polluters to make economic gains from trading, after deducting transactions costs incurred in conducting trades, possible.
- Trading rules must be clearly established, assure that water quality goals will be satisfied, but must also be designed to facilitate trading. Rules that are overly complex and costly create barriers to trading activity.
- Successful trading requires the development of institutions for organizing trade that are trusted by and effective for intended program participants.
The US leads in the development of water quality trading initiatives, with 22 instances located in 14 states. Agriculture is included as a potential participant in several US initiatives. Some of these are one-time sole-source offsets in which voluntary agricultural pollution reductions are used by a regulated point source to address facility-specific compliance problems. Agriculture is also a potential participant in several watershed based trading programs that envision routine trading between multiple point and nonpoint sources. The most notable of these are the Greater Miami River Watershed Trading pilot program in Ohio and the Pennsylvania Water Quality Trading program, both initiated in 2005. Both involve nutrient trading between point and agricultural nonpoint sources. The US also has one watershed-based trading program limited to agricultural sources, the Grassland Farmers selenium trading project established in 1998 in the San Joaquin Valley in California. The Grassland Farmers traded and met pollution reduction goals for the two year period before trading was suspended due to the development of a selenium recycling project that eliminated the need for trading. The Greater Miami program is producing trades that promise reductions in nitrogen loads from agriculture, and has some innovative features that make it an important model for trading with agricultural nonpoint sources. However, program development and trading activity have been substantially subsidized by federal grants. The Pennsylvania nutrient trading program has only a few trades since its inception.

Emissions trading is typically described as a market-based pollution control instrument that sets a cap on the total emissions of a pollutant. Market transactions allocate emissions under the cap among individual pollution sources. The role of trading is to harness market forces to promote cost-efficiency in emissions reductions. WQT programs that allow agricultural participants conform to this description only in the case of New Zealand’s Lake Taupo program and the Grassland Farmers selenium trading program in the US. Both of these are cap-and-trade programs designed to achieve specific pollution reduction goals from agricultural sources. The Canadian and US nutrient WQT programs that include agricultural sources are only partially capped. These programs allow trading between point sources that are subject to explicit regulatory limits and agricultural sources that are not. They allow point sources to use pollution reductions produced voluntarily by agricultural nonpoint sources to offset point source emissions as a means for complying with the point sources’ emissions limits. Trading rules are typically designed with the intent that agricultural offsets produce a net reduction in total pollution. For example, the Ontario South Nation River program requires a reduction of 4 kg of phosphorus from an agricultural source for each kg of point source phosphorus emissions allowed. Canadian and US nutrient WQT programs essentially create profit-making opportunities for agriculture that can reduce agricultural pollution, but do not in fact cap agricultural pollution.

The partially-capped nutrient trading model used in Canada and the US was developed by water quality managers seeking to improve the efficiency and effectiveness of water pollution control by adapting a first-generation (i.e., pre cap-and-trade) air emissions trading model to the trading of agricultural nonpoint pollution. This adaptation took place within water pollution policy frameworks that did not actively regulate agricultural nonpoint pollution that did not envision trading. An open question is the potential of trading to efficiently manage fully capped agricultural pollution. Agricultural and other nonpoint pollution can pose significant technical challenges to a fully capped trading design. The science of designing WQT programs with nonpoint sources is limited but has been receiving attention from researchers as the interest in them grows. This report summarizes some of the results from that literature. One lesson is that some heuristics used in the design of point-nonpoint trading programs are scientifically flawed and may lead to designs that diminish the capacity of WQT to efficiently and effectively achieve water quality goals.
WATER QUALITY TRADING IN AGRICULTURE

by

James Shortle

1. Introduction

Water quality trading (WQT) refers to the application of emissions trading to water pollution control. The concept was introduced by John Dales in 1968 as a mechanism for efficiently managing water pollution in Ontario, Canada. Dales proposed the creation of tradable rights to pollute water. A right would specify an allowed volume of emissions during a specified period of time (e.g. nitrogen emissions per year). A polluter’s emissions would be limited to the number of rights held by the polluter. The pollution control authority would control the total level of pollution by controlling the total supply of pollution rights available. Dales imagined a market in pollution rights emerging in which polluters with relatively low pollution abatement costs would reduce their emissions to sell their rights to polluters with relatively high abatement costs. Such trades would encourage an allocation of emissions reductions across polluters that minimized the total costs of pollution abatement.

Since Dales’ proposal, developments in emissions trading have largely occurred in the domain of air pollution control. The most prominent examples are the US cap-and-trade (CAT) emissions trading scheme for sulfur dioxide (SO\textsubscript{2}) emissions established under the 1990 US Clean Air Act Amendments, and the European Union’s Emissions Trading Scheme (EU ETS), a CAT system for regulating carbon dioxide (CO\textsubscript{2}) that was established in 2005 to pursue EU commitments under the Kyoto Protocol. Only recently has water quality trading drawn substantial interest from policy makers for water pollution control. The causes of this interest are varied, but a key consideration is the expectation that market-based trading can achieve water quality goals at lower cost than traditional regulatory approaches. This expectation emerges in part from successes of air emissions trading programs implemented to date. For example, the US SO\textsubscript{2} emissions trading program has been estimated to save one billion dollars (US) annually compared to traditional regulatory alternatives (Carlson et al., 2000).

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2. Dales did not use the now standard label WQT to describe trading of rights to pollute water. Effluent trading was the more common label until recently. Crocker (1966) is credited along with Dales for creating the concept of emissions trading. The application in Crocker’s work was to air emissions.
A 2008 survey of WQT programs around the globe conducted by the World Resources Institute (WRI) identified 26 programs for which trading rules had been established and in which trading could occur, 21 programs that were under consideration or in development, and ten programs that were completed or inactive (Selman et al., 2009). The US leads in the application of WQT, with all but six of the 57 programs identified in the WRI survey located there. Australia, Canada, and New Zealand are the other countries in which WQT programs have been implemented and are now active. Trading is being studied by Finland, Sweden, and other countries surrounding the Baltic Sea to address nutrient pollution in the Baltic Sea (Green Stream Network, 2008). WQT is now widely considered as a valid choice in the set of water quality management options by various NGOs advising environmental policy makers, and is the subject of an emerging literature on the merits and the “how to’s” of trading aimed at policy makers (e.g. Jones et al., 2005; OECD, 2004).

This report focuses on the application of WQT to agriculture. WQT is widely viewed by water policy makers and analysts as a promising method for reducing water pollution from agriculture, and for improving the cost-efficiency of emissions reductions between point and agricultural nonpoint sources of pollution. WQT programs involving agriculture have been implemented for watersheds in Canada, New Zealand, and the US (Table 1), and are being considered elsewhere.

The report begins with a review of basic concepts in WQT. It then describes leading applications of WQT that include agricultural sources in OECD countries. The remainder of the report is devoted to normative aspects of the design of WQT programs for agriculture. This discussion addresses criteria for designing and evaluating WQT programs, and key issues in program design when agricultural emissions are intended to be capped and allocated by a trading program. It is important to emphasize that WQT is not a mature technique, but rather an emerging method. The number of successful applications is limited and recent in time. This is especially true for applications to agriculture. In consequence, this report focuses on describing significant initiatives and approaches to successful WQT programs for agriculture.

3. The emphasis on the word could in this sentence is to highlight the difference between a program that has been developed and in which trading is allowed, and a program in which there is significant trading activity. Routine trading has been the exception rather than the norm in WQT programs.

4. Sources of water pollution are generally distinguished as point or nonpoint according to the pathways the pollutants or their precursors follow from the place of origin (e.g. a farm) to the receiving water body. Pollutants from point sources are discharged directly into receiving waters at discrete identifiable locations such as the end of a pipe or ditch. Pollutants from nonpoint sources follow indirect, diffuse, and often complex pathways to water bodies. Nonpoint sources can sometimes be converted to point sources by collecting and channelling diffuse emissions when technically and economically feasible (Shortle and Abler 1997). Agriculture contributes to both point and nonpoint pollution. Runoff from fields and pollutants leaching into ground water, for example, exemplify nonpoint pollution. Discharges of animal wastes from pipes or ditches into streams, for example, exemplify point source pollution. The classification can also be a function of law. For example, confined animal operations in the US are regulated as point or as nonpoint sources depending on the size of the facilities – large confined animal operations are treated as point sources and required to have and comply with point source discharge permits (Ribaudo 2009).
2. Basic Concepts

2.1 Emissions Trading

Traditional air and water pollution regulations entail imposing periodic (e.g. annual) maximum limits on emissions from specific sources (e.g. smokestacks, outfalls), and requiring that those limits be met at the source. The requirement that limits are met at the source prevents emissions reductions from one source being used to meet the requirements of another. Prohibiting the use of emissions reductions from one source to offset emissions from another serves no environmental purpose if environmental conditions are unaffected by the offset. However, the inability to use offsets increases the costs of pollution control when the incremental cost of pollution abatement differs between sources.

Emissions trading introduces flexibility into how emissions limits can be met. With trading, a source may meet the limit on its emissions in part or in whole (depending on trading rules) by acquiring offsetting emission reductions from other sources. To illustrate the concept and the potential cost saving from trading, consider the Ontario South Nation River Total Phosphorus Management Program, a WQT for phosphorus in the Ontario South Nation River watershed, in Canada.\(^5\) Regulatory restrictions for wastewater limit wastewater treatment plants to 0 kg phosphorus emissions for new or expanded plants. However, the WQT program allows 15 municipalities and two industrial point sources to meet their limits through offset projects that reduce P from agricultural sources. The program requires that agricultural offsets remove 4 kg of P from agricultural sources for every 1 kg of P that the point source discharger contributes to the watercourse. The average cost of projects that reduce P in agricultural runoff in the watershed is CAD 300/kg. In one study of the program, the cost of complete removal of phosphorus (P) in municipal wastewater emissions in the watershed using on-site treatment was estimated at about CAD 2,000/kg of P removed. Using the 4:1 trade ratio\(^6\) the cost of satisfying the standards through agricultural offsets was estimated at about CAD 1,200/kg. These estimates indicate a CAD 800/kg savings from agricultural offsets over the cost of on-site wastewater treatment. All point sources have chosen the cheaper offsets since the inception of the program.

2.2 Emission Reduction Credit Trading versus Cap-and-Trade Allowance Trading

Although there are variations, emissions trading is commonly framed as being implemented through the trading of emission reduction credits (ERCs) or emissions allowances (permits) in a CAT program.\(^7\) The concept of ERC trading originated with innovations in air emissions regulation in the US in the late 1970s. ERC trading is essentially a modification of traditional emissions regulations that allows the source-specific emissions limits to be met with ERCs acquired from other sources. ERCs are produced by over-compliance with regulatory requirements (i.e., emissions are reduced below the regulatory limit). Thus, in ERC trading, ERCs flow from sources that over-comply with regulatory requirements to sources that under-comply.

\(^5\) This discussion is based on O’Grady and Wilson (undated) and O’Grady (2008, 2011).

\(^6\) Trade ratios in WQT indicate the units of pollution reduction that a user of offsets must acquire to offset a unit of its own emissions.

\(^7\) Emissions trading is often referred to as emissions permit trading (e.g. Sterner, 2003). The notion is that a permit defines the allowable emissions of a source, and that a source may modify its allowable levels by purchasing permits from or selling permits to others. But emissions trading need not entail the trading of emissions permits. The Canadian and US WQT programs do not, for example, entail permit trading.
CAT also emerged with innovations in US air emissions regulations, in this case during the 1990’s. In a CAT program, emissions allowances provide explicit rights to pollute and define allowable emissions levels. The cap in CAT comes from the limitation on the total allowable emissions across all sources. Specifically, in a CAT system, the regulator sets an upper bound on emissions necessary to achieve an environmental goal, and limits the total allowances to the level needed to achieve the goal. Allowance trading within this cap determines how emissions are allocated across sources.

ERC and CAT trading programs are sometimes discussed as though they are equivalent mechanisms. The differences between them can be profound depending on details of implementation. A fundamental difference is that CAT programs by definition entail explicit caps on aggregate emissions where as ERC programs do not. This distinction is illustrated by WQT programs for agriculture in Canada and US. These programs are partially capped ERC trading systems (Stephenson et al., 2009). In both nations regulatory limits (i.e., caps) are imposed on industrial and municipal point sources, but emissions from agricultural nonpoint sources are largely unregulated (Weersink et al., 1998). WQT programs that include agriculture, such as the Canadian Ontario South River Nation Total Phosphorus Management Program discussed above, allow point sources to meet their permit requirements by acquiring ERCs from uncapped agricultural nonpoint sources. This trading design can help point sources meet their regulatory limits at lower cost, but the trading system does not limit the pollution from the uncapped sources. Issues that can emerge in partially capped ERC trading and other differences between CAT and ERC programs will be addressed further in subsequent sections.

2.3 The Organization of Trading

Emissions trading can be organized in a variety of ways. The options have been broadly characterized as exchanges, bilateral negotiations, and clearinghouses (Woodward and Kaiser, 2002). Exchange markets are exemplified by stock and commodity exchanges where buyers and sellers meet in a public forum to set prices and execute trades. Exchange markets are well suited to trading highly standardized commodities in thick markets. They have been used for some major CAT air emissions markets, but are generally not well-suited to water quality trading due to difficulties in standardizing water pollutants as a tradable commodity (Woodward and Kaiser, 2002). Bilateral negotiations are common when buyers face a diversity of sellers and the characteristics of the goods are variable. This method, sometimes executed through brokers, is common in existing WQT markets (Selman et al., 2009). Clearinghouses create a market intermediary that buys allowances or ERCs from sellers, and sells allowances or ERCs to buyers. Clearinghouses differ from brokers in a bilateral market in that clearinghouses eliminate all contractual or regulatory links between sellers and buyers so that parties interact only with the intermediary (Woodard and Kaiser, 2002). Clearinghouses are also common in WQT programs (Selman et al., 2009).

2.4 Trading and Market-Based Trading

Emissions trading is commonly referred to as a market-based pollution control instrument. In the pure market-based trading envisioned by the concept’s originators, trades are the result of voluntary transactions between polluters, or through market-oriented intermediaries, and competition in the market place is encouraged. The concept of WQT is being applied to mechanisms that correspond to this vision, but also to mechanisms that present no or limited opportunities for buyers and sellers to interact or to compete. Current trading programs offer a range of exchange mechanisms, with some

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8. The CAT concept stems from the academic research of Dales (1968), Crocker (1966), and Montgomery (1972).
providing significant opportunities for market-like participation, and others that do not. Trading in the water quality context has come to mean water pollution control regimes that allow source-specific emissions limits to be achieved by emissions reductions performed by other sources, without specifying the specific mechanism through which trades are executed.

An example of a trading program that is not market-based is the Connecticut Nitrogen Credit Exchange Program (CNCEP), which was established in 2002 to reduce nitrogen loads to Long Island Sound from the Connecticut River in the US. The program is limited to point sources (79 wastewater treatment plants). The plants are annually assigned individual discharge limits to achieve an increasingly stringent cap on nitrogen loads to the Sound. Plants generate ERCs when they reduce nitrogen discharges below their assigned limits. Plants that fail to meet their limits must acquire ERCs to cover the shortfall. The price of ERCs is set by a Nutrient Credit Advisory Board appointed by the state legislature. Buyers and sellers do not interact in a market. At the close of each year the state environmental agency determines each plant’s actual discharges, and the ERCs earned or required to be in compliance. The agency also purchases ERCs generated in excess of the amount required to achieve the aggregate emissions cap. Economic incentives are clearly present in the CNCEP, but the exchange is not truly a market place in which buyers and sellers compete. In this case trading is organized through a clearinghouse, the state environmental agency, but the conduct of trading does not harness competitive processes for cost-minimization.

Canada’s Ontario South Nation River trading program is also not market-based. The program is managed by South Nation Conservation (SNC), a long established natural resource conservation agency for the watershed. Point sources purchase ERCs from the program’s Clean Water Fund. The SNC contracts with farmers to install agricultural Best Management Practices (BMPs) that generate ERCs. There are no explicit market determined prices for ERCs, nor market-like negotiations or competition between farmers and ERC buyers. The program is analogous to a traditional cost-sharing program for BMP adoption, with the twist that the program is implemented by a watershed authority and funded by point sources of water pollution.

An example of a genuinely market-based trading system is the Hunter River Salinity Trading Scheme in New South Wales, Australia. The scheme was initiated in 1995 to manage saline water emissions from coal mines and electricity generators licensed to discharge salt to the Hunter River (NSWDEC, 2006). Monitoring points along the river measure whether the river is in low flow, high flow or flood flow. When the river is in low flow no discharges are allowed. During high flow limited discharges are allowed subject to restrictions based on a licensee’s holdings of tradable salt credits. An online trading platform has been developed for exchanging credits, with prices and credit transactions negotiated by buyers and sellers.

2.5 The Economic Case for Trading

The textbook economic case for trading as a more efficient mechanism for pursuing environmental goals than traditional emission regulations assumes that trading is market-based. Minimizing abatement costs incurred in achieving a water quality target requires cost-minimizing choices at two levels. One is at the individual polluter level. At this level cost-minimization requires that individual polluters use the mix of pollution prevention and abatement technologies that minimize their individual costs. Cost minimization at the individual polluter level is served by instruments that allow polluters to make and benefit from choices that reduce their compliance costs. Trading is such an instrument, but so too are others that allow polluters to choose the methods they use to reduce their own emissions. The second level is in the allocation of pollution control across the set of polluters. At this level the task is to allocate emissions reductions across polluters to minimize their collective costs.
of achieving the target. It is at this function that market-based trading is considered especially useful (Tietenberg and Johnstone, 2004).

The capacity for a regulator to allocate emission among alternative sources to minimize the costs of pollution abatement is contingent on the ability of the regulator to compute the cost-minimizing allocation. An essential requirement to compute the cost-minimizing allocation is a complete knowledge of the technologies for pollution abatement and their relative costs for each polluter. Such information is typically private (i.e. polluters will typically know more about their technological option and costs than a government agency), and polluters have multiple incentives to hide or misrepresent costs. Regulators may use engineering cost studies to obtain cost information needed to conduct regulator-directed allocations, but these studies will entail expenses that must be repeated to keep current, and will be subject to error. The fundamental economic case for market-based trading is that the public sector need not expend resources to obtain information needed to estimate cost-minimizing allocations of emissions. In the words of Tom Crocker, an early proponent of trading, in a market-based trading scheme the, “… pollution control authority’s responsibilities…will not have to include the guesswork involved in attempting to estimate individual emitter …. [abatement cost] functions” (Crocker 1966, p. 81).

The motive for a buyer of ERCs or emissions allowances in a market-based trading scheme is that the expense of the purchases is less than the costs of reducing its own emissions. The motive for a seller of ERCs or allowances is that revenues from the sales exceed the costs of reducing its emissions. These cost-differences imply that voluntary trades between buyers and sellers will be mutually beneficial. They also entail incentives to shift pollution abatement from polluters with high abatement costs to polluters with low abatement costs. Provided that there are no significant barriers to discovering and negotiating mutually beneficial trades, trading would be expected to eliminate potential cost-savings from trading, implying that the costs of pollution control are minimized, within the rules of the trading program to assure that water quality goals are satisfied.

This textbook vision of market-based trading producing efficient outcomes emerges from theoretical research (e.g. Coase 1960, Crocker 1966, Dales 1968; Montgomery, 1972), numerical modeling studies of the potential benefits of replacing traditional regulatory approaches with trading (e.g. Atkinson and Tietenberg, 1991; Hanley et al., 1998;), and more recently by the results of air emissions trading experiences that show cost-savings realized in practice (Carlson et al., 2000; Joskow et al., 1998; OECD, 2004; Tietenberg, 2006a,b). The textbook vision is best approximated in practice by the CAT markets for SO₂ emissions to air in the US and the carbon market in the EC (e.g. Joskow et al., 1998).

2.6 A Complication: Trading Nonpoint Pollution

The fundamental importance of natural factors that vary across space (e.g. soils, topography), or space and time (e.g., weather), to agricultural production and its environmental impacts, imply that cost-minimizing solutions to agricultural externalities will almost always be highly site-specific (Lichtenberg, 2004). This implies that a significant degree of pollution control cost heterogeneity is

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9. This statement and the next assume that polluters seek to minimize their pollution control costs. This is in general a reasonable presumption. The statements also assume that the permit or credit market is perfectly competitive, and the output market in which polluters compete is perfectly competitive. If the market is not perfectly competitive, then trading decisions may be influenced by strategic considerations in the emissions or output markets. However, ex post evaluations of trading indicate that such market structure issues do not have a large impact on market efficiency (Tietenberg and Johnstone, 2004).
likely to exist in agricultural abatement, especially as the geographic scope becomes smaller. This cost-heterogeneity along with imperfect public knowledge of these costs would suggest that trading could be a very useful tool for efficiently managing water pollution from agriculture given the textbook vision of trading. However, there are important features of the agricultural problem that limit the direct relevance of the textbook model.

This textbook vision of efficient emissions trading assumes that emissions (1) can be accurately metered for each regulated emitter, (2) are substantially under control of the polluter, and (3) that the spatial location of emissions within the market does affect environmental outcomes. The first two requirements of the textbook model are necessary to meaningfully define tradable property rights in actual emissions. Neither of these requirements is satisfied by the large proportion of polluting emissions from agricultural sources. Agriculture is predominantly, though not exclusively, a nonpoint source of water pollution. The diffuse pathways that nonpoint pollutants follow from farms to water resources typically make metering agricultural emissions routinely and accurately prohibitively expensive, thus violating the first assumption. Further, weather plays a large role in determining the volume, timing, and form of water pollutants from farm fields, pastures, and barnyards. This introduces a significant random component in agricultural pollution, and implies that the timing and levels of emissions are not completely under control of agricultural managers, thus violating the second assumption. Farm practices to reduce nonpoint source pollution are appropriately viewed as improving the probability distribution of pollution rather than a deterministically controlled level of pollution.

Further complicating the design of WQT markets, whether for agriculture or other water pollution sources, is that the spatial location of emissions is very important to the impact on water quality. For example, nutrients from a farm or wastewater treatment located far upstream from an estuary impaired by nutrients will typically have a smaller impact on water quality conditions in the estuary than an equal amount of nutrients released further downstream. Differences in the impacts of emissions on water quality related to location create complications for design of market that are effective and efficient in achieving water quality improvements (Cason et. al., 2003; Cason and Gangadharan, 2005; Tietenberg, 2006a, b).

These and other characteristics of agricultural nonpoint pollution require that appropriate models for WQT with agriculture differ from the idealized models of academic theory and the highly visible CAT models for air emissions in the US and Europe (Horan and Shortle, 2011; Shortle and Horan, 2008). WQT trading models for agriculture are emerging from water quality agencies seeking to realize the benefits of trading while addressing the challenges associated with nonpoint pollution. The degree to which the models emerging from agency innovation realize cost savings and achieve environmental targets is an open question (Ribaudo and Gottlieb, 2011). Academic research has identified limitations of these emerging models and suggested innovations to address these shortcomings. These issues will be taken up further in the sections on market design.

3. Water Quality Trading Initiatives: The United States

A handful of WQT programs were implemented in the US from the early 1980s to the mid-1990s, largely in the form of pilot or demonstration projects (Morgan and Wolverton, 2005). Interest in WQT expanded greatly after the mid-1990s. A key factor explaining this increased interest was the need for innovation to improve the effectiveness and cost-efficiency of water quality protection. The history of environmental markets suggests that trading programs are considered and adopted after traditional regulatory approaches have failed (Tietenberg, 2006b). This is distinctly the case for WQT in the US.
Since the early 1970s, water pollution control in the US has been regulated largely through emissions limits applied to industrial and municipal point sources of water pollution. Large confined animal feeding operations (CAFOs) have been subject to the same types of federal regulations as industrial and municipal point sources for the past decade (Ribaudo, 2009). The number of farms regulated as point sources is a small proportion of the total number of farms. Agricultural nonpoint source pollution has been approached differently, through an array of local, state, and federal initiatives that emphasize voluntary adoption of pollution control practices encouraged by subsidies. These initiatives have fallen short of what is needed to achieve established water quality goals. Agricultural nonpoint pollution remains largely unregulated, and is a leading cause of water quality problems across the nation (Ribaudo, 2009; USEPA, 1997, 2002, 2005).

The problems resulting from the historical structure of water pollution control go beyond the failure to achieve water quality goals. The water quality gains that were achieved were overly expensive because the regulatory framework did not allow point sources to use offsets from other point sources or from nonpoint sources to help meet their regulatory limits, and because of constraints on technological choices in pollution permits (Davies and Mazurek, 1998; Ribaudo, 2009; Shabman and Stephenson, 2007). A US Environmental Protection Agency (USEPA) study estimated annual savings of nearly a billion dollars from pursuing water quality goals using approaches that encourage efficient emissions allocations among and between point and nonpoint sources (USEPA, 2001).

Failure to achieve water quality goals led to lawsuits requiring the USEPA to implement the Total Maximum Daily Load (TMDL) provisions of the Clean Water Act (CWA) in the mid-1990s. These provisions require state water quality authorities to establish pollution load goals for both point and nonpoint sources in waters that do not meet water quality targets, and to develop programs to achieve the designated goals (Ribaudo, 2009). Interest in WQT emerged in this context as a means to achieve TMDLs, to expand the reach of water pollution controls to include agricultural nonpoint sources, and to improve the economic efficiency of water pollution control allocations among and between point and nonpoint sources. Notably, state water quality agencies have been the innovators in the development of WQT programs. These initiatives have been actively supported by the USEPA since 2003, through policy guidelines that encourage trading for selected pollutants, technical guidance for the development of programs, and funding for demonstration projects (USEPA, 2003, 2004, and 2007).

A USEPA website that cumulatively tracks WQT initiatives in the US listed 42 initiatives across 23 states in March 2010 (USEPA, 2010). These initiatives include planning exercises, legislation to create programs, pilots, and active trading programs. Agriculture is addressed in many, though not all of these initiatives.

### 3.1 One Time Offsets

WQT in the US has taken on a variety of types (Morgan and Wolverton, 2005). The first type in the development of US WQT is a one-time offset agreement. US point sources are regulated through emissions permits. Traditionally, the permitted emissions limits were to be met by the permittee’s own emissions. Offset agreements allow the limits to be met in part by a reduction from another pollution

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10. To give a sense of the small number of farmers regulated as point sources, the 2007 US Agricultural Census (USDA, 2009) shows a total of 2,204,792 farms. Of those, 907,228 were operations with livestock. The US EPA estimates that 20,000 of these operations are defined as CAFOs under federal regulations (Bonnellycke, 2009).

11. The Clean Water Act is the key legislation governing surface water pollution control in the US.
source. Offset agreements have been used in cases where conventional facility-specific limits would have prevented expansion of the facility or the entry of new sources (Morgan and Wolverton, 2005). Nonpoint source reductions are the most common source of the offsets, and several of these were agricultural offsets. In two prominent examples, the Minnesota Pollution Control Agency allowed industrial point sources on the Minnesota River (Rahr Malting Company in 1997 and the Southern Minnesota Beet Sugar Cooperative in 1999) to utilize agricultural and other nonpoint source nutrient pollution reductions to help meet their permit requirements. The point sources were responsible for identifying nonpoint source trading partners, and assuring the continuing performance of the nonpoint BMPs (e.g. soil erosion controls, cattle exclusion, rotational grazing, critical area set-asides, constructed wetlands, and cover cropping) implemented on the properties of nonpoint sources (Feng et al., 2006).

3.2 Trading Programs

One-time offsets have emerged as a WQT mechanism to solve facility-specific permit compliance problems. They represent a positive development for improving the efficiency of US water pollution control within the context of the legal structure created by the CWA. Some states have implemented programs to facilitate trading between multiple sources contributing to the pollution of specific water bodies. These programs are typically implemented as mechanisms to help achieve a water quality standard as expressed by a TMDL or in other forms (Morgan and Wolverton, 2005; USEPA, 2007). The Connecticut Nitrogen Credit Exchange is a prominent example of a WQT program developed to achieve a TMDL. A few trading programs allow trades only between point sources, or between nonpoint sources, but most allow trades that offset point source emissions with reductions in nonpoint emissions. Nutrients (nitrogen and/or phosphorus) are the tradable pollutants in most programs, but some programs involve other pollutants including metals, selenium, temperature, and water flow. The most significant implementations that involve trading with agricultural sources are California’s Grassland Areas program, Ohio’s Greater Miami River program, and Pennsylvania’s program for the Chesapeake Bay. These programs will be described in the next three sections (Table 1).

Some states are developing general trading policy frameworks that would apply to any waters within the state’s boundaries (as opposed to within specific watersheds). Several interstate initiatives are also underway for developing trading policies for watersheds that encompass multiple states. An example of the latter is the Chesapeake Bay Trading Guidance developed by the USEPA Chesapeake Bay Program for the very large multi-state Chesapeake Bay watershed.

3.3 California Grassland Areas Program

The Grassland Drainage Area is an agricultural region on the west side of the San Joaquin Valley. Soils there contain high levels of selenium, a naturally occurring nonmetallic trace element. Selenium dissolves in irrigation water. Drainage systems designed to remove excess water from fields transport selenium to waterways where it is a threat to fish and wildlife. Significant damages to ecosystems in the 1980s led to initiatives to reduce selenium levels through voluntary adoption of BMPs to reduce

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12. US point source discharge permits impose technology-based effluent limits (TBELs) on all regulated point sources. They may also impose additional limits, referred to as water quality based effluent limits (WQBELs), if required to meet in-stream water quality standards. National water quality regulations do not allow the use of offsets to meet TBELs but will allow them to meet WQBELs.

13. This description is based on McGahan (2001), Morgan and Wolverton (2005), and Woodward et al. (2002).
selenium in drainage water. Continuing problems led to new initiatives in the mid-1990s. Grassland Area Farmers (GAF), an association of seven irrigation districts containing approximately 39,254 hectares of irrigated farm land, was established in 1996 to implement the Grassland Bypass Project. The Project consolidated subsurface drainage across the participating districts, and uses a canal (The San Luis Drain) owned by the federal Bureau of Reclamation to convey the flows around habitat areas. The canal flows into the ecologically sensitive Kesterson Reservoir. The agreement established a schedule of monthly and annual selenium load limits, and imposed a schedule of fees on the GAF for violations of the limits.

The GAF implemented an array of practices to reduce selenium in drainage water within the participating irrigation districts. Additionally, with funding support from the USEPA, the GAF developed a trading program that allowed the participating districts to meet district-specific selenium limits through trading. Specifically, the total allowable regional selenium load is allocated among the member irrigation districts. Districts could meet their load allocations through selenium reductions within the district or purchase selenium offsets from other districts. Trades are negotiated between individual districts. The program produced 39 trades and met water quality goals over a two-year period after implementation. Trading was subsequently suspended due to the development of a drainage recycling project that eliminated the need for trading.

There are several interesting features of this program. The most significant is that it entails a cap on agricultural sources. This differentiates the program from the dominant North American WQT model for agriculture in which agricultural sources are uncapped and trading with agricultural sources serves primarily to reduce point source compliance costs. Another significant and related feature is the role of monitoring. Trading programs for agriculture generally do not measure agricultural emissions because the nonpoint nature of those emissions makes routine accurate measurement infeasible. Instead, calculations of agricultural nonpoint pollution emissions are used in place of actual emissions. Trading in the GFA is based on actual emissions. This is made possible by the trading being between irrigation districts, not farmers, and the irrigation districts collecting drainage water in sumps before pumping into the San Luis Drain. The technology of drainage water management implemented by the GFA converted nonpoint emissions from farms into point source emissions from irrigation districts. The trading program is appropriately considered a point-point trading program. Districts must contend with the usual nonpoint management problems when managing the emissions they receive from farms within their districts. A third feature is the pollutant. Nutrients are the focus of programs involving agricultural sources. This program involves a measurable nonmetallic trace element.

3.4 Greater Miami Watershed Trading Pilot Program (GMWTPP)\(^{14}\)

The nearly 10,360 km\(^2\) Greater Miami Watershed is located in southwestern Ohio. Agriculture is the major land use in the watershed, but it contains several cities with populations in excess of 50,000, and a total population in excess of about 1.5 million. Water quality standards in portions of the watershed are not met. Nutrients and sediments from agricultural lands are significant causes of water quality problems. A TMDL intended to correct the impairments has been developed for one subwatershed, with additional TMDLs scheduled for others.

The GMWTPP was established in 2005 as a means of exploring market mechanisms for accelerating water quality improvements. It provides regulated point sources with the opportunity to purchase nutrient ERCs before tighter restrictions on emissions are imposed through the TMDLs, or in response to new instream nutrient criteria. The project is managed by the Water Conservation

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\(^{14}\) This description of the GMWTPP is based on WCS (2005), and communications with Dusty Hall, Manager, Program Development, Miami Conservancy District.
Subdistrict (WCS) of the Miami Conservancy District (MCD). The MCD was established in the early 1900s with a core mission of flood control. The WCS serves as a clearinghouse, buying pollution reductions accomplished by agricultural and other nonpoint sources and transferring ERCs to point sources.

The trading program has five Founding Investors – the cities of Dayton, Englewood, and Union, Butler County, and the Tri-Cities Wastewater Authority (representing three cities). Each of these investors has one wastewater treatment plant except Butler County which has multiple plants. This group provided USD 1.3 million to finance the program for its first six years.

ERCs for nitrogen and phosphorus are generated by installation of BMPs that reduce nutrients emissions to watersheds, rivers, and streams, with an ERC for a nutrient type being equal to one pound (about 0.454 kg) of reduction of the nutrient. The baseline for ERC calculation is the level of emissions that would have occurred prior to the implementation of the BMPs that generate the ERC, and the total amount of the emissions reduction relative to that baseline is credited. Activities that generate ERCs must be voluntary (activities that would not have been forced by legal mandates), new, and not funded by other conservation incentive programs.

Like most North American point-nonpoint trading schemes, trade ratios, defining the number or ERCs that must be acquired to offset a unit of regulated emissions, are utilized in the GMWTPP. However, the rationale for trade ratios in the GMWTPP is unique to the program. The trade ratios are designed to serve the program goal of accelerating water quality improvements. Trade ratios of between 1:1 and 3:1 are established to incentivize early, voluntary participation by point sources and to recognize the water quality attainment status of the receiving water body into which the buyer discharges.

Like Canada’s Ontario South River Nation WQT program, farmers do not participate directly in the trading program. The WCS purchases ERCs from Soil and Water Conservation Districts (SWCDs) in the watershed which in turn contract with farmers to install BMPs. The watershed contains 14 SWCDs that are eligible to participate, though some have only a small proportion of their service areas, defined along county boundaries rather than watershed boundaries, included in the eligible watershed area. Nine of the SWCDs have been active in the program.

The WCS obtains resources for purchasing ERCs partly from point sources purchasing ERCs, but it also funds purchases of nonpoint reductions, and operates the program, with federal grants it has received that are intended to support the development of innovative trading programs.

An interesting feature of this program is procurement (reverse) auctions are used to purchase ERCs. While procurement auctions are commonly used by industry and institutions seeking to minimize the costs of purchasing supplies and equipment, it is a novel approach to acquiring ecosystem services from agriculture that has merit as a mechanism to help minimize the Conservation agency's expenditures on ERCs and correspondingly, maximize the number of ERCs it can purchase within its budget constraints.

As of June 2011, nine rounds of project submittals resulted in funding for 345 agricultural projects generating more than 1,000,000 ERCs over the life of the projects. These are to be generated

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15. Soil and Water Conservation Districts are autonomous local governmental units. They are creations of state law, but inspired by federal soil and water conservation initiatives in the 1930s. They play a central role in administering federal and state environmental and resource conservation programs for agriculture.
over the contractual periods of the various projects with a maximum of 20 years and minimum of one year. This translates to about a 453 metric ton reduction in nutrient discharges. Slightly more than 1.5 million dollars (US) will be paid to agricultural producers for these ERCs.

About USD 89 thousand have been allocated to the SWCDs for assistance and oversight. The WSC has incurred operating costs averaging about USD 200 thousand per year for the first six years. Program funds have come from discharges (USD 1.3 million) and from federal grants. A tenth round of project funding was announced for the summer of 2011.

3.5 Pennsylvania Nutrient Credit Trading Program (PANCTP)\textsuperscript{16}

The PANCTP is potentially the most important emerging WQT program for agriculture in the US due to the significance of the water quality problem addressed – the flow of nutrients from point and nonpoint sources from Pennsylvania to the Chesapeake Bay, and importance of agriculture to the problem.\textsuperscript{17} The Chesapeake Bay is the largest estuary in the US. Its 165,534 km\textsuperscript{2} watershed encompasses parts of five Mid-Atlantic States, and the nation’s capital. The Bay’s ecosystems are severely impaired by nutrient pollution. About 58,389 km\textsuperscript{2} of the Bay’s watershed is located in Pennsylvania. The state contributed 44\% of the estimated nitrogen and 24\% of the estimated phosphorus reaching the Bay in 2009. Pennsylvania agriculture was the source of 56\% of the estimated nitrogen and 44\% of the estimated phosphorus entering the Bay from the state.

The Bay has been a focal point of federal and state initiatives to reduce nutrient pollution from agriculture and other sources for decades. Beginning in 1983, there have been several agreements between the USEPA, the Governors of Maryland, Pennsylvania, and Virginia, and the Mayor of the District of Columbia, establishing the Chesapeake Bay Program, setting nutrient reduction goals, and developing strategies for nutrient reduction. Large public investments have been made to understand the causes and consequences of nutrient pollution, develop models to support science-based management, and fund initiatives to reduce nutrient loads. Yet, the problems remain – largely due to limited success in implementing policies that effectively reduce stresses, especially nutrients and sediment from agricultural and other nonpoint sources (Boesch \textit{et al.} 2001; Obama, 2009; USEPA and USDA Office of Inspector General Office 2006). A TMDL establishing quantitative limits on nutrient and sediment pollution was issued by the USEPA in December, 2010.

Pennsylvania established the WQT program in 2005 as one element in a set of initiatives to meet its obligations under the Bay agreements, and in anticipation of the 2010 Bay TMDL. The program is administered by Pennsylvania’s Department of Environmental Protection (PADEP). Notably, the WQT program and other Pennsylvania initiatives to reduce nutrient flows to the Bay address a transboundary problem: the state is a leading source of nutrients to the Bay, but the state’s boundaries include no portion of the Bay. The trading program was developed as a partially capped ERC trading program that would allow uncapped agricultural nonpoint sources to provide ERCs to capped point sources. The program also allows point sources to generate ERCs for sale to other point sources.

Farmers produce ERCs for nitrogen and phosphorus by installing BMPs that reduce nutrients flowing into the Bay. Unlike the GMWTPP, the baseline for calculating nutrient reductions is not the level of emissions to the Bay watershed that would have occurred with the practices in place prior to

\textsuperscript{16} This description of the Pennsylvania program is based on PADEP (2010), and communications with Ann Roda, Water Planning Office, Pennsylvania Department of Environmental Protection.

\textsuperscript{17} Pennsylvania contributes nutrients to the Bay from the Potomac and Susquehanna Rivers. The Susquehanna is by far the more significant of the two.
the implementation of the BMPs that generate the ERC. The PANCTP requires that farms comply with applicable state erosion and nutrient management laws, and meet “threshold” nutrient reduction requirements, to be eligible to produce and sell ERCs. Nutrient reductions produced by compliance with these baseline requirements do not earn ERCs. Further, unlike the GMWTPP, the total amount of the eligible emissions reduction to the Bay watershed is not credited. The amount of nutrients that reach the Bay from upstream discharges is less than the amount of upstream discharges because of various physical, chemical, and biological processes that attenuate nutrient flows as they move downstream. The PANCTP ERC computations take these attenuation losses into account so that ERCs estimate the reduction in nutrients, after baseline compliance requirements are met, that actually reach the Bay. This ERC is then subjected to a 10% in-kind tax, so that farmers can only sell 90% of the ERC. The in-kind tax is used to fund an ERC reserve fund that is intended to provide a buffer against defaults by ERC suppliers for regulated sources that purchased ERCs to meet their regulatory requirements. No uncertainty trade ratio is applied to the resulting tradable credits. However, the threshold and other adjustments imply that more than a one unit reduction in nitrogen or phosphorus leaving a farm is required to offset a unit of point source emissions.

PADEP has structured the program to allow and facilitate market-based trading. Farmers and credit buyers can participate and compete directly in the market. The state funded the development of an online tool for calculating and registering ERCs to facilitate program participation. In 2010, the state launched a Nutrient Credit Clearinghouse managed by the Pennsylvania Infrastructure Investment Authority (PENNVEST), a state agency traditionally charged with financing water infrastructure investments. Credit exchanges can be made through bilateral negotiations, but PENNVEST will also hold auctions. The program offers greater opportunities to benefit from market-based trading that other North American WQT programs yet developed.

Prior to the creation of PENNVEST’s clearinghouse, the program had eight trades, all involving the sale of agricultural ERCs. The trades produced nitrogen ERCs ranging from about 4 kg to 9,072 kg, with an average of 2,251 kg, and phosphorus ERCs ranging from about 1.4 kg to 33 kg with an average of 14 kg. These figures are annual amounts over the life of the contracts. Contracts range from 3 to 20 years. Prices range from USD 8.41/kg to USD 33.10/kg for nitrogen, and USD 8.84/kg to USD 22.07/kg phosphorus. All but one of the trades was organized by an aggregator working with groups of farmers to provide ERCs in sufficient quantities to meet the needs of large point sources. PENNVEST held auctions in October, 2010 and November 2010. The first auction was for three year forward contracts. Seven bids were submitted to purchase and nine bids were submitted to sell nitrogen ERCs. The auction resulted in contracts for 9,525.44 kg of nitrogen ERCs annually at a price of USD 6.10/kg. The second auction was for a forward contract for compliance year 2010-11. Eight bids were submitted to purchase and twelve bids were submitted to sell nitrogen ERCs. This auction resulted contracts for 18,597.29 kg of nitrogen ERCs at a price of USD 6.06/kg. Bids were submitted to sell phosphorus ERCs in both auctions but there were no bids submitted to purchase.

The trade volume thus far is miniscule considering that there are nearly 200 point sources and thousands of farms in the geographic scope of the market. Though there has been no formal research, there is reason to believe that the rate of uptake of trading has been slowed by limited awareness of the opportunity to trade, limited information about the merits of trading to both buyers and sellers, uncertainty about benefits from participation, and the pace at which load restrictions are being phased in.

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18. Analogous rules are applied to point sources that generate credits by reducing emissions below their regulatory requirements.
The states of Maryland, Virginia, and West Virginia also located in the Chesapeake Bay watershed and significant contributors to nutrient loads to the Bay, have also recently implemented nutrient credit trading programs that include agriculture for rivers within their boundaries. The programs in these states lag Pennsylvania’s in market development and trading activity. The US Environmental Protection Agency’s Chesapeake Bay program is studying the development of nutrient trading program that would allow trading across state borders in the Bay watershed.

3.6 US Program Evaluation

Several ex post evaluations of US WQT programs have been conducted. These evaluations have largely addressed initiatives implemented prior to the USEPA (2003) trading policy guidelines and related initiatives to improve the success of WQT in the US.

The most noted feature of US WQT programs in these ex post evaluations is the limited participation by potential traders and the lack of trading activity (e.g. Breetz et al., 2004, 2005; Hoag and Hughes-Popp, 1997; Jarvie and Solomon, 1998; King, 2005; Morgan and Wolverton, 2005; Ribaudo et al., 1999; Shabman et al., 2002; Stephenson and Norris, 1998). Reasons for low or no trade volumes reported in interviews with program managers include lack of trading partners, lack of adequate regulatory drivers (e.g. limits on effluents are not sufficiently stringent to create a demand for trades), uncertainty about trading rules, legal and regulatory obstacles to trading, high transactions costs, cheaper alternatives for point sources to meet regulatory requirements than trading with nonpoint sources, or simply, the programs being too new to permit trades (Morgan and Wolverton, 2005). These reasons, which are consistent with the evaluations of other ex post analyses, suggest flaws in the design of the market place in some cases, and the absence of underlying economic conditions needed for gains to trade in other cases. Accordingly, it might be expected that better market designs could improve market activity and the economic outcomes of those markets. Breetz et al. (2005) find that trust and communication barriers have contributed significantly to low participation rates for farmers in trading experiments that have engaged agriculture. They conclude that engaging trusted third parties, like traditional agricultural resources conservation agencies, or embedded ties may reduce farmers' reluctance to participate.

Programs developed since the mid-2000s have had the opportunity to benefit from the lessons of these prior experiences, and the investments the US EPA and other (e.g., states, NGOs) entities have made in the development of technical materials and templates to guide program development. Programs like the GWTPP and the PANCTP show greater attention to the needs of a working market place than earlier implementations, and have exhibited an adaptive approach to market development that bodes well for their futures. These programs cannot yet be judged complete successes but their results, though mixed, do support continuing interest in the method.

4. Water Quality Trading in other OECD Countries

4.1 Australia

Australia is a source of innovation in WQT for industrial point sources, but not for agriculture. The Hunter River Salinity Trading Scheme in New South Wales is an important example of the methods and merits of market-based WQT. The Hunter River drains the largest coastal catchment in New South Wales, covering approximately 22,000 km². This point-point salinity trading program applies to coal mines and power plants. It was initiated as a pilot in 1995 and made fully operational in

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19. Ex post evaluation refers to analyses that examine the performance of trading programs based on their actual outcomes (OECD, 2004).
Assessments indicate that it has achieved the water quality targets it was intended to achieve, done so at lower cost than would have been the case under the pre-existing regulatory scheme, and allowed expansion of economic activity that might not have otherwise occurred (Collins, 2005; NSWDECCW, 2010). Another point-point trading program in **Australia** is the South Creek Bubble Licensing Scheme in the South Creek area of the Hawkesbury-Nepean River. This scheme allocates emissions between three sewage treatments in the Sydney metropolitan area (NSWDECCW, 2009).

A trading program under consideration by the Queensland Environmental Protection Agency is of potential importance to agriculture. If developed, this program will trade nutrients from urban and agricultural sources to protect the ecologically significant Moreton Bay near Brisbane (QERE, 2010).

4.2 **Canada**

The Ontario South Nation River Total Phosphorus Management Program (OSNTPMP), initiated in 2000, is a leading implementation of WQT involving agriculture (Table 1). The 4,000 km² Ontario South Nation River watershed is located in eastern Ontario. The OSNTPMP is a partially capped ERC program that allows new or expanding wastewater dischargers to release phosphorus into the waterways if they offset the increased phosphorus load by reductions from nonpoint sources. A 4:1 trade ratio is used to address uncertainty in nonpoint load reduction levels and their environmental effectiveness. South Nation Conservation (SNC) negotiates trades with the dischargers. Payments to the SNC are placed in the Clean Water Fund which is used to help finance projects that generate ERCs. The SNC has long been involved in working with landowners to install conservation practices in the watershed. ERC sales augment other funding sources used to finance installation of BMPs. During the period from 2000 to 2009, 269 phosphorus-reducing projects were implemented through the watershed’s Clean Water Fund, producing an estimated 11,843 kg reduction in phosphorus. Over this period the program spent CAD 708,403 in grants on agricultural and other projects, and CAD 173,225 for program delivery.

The underlying drivers of this program are analogous to those that have driven the development of WQT programs involving agriculture in the **US** – trading with agricultural nonpoint sources offers a lower cost way to achieve point source emission limits than on-site waste water treatment. The success of the program stems in part from the significant cost-savings that can be achieved through trading, which provides a strong economic driver for the activity. The success also stems from the effectiveness of the SNC in engaging farmers to participate in the program. In **Canada**, as in the **US**, farmer participation in trading appears to be enhanced by the active engagement and mediation of a trusted third party, in this the case, the SNC.

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20. This discussion of the OSNTPMP is based on O’Grady (2008, 2011) and communications with Dennis O’Grady, General Manager, South Nation River Conservation.
Table 1. Agricultural Water Quality Trading Case Studies

<table>
<thead>
<tr>
<th>Program</th>
<th>Canada</th>
<th>New Zealand</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus Management</td>
<td>Ontario South Nation River Nitrogen Trading Program</td>
<td>Lake Taupo Nitrogen Tradable Loads Program</td>
<td>Greater Miami River Watershed Trading Pilot</td>
</tr>
<tr>
<td></td>
<td>Environment Waikato Grassland Area Farmers (GFA)</td>
<td></td>
<td>Pennsylvania Water Quality Trading Program</td>
</tr>
<tr>
<td>Administrator</td>
<td>South Nation Conservancy (SNC)</td>
<td>Grassland Area Conservancy District (MCD)</td>
<td>Pennsylvania Department of Environmental Protection</td>
</tr>
<tr>
<td>Year initiated</td>
<td>2000</td>
<td>2010</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Pollutant</td>
<td>Phosphorus</td>
<td>Nitrogen</td>
<td>Selenium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nitrogen, Phosphorus, Sediments</td>
</tr>
<tr>
<td>Eligible pollution sources</td>
<td>Industrial, municipal, agricultural</td>
<td>Agricultural</td>
<td>Industrial, municipal, agricultural</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agricultural</td>
<td>Industrial, municipal, agricultural</td>
</tr>
<tr>
<td>Commodity type</td>
<td>Emissions reduction credits (ERCs)</td>
<td>Emissions allowances</td>
<td>Emissions allowances</td>
</tr>
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<td></td>
<td></td>
<td>Emissions allowances</td>
<td>Emissions reduction credits</td>
</tr>
<tr>
<td>Emissions quantification</td>
<td>Calculated</td>
<td>Calculated</td>
<td>Measured</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Calculated</td>
</tr>
<tr>
<td>Agricultural sources capped?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Market Organization</td>
<td>SNC sells ERCs to point sources. Proceeds are used to fund agricultural projects. Farmer do not participate directly.</td>
<td>The market is designed for voluntary exchange between landowners or third party agents. An online registry has been developed for posting offers.</td>
<td>Trades are negotiated between the 7 irrigation district members of the GFA association. Farmers do not participate directly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MCD buys ERCs from Soil and Water Conservation Districts (SWCDs) using reverse auctions. The SWCDs use the proceeds to fund agricultural projects. Farmers do not participate directly. The program is funded by ERCs sold to municipal waste water treatment plants and federal grants.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The market is designed for voluntary exchange credit suppliers and demanders, or third party agents. An online registry has been developed for posting offers. A clearing house intended to increase market activity was created in 2010.</td>
</tr>
</tbody>
</table>

(continued)
Table 1. Agricultural Water Quality Trading Case Studies (continued)

<table>
<thead>
<tr>
<th></th>
<th>Canada</th>
<th>New Zealand</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline participation</td>
<td>None. Farmers do not</td>
<td>Initial allowance allocation</td>
<td>TMDL</td>
</tr>
<tr>
<td>requirements or initial</td>
<td>participate directly. Eligible</td>
<td>is based on the average</td>
<td>Credits generated by agricultural projects funded</td>
</tr>
<tr>
<td>allowances</td>
<td>projects are funded by SNC.</td>
<td>nitrogen losses between 2000</td>
<td>by the program cannot be funded by other programs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and 2005</td>
<td>or otherwise required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Farmers must meet minimum nutrient and sediment</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>management requirements to be eligible to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>participate.</td>
</tr>
<tr>
<td>Trading activity</td>
<td>Yes. The program has</td>
<td>Emerging</td>
<td>Yes. Six reverse auctions have been conducted</td>
</tr>
<tr>
<td></td>
<td>produced emissions</td>
<td></td>
<td>providing funding for 99 agricultural projects.</td>
</tr>
<tr>
<td></td>
<td>reductions and cost savings</td>
<td></td>
<td>Yes. Very low compared to the expected potential.</td>
</tr>
</tbody>
</table>

4.3 New Zealand

Environment Waikato, New Zealand, has recently initiated a trading program for Lake Taupo, the largest freshwater lake in New Zealand (Table 1). The lake’s watershed is 3,487 km² in size. About 19% of the land area is agricultural. Nitrogen leaching from grazing-based farming systems and other sources cause nutrient pollution problems, leading Environment Waikato to seek a 20% reduction in nitrogen loads.

The program is exceptional in that it is being designed as a CAT program with a primary objective of reducing nutrient loads from agriculture unlike the partially capped programs that dominate North American WQT applications that function primarily as a mechanism for reducing the costs of industrial and municipal point source compliance. Landowners receive nitrogen allowances based on historical land uses. It is also notable that the program envisions market-like allowance trading among farmers. Farmers seeking to increase their nitrogen discharges above their allowed levels will be required to acquire allowances from others. Environmental authorities for the region set up the Lake Taupo Protection Trust in 2007 to administer an NZD 81 million public fund to be used for various activities to achieve the 20% reduction goal, including purchasing a permanent reduction in the nitrogen allowances.

4.4 The Netherlands

Though not a WQT program in the conventional sense, the Netherlands implemented an innovative trading program that deserves mention in the context of markets for managing agri-environmental externalities. Beginning in the 1960s the Netherlands began to experience a highly animal intensive agriculture that created significant soil, and surface and ground water quality problems resulting from the huge volume of animal wastes produced relative to the land area,

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21. This discussion is based on Woosink (2002) and OECD (2007).
especially in the eastern and southern portions of the nation. Regional limits on expanding existing and new operations were established in 1984 but were inadequate to address the problems caused by the expansion of animal agriculture. Farm-level manure quotas were introduced in 1987. The quotas were implemented in the form of manure production rights. Transfers of rights were highly restricted. The limits on transfers were recognized to hamper changes in the structure of agriculture needed to solve the manure problem, leading to new rules to allow quota trading in 1994. The nation was divided into a manure surplus and deficit regions. Trading was allowed from the surplus region to the deficit region. Manure management policy was further modified in 1998 with the introduction of the Minerals Accounting System (MINAS). This approach switched the regulatory target from limiting manure production to balancing nutrient inputs (nitrogen and phosphorus brought onto farms in fertilizers, animal feeds, animal manures, other sources) and outputs (nutrient leaving farms in animal and other products). Farmers were required to pay levies on surplus nutrients if the surplus exceeded specified levels. Thus, the tradable quota system was essentially replaced by a system of taxes on surplus nutrients. The MINAS approach was modified repeatedly after its introduction, and was replaced in 2006 with a system of application standards for both nitrogen and phosphate. The standards limit the use of fertilizers for both nitrogen and phosphate, and the use of animal manure for nitrogen. This last change was the result of a finding by the European Court of Justice that the MINAS approach was in violation of the European Union’s Nitrate Directive.

The Dutch tradable rights system to manage animal manures was the first market-based trading mechanism for managing agri-environmental problems. During its limited existence between 1994 and 1997, there were thousands of trades, although even this volume was small relative to the potential. The program differed significantly from the agricultural WQT programs that have been developed in the Canada, New Zealand, and the US in many respects. Most notably, it did not use a measure of agricultural emissions of water pollutants from farms (e.g. nitrogen, phosphorus) as the commodity traded. Instead, a proxy, the predicted phosphate content of manure (which varies by animal type and other factors) was the commodity. The use of such an indirect proxy is a plausible alternative model of trading that has been suggested in academic literature on the use of trading schemes to address agri-environmental problems when more direct measures of emissions are unreliable or prohibitively costly to measure (e.g. Horan et al., 2002; Shortle and Horan, 2001, 2008). Ex post assessments suggest that the program contributed to environmental improvements, though the specific contribution is difficult to assess due to other influences. These assessments also suggest that design features, including the significant complexity of compliance and associated transactions costs, limited trading and the realization of potential efficiency gains. Still, the experiments suggest that manure markets may offer a useful tool for addressing nutrient pollution problems in regions with animal intensive production.

5. Water Quality Trading Performance Criteria

Previous sections have described the concept of WQT and major implementations of WQT involving agriculture. This discussion indicates a range of design parameters and a range of choices of those parameters in practice. The remainder of this document takes a more normative perspective on the design of WQT programs for agriculture. The purpose is to identify key considerations in program design and evaluation. This section presents general criteria for evaluating program designs that are commonly used for assessing pollution control instruments (e.g. Tietenberg and Johnstone, 2004), and issues and implications for WQT associated with these criteria. These criteria may be applied prospectively to guide program design, or retrospectively to evaluate actual performance.
5.1 Environmental Effectiveness

Environmental effectiveness refers to the capacity of an environmental instrument to achieve a stated environmental objective, such as a specific limit on polluting emissions. Trading programs, especially in CAT form, are generally thought to perform well by this criterion, with caveats that the characteristics of the pollution problem, and the particulars of the program implementation matter to the outcome (Tietenberg and Johnstone, 2004). Trading programs are sometimes referred to as quantity controls. This description emerged from research comparing stylized CAT programs, to emissions taxes, which are often referred to as price controls (e.g., Wietzman, 1974). Emission taxes do not explicitly limit emissions. The level of emissions when regulated with an emissions tax will be more uncertain than when regulated by a quantity control. A result of this research is that CAT is preferable to price controls when society seeks greater certainty in environmental outcomes.

While WQT may have the capacity to provide more certain environmental outcomes than price instruments for water pollution control, it would be inappropriate to assume that WQT provides a high degree of certainty, or that WQT provides greater certainty than other regulatory instruments when managing agricultural nonpoint pollution. As noted previously, nonpoint pollution cannot be controlled with certainty. Pollution control practices can reduce the probability and severity of polluting events, but the level of pollution will have a random component related to weather, uncertain effects of BMPs on emission, and other factors. Uncertainty is therefore an inherent feature of agricultural nonpoint pollution management regardless of the instrument type. Factors likely influencing the degree of uncertainty will include pollution type (e.g., nitrogen, phosphorus, sediments, pathogens), the structure of agriculture (e.g., cereal production, low intensity grazing, concentrated animal operations), characteristics of the physical environment (e.g., weather patterns, watershed characteristics), and specific features of the choice and implementation of the pollution control instruments (e.g., Borisova et al., 2005). There is no systematic evaluation of these issues available at this time. Developers of WQT trading programs for agriculture are clearly cognizant of uncertainty, with the result that managing uncertainty is generally a key issue in the choice and design of WQT programs with nonpoint sources.

It is important to note that WQT programs for agricultural nonpoint pollution are almost always designed to manage predicted agricultural emissions rather than actual emissions. Specifically, the commodities traded are not actual emission but predicted emissions, and trading rules apply to predicted emissions rather than actual emissions. It is therefore important when conducting ex post evaluations of such programs to measure impacts based on actual water quality conditions rather than predicted impacts. This is because the models used to predict nonpoint pollution are subject to significant prediction errors with the result that actual outcomes and predicted outcomes may differ substantially. It is also important to note that natural variability in water systems and lags in the response of aquatic ecosystems to changes in pollution loads can mean that years of observation may be required to determine the impacts of program on water quality conditions (NRC, 2001).

While WQT programs implemented for agricultural nonpoint pollution have not been developed first and foremost as instruments to achieve pollution control objectives for agriculture, effectiveness remains a key consideration. Active North American trading programs have been developed first and foremost to reduce the costs of industrial and municipal point source compliance through agricultural offsets. These trading programs compliment but have not been implemented to replace a suite of other government programs (e.g. the US Environmental Quality Incentives Program) that are explicitly designed to address water quality impacts from agriculture. The ecological validity of trading even in this limited context requires that the use of agricultural offsets for point source compliance should effectively serve the same water quality standards.
5.2 Economic Efficiency

Economic efficiency is concerned with the extent to which an environmental instrument can achieve its stated objective at minimum cost. Market-based trading is generally considered to perform well with respect to this criterion. However, the actual performance with respect to this criterion will depend on details of implementation. For example, WQT programs involving point sources in the US must comply with complex regulatory requirements for point sources under the Clean Water Act. These requirements greatly limit the flexibility of point sources, and trading programs with point sources, to fully utilize trading to efficiently achieve water quality goals (Shabman and Stephenson, 2007).

Further, the expectation that market-based trading performs well by this criterion presupposes that an appropriate trading model has been applied. Existing water quality trading programs borrow heavily from models for air emission trading. Yet, water pollution trading when it involves nonpoint sources of pollution, requires significant departures from conventional air emissions trading models (Shortle and Horan, 2008). Recent research suggests that the information and other transactions costs in the design and administration of WQT programs that appropriately address the nonpoint problem limit the potential efficiency gains compared to programs limited to point sources (Horan and Shortle, 2011; Ribaudo and Gottleib, 2011), and that other types of economic incentive may outperform WQT programs (Borisova et al., 2005).

5.3 Dynamic Incentives

Dynamic incentives refer to the capacity of an instrument to encourage innovation that reduces pollution and the costs of pollution control. To have this effect, instruments must allow polluters to benefit from such innovation. Emissions trading programs are thought to perform well by this criterion because innovations that reduce the cost of reducing emissions will enable net purchasers of allowances to reduce expenditures on allowances, and net sellers of allowances to profit more from their allowances sales. Thus, innovation can be encouraged on both side of the market. The operation of this incentive can be dampened if the set of practices that polluters allowed to control emissions is unduly limited.

5.4 Public Sector Costs and Capacities

Developing, implementing, and administering WQT programs for agriculture requires public resources and places demands on public sector capabilities. This is true of any environmental policy instrument. And like any other instrument, the extent of the resource needs for program development, implementation, and monitoring and enforcement, will depend on specifics of program design.

Market-based trading is generally considered to perform well with respect to the public sector costs with caveats that the characteristics of the pollution problem, and the particulars of the program implementation matter to the outcome (Tietenberg and Johnstone, 2004). Indeed, the essential argument for market-based trading in the textbook case is that it allows the public sector, if it seeks to achieve maximum efficiency in water pollution control, to forego the information costs needed to compute least cost allocations for specific environmental goals. This means public sector cost savings from trading compared to other instruments when the assumptions of the textbook model apply. However, as has been noted previously, some pollution problems approximate the textbook model reasonably well, while others, including agricultural nonpoint water pollution, do not. Horan and Shortle (2011) demonstrate that the information-cost-saving principle does not apply to nonpoint pollution when regulatory authorities are concerned with uncertainty in nonpoint pollution control. This finding diminishes but does not necessarily eliminate the appeal of water quality trading for
agricultural nonpoint sources. The implication is that investments in program design are crucial to achieving desired economic and ecological outcomes, and that WQT programs must be carefully evaluated for their economic and ecological potential.

5.5 Ancillary Benefits and Costs

Agricultural lands provide a range of ecosystem services. Examples are water supply and quality, wildlife habitat, and carbon sequestration. Changes in agricultural land uses to control pollution will affect water quality services, but may also affect the supply of other ecosystem services from agricultural lands. When positive these changes would represent ancillary environmental benefits from land use change. For example, technologies used to reduce nutrients from agricultural lands include creation of wetlands (e.g. Crumpton et al., 2008). Wetlands provide a variety of services beyond nutrient abatement. They provide bird habitat, flood control, and sediment retention (Knight, 1997; MEA, 2005; Tiner, 2003). They also sequester carbon. Wetlands are much more effective in sequestering carbon than managed agricultural systems (McCarty and Ritchie, 2002). The provision of such ancillary environmental benefits has been used in the US to help justify the establishment of trading programs that allow point sources to meet their regulatory requirements through the use of agricultural nonpoint source offsets (Heberling et al., 2007: USEPA, 2003; WSC, 2005).

Ancillary benefits may also be economic. For example, trading can be designed to produce government revenues that could be used to serve public purposes in environmental or other domains. Specifically, CAT allowances can be transferred from the public sector, which creates the allowances, to the private sector users through various methods. One method is to auction allowances to polluters, thus generating revenues for public purposes.

Noting that existing trading programs are, with a few exceptions, designed to transfer funds from industrial and municipal point sources to farmers, a possible domain of ancillary economic interest to OECD members could be the international trade distortions associated with trading compared to those associated with agri-environmental policies that use public expenditures to subsidize pollution reductions. This issue has not received attention in the literature on trading. There are three key considerations. First, that a policy has a trade impact does not mean that it causes international trade distortion. Policies that internalize an externality may have an international trade impact but will not distort international trade. This is acknowledged in the green box provisions of the Uruguay Agreement on agriculture in which support measures implemented under defined environmental programs are provided a limited exemption from disciplines on domestic support. Second, the creation of an additional source of income for farmers through government action is not necessarily treated as being internationally trade distorting, even if an externality is not being internalized. A range of programs that increase competitiveness in the farming sector that do not involve the payment of a subsidy directly linked to agricultural output are viewed to be acceptable in the WTO context. Also WTO rules do not discipline measures that provide an indirect enhancement for producers’ incomes. Finally, inflows of funds into agriculture do not inevitably translate into a production and international trade distortions. This issue is at the center of the debate on decoupled payments.

5.7 Fairness, Equity and Political Acceptance

An important feature of trading programs is flexibility in influencing the distribution of economic outcomes. This feature can be exploited to increase the acceptability of programs, or improve the perceived fairness. The key tools in affecting distributional outcomes are choices about baseline requirements in an ERC program or initial allowances in a CAT. The returns from producing ERCs in an ERC program, for example, are inversely related to the stringency of the baseline requirement.
One reason for the appeal of trading to US state environmental agencies charged with implementing TMDLs is that it is an alternative to politically unpopular direct regulation of agricultural sources. Public funding for agricultural subsidies in the US has been inadequate to induce the changes in agricultural practices needed to achieve water quality goals. Competing demands for public funds make increased financing of BMP subsidies from general funds unlikely (Shortle et al., 2010). Trading programs can provide another source of revenue to finance reductions in agricultural and other nonpoint source loads (Shortle and Horan, 2006; Stephenson et al., 2009). Specifically, agricultural nonpoint sources can voluntarily agree to reduce pollution by entering into contracts in which they are paid for generating ERCs. Thus, rather than pollution control imposing a cost, it produces a return. The revenue stream in this case is generated by entities that purchase agricultural ERC, typically industrial or municipal point sources in the design of US programs. This function is evident in both the Greater Miami River and Pennsylvania programs described previously.

5.8 Context Specific Criteria

The general performance criteria outlined above are important and widely used for evaluating pollution control instruments. It is also important to recognize that WQT programs are designed to solve specific problems and to pursue context-specific goals. These goals that may include or go beyond those implied by the general criteria (Stephenson et al., 2009).

6. Market-Based Water Quality Trading Program Design: Realizing the Promise

WQT program design is the general structure and operational rules selected to pursue the goals of a program. It should also include policies that are pursued to encourage the functioning of the market place. The design must cover the following topics:

- *Pollutant(s) traded, the geographic scope of the market, and the entities that are eligible to participate in the market, and the commodities that will be traded in the market.*
- *Trading rules to assure water quality goals are met.*
- *Limits (caps) on the aggregate supply of the commodities such that feasible market allocations of polluting emissions, given the trading rules, do not violate the environmental goal(s).*
- *Mechanisms for measuring, monitoring, and enforcement.*
- *Market place development.*

Planners developing WQT programs face three fundamental challenges in their choice of the design. One is to assure that the program complies with applicable law. For example, US WQT programs involving point sources must comply with the CWA. A second challenge is to assure that trading within the program can achieve the water quality goals the program is intended to achieve. This task requires incorporating the relevant science and technology of water quality management into the program design. The third task is to create a market place in which polluters will participate and trade in ways that serve the economic and other objectives of trading. This task requires attention to effects of the program on economic incentives that influence participation and trading decisions, and thus to the economic science of trading.

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22. Pollutants are not physically exchanged in markets. Rather, markets exchange property rights in pollution. The commodity definition specifies what is actually traded.
Guidelines and manuals have been developed to facilitate the development of water quality trading programs. For example, the USEPA has developed various technical manuals (e.g. USEAP, 2004, 2007). These manuals describe practices that must be followed for legal compliance, and provide guidelines for good practice. There are aspects of program design that have widespread agreement as good practice. But there are others for which there is disagreement. Trading experience for air and for natural resources (e.g. tradable water rights and fisheries catch quotas) provide useful lessons, but there are unique complexities in water quality management. The knowledge needed to address the complexities of designing water quality markets is incomplete due to the limited experiences in WQT, and the limited science to support water quality management in general (NRC, 2001) and WQT in particular (Shortle and Horan, 2008).

6.1 Tradable Pollutants

Assessment of the suitability of pollutants for management through trading requires consideration of both the physical processes of pollution, and the economics of trading. Markets function to balance supply and demand. They are known to work well when:

- The commodity traded is easily measured and homogeneous (standardized).
- Property rights are well-defined and secure.
- Individual supplies and demands add up linearly to determine total supply and demand.
- The market is competitive.

These are characteristics of the idealized markets of economic theory, and the idealized markets for pollution trading. Significant departures from these characteristics pose problems for markets. These problems will be exhibited in increased complexity of market design, increased complexity of market participation and trading, and increased private and public transaction costs. These factors may limit participation in markets by potential trades, which can limit potential efficiency gains from trading, and limit the realization of efficiency by those who participate (Shortle and Horan, 2008).

These considerations imply that trading makes the most sense for addressing water quality problems in which (1) water quality targets for stream reaches, lakes, estuaries, etc. can be achieved by limiting the total mass of the regulated pollutant or pollutants that enter the water body, (2) the total mass reaching the water body can be reasonably approximated as a linear adding up of emissions from regulated sources, and (3) emissions can be easily measured and precisely controlled. These conditions will rarely, if ever, be satisfied by water pollutants. The third requirement is transparently violated by agricultural nonpoint source pollutants.

Perfection should not be the enemy of the good. Thus, the assessment of suitability requires analysis of whether a market that can perform reasonably well given the objectives of the program can be constructed, and ultimately, the results of trading in practice. Nutrients, which are perhaps the most important agricultural pollutant worldwide, have been successfully traded by economic and water quality criteria between point sources, and appear to be promising for agricultural nonpoint sources based on properties of the pollutant and the results of experiments like the Ontario South Nation River trading program. More will be learned for nutrients and other prospective pollutants (e.g. sediments) with experience, advances in water quality science, and advances in understanding of how to design markets that work.
6.2 Geographic Scope and Polluter Participation23

Water quality markets will usually be designed to achieve a pollution load target for specific water bodies. In principal, the geographic scope of the market should include the land areas, and in the case of atmospheric deposition to water, the air sheds that contribute to water pollution loads in the specified water body. The geographic areas may be small, like that of the Ontario South Nation River trading program, or quite large, like that of the proposals for a Chesapeake Bay trading program. In principle, all pollution sources that contribute should be included. In practice, the costs of management information, administration, and enforcement may lead to some shrinkage in the set of regulated polluters. Thus, a large air shed may be excluded if it is a small contributor to the load and the costs of extending trading to air emissions are large. Small polluters may be excluded if the costs monitoring enforcement are large and their collective contributions to the pollution load are small. This will be an important issue in the design of agricultural problems. While agriculture is a large cause of water quality problems, the pollution often comes from many farms which individually contribute little to the overall problem. The economic literature on agricultural nonpoint pollution control demonstrates that targeting pollution efforts to subsets of polluters can enhance program efficiency (Shortle and Horan, 2001).

The size of the trading area will influence the number of potential traders and the competitiveness of the program. Very small areas may have few potential participants, limiting the gains from competition in a market-based trading program. But small numbers do not preclude some realization of gains. This is demonstrated by one-time offsets trades in the US and the results of the Ontario South River Nation trading program in Canada.

6.3 What to Trade: Emissions, Predicted Emissions, or Other Environmental Indicators?

Emissions trading involves an exchange of legal rights and responsibilities related to the location, timing, levels, and composition of polluting emissions. One element of the trading design is the specification of the observable indicator of environmental performance to which the rights and responsibilities pertain. That is, what is the commodity that is traded? This issue takes on special significance in WQT with agricultural nonpoint sources.

 Tradable environmental indicators must be observable so that trading is enforceable, and under the control (directly or indirectly) of the polluter if the polluter is to be held responsible for noncompliance. Metered emissions located in space and time of the pollutant or pollutants of concern are the presumptive choice of the environmental performance indicator when emissions can be metered accurately and at reasonable cost, and when emissions are substantially under the control of the polluter (Oates, 1994). Metered emissions are often plausible for defining the commodity for point sources of water pollution, but not for nonpoint sources.24 Nonpoint emissions from individual farms are typically highly stochastic and unobservable. The stochastic nature means that nonpoint sources cannot control actual emissions; they can only control the probability distribution of their emissions.

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23. Trading is inherently a watershed or catchment based approach to water quality management that allocates pollution loads among alternative sources within and/or across sectors. There are other approaches. Cooperative water protection areas found in some European countries like Germany are an example. Market-based trading emphasizes efficiency as an objective and relies on exchanges of rights subject to rules and regulations to achieve economically and ecologically desired outcomes.

24. Point source emissions may be measured with a varying degree of accuracy depending on the pollutant and the quantification methods. The latter include continuous measurement of flow and effluent concentration, periodic sampling, and modelled estimates for pollution control practices. The preference for trading is a direct measurement, but cost and accuracy must be considered.
Unobservable emissions make imposing limits on actual emissions impossible. In consequence, some other observable construct must serve as the basis for defining the tradable commodity.

The selection of the commodity must be guided simultaneously by water science and technology to assure that trading can meet water quality targets, by the economics of trading so that the market place will serve the economic functions of trading, and by public sector costs and capacities. Specific considerations include:

- **The correlation between the commodity and water quality conditions over time and space.** In general, the higher the correlation, the better is the commodity.

- **The ease with which the commodity can be observed for the purposes of compliance monitoring and enforcement.** Monitoring cost is a barrier to trading. Other things equal, the lower the cost, the better. However, there may well be a tradeoff between the monitoring cost and the environmental performance.

- **The farm level cost and complexity of computing the indicator.** Cost and complexity increase the transactions cost of trading and are a barrier to participation and trading activity.

- **The costs and complexity of trading the commodity.** Markets work best when the commodities they trade are highly standardized and easily understood by market participants.

- **The cost of developing the commodity.** Agricultural nonpoint commodities are typically environmental performance indicators that are calculated using formulas using observations of farm practices. Agencies must select formulas they will use. Agency options can range from research-based models and methods for specific water bodies to interpretations of the results of peer-reviewed studies. The cost and capacity of the agency to administer the method, as well as the accuracy, must be factors in the selection.

In virtually all WQT programs, the agricultural nonpoint commodity is defined in terms of a predicted discharge (or discharge reduction). The prediction is obtained using estimates of the effects of agricultural BMPs on the average volume of the nonpoint discharge for a specified unit of time. The quantification may be at the source (e.g. the reduction in the annual average pounds of nitrogen at the field edge for a particular farm), or adjusted to reflect the amount of the pollutant that moves from the source to a location at which a total load or concentration target has been set (e.g. the reduction in the annual average pounds of nitrogen delivered to a lake or estuary from a farm). Procedures for the quantification can vary greatly in complexity and accuracy.

To illustrate the procedure, Pennsylvania’s nutrient ERC trading program is designed to reduce nitrogen and phosphorus loads to the Chesapeake Bay. The state’s Department of Environmental Protection has developed a spreadsheet that farmers (or third party agents) can use to calculate nitrogen or phosphorus reduction ERCS from the implementation of agricultural BMPs from an approved list of practices (PADEP, 2010). The ERCS are estimates of the steady state annual average reduction in the nitrogen or phosphorus levels delivered to the Bay from a farm. The spreadsheet uses estimates of the nitrogen reduction efficiencies of BMPs to calculate the reduction of nutrient loads at the farm, and applies two factors from the USEPA’s Chesapeake Bay model to estimate the proportion of nutrients that move from farms to the Bay. One factor is the proportion of the nutrients that are expected to move from the farm to the edge of the subwatershed in which the farm is located. The second factor is the proportion of the nutrients that are expected to flow from the subwatershed to the Bay.
Two important aspects of the use of predicted reductions should be noted in comparison to trading actual metered emissions. One is the enormous uncertainty about the actual water quality outcomes of individual trades based on predicted emissions. This uncertainty has two sources. One is the inherent natural variability of nonpoint pollution. A second is that scientific understanding of the effects of BMP adoption on statistical descriptors of water quality conditions, such as means and variances, in particular locations is highly limited. This implies significant uncertainty about the impacts of BMP adoption on water quality conditions, and potentially large prediction errors (NRC, 2001).

A second aspect to note about the use of predicted emissions rather than metered emissions in trading is that the flexibility in the choice of abatement methods, that is fundamental to the case for emissions trading, is limited. Trading programs will typically limit BMP choices to options that have been demonstrated to be effective through scientific study. The set of practices addressed in research will typically be limited relative to the domain of technological options for pollution control. Limiting control options is a barrier to innovation, but also an understandable choice when contending with uncertainty about environmental impacts. This limitation can be addressed by allowing mechanisms to expand those lists with new information or reward efforts to measure outcomes with more certainty (more directly) (Stephenson et al., 1998).

An alternative approach to the use of predicted nonpoint emissions as the tradable nonpoint commodity is to define the nonpoint commodity directly in terms of observable on-farm inputs or practices that affect nonpoint pollution flows. Conceptually, markets can be designed which would allow trades in the use of inputs, such as fertilizer, that affect nonpoint loads (Shortle and Abler, 1997; Shortle and Horan, 2001). The Dutch manure quota is an example. Practically, this approach makes the most sense when the flow of nonpoint externalities can be closely tied to a single input or practice. Otherwise, provided the reliability is sufficient to have confidence in the achievement of water quality goals, trading predicted emissions is preferred.

A third approach to defining the nonpoint commodity, that has been discussed in the academic literature but that has not been adopted in practice, is the trading of a multi-attribute commodity (Shortle and Horan, 2006; Ghosh and Shortle, 2010). The proposed multi-attribute commodity is the predicted reduction that has become the norm for nonpoint WQT, with additional indicators of the reliability of the prediction. Essentially, the commodity would be explicitly graded for its reliability. Factors that might affect reliability include the types of the BMPs, the location in a watershed, and monitoring protocols. The objective of the multi-objective commodity definition would be to explicitly incentivize measures to reduce water quality risks associated with trading nonpoint pollution.

6.4 What to Trade: Allowances or Emissions Reduction Credits?

The commodity definition, that is the definition of what to trade, also specifies the nature of the rights and responsibilities that pertain to the commodity. A fundamental issue here is whether to use allowance or ERCs. CAT allowance trading is what economic research on efficient trading would generally recommend provided that the prerequisite conditions exit (e.g. Shabman and Stephenson, 2002; Stavins, 2007; Sterner, 2003). One reason is that the CAT approach implies an explicit cap on aggregate emissions where as the ERC approach does not. This issue will be discussed further below when discussing cap design. A second reason is the hypothetical nature of ERCs. ERCs are a prediction of the reduction in emissions that result from voluntary action to reduce emissions below
the level that would exist without the voluntary action. The level that would exist without the voluntary action is uncertain because it cannot be observed. This risk is that an actual pollution reduction associated with an ERC may be less the pollution reduction credited. In this case the ERC will not truly offset an equivalent unit of actual emissions by the ERC purchaser.

Still, there are several factors that may lead to the choice of ERC trading. One is when trading is developed within a pre-existing regulatory framework that necessitates the choice. The ERC trading schemes in the US and Canada are examples. In both cases, point sources are subject to regulatory restrictions defining their allowable emissions. ERC trading becomes a mechanism that increases the flexibility with which those requirements are met. Another factor relevant to the choice between allowance and ERC trading with agricultural sources is the relative degree of uncertainty about changes in emissions versus the overall level of emissions. Point source allowances are plausible because point source emissions are often meterable. The emissions that come from individual nonpoint sources are uncertain. In consequence, an allowance would require a calculation of the level of the emissions from the source. But methods for predicting nonpoint emissions appear to have greater skill in estimating changes in emissions than levels of emissions (Gitau and Veith, 2007; Rotz et al., 2006)). This suggests the dominant ERC trading approach may be more consistent with the underlying science and technology than an allowance trading approach.25

ERCs are traditionally defined as emission reductions below regulated levels. The regulated level defines the baseline emissions level for calculating the ERCs resulting from emissions reductions. This approach cannot be used for obvious reasons when defining ERCs for unregulated agricultural sources. Thus, ERC trading for unregulated agricultural sources requires rules for defining the agricultural baseline emissions for ERC calculation. There are two basic approaches. One is a date-based baseline. In this approach, the baseline emissions for a farm are the emissions that would result from the farming practices in place when the program was implemented. Implementation of any additional allowed BMPs for ERC generation would then be creditable. This is the most common approach in US programs (Morgan and Wolverton, 2005). The alternative, exemplified by Pennsylvania’s program, is to specify a minimum set of pollution control practices that must be implemented to be eligible to participate. In this approach, farmers who seek to participate in trading, and who do not meet the baseline requirements, must incur costs to install the baseline practices before they cannot benefit from trading. This cost is a barrier to program participation that will diminish program efficiency. Essentially, this rule the regulatory agency disqualifies the “lowest hanging fruit”; the least costly reductions cannot be offered as credits (Ghosh et al., 2009). The first approach is also perceived as unfair to so-called good actors who voluntarily adopt BMPs prior to program implementation for which they cannot be rewarded through trades while so-called bad actors can. The first approach can also be argued to create incentives to use less environmentally friendly practices prior to program implementation if farmers anticipate the creation of the program since this strategy would increase their benefits from participation.

Allowance trading also requires a baseline decision, in this case, the initial allowance of emissions, if any. There are again a several approaches. One is no initial allowance. In this case, polluters would receive their initial allowances by purchasing them from the pollution control authority. In another, initial allocations may be based on past pollution or pollution causing activities. This approach, which is sometimes referred to as grandfathering, is the approach in New Zealand’s

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25. The Lake Taupo Nitrogen Trading Program in New Zealand is an exception to the dominant practice. It is a CAT allowance trading program. The Grassland Area Farmers trading program in California is also an exception. It that case, the tradable emissions were in fact meterable.
Lake Taupo CAT program. Farms’ initial nitrogen allowances are based on their estimated highest annual discharge between July 2001 and June 2005. The range of options is useful for crafting programs that are politically acceptable or that meet equity objectives. Ancillary economic benefits are also a consideration. Auctioning initial allowances offers a source of government revenue.

Another difference to note between allowance trading and ERC trading is the liability for noncompliance. In an allowance trading program, the owner of the allowances is liable for noncompliance if actual emissions exceed the allowed emissions. In ERC trading, the ERC buyer uses the ERC purchased as a technique to meet a regulatory obligation. The buyer is legally liable for failure to meet its regulatory obligation, which would result from contractual nonperformance or failures on the part of the ERC supplier. This implies a risk for an ERC purchaser that would not exist in an allowance trading system.

6.5 Trading/Exchange Rules

To assure compliance with water quality targets, trading programs typically seek to translate spatial and source heterogeneity of pollutant loads across space and pollutant (e.g. point, nonpoint) types into equivalent water quality results. Restrictions on the exchange of metered or predicted emissions reductions based on location or type are used for this purpose. These restrictions often take the form of trade ratios that specify how many units emissions of one type or location may be exchanged for units of another type or location. Specifying trade ratios to establish equivalence requires sufficient knowledge and analytical tools to reliably estimate the impacts of changing discharge locations or discharge types in the watershed.

One such adjustment is for differences in the location of discharges in a watershed on the ambient impacts of the discharge. Ratios used for this purpose are typically constructed from delivery or attenuation ratios — the proportion of the emissions that are actually delivered to the water body of concern from a particular location (USEPA, 2007). For instance, if 100% of source A’s discharges enter an estuary directly while only half of source B’s discharges are transported to the estuary, other things being equal, it would be appropriate for source B’s discharges to trade for source A’s discharges at a ratio of 2:1. It should be noted that this spatial adjustment may be made in the commodity definition rather than exchange rules. For example, the commodity may be defined in terms of the amount of pollution delivered downstream. This adjustment is exemplified the Pennsylvania nutrient trading system which defines ERCs in terms of nutrient delivered to the Bay rather than in terms of nutrient reductions at the source.

A second common adjustment is to account for differences in commodity types. Of particular importance in WQT programs in which point sources trade a metered commodity but nonpoint sources trade a predicted commodity is a point-nonpoint (P-NP) trade ratio. This ratio is used to restrict allowable trades between metered point source emission and predicted nonpoint emissions. P-NP trade ratios are typically defined in terms of the reduction in nonpoint emissions required to offset a unit of point source emissions. They are sometimes called uncertainty ratios to reflect the fundamental motive for the adjustment – the greater relative certainty of point to nonpoint emissions reductions. When trades occur in predicted emissions, the market contains no explicit information of the reliability of the pollution reductions resulting from nonpoint sources. In consequence, WQT programs that use predicted emissions as commodities typically implement restrictions on trade intended to address the uncertainty of nonpoint emissions reductions. P-NP trade ratios in existing programs are almost all in excess of unity, implying that more than one unit of nonpoint reduction will be required to offset a unit of point source emissions. Ratios of 2:1 or higher are common in US programs (Morgan and Wolverton, 2005). The rationale for trade ratios in excess of one is to obtain a margin of safety for nonpoint uncertainty in trades between point and nonpoint. Thus, if a point source avoids a one unit
design in emission through the purchase of a nonpoint ERCs, it must, with a 2:1 ratio for example, purchase 2 units of predicted nonpoint reductions for the allowed unit, giving a margin of error of one unit.

Designing P-NP trade ratios to address nonpoint risk has been a focus of economic research on risk management in point–nonpoint trading (Horan et al., 2002; Horan, 2001; Malik et al., 1993; Shortle, 1990). There are three essential insights. One is that P-NP trade ratios applied uniformly to all point-nonpoint trades, such as applying the 2:1 ratio to any such trade, diminishes the efficiency and ecological effectiveness of trading. The reason is that a uniform ratio doesn’t recognize variations in the reliability of predicted emissions reductions across nonpoint trades, doesn’t reward trades that have greater reliability than implied by uniform ratio, and doesn’t penalize trades with lower reliability. Thus, other things being equal, P-NP trade ratios should be dependent on the actual reliability of the trades. The problem in implementing this lesson is the information and transactions cost associated with estimating trade-specific ratios, and therefore a tradeoff between trading efficiency and effectiveness and transactions costs.

A second insight is that P-NP trade ratios that best manage nonpoint risk may be less than 1:1, rather than in excess of 1:1 as is the norm. This conclusion may be counter intuitive, but the underlying principle is straightforward. A P-NP trade ratio is essentially a tax on the purchase of ERCs or allowances from nonpoint sources since it requires purchasing multiple ERCs or allowances to offset a unit of point source emissions. As a tax on nonpoint trades, it depresses purchases of predicted nonpoint reductions. If water quality risk decreases with the reductions in predicted nonpoint pollution, then risk is diminished by encouraging, rather than discouraging, purchases of nonpoint ERCs or allowances. This encouragement will occur with ratios that are less than unity. The third insight is that trade ratios should be selected integrally with choices of other design parameters, such as the commodity definition, baseline requirements, and the emissions cap. This is because design parameters do not have independent effects on program outcomes. The choice of one parameter influences the effects of others. For example, in an ex ante analysis of WQT, Horan and Shortle (2005) demonstrate that P-NP trade ratios in a partially capped trading program should be higher than those in a fully capped program.

These insights from research on optimizing program design are contrary to actual practice, where P-NP trade ratios are almost always uniform across nonpoint sources, often (substantially) more than one, and specified independently of other trading program design parameters (Shortle and Horan, 2008). In their survey of trading programs, Selman et al. (2009) found no instances where P-NP ratios were derived based on scientific information. Instead, these ratios were generally set at a value deemed politically acceptable to stakeholders. Yet methods for estimating these ratios have been developed in the scientific literature on trading (Shortle and Horan, 2008). The use of ad hoc approaches to developing key program parameters when scientific methods support appropriate choices indicates a need to better engage science in the development of water quality trading programs.

Several other trading ratios are found in existing trading programs (e.g. retirement ratios, insurance/reserve ratios). In general, they are intended to leverage up the pollution reductions from trades and increase the likelihood of achieving water quality goals by increasing the number of ERCs required to offset avoided emissions reductions. However, it must be remembered that trade ratios that increase the costs of trading will act as disincentives to trade and thus potentially diminish the economic and possibly the ecological benefits of trading.
6.6 Emission Caps

The role of the cap is to assure that the aggregate market supply of polluting emissions doesn’t violate the environmental goal(s). To be effective, a cap must adequately cover existing and new sources of pollution. There is, however, an economic issue here. Monitoring and enforcement costs increase with the number of regulated polluters. While all new and existing sources should be covered in principle, limited budgets for program development and administration may require limiting regulated polluters by size, type, or location. In a CAT allowance trading system, new or expanding sources must purchase allowances within the cap to permit the increase or expansion. In an ERC trading system, rules are required so that new sources buy into the existing cap by purchasing ERCs from existing sources.

The size of the cap refers to the total supply of pollution as defined by the commodity definition, adjusted for equivalence by location and type if necessary, by regulated sources subject to the cap. The cap is not directly a restriction on polluting emissions – it is a restriction on pollution allowances or ERCs. The numerical cap given the commodity definitions and trading rules should be defined so the actual emission will satisfy the water quality target within an acceptable margin of error. This will require a capacity to estimate the impact of trading on water quality outcomes (Shortle and Horan, 2008). In general, the greater the uncertainty about pollution loads from sources in or (see below) outside the cap, the tighter the cap must be to reliably achieve water quality goals (Shortle and Horan, 2008). Correspondingly, the tighter the cap, the higher the costs of pollution control.

Cap design in a system that is not fully capped poses significant challenges. First, in such a system, the cap for regulated sources must compensate for emissions from uncapped sources. Second, perverse water quality outcomes can arise from trades with sources outside of the cap. An example is a problem sometimes referred to as leakage (Stephenson et al., 2009). Leakage occurs when the actions that an uncapped ERC supplier takes to produce ERCs induces an activity that increases pollution that is not accounted for because it occurs outside the cap. As an example, a farmer generates ERCs by taking crop land out of production to install a riparian buffer. Holding all other farming activities constant, the buffer reduces nutrients and sediments from the farm. The farmer may respond to the reduction in crop land by increasing the intensity of production on the remaining land, possibly offsetting to some degree the reduction due to the riparian buffer. This leakage can occur because the entire farm is not subject to a cap.

6.7 Market Development

The creation of rules under which polluters can trade won’t necessarily lead to trading activity and efficient outcomes. Trading requires that participants perceive and realize gains from trade. Several conditions are required for gains from trade to exist. One requirement is that emissions limits are in place and binding for some sources. Obviously, a polluter who chooses to emit below the level of its limit without market incentives to do so will have no demand to purchase ERCs or allowances. Without a demand for ERCs or allowances, there will be no trading. The absence of adequate regulatory drivers has been cited as factor in the lack of trading activity in some US WQT programs.

A second requirement is that incremental abatement costs differ across sources. A mutually beneficial trade requires that the seller of ERCs or allowances receives more in revenues from the sale than the costs of producing the emissions reduction, and that buyer spends less on purchasing ERCs or allowances than the abatement costs it avoids. These conditions can only occur if there are variations in incremental abatement costs across sources. The common expectation of cost savings from initiating trading with between regulated point sources and lightly regulated agricultural nonpoint sources stems from the reasonable conjecture that the incremental costs of reducing agricultural
emissions is lower than for point sources. This conjecture is based on the understanding that the incremental costs of pollution control often increase with the level of pollution control. That is, it costs more to reduce the next unit of pollution than the last. In watersheds where point source emissions have been substantially reduced through regulatory initiatives but agricultural sources have not, it may well be that the incremental costs for agriculture are lower than for point sources.

Finally, the transactions costs from trading cannot exceed returns from trading (Stavins, 1995; Malik, 1992; Krutilla, 1999). The cost of coordinating buying and selling between trading participants includes search and information costs, contracting costs, and trade approval costs. There are several features of water quality trading with agricultural sources that increase transactions costs (McCann and Easter, 1999; Shortle and Horan, 2008; Woodward, 2006). One is the host of complications posed by characteristics of nonpoint pollution that have been discussed above. Nonpoint commodities are complex to define and measure, and require complex rules to assure water quality equivalence of trades. Complexity is detrimental to efficient markets. Another complication is the asymmetric nature of suppliers and demanders in water quality markets. Point sources tend to be small in number but large in size, both financially and in terms of pollution loads, compared to farms and other nonpoint sources. This difference in size and number may adversely affect competition in the market place. Point sources achieve on-site pollution control largely through lumpy long-lived capital investments where as farms will typically seek to achieve reductions through measures that leave them greater flexibility to respond to agricultural market conditions. A significant portion of point source pollution managers will be municipalities that are not market oriented in managing sewage treatment plants and storm water runoff. In consequence, point sources will be inclined to seek long term contracts while farmers will be inclined to short term contracting. The mismatches in contract volumes and durations will create problems for market coordination.

Trading structure and rules will affect the costs and returns and must be considered accordingly. But, effective trading will also require that the water quality authority invest in the development of formal and informal market institutions that facilitate trade (O’Grady, 2011). As discussed in the review of extant programs, different exchange arrangements exist, and are being innovated to meet the unique circumstances of particular trading programs. Still, there are likely significant payoffs from research and demonstration to develop effective institutional structures for alternative settings.

6.8 Policy Coordination

OECD countries have multiple objectives for agriculture and an array of policies to pursue them. These policies can interact with trading programs in ways that may enhance or detract from farmer participation and trading activity. Alternatively, trading programs may influence outcomes from other agricultural policies. Such interactions suggest the need to consider coordination issues in policy implementation.

An example that illustrates the issue is the treatment of emissions reductions that result from BMPs subsidized by public conservation or funds in US ERC trading programs. Should farmers be allowed earn credits that they can sell from practices that are financed in part by government agencies or other entities? Pennsylvania, for example, allows farmers to sell credits produced by BMPs for which they received federal cost-sharing money. An obvious concern is the apparent waste of scarce conservation funds from what is referred to as double dipping – farmers being paid twice for the same pollution reduction. Other programs, like the Greater Miami trading program, will not credit BMPs that have been financed by other mechanisms. However, allowing double-dipping can be argued to have some merit when it influences participation decisions. For example, when BMP installation is financed through cost-shares, farmers must have sufficient private benefits from the BMP to warrant their own spending. If these private benefits are inadequate, then they may not choose to participate.
Water quality and other conservation benefits will not occur. The possibility of selling credits would improve the economics of adoption and thus be potentially beneficial. In an ex ante analysis of water quality trading in Pennsylvania, Horan et al. (2004) find that allowing double dipping could improve the performance of the trading program.

7. Trading Versus Other Agri-Environmental Instruments

Trading is one among an array of instruments available to policy makers for addressing agri-environmental externalities. The array includes input restrictions (e.g., regulations on pesticides), practice restrictions (e.g., restrictions on manure management or tillage practices), taxes on inputs (e.g., fertilizers) or environmental performance indicators (e.g., nitrogen or phosphorus balances), cost-sharing subsidies for best management practices, and payments for performance (e.g., contracts compensating farmers for lost income and expenses from converting crop land along streams to riparian forest).

There is scant literature comparing trading to alternative approaches. An exception is Borisova et. al. (2005) and the comparison there is limited. The challenges that have been noted here for designing efficient trading programs for agriculture, apply to other agri-environmental instruments. These challenges include the inability to routinely monitor agricultural pollution loads at reasonable cost, the weather-driven variability of agricultural pollution, the spatial heterogeneity of agriculture and its impacts on the environment, and the temporal variability of agricultural production conditions. These challenges generally imply that any instrument will have limitations with respect to efficiency and effectiveness, and make the specifics of the instrument design and the context in which it is applied critical to instrument performance (Shortle and Horan, 2001). These facts make generalizations about the comparative merits of instruments difficult. They also imply that mixtures of instruments that utilize the strengths of one to offset the weaknesses of another will often make sense as means to efficiently and effectively address problems. The appropriate mixtures will depend on context.

Market-based trading has several potential strengths worth considering in an instrument mix. One is an emphasis on environmental performance versus effort. Agri-environmental policies often focus on the methods of environmental protection rather than the outcomes. This can result in adverse outcomes with respect to efficiency and effectiveness (OECD, 2010). Second, it provides individual polluters with an incentive to seek least cost improvements in their environmental performance, promoting cost-efficiency and beneficial innovation. Third, trading is explicitly a mechanism for allocating pollution loads reductions cost-effectively across multiple polluters. These attributes will also be present in other instruments that focus on environmental performance, rather than effort and that utilize payments or charges based on environmental performance. In a well-designed and administered, fully capped system, trading also assures achievement of environmental targets. Implementing such a system is, however, no small challenge.

8. Summary and Conclusions

Water quality trading is a forty year old concept that is now drawing significant interest as a mechanism for cost-efficient control of water pollution. Initiatives have been implemented in Australia, Canada, New Zealand, and the US, and are being considered elsewhere.

Canada and New Zealand each have one trading program. Both involve agricultural sources. The Canadian program, initiated in 2000, allows phosphorus trading between point and agricultural nonpoint sources in the Ontario South Nation River watershed. Notably, the program does not cap agricultural sources. Instead, agricultural trades are used as offsets by point sources to meet their
regulatory requirements. It has produced both pollution reductions and cost savings. The New Zealand program was developed to reduce nitrogen pollution from agriculture in Lake Taupo, located on the North Island. This program is limited to agriculture. It is unique in that it is the only active cap-and-trade program for controlling agricultural pollution. The program was in development for nearly a decade and only recently became active. It is too new for an assessment of its success. Interest in trading for water quality problems with agricultural sources in Canada and New Zealand goes beyond these initiatives, with studies for developing trading program for other water bodies in both nations.

**Australia** has a couple of active trading programs for point sources, including the highly successful Hunter River Salinity Trading Scheme, but none at the present for agricultural sources. A nutrient trading program that would include agricultural sources is being considered for Moreton Bay.

**US** water quality trading initiatives date from the early 1980s. Early programs were experimental and resulted in few trades. Interest in trading has increased since the mid- to late 1990s in response to water quality policy developments (the US EPA TMDL program) and the observed success of US air emissions trading programs. The US now leads in the development of water quality trading initiatives, with 22 instances located in 14 states, and more are being proposed. State water quality agencies have been the innovators, but they have received significant support and encouragement from the US EPA in the form of national policy guidelines for water quality trading, technical assistance, and funding to support program development.

**US** initiatives vary in type. The simplest is one-time sole-source offsets to address facility-specific permit compliance problems for regulated point sources. Agriculture is the most common source of offsets in these trades. More complex are programs to implement and facilitate routine trading between multiple point and/or nonpoint sources. These programs are typically for specific watersheds. Six of these programs are limited to point sources, but most include point and nonpoint sources, and some include agriculture. The most active watershed-based trading program that includes agriculture is the Greater Miami River Watershed Project in Ohio. Several states have developed rules that govern trading for all sources within their boundaries. Like the Ontario South River Nation trading program in Canada, active US programs that allow agricultural trades do not cap agricultural emissions. Instead, agricultural trades provide offsets used by point sources to meet their regulatory requirements.

Although trading is a significant and promising innovation for improving the efficiency of US water pollution control, the results to date are mixed. There have been some noteworthy successes, but trading activity has more often been too limited to produce expected efficiency gains. Performance problems are not the result of active trading failing to achieve water quality goals, but inactive trading failing to achieve potential cost-saving. Lessons learned from *ex post* evaluations of WQT programs include:

- Binding regulatory limits on pollution levels are essential for trading activity to occur. Such limits are essential to create the incentives for polluters to seek out options for pollution control cost savings.
- Trading activity also requires sufficiently large differences in pollution control costs between polluters to that make economic gains from trading, after deducting transactions costs incurred in conducting trades, possible.
- Trading rules must be clearly established, assure that water quality goals will be satisfied, but must also be designed to facilitate trading. Rules that are overly complex and costly
create barriers. Successful rule development must integrate the science of water quality management with the economics of market development.

- Successful trading requires the development of institutions for organizing trade that are trusted by and effective for intended program participants.

It is important to emphasize that water quality trading programs differ substantially from the well-known large scale cap-and-trade markets for sulfur dioxide air emissions in the US and carbon emissions in the European Union, and from the text-book models of emission trading that define conventional understanding of the concept of emissions trading. These differences include:

- Water quality trading programs are not defined at national or international scales. Instead, they address specific local or regional water quality problems within well-defined hydrological boundaries.

- With a few exceptions, existing water quality trading programs make limited use of markets in the conventional sense. The most effective agricultural trading models to date make use of traditional agricultural soil and water conservation institutions to recruit farmers and fund agricultural pollution reduction projects, and do not engage farmers directly in trading.

- Textbook models assume, and the major cap-and-trade programs are defined for, point sources of pollution. Some water quality trading programs are limited to point sources, but most include agricultural or other nonpoint sources.

- By definition, the textbook models and the large cap-and-trade programs place a cap on the total emissions of eligible participants. Markets serve to allocate emissions under the cap among the various sources. With one exception, active water quality trading programs with agricultural nonpoint sources are only partially capped. These programs do not limit agricultural nonpoint pollution. Instead, they allow point sources to use pollution reductions produced voluntarily by agricultural nonpoint sources as a technology for point source regulatory compliance. These water quality trading programs essentially create profit-making opportunities for agriculture that can reduce agricultural pollution, but do not in fact cap agricultural pollution.

These differences emerge for several reasons. One is the comparatively small spatial scales appropriate to water quality management. Another is the regulatory context in which the trading programs were developed. The cap-and-trade air emission programs result from legislation specifically intended to create them. Most water quality trading programs have emerged as innovations within, and constrained by, existing water pollution control laws and policies that did not envision trading. Thus, for example, US and Canadian pollution control policies do not explicitly regulate emissions from most agricultural nonpoint sources. In consequence, trading programs developed consistent with the broader policy framework do not cap them either. Instead these programs use agricultural nonpoint offsets as off-site technologies that can be used for point source compliance. Further, these programs are analogous to first-generation (pre cap-and-trade) air emissions trading programs in the US that similarly emerged as cost-saving innovations within a pre-existing regulatory framework that did not specifically enable trading. Thus, these programs trade emissions reduction credits rather than emissions allowances. Third, the textbook model of trading that has guided the development of cap-and-trade air emissions trading assumes participants are point sources. The point source model does not address challenging measurement and management issues associated with nonpoint pollution.
The growing interest in WQT trading is leading to research to develop trading models suited to nonpoint pollution. One lesson from this research is that common heuristics used in the design of point-nonpoint trading programs are scientifically flawed and may lead to designs that diminish the capacity of WQT to efficiently and effectively achieve water quality goals.

In sum, WQT can be viewed a promising innovation for water quality management in agriculture rather than a mature technique. There have been some notable successes, but there are also cases where little has been accomplished. Trading experiences will provide lessons to help determine the best applications and designs, but additional research on the science of trading for fully capped agricultural sources will be needed if water quality policy makers choose to make significant use of trading for managing agricultural nonpoint pollution.
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