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Comparing Water Quality Trading Programs: What Lessons Are There To Learn?

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Abstract. Water quality trading is being widely explored and, as we show, increasingly implemented as a means of providing flexibility and lowering the costs of meeting water quality goals. A comparison between existing and evolving trading programs in Australia, New Zealand and North America illustrates both differences and similarities among programs and identifies the main hurdles to trading as well as some key factors for program success. These can be used to design more effective programs.

1. Introduction

Water quality is rapidly becoming one of the world's most pressing environmental concerns (Millennium Ecosystem Assessment, 2005). Nutrient over-enrichment, one of the leading causes of water quality impairment, has led to the eutrophication of many lakes, rivers, and streams, as well as hypoxic (or oxygen-depleted) zones forming in receiving waters such as the Black Sea (Eastern Europe), the Pearl River Delta (China), the Gulf of Mexico, and Chesapeake Bay (U.S.). Eutrophication in turn can lead to nuisance and toxic algae blooms, loss of subaquatic vegetation (and its valuable nursery habitat), fish kills, shifts in species' richness and abundance, and formation of dead zones, i.e., areas so low in oxygen they cannot support life. At least 816 coastal areas around the world have been recognized as experiencing some form of eutrophication or nutrient over-enrichment. Of these, 481 are hypoxic (Diaz and Rosenberg, 2008; Selman et al., 2008; Diaz et al., 2011). Surveys have found that 78 percent of the assessed coastal areas in the continental United States experienced moderate to high[1] eutrophic conditions (Bricker et al., 2007). In Europe, approximately 65 percent of the Atlantic coast exhibits symptoms of eutrophication (OSPAR Commission, 2003).

Similarly, a survey of freshwater lakes between 1988 and 1993 showed eutrophic conditions in 54 percent of lakes in Asia, 53 percent in Europe, 48 percent in North America, 41 percent in South America, and 28 percent in Africa (ILEC/Lake Biwa Research Institute, n.d.). Looking more closely at the United States, in 2004, 44 percent of assessed rivers and streams, 64 percent of assessed lakes, reservoirs and ponds, and 30 percent of assessed estuaries were threatened or impaired for their designated uses (United States Environmental Protection Agency, 2009). In New Zealand, 44 percent of the monitored lakes were eutrophic or worse (Verburg et al., 2010), and water quality degradation is threatening iconic waterbodies such as Lake Taupo and the Rotorua Lakes.

In developed countries in the past, point sources (such as wastewater treatment facilities) were the

[1] Overall eutrophic condition was assessed by evaluating the occurrence, spatial coverage, and frequency of five characteristics: chlorophyll *a*, macroalgae, dissolved oxygen, submerged aquatic vegetation, and nuisance/toxic blooms. Moderate eutrophic condition is where these occur less regularly and/or over a medium-sized area. High eutrophic condition is where these occur periodically or persistently and/or over an extensive area (i.e., 50% or more of the system).

primary source of nutrients entering waterbodies. However, with the enforcement of controls on point-source nutrients, nonpoint sources, primarily agriculture and stormwater, have become the primary sources (Millennium Ecosystem Assessment, 2005). Approximately 82 percent of the nitrogen and 84 percent of the phosphorus in U.S. lakes, rivers and estuaries come from nonpoint sources (Carpenter et al., 1998). Similarly, in the Lake Taupo catchment in New Zealand, more than 90 percent of the nitrogen impairing the lake is from nonpoint sources (Rutherford and Cox, 2009). In developing countries, point sources still discharge large quantities of nutrients alongside growing nonpoint source discharges, again primarily agricultural.

One of the policy options being explored to address water quality degradation is nutrient caps, coupled with the market-based instrument nutrient or water quality trading (WQT). Nutrient caps can be placed on individual facilities or on a larger geographic area such as a watershed. WQT is a mechanism that allows sources under the cap to achieve their allocations in a manner that is most cost effective. The number of WQT programs is expanding within the United States, with programs also operating in Canada, Australia, and New Zealand. As with any policy its design and implementation affects its effectiveness in meeting its objective. This study explores similarities and differences in the design and implementation of some trading programs around the world to identify key factors for success and note what lessons can be learned from these programs. The aim is to guide new and emerging programs about the avenues to pursue and pitfalls to avoid when establishing a WQT program.

2. Background to water quality trading

WQT is not a new concept. Using pollution or emissions trading to address environmental damage first started to appear in the literature in the late 1960s (Crocker, 1966; Dales, 1966), the theory becoming reality when the United States Environmental Protection Agency authorized limited emissions trading for air pollutants in 1975. From the 1980s WQT was being seen as a possible policy solution for mitigating the costs of achieving water quality goals (David et al., 1980; Sergerson, 1988). Since then, many authors have written on topics covering economic feasibility (Faeth, 2000; Faeth and Greenhalgh, 2002; Greenhalgh and Sauer, 2003), design options (Selman et al., 2009; Horan and Shortle, 2011; Ribaudo and Gottlieb, 2011), critiques (Stephenson et al., 1999; King and Kuch, 2003; King 2005; Ribaudo and Gottlieb, 2011; Stephenson and Shabman, 2011), and trading program reviews (Hoag and Hughes-Popp, 1997; Woodward, 2003; Breetz et al., 2004; Selman et al., 2009; Yerex, 2009; Stephenson et al., 2010), though few, if any, have systematically compared a large number of programs from a number of countries to identify key factors that facilitate the success of a program.

2.1 Trading basics

WQT is premised on the fact that costs to reduce discharges differ between individual sources depending on their size, location, scale, management, and overall efficiency. Policy that underpins trading involves the regulation of some or all discharge sources, with trading giving the regulated sources the flexibility to comply with their regulatory obligations by purchasing equivalent reductions in the relevant pollutant elsewhere. The regulatory obligations are most often in the form of a watershed cap or limit for total pollutant discharges within a watershed or individual source permit or allowance limits for a pollutant discharge. Where a regulatory watershed cap is mandated then this cap is then allocated to sources. Most often, point sources are regulated using individual discharge permits or allowances, while the nonpoint sources are still largely unregulated, though some exceptions do apply (e.g., New Zealand regulates agricultural nonpoint sources).

The commodity being traded in WQT programs is either a discharge allowance (from regulated sources) or reduction credits (from non-regulated sources). The ability to trade discharge allowances or reduction credits creates an incentive for those who can reduce their discharges most cost effectively to do so and sell excess reductions to those for whom the cost of reducing discharges is higher. Participation in trading programs is always voluntary for both buyers and sellers. WQT is most often associated with nutrients (phosphorus and nitrogen), though a handful of programs have developed around other pollutants such as salinity and temperature.

There is an extensive literature on the theoretical basis for WQT, which can be sourced for more detailed accounts on the underlying premise behind WQT (e.g., King and Kuch, 2003; Tietenburg, 2006; Horan and Shortle, 2011).

2.2. Concerns around WQT

Water quality trading, especially when nonpoint sources are involved, does not fit a classical "textbook" market (Shortle, 1987, 1990; Malik et al., 1993; Horan, 2001 in Horan and Shortle, 2011) where discharges can be accurately measured and controlled and the impact of the pollutant is the same regardless of where it is discharged (Horan and Shortle, 2011). Nonpoint-source pollution, such as that from many agricultural sources, enters waterways diffusely via surface runoff or subsurface leaching and is highly variable depending on factors like soil type, landscape topography, and rainfall. This makes it highly unpredictable and difficult to measure. This means that the establishment of WQT programs is less straightforward than for some other pollutants such as carbon and sulfur dioxide emissions.

King and Kuch (2003) in their critique identified supply, demand, and institutional issues that confront WQT programs in the United States. Supply issues relate to the size of agricultural conservation subsidies, and mandatory requirements for specific management practices in some states, as they reduce the number of eligible agricultural nutrient reductions available for trading. This affects programs where a practice or nutrient reduction baseline has to be met before reduction credits can be traded (Ribaudo and Gottlieb, 2011). The trading eligibility baseline is meant to ensure the additionality of the reductions, but often makes the credits expensive. King and Kuch (2003) note that conservation payments compete with WQT for the funding of farm-based nutrient reduction practices and some farmers fear that if WQT is successful it could increase public awareness of farm contributions to water quality degradation or lead to a reduction in government conservation payments. However, given the current financial climate in the United States and indications of marked decreases in funding for U.S. Farm Bill Programs (Associated Press, 2011; Hagstrom, 2012; O'Toole, 2012), there may be an increased incentive for the agricultural sector to look to other funding sources for the implementation of nutrient reduction practices.

Demand-side issues have been addressed by several authors (King and Kuch, 2003; Selman et al., 2009;[2] Ribaudo and Gottlieb, 2011). Identified issues relate to the size of the trading ratio (which can increase the cost of purchased allowances/credits), the transaction costs associated with finding credits/allowances to purchase and the trade approval process, liability for noncompliance resulting from underperforming practices associated with the purchased allowances/credits, nonpoint-source calculation methodologies, chosen market structures, and the stringency of the cap and its enforcement. Many of these issues are further elaborated in Section 4 of this paper.

The institutional barriers identified by King and Kuch (2003) also related to supply-and-demand issues. For instance, ways to account for the different impacts of various activities can be dealt with via trading ratios, and trade approval processes can impact transaction costs.

Despite concerns around WQT, many programs are being developed both in the United States and elsewhere. To address the concerns and issues raised above and in this paper, various government agencies and nonprofit organizations are developing tools and guides to facilitate the development of successful WQT programs. These include guides for regulatory agencies and WQT program administrators (United States Environmental Protection Agency, 2004, 2007) and for farmers who are interested in participating in trading (e.g., Virginia Department of Environmental Quality, n.d.; Conservation Technology Information Center, 2006; Waikato Regional Council, 2011), calculation tools such as the Nitrogen Trading Tool (Gross et al., 2008) and OVERSEER® (Ledgard et al., 1999) and market infrastructure (e.g., NutrientNet,[3] Markit Environmental Registry[4]), and web-based training modules.[5]

2.2. Existing water quality trading programs

Many WQT programs, such as The Long Island Sound Nitrogen Credit Exchange Program, focus on point sources, as their discharges are relatively straightforward to measure, document, and regulate. The monitoring of nonpoint-source discharges and the attribution of those discharges to particular sources is significantly more challenging. It is only now that we are seeing programs emerge that focus on regulating nonpoint sources. The Lake Taupo Nitrogen Trading Program in New Zealand has reg-

[2] This policy brief contains a subset of the analysis contained in Section 4 of this paper.

[3] NutrientNet (www.nutrientnet.org) is an online marketplace for WQT programs being used by the Maryland Nutrient Trading Program.

[4] Markit Environmental Registry is an online registry to register completed trades for several environmental commodities, including water. www.markit.com/en/?

[5] http://cfpub1.epa.gov/npdes/wqtraining.cfm (accessed August 10, 2012)

ulated nonpoint sources by setting a target to maintain nitrogen losses from agricultural nonpoint sources at the highest nitrogen leaching year between 2001 and 2004. In addition, a not-for-profit trust has been established with government funding to permanently reduce the nitrogen load to the lake by 20 percent.

More commonly, nonpoint sources remain unregulated and are included in trading programs as potential sources of nutrient reduction credits. Nonpoint nutrient reduction costs are often lower than the compliance costs for a point source, providing an incentive for the point sources to purchase nonpoint-source nutrient reduction credits. In such cases the establishment of appropriate baselines is important if additional reductions in total discharge are to be ensured. Two programs that allow point source and nonpoint-source trading are the South Nation Total Phosphorus Management Program, which targets phosphorus, and the Pennsylvania Nutrient Credit Trading Program, which targets nitrogen and phosphorus.

3. Assessment methodology

A comparison was undertaken of 63 WQT programs from the United States, Australia, Canada, and New Zealand. The data and analysis contained in this paper are drawn from a variety of sources including discussions with WQT experts[6] who comprised an advisory panel to oversee this analysis, in-person interviews with various program stakeholders, phone interviews with trading program administrators, and a review of literature. The analysis contained three main components: (1) updating the status of WQT programs, (2) conducting in-person interviews, and (3) a comparative analysis of programs.

3.1. Updating the status of programs

To enable a systematic comparison of programs we identified criteria to use to compare programs (Table 1). These criteria were based on previous reviews (e.g., Breetz et al., 2004), our experience of working with programs, and input from the advisory panel. Data collection was based on a combination of phone interviews, e-mail, and Internet searches. Where possible, program administrators were contacted to ask for the current status of the program, recent trades, and the outlook moving forward

3.2. Stakeholder interviews and comparative analysis

To gain a better understanding of how programs are operating and get insights into why some programs have failed to flourish, we conducted a series of in-depth interviews with eight trading programs:

- Long Island Sound Nitrogen Credit Exchange Program, Connecticut
- South Nation Total Phosphorus Management Program, Ontario, Canada
- Great Miami River Water Quality Credit Trading Program, Ohio
- Lake Taupo Nitrogen Trading Program, New Zealand
- Cherry Creek Water Quality Trading Program, Colorado
- Chatfield Water Quality Trading Program, Colorado
- Pennsylvania Nutrient Credit Trading Program, Pennsylvania
- Red Cedar River Water Quality Trading Program, Wisconsin

We used the information collected during the program status update to select the eight trading programs to interview. They were chosen to reflect a mix of participant types, market structures, nonpoint-source credit calculation methodologies, scale, and the number of trades that had occurred. To ensure our observations were not based on a single stakeholder group and be biased to their views, we interviewed a suite of stakeholders involved with or affected by a program, including program administrators, wastewater treatment plant operators, farmers participating in the program, representatives who enroll farmers in trading programs, and citizen, environmental, and agricultural representatives. For the Lake Taupo Nitrogen Trading Program we also interviewed the Māori indigenous landholders. Māori hold large areas of land in the Taupo watershed and face some different constraints to most other types of landholders. Most important of these is the communal nature of landownership which, to date, has often resulted in the underdevelopment of their land because of the challenges around collective decision-making and their beliefs around land stewardship (e.g., healthy land and water being the essence of their existence and the need to protect the land for future generations). This has left them feeling disadvantaged under some policy designs as water quality regulation and WQT programs have evolved.

[6] Experts included Paul Faeth (Global Water Challenge), Virginia Kibler (U.S. Environmental Protection Agency), Mark Kieser (Kieser & Associates), Dennis King (University of Maryland), Clay Landry (WestWater Research LLC), and Ronda Sandquist (Jackson Kelly, PLLC).

Table 1. Criteria to compare water quality trading programs.

Category	Details collated
General details	Location, general overview of the program, pollutant traded, nature of program (pilot, trading program), program participants (point, nonpoint source) program administrator
Underpinning policy	Relevant agricultural policy and regulatory policy, status of regulatory policy
Trading status	Operational status of program (including year operational), most recent trade (including names of trade participants), trading volume of program, price of credits/allowances, method for determining price (if any)
Trading rules	Method to determine nonpoint-source reduction in nutrient losses or water quality improvement, trading ratio used, liability, structure of the market
Program obstacles	Stated issues with how trading program is operating
Other observations	Notes on any other observations about the trading program

The main set of interviews were conducted between February and April 2007, with follow-up interviews to confirm observations were still valid and identify additional issues and observations being undertaken with the trading programs operating in Chesapeake Bay and in Lake Taupo, New Zealand, in 2010 and 2012. A set of interview questions were developed in concert with the advisory panel to ensure consistent information was collected during the interview process. The key factors that the interviews sought detail on were the criteria listed in Table 1 plus the program's successes, identified hurdles to trading, and options to overcome those hurdles.

The trading programs were compared across seven factors: drivers, participants, allocation methodologies, nonpoint-source nutrient reduction calculations, trading ratios, type of market, and trading activity. These factors were based on recommendations from the expert advisory panel and those found in the literature. From the interviews we compiled the set of successes, hurdles, and options that could overcome hurdles, deciding on those that were common among multiple programs, and those identified as controversial and challenging during the development of programs.

4. Comparing water quality trading programs

Of the 63 programs assessed, 33 were active[7] (Table 2) with the other 30 programs being those that are or have been under consideration or development or are now inactive[8] (Table 3). Nine trading programs were assessed from outside the United States: two from New Zealand -- Lake Taupo Nitrogen Trading Program (active) and Lake Rotorua (under consideration); three from Canada -- South Nation Total Phosphorus Management Program (active), Lake Simcoe Watershed program (under development), Lake Winnipeg Basin (under consideration); and four from Australia -- Hunter River Salinity Trading Scheme (active), South Creek Nutrient Trading Scheme (active), Murray-Darling Basin Salinity Credits Scheme (active), and the Moreton Bay Nutrient Trading Scheme (under consideration). In addition, we assessed the state-level WQT guidance, policy, or rules that had been or were being developed in 12 states in the United States (Table 4). The WQT programs were compared against the six factors listed in Section 3.2.

[7] While programs may have finalized their trading program design and trades can occur, this does not mean that actual trades have occurred.
[8] Since the initial review of programs was undertaken, some active programs are now inactive. However, they still provide valuable information on program design, hurdles and factors for success.

Table 2. Active water quality trading programs (see text for further explanations of categories and terms).

Program name	State/Country	Participants[b]	Type of market[d]	Date of inception
Hunter River Salinity Trading Scheme[a]	New South Wales, Australia	PS-PS	Exchange	1995[h] 2002[f]
South Creek Bubble Licensing Scheme	New South Wales, Australia	PS-PS (trialing NPS)	Clearinghouse (bubble permit)	1996[f]
Murray-Darling Basin Salinity Credits Scheme[a]	South-Eastern Australia	States[c]	Bilateral	1998[f]
South Nation Total Phosphorus Management Program[a]	Ontario, Canada	PS-NPS	Clearinghouse	1998[f]
Lake Taupo Nitrogen Trading Program[a]	New Zealand	NPS-NPS	Bilateral	2009[f]
Grassland Area Farmers Tradable Loads Program[a]	California, U.S.	Irrigation districts[c]	Bilateral	1998[e]
Bear Creek Trading Program[a]	Colorado, U.S.	PS-PS/NPS	Bilateral	2006[e]
Chatfield Reservoir Trading Program[a]	Colorado, U.S.	PS-PS/NPS	Clearinghouse/ bilateral	1996[f]
Cherry Creek Basin Water Quality Authority Trading Program[a]	Colorado, U.S.	PS-PS/NPS	Clearinghouse	1997[e] 2003[g]
Dillon Reservoir Pollutant Trading Program[a]	Colorado, U.S.	PS-NPS	Bilateral	1984[f]
Long Island Sound Nitrogen Credit Exchange Program[a]	Connecticut, U.S.	PS-PS	Clearinghouse	2002[e]
Delaware Inland Bays[a]	Delaware, U.S.	PS-NPS	Sole-source	2007[f]
Lower St Johns River Water Quality Credit Trading Program	Florida, U.S.	PS-PS/NPS	Bilateral	2010[f]
Maryland Nutrient Trading Program[a]	Maryland, U.S.	PS-PS/NPS	Exchange/bilateral	2010[f]
Minnesota River Basin Trading Program[a]	Minnesota, U.S.	PS-PS	Bilateral	2005[f]
Rahr Malting Company Permit[a]	Minnesota, U.S.	PS-NPS	Bilateral	1997[f]
Southern Minnesota Beet Sugar Cooperative Permit[a]	Minnesota, U.S.	PS-NPS	Clearinghouse	1999[f]
Las Vegas Wash	Nevada, U.S.	PS-PS	Clearinghouse (bubble permit)	2010[f]
Taos Ski Valley[a]	New Mexico, U.S.	PS-NPS	Sole-source/bilateral	2004[f]
Fall Lake	North Carolina, U.S.	PS-PS/NPS	Sole-source/bilateral	2011[f]
Neuse River Basin Nutrient Sensitive Waters Management Strategy[a]	North Carolina, U.S.	PS-PS/NPS	Clearinghouse	1998[f]
Jordan Lake	North Carolina, U.S.	PS-PS/NPS	Sole-source/bilateral	2009[f]
Tar-Pamlico Nutrient Reduction Trading Program[a]	North Carolina, U.S.	PS-PS/NPS	Clearinghouse (bubble permit)	1989[f]
Great Miami River Watershed Water Quality Credit Trading Program[a]	Ohio, U.S.	PS-PS/NPS	Third-party broker	2005[e]
Ohio River Basin Trading Program	Ohio, U.S.	PS-PS/NPS	To be determined	2012[h]
Sugar Creek (Alpine Cheese Trading Program)[a]	Ohio, U.S.	PS-NPS	Third-party broker	2006[f]
Clean Water Services Permit, Tualatin River[a]	Oregon, U.S.	PS-PS/NPS	Third-party broker/ sole-source	2004[f]
Williamette Partnership (Rogue)	Oregon, U.S.	PS-NPS	Sole-source	
Williamette Partnership (Williamette)	Oregon, U.S.	PS-NPS	Sole-source	
Williamette Partnership (Lower Columbia)	Oregon, U.S.	PS-NPS	Sole-source	
Pennsylvania Nutrient Credit Trading Program[a]	Pennsylvania, U.S.	PS-PS/NPS	Clearinghouse	2006[e] 2009[f]

Table 2 (cont'd). Active water quality trading programs (see text for further explanations of categories and terms).

Program name	State/Country	Participants[b]	Type of market[d]	Date of inception
Virginia Water Quality Trading Program	Virginia, U.S.	PS-PS/NPS	Clearinghouse/ bilateral	2006[f]
Red Cedar River Nutrient Trading Pilot Program[a]	Wisconsin, U.S.	PS-NPS	Third-party broker	1997[f] 1999[h]

a: Program has transacted at least one trade or offset; b: NPS -- nonpoint source, PS -- point source; c: Programs differ from others as salinity credits are held by participating Australian States or irrigation districts in the Grassland Program, not individual sources; d: market types are described in section 4.6 and a bubble permit is where an aggregate discharge limit is set for all sources under the "bubble" meaning no one entity is responsible for meeting a specified discharge limit, but collectively they must not violate the aggregate limit; e: refers to when the trading program was finalized and trading could commence; f: refers to when trading was allowed, under a general permit, individual permit or legislation; g: refers to when revised trading guidelines were finalized; h: refers to when a demonstration or pilot program commenced.

Table 3. Water quality trading programs/initiatives in development, under consideration or where trading was considered or is now inactive (this is not meant to be an exhaustive list).

Program Name[a]	State/Country	Participants[b]	Type of Market
Moreton Bay Nutrient Trading Scheme	Queensland, Australia	PS-PS/NPS	TBD
Lake Simcoe Watershed	Ontario, Canada	TBD	TBD
Lake Winnipeg Basin	Manitoba, Canada	TBD	TBD
Lake Rotorua	New Zealand	NPS-NPS	TBD
Lower Colorado River	Colorado, U.S.	TBD	TBD
Lake Allatoona	Georgia, U.S.	PS-PS or PS-PS/NPS	TBD
Charles River Flow Trading Program	Massachusetts, U.S.	PS-PS	Bilateral
Vermillion River	Minnesota, U.S.	TBD	TBD
Upper Mississippi River Basin	Minnesota, U.S.	PS-NPS	Clearinghouse
Passaic River	New Jersey, U.S.	PS-PS/NPS	TBD
Lake Tahoe	Nevada, U.S.	NPS-NPS	Third party broker
Truckee River Water Quality Settlement Agreement	Nevada, U.S.	PS-NPS	TBD
Shepherd Creek	Ohio, U.S.	PS-NPS	Third party broker
Upper Little Miami River Basin	Ohio, U.S.	PS-NPS	TBD
Portland Tradable Stormwater Credit Initiative	Oregon, U.S.	PS-PS	TBD
Bear River	Utah/Wyoming/Idaho, U.S.	TBD	TBD
West Virginia-Potomac Water Quality Bank and Trade Program	West Virginia, U.S.	PS-PS/NPS	Exchange
Clear Creek (I)	Colorado, U.S.	PS-PS[c]	Sole-source
Boulder Creek Trading Program (I)	Colorado, U.S.	PS-NPS	Sole-source
Lower Boise River Effluent Trading Demonstration Project (I)	Idaho, U.S.	PS-NPS	Bilateral
Middle Snake River (I)	Idaho, U.S.	PS-PS	Bilateral
Upper Moquoketa and South Fork Moquoketa Watersheds Nutrient Trading Directory (I)	Iowa, U.S.	NPS-NPS	Bilateral
Sudbury River, Wayland (I)	Massachusetts, U.S.	PS-PS	Bilateral
Kalamazoo River (I)	Michigan, U.S.	PS-NPS	Third party broker
Passaic Valley Sewerage Commission Pretreatment Trading (I)	New Jersey, U.S.	PS-PS	Bilateral
New York City Watershed Phosphorus Offset Pilot Programs (I)	New York, U.S.	PS-PS	Sole-source
Lake Champlain (I)	New York/Vermont, U.S.	PS-PS	Sole-source
Cape Fear (I)	North Carolina, U.S.	PS-NPS	TBD
Fox-Wolf Basin (I)	Wisconsin, U.S.	PS-NPS	Bilateral
Rock River (I)	Wisconsin, U.S.	PS-NPS	Bilateral

a: this list contains programs where WQT was considered, is underdevelopment or in now inactive [(I) indicates the program is now inactive]; b: NPS = nonpoint source; PS = point source; TBD = to be determined; c: in the Clear Creek program, a mining company financed clean-up efforts at an abandoned mine. Mines are "orphan" sources: they are not permitted, not owned by an individual, and are difficult to monitor, but are similar to point sources because they are one central source of pollutant loading.

Table 4. U.S. states and regions with water quality trading guidance, policy, or rules.

Active Guidance, Policy or Rules
- Connecticut State Trading Legislation
- Idaho Pollutant Trading Guidance (2010)
- Maryland State Trading Policy
- Michigan Water Quality Trading Rules (Legislation effective 2002)
- Ohio State Trading Rules (Rules adopted January 2007)
- Oregon Trading Guidance (Internal Management Directive, Jan 2005)
- Pennsylvania State Nutrient and Sediment Trading Policy (Final policy and guidelines, Dec 2006)
- Virginia State Trading Rules (2006)
- Colorado State Trading Policy (2004)

Guidance, Policy or Rules in Development
- Florida State Trading Rules
- Minnesota State Trading Policy

Inactive Guidance, Policy or Rules
- Chesapeake Bay Trading Policy

4.1. Market drivers

The driver for all trading programs has been the implementation or forthcoming implementation of nutrient caps or limits, either as water quality goals or nutrient water quality criteria, which are then allocated to the various sources within a watershed.

In the United States, the Clean Water Act 1972 regulates point sources, requiring them to meet water-quality-based effluent limits. These limits are typically based on state nutrient water quality criteria, which are translated into Total Maximum Daily Loads (TMDL) for waterbodies.[9] Regulated facilities are assigned permits via the National Pollutant Discharge Elimination System (NPDES) that limit their nutrient discharge. These, together with the clear endorsement by the U.S. Environmental Protection Agency (2003) on the use of WQT to meet TMDLs and improve water quality, have resulted in a proliferation of trading programs. Twenty-five[10] of the active trading programs in the United States have been driven by TMDLs and three by the threat of a TMDL. Similarly, most of the U.S. programs under consideration are driven by TMDLs or the threat of one.

More-localized resource caps have been the main drivers in other countries. Under the Resource Management Act 1991 (RMA), which grants regional government authorities in New Zealand the authority to make resource management decisions, the Waikato Regional Council has imposed nitrogen discharge caps on all sources in the Lake Taupo watershed. More programs may also emerge in the future as a result of the National Policy Statement for Freshwater (New Zealand Government, 2011), which requires the establishment of water quality limits for all waterbodies in New Zealand by 2030. The South Nation Total Phosphorus Management Program in Ontario, Canada, is driven by the Provincial Ministry of Environment (MOE) guidelines. MOE is responsible for water quality and for licensing the operation of wastewater treatment plants in Ontario, and stipulates that if water quality guidelines are exceeded then no new pollutant discharge is allowed in a watershed (O'Grady and Wilson, n.d.).

In Australia, the Hunter River Salinity Trading Scheme in New South Wales is driven by specific salinity concerns for the Hunter River and the subsequent setting of a numeric environmental goal for the river by the NSW Environmental Protection Agency (NSW EPA). The major point sources hold

[9] Under section 303(d) of the Clean Water Act (CWA), states must assess their waters every 2 years and create a list of impaired waters, i.e., those waters that do not meet water quality standards. States are then required to create TMDLs for waterbodies on the 303(d) list of impaired waters. A TMDL defines the maximum amount of a pollutant that can be discharged into a waterbody and still maintain water quality standards. During the TMDL development process, pollutant loads are allocated among the various sources in a watershed (point and nonpoint) so that water quality standards can be met.

[10] Including two programs in Colorado that are driven by Regional Total Maximum Annual Loads.

an Environmental Protection License to discharge[11] (NSW EPA, 2008a). Similarly, the NSW EPA for the South Creek Bubble Licensing Scheme also mandated a total pollutant load limit for South Creek and allowed the affected wastewater treatment plants to trade to stay within that limit (NSW EPA, 2008b).

The stringency of the cap is important for creating the need for trades to occur. Therefore, where regulation and trading programs have been established in anticipation of future water quality issues there will be some room to increase discharges under a cap. In this situation it will be less contentious to agree on trading rules and few, if any, trades will occur until discharge levels reach their caps. In situations where the water quality goal is to return to a past water quality state or to maintain existing water quality then the cap will be more stringent and trades can be expected within shorter periods.

4.2. Participants

The variation in eligible participants for the assessed trading programs is outlined in Tables 2 and 3. There is only one regulated nonpoint-nonpoint source program -- the Lake Taupo Nitrogen Trading Program in New Zealand. Six programs were regulated point-point source programs with all other programs being point-nonpoint source programs. These latter programs regulated point sources and allowed trades with other regulated point sources or nonregulated nonpoint sources.

4.3. Allocation of caps and baselines

As each trading program is based on some form of nutrient cap, this cap has to be allocated between the relevant sources. All trading programs face the same challenges when determining the allocation methodology as there will be “winners” and “losers” no matter how the cap is allocated among sources.

The allocation of discharge limits to point sources has most commonly been a free allocation based on design flow, estimated future flows, or existing flows. This means that, in the short term, point sources like wastewater treatment plants have rarely been in danger of violating their allocated discharge limit. However, the increase in urban growth is now threatening wastewater treatment plants’ ability to meet their discharge limits in a number of programs (e.g., Cherry Creek and Chatfield trading programs). Similarly, the Lake Taupo Nitrogen Trading Program is giving a free allocation of discharge allowances to farmers based on recent nitrogen discharge levels.[12] Landholders will only begin to encounter difficulties in meeting their allocated allowance permit if they increase production or convert to more-nitrogen-intensive land uses. In some cases, such as the South Creek Bubble Licensing Scheme and the Tar-Pamlico Nutrient Reduction Trading Program, the point sources involved must, in aggregate, meet the cap, and there is no allocation to individual sources.

As nonpoint sources are typically not regulated, their baseline nutrient discharges have to be established before they are able to trade any nutrient reduction credits. This baseline is often based on current management practices. Alternatively, a baseline year might be established, beyond which any additional nutrient reducing management practices are eligible to generate credits. In some instances, trading programs have established more rigorous nonpoint-source baselines that attempt to address issues of fairness and distinguish between “good actors” (i.e., those farmers that have consistently employed good management practices) and “bad actors” (i.e., those farmers that have not consistently employed good management practices). In this way, the baseline ensures that bad actors are not generating credits for management practices they should have already been implementing. For example, Virginia’s nonpoint-source trading guidelines require that farmers must have already implemented a suite of management practices, including cover crops, conservation tillage, and streambank fencing, before they are eligible to generate credits within the trading program.

The Hunter River Salinity Trading Program uses an auction mechanism rather than allocating the cap to discharge sources. Every 2 years, a set number of available credits expire and they are re-auctioned. This provides an income stream to the administrative agency and means that credits are not necessarily assigned to one source for a long period. Those that purchase credits in the auction can either redeem them for their own compliance purposes or trade them.

[11] Environment protection licenses are a central means to control the localized, cumulative and acute impacts of pollution in NSW, Australia. They set limits on the pollutant loads emitted by holders of environment protection licenses, and links license fees to pollutant emissions.

[12] Farmers are regulated for their nitrogen discharges, and their discharge limit is based on their highest annual nitrogen discharge between July 2001 and June 2005.

4.4. Nonpoint-source nutrient-reduction calculations

As nutrient losses from nonpoint sources are difficult to measure, programs have to identify the approach they will use to determine the nonpoint-source nutrient losses. Three approaches providing increasing levels of accuracy are commonly used:

- General Models (low accuracy) -- This approach uses predetermined, standardized nutrient reduction values to estimate the nutrient benefit from implementing a practice regardless of location or other site-specific characteristics. The nutrient reduction value for each practice is based on average expected discharge calculated through scientific literature or modeling and does not change across the catchment. Red Cedar River Nutrient Trading Pilot Program, South Nation Total Phosphorus Management Program, and Virginia Water Quality Trading Program use this approach. This approach is appealing as it is simple and farmers know in advance the reductions they can achieve for implementing a practice. However, it reduces the ability to capitalize on the biophysical heterogeneity within a watershed, potentially reducing trading opportunities.
- Site-specific Models (moderate accuracy) -- Based on accepted nutrient calculation methods, this approach takes into account site-specific variables, such as soil type, slope, and fertilizer application rate to estimate nutrient reductions from various practices. The Pennsylvania Nutrient Credit Trading Program, Great Miami River Watershed Water Quality Credit Trading Program, Michigan Water Quality Trading Rules, and the Lake Taupo Nitrogen Trading Program use this approach. Employing site-specific models is more cost effective than monitoring and has the potential to more accurately assess nutrient loads at the farm level as compared to average values derived from general watershed-level models such as the Chesapeake Bay Watershed Model in the United States.
- Direct Monitoring (high accuracy) -- This approach is the most costly and is not readily applicable to all nutrient sources or practices that reduce nutrient losses. Many of the Colorado trading programs (e.g., Chatfield Reservoir Program) require the regulated point sources to monitor the performance of the practices that were implemented to offset their nutrient discharge.

4.5. Trading ratios

Trading ratios, sometimes referred to as discount factors, are used to account for various factors that affect the fungibility between discharges in a WQT program. Four types of ratios are commonly used: delivery ratios, uncertainty ratios, equivalency ratios, and retirement ratios. Most trading ratios are expressed as a ratio. For instance, a 2:1 trading ratio means that for every 2 pounds of nutrient reduced, one credit is generated. Delivery ratios, however, are usually expressed as a percentage.

Many programs use trading ratios, though the purpose of them is often not clearly defined. In the Ohio trading rules, a 2:1 trading ratio is applied to nonpoint-source reductions -- ostensibly for uncertainty. However, if the trade takes place within a TMDL watershed, the trading ratio is 3:1. While it is not explicit, it appears that the purpose of the larger trading ratio applied in a TMDL watershed is to realize a net water quality benefit from nonpoint-source management practices. In contrast, the permit for Southern Minnesota Beet Sugar clearly defines the required 2.6:1 trading ratio as follows: 1.0 for the basic load offsetting, 0.6 for an "engineering safety factor reflecting potential site-to-site variations," and 1.0 for water quality improvement. Below are descriptions of the four types of trade ratios used in WQT programs:

- Delivery ratio (or attenuation factors) -- accounts for nutrient transport and deposition within a watershed. The Pennsylvania Nutrient Credit Trading Program, Maryland Nutrient Trading Program, and Virginia Water Quality Trading Program use model-derived delivery ratios from the Chesapeake Bay Watershed model (Cerco and Noel, 2004), while the Minnesota River Basin Trading Program uses model-derived delivery ratios to convert trading units to "Jordan units" to account for the attenuation of phosphorus from various points within the watershed to a monitoring point in Jordan, Minnesota. Some programs have quite high ratios, such as the South Nation Total Phosphorus Management Program, which has a 4:1 trading ratio to compensate for delivery as well as uncertainty (most trading ratios are not above 3:1). Other programs, like the Great Miami Trading Program, only allow credits to be bought upstream of a purchasing facility to ensure adequate nutrient reductions have occurred for the needed trade, and to protect nutrient-sensitive headwaters.

- Uncertainty ratio -- hedges against uncertainty regarding whether or not a nonpoint-source nutrient reducing practice will yield its estimated amount of reductions. Its purpose is to mitigate risk should a management practice underperform. The Lower Boise River Effluent Trading Demonstration Project and the Minnesota River Basin trading program clearly defined uncertainty ratios, while most other programs do not explicitly state an uncertainty ratio. However, in many instances it appears that the stated trading ratio for point-source to nonpoint-source trades does include an uncertainty ratio.
- Equivalency ratio -- used when one or more pollutants are traded in a market to achieve the same environmental result. While some pollutants have the same environmental effect, on occasion one pollutant may be more potent than another. An equivalency ratio is needed to make the two pollutants equivalent to one another. The Rahr Malting Company in Minnesota, for instance, is regulated for chlorophyll biological oxygen demand (CBOD) and applies an equivalency ratio of 8 pounds of CBOD for every pound of phosphorus. This reflects the relative impacts on chlorophyll from phosphorus runoff and from CBOD discharge. In the Tualatin River, Oregon, the Clean Water Services (CWS) Permit regulates temperature. To meet its temperature goal, CWS allows management practices that provide riparian buffers for shade or increase flow to the river. The impact of both shade and flow are calculated relative to temperature to define the number of thermal credits awarded by these different activities.
- Retirement ratio (or environmental benefit ratio) -- retires a certain portion of the credits from each trade to ensure the trading program achieves a net water quality benefit. The Michigan Water Quality Trading Rules specify a water quality contribution where ten percent of a source's reduction in nutrient discharge is given to the state environmental agency to address uncertainty and provide a net water quality benefit.

Most trading programs lack scientifically-based uncertainty, and sometimes delivery ratios; instead, values for these ratios are often chosen arbitrarily or based on political feasibility. Large trading ratios, particularly uncertainty ratios, tend to discourage trades as they result in higher credit prices. All or some of the four types of trading ratios are used by most trading programs in the United States and Canada. Of the 28 active trading programs in the United States, 25 use some form of trading ratio, with another considering using trading ratios in the future. Delivery ratios appear to be considered in the Australian programs, but the Lake Taupo Nitrogen Trading Program in New Zealand does not specify the use of any form of trading ratio.

4.6. Type of market

The type of market defines both how trading will occur and the infrastructure that may be needed to support the trading program. The programs fell into five market categories. Sole-source offsets, bilateral negotiations, clearinghouse, and exchanges markets were described by Woodward and Kaiser (2002) and Woodward et al. (2004)[13]; while third-party brokers were added to refine the various types of markets further as there is a growing prevalence of intermediaries, acting more as pass-through organizations than clearinghouses, that are bundling and re-selling credits at a fixed price. A description of the market categories are:

- Sole-source offsets -- Sources are allowed to increase nutrient discharge at one point if they reduce their nutrient discharge elsewhere (either on or off site). In both cases the nutrient reduction efforts are undertaken by the regulated sources. Four active programs have this type of market, three more are bilateral and sole source offsets, and another is a third-party broker with sole-source offsets.
- Bilateral negotiations -- Trades are characterized by one-on-one negotiations where a price is typically arrived at through a process of bargaining and not simply by observing a market price. This type of market generally has high transaction costs. Of the 33 active trading programs, 14 allow bilateral negotiations
- Clearinghouse -- An intermediary in a trading program that aggregates credits from different sources with different prices and converts them to a fixed-price commodity that is re-

[13] Woodward and Kaiser (2002) and Woodward et al. (2004) also provide an overview of the benefits of the different market structures.

sold. For example, a clearinghouse may aggregate point-source reductions for re-sale at a fixed price (e.g., Long Island Sound Nitrogen Credit Exchange Program) or be the central body to which point sources pay noncompliance fines and they in turn pay farmers to install nutrient-reducing management practices (e.g., Tar-Pamilico Nutrient Reduction Trading Program). Commonly, the clearinghouse has been established as part of the trading program. Eleven of the active trading programs have clearinghouses.

- Third-party Broker -- An intermediary in a trading program that aggregates credits from different sources with different prices to either re-sell directly to a buyer or bundle credits together creating large credit lots for sale. In practice, the broker frequently sources the nutrient reduction credits from the agricultural sector and operates independently of the program itself. The four active programs where third-party brokers are active are the Red Cedar River Nutrient Trading Pilot Program, Great Miami River Water Quality Credit Trading Pilot Program, Clean Water Services Permit, and Sugar Creek-Alpine Cheese Trading Program, all in the United States.
- Exchange market -- Where buyers and sellers meet in a public forum (e.g., on-line) with all commodities being equivalent and all prices observed. An exchange is characterized by its open information structure and fluid transactions between buyers and sellers. The Hunter River Salinity Trading Program uses an exchange market with real-time trading. Maryland Nutrient Trading Program also has an exchange with bilateral agreements.

4.7. Trading activity

Most active programs have experienced at least one trade. In 2006, there were 236 point-source facilities in the United States covered by permits that allowed trades. Of these, 121 facilities had traded at least once over the life of the permit (Ginny Kibler, U.S. EPA, personal communication). Unfortunately, there is no accurate record of the total number of trades completed each year, though there is most certainly a wide discrepancy in the trading activity of individual facilities. While most facilities have traded once, some facilities have completed many trades. For example, the Southern Minnesota Beet Sugar Cooperative Permit has completed at least 256 trades, and Clean Water Services, which trades within the Tualatin River, has completed at least 25 trades.

In 2009, 43 facilities purchased credits in The Long Island Sound Nitrogen Credit Exchange Program (Connecticut Department of Energy and Environmental Protection, 2011) and between 2002 and 2009, 15.5 million credits have been traded (Connecticut Department of Environmental Protection, 2010).

Approximately 980 trades have been completed in the Hunter River Salinity Trading Scheme between its inception in September 2002 and August 2012, and the South Nation Total Phosphorus Management Program in Canada has had at 10 trades (Ronda Boultz, South Nation Conservation, personal communication, 2012). The Lake Taupo Nitrogen Trading Program between 2009 and February 2012 has completed 26 trades with prices for permanent reductions between NZD350-400/kg N (~USD265-303) and temporary or leased reductions about NZD25/kg N/year (~USD19) (Natasha Hayward, Waikato Regional Council, personal communication, 2012). While many programs have experienced numerous trades, others such as the Cherry Creek have had very few, if any, trades. Since 1999, there have been 3 trades in the Cherry Creek program.

5. Hurdles encountered and factors contributing to the success of WQT programs

The hurdles and factors for success loosely fall into three interrelated categories -- design, development and operation.

5.1 Design

Program goals and "success" metrics

Many WQT programs do not have a clearly articulated program goal or a monitoring strategy for measuring program success. Some goals outlined for WQT programs were to reduce the compliance costs for regulated sources, achieve an overall water quality benefit beyond that of a regulation, provide net water quality improvements from agriculture, and maintain water quality as watershed land use intensifies. Clearly-defined goals will provide guidance during the program development phases and also manage stakeholder expectations. For example, regulated point sources may expect that a WQT program's goal is to reduce their compliance costs, and not achieve an overall water quality improvement. Therefore, unless this is clearly articulated, point sources may resist the use of trading ratios to improve overall water quality as ratios increase credit prices, whereas point-source objections might be handled more expeditiously if all goals were defined.

Well-defined goals should prevent future criticism about attaining the program goals, e.g., where a program's goal is solely to reduce compliance costs then it cannot be criticized for not achieving net water quality benefits, and assist with defining metrics to assess program performance against its goals. This could be a mix of ambient water quality monitoring and other metrics. In situations, such as in New Zealand, where there are long time-lags between reduced nutrient discharges and observed improvements in water quality, additional metrics may be needed to demonstrate progress towards water quality goals.

Market drivers

A common failure identified in the interviews was the inadequacy of market drivers. In the United States, water quality standards are the primary driver of WQT setting the nutrient criteria that wastewater treatment plant permits must comply with. If the waterbody does not meet one or more water quality criteria, the waterbody is defined as a "listed water" and a TMDL is developed. TMDL development, however, may take many years, and often not all elements of a TMDL are enforced (e.g., nonpoint sources like agriculture and urban stormwater are usually not subject to meeting their load allocations). Given that most point sources are allocated caps higher than their current discharge levels, this means they are not required to make any immediate reduction in their nutrient discharge. As a result many programs have had little or no trading activity since their inception. For example, the Cherry Creek trading program has had 3 trades since 1999. On the other hand, programs like the Lake Taupo Nitrogen Trading Program have had 26 trades since 2009 as the allocated caps for individual sources were set at a historical nutrient leaching level.[14]

Watershed size also plays a role in program development as the larger the potential market, the greater the opportunities for trades to occur and for them to capitalize on the heterogeneous cost structures of potential participants (e.g., there are 183 significant discharge sources eligible to trade in the Susquehanna Basin, which is one of two trading basins in the Pennsylvania Chesapeake Bay Trading Program). Small watersheds, if trading is at all feasible, are more suited to bilateral trades or sole-source offsets than clearinghouse and exchange market structures.

Successful programs enforce their market drivers (e.g., nutrient water quality standards, nutrient caps, nitrogen and phosphorus permit limits) and the drivers were adequate to create demand.

Compliance and liability

How liability is assigned and addressed can affect the establishment and participation in WQT programs. Early attempts to establish a WQT program in the Rock River (Wisconsin) were rejected primarily on liability grounds. As regulated sources are liable for meeting their permitted discharge levels, there is a degree of reticence to trade with other sources, especially with those sources whose nutrient discharges are more uncertain like many agricultural nonpoint sources. Setting aside "insurance" credits or credit reserves is an approach used by some programs (e.g., Great Miami Trading Program, South Nation Total Phosphorus Management Program, Pennsylvania's Chesapeake Bay Trading Program) and by brokers or aggregators who on-sell nonpoint-source credits (e.g., in Pennsylvania's Chesapeake Bay Trading Program) to insure against under-performance or failure of nutrient-reducing management practices.

Establishing a "true-up" period is another approach. True-up periods are where regulated sources are given additional time after their compliance date to identify the full liability they hold and to purchase sufficient contemporaneous credits or permits to cover that liability (e.g., Long Island Sound trading program). This is useful for those regulated sources who do not know their full liability before the end of the compliance period. Allowing regulated sources to purchase contemporaneous credits in advance for use in future years also helps with their planning and construction process for the timing of upgrades (in the case of point sources). Purchasing credits in advance mitigates risk associated with supply uncertainties. It may, however, lead to a preference for practices that reduce nutrient losses for longer periods such as structural practices (e.g., streambank fencing and manure storage facilities) and riparian easements, as opposed to short-term field practices (e.g., no-till and cover crops).

[14] Interestingly, indigenous Māori stakeholders were advocating that a more stringent watershed cap was needed to maintain the spiritual health of the lake. If they had been successful, then even greater trading activity could have been expected.

Designing markets to mitigate risks for those purchasing reductions in nutrient losses will improve the probability of program success.

Calculation methodologies

Inconsistent, fixed, and nonscientific methods to calculate nutrient reductions (particularly from nonpoint sources) and to determine trading ratios can impinge the credibility of a WQT program. Standardizing calculation methodologies reduces transaction costs and makes the credit approval process timelier, e.g., Great Miami Trading Program's standard calculation methodologies. Standardization also provides consistency and comparability between offered reductions (e.g., there is currently an effort underway in Chesapeake Bay to develop a common credit estimation tool based on the Nitrogen Trading Tool (Gross et al., 2008) and NutrientNet, while the Lake Taupo Nitrogen Trading Program uses the OVERSEER® model). When these calculations are available from a centralized location, it also improves accessibility and transparency in the program. Underpinning methodologies with robust science will improve the environmental integrity and credibility of programs.

Frequently, trading ratios are based on political feasibility rather than being scientifically based, and it is not clear what the trading ratio is accounting for. To improve scientific credibility, the Lower Boise Trading Program planned to use uncertainty ratios based on the confidence interval of their calculation methods, and the methodologies within NutrientNet for Chesapeake Bay use nutrient attenuation factors from the Chesapeake Bay Watershed Model (Cerco and Noel, 2004) to underpin their delivery ratios. In some instances, adaptive management processes have been specifically established to allow for improvement in knowledge (e.g., Great Miami Trading Program will monitor 5 to 10 percent of implemented management practices to assess practice effectiveness and revise calculation methodologies where necessary).

5.2 Development

Development processes

Many of the programs surveyed were designed "from scratch" and in hindsight could have learned from other efforts to design programs and nutrient reduction calculation methodologies. As more programs become operational there is an increasing body of knowledge on how to design and implement WQT programs and run stakeholder processes, and guidance, such as that developed by the U.S. Environmental Protection Agency (2004, 2007), is evolving to assist WQT program development. Regulatory certainty like the EPA's water quality trading policy (United States Environmental protection Agency 2003) has also provided assurance that nutrient reductions achieved through trading will be recognized for compliance purposes. In areas were little guidance exists, agencies are increasingly consulting with each other and asking for national-level guidance. For instance, regional authorities in New Zealand are asking national government agencies for guidance on how to allocate a watershed cap to individual sources (Regional Council Forum, personal communication, 2012).

Not "reinventing the wheel" regarding program design and credit calculation methodologies can facilitate the development of WQT programs and speed their development process.

Stakeholder engagement, education, and transparency

Insufficient stakeholder engagement created distrust in many programs, while in others the lack of knowledge around WQT (and what it is not) created misconceptions and tension during stakeholder processes and program implementation. The South Nation Total Phosphorus Management Program, for example, had little initial outreach, leading some farmers to believe the program was a "license to pollute" for point sources. It took 3 years of stakeholder education and negotiation to address the farmers' issues and before stakeholders were comfortable with the program. Similarly, the lack of transparency around the Long Island Sound Program development meant legislation to establish the program was not passed until a more open process was undertaken to redraft the legislation. Before the Great Miami Trading Program was developed, over 75 stakeholder meetings were held to inform stakeholders about the trading program. As a result many stakeholders were fully supportive of the program.

Stakeholder engagement and education also applies to regulating agency staff as they can also hinder program development. A lack of understanding on how WQT fits within the relevant regulatory framework (e.g., U.S. Clean Water Act or New Zealand's Resource Management Act) can result in a misrepresentation of trading concepts and legislative constraints during program development. Appropriate buy-in from regulatory staff can also hinder development, especially when senior engaged personnel leave or there are no resources provided for the extra work burden placed on an agency to administer a WQT program. For instance, when senior-management trading advocates left the relevant agencies in Michigan and Wisconsin, the development of WQT programs stalled. Cherry Creek and Chatfield programs suffered resistance and suspicion from mid-level management because of lack of additional resources to administer programs which resulted in complex review processes and administrative hurdles for trades, thereby discouraging trades.

Inclusive and early stakeholder processes also help build trust in a program and should include all affected parties, such as point sources, the agricultural community, environmental groups, developers, and state environmental agencies.

Local trading "champions" were also a successful factor for some programs, as they generated "grassroots" enthusiasm helping to push programs forward. Both the Great Miami Trading Program and the South Nation Total Phosphorus Management Program credit local champions as key ingredients for their programs.

Inclusive processes that ensure stakeholders play a role in program development minimize distrust, and increasing stakeholder knowledge of WQT concepts and how programs operate will reduce tension during the development process.

Allocating caps to individual sources

One issue that causes tension during the design and implementation of most WQT programs is the allocation of the watershed cap to individual sources. Allocation issues are not strictly a WQT program issue as they are related to the establishment of the regulation not the program. However, where a WQT program is being simultaneously developed it frequently forms part of the trading debate.

While a variety of approaches have been used, there is no resolution of a preferred approach. This is primarily because when a resource is capped it constrains discharges, meaning that all sources will be negatively impacted (whether it be now or in the future, depending on the stringency of the cap), either from the lost opportunity cost of future activity or sunk costs associated with constraining current activity.

Disagreements between stakeholders and the regulatory agency over nutrient load allocations has led to protracted negotiations, limited stakeholder buy-in, and nutrient load allocations that are not equitable. For example, the Pennsylvania Nutrient Credit Trading Program's initial waste load allocations were contested by the point-source community and resulted in a lengthy re-negotiation by point sources to a level more favorable to their bottom line. In the Lake Taupo Nitrogen Trading Program, the forestry industry contested the use of an "existing use" load on the grounds that they were disadvantaged by such an allocation as they had not intensified their land use and were now being penalized for that. This issue was negotiated with the regional authority for 6 years culminating in an Environment Court[15] appeal. The allocation of nonpoint-source loads is now being debated for many watersheds in New Zealand. Another allocation option being explored in New Zealand for nonpoint source allocation of nutrient caps is to base the allocation on land capability rather than existing use (Carren et al., n.d.).

5.3. Operations

Transaction costs

High transaction costs were often noted as a deterrent for program participation, including time taken for trades to be approved, time taken for buyers and sellers to find each other, and direct costs of trading. For example, the trade approval process for the Cherry Creek and Chatfield trading programs is not standardized, with permits often unnecessarily being re-written and approved with each trade. This makes their approval process very lengthy.

To counter these concerns, programs have established a number of processes to streamline the trading process. Some elements used to reduce transaction costs include the use of a clearinghouse market structure (e.g., Long Island Sound Trading Program, South Nation Total Phosphorus Management Program, Great Miami Trading Program), creating a market infrastructure so buyers and sellers can find one another (e.g., using NutrientNet, which is being used by the Maryland Nutrient Trading Program), and standardizing the credit and trade approval process (e.g., Pennsylvania Chesapeake Bay and Long Island Sound trading programs). Permits can also be written to allow for trading by setting two discharge limits: one where there is no trading and one with trading; and include any additional reporting requirements.

For non-regulated nonpoint sources the transaction costs associated with credit estimation and aggregation have been reduced by leveraging soil and water conservation districts to sign farmers up for

[15] The Environment Court in New Zealand is where all legal appeals to proposed environmental policy are made.

the program (e.g., Great Miami Trading Program), standardizing nonpoint-source credit calculations (e.g., within NutrientNet in the Maryland Nutrient Trading Program; calculation spreadsheets used in the Great Miami Trading Program), and providing consultants to help farmers and point sources with the trading process (e.g., The Deschutes River Conservancy assists farmers in the Willamette/Tualatin trading program).

The Pennsylvania Chesapeake Bay Trading Program has also written "model" contracts to serve as templates for trading contracts and were drawn up by the administrating agency's legal staff. While use of the contract is not mandatory, its use will forgo legal fees and other costs associated with the drawing up and review of the sales contracts, thereby reducing those costs.

Implementation

To facilitate WQT, a number of programs made changes to or took advantage of existing operational processes. In the United States, NPDES permits either lacked nutrient limits or had limits expressed as a total nitrogen or total phosphorus concentration. To establish WQT programs NPDES permits need to be re-written to express nutrient limits as a monthly or annual mass-based effluent limit. In the Lake Taupo Nitrogen Trading Program, nonpoint sources were being regulated, and processes to change their status from permitted to controlled activities[16] were needed. In most instances, the same compliance period for all regulated facilities has been established for most programs to allow sources to buy and sell contemporaneous credits or permits (e.g., the compliance period for all NPDES permits in the Pennsylvania program is October 1 to September 30).

To facilitate participation by the agricultural sector, many programs have used organizations farmers are familiar with to engage them in WQT programs. The Tualatin Temperature Trading Program uses conservation district staff to identify and enroll farmers in the program at the same time they are engaging them for sign-up in the USDA-NRCS Conservation Reserve Enhancement Program. The South Nation Total Phosphorus Management Trading Program uses local farmers to sign other farmers up for the program, and the Great Miami Trading Program draws upon the resources of conservation districts in the watershed to enroll farmers in the trading program.

Trades can be further facilitated by the choice, if any, of platform or infrastructure used to support the trading program. The Maryland Nutrient Trading Program, which uses the NutrientNet platform, has designed NutrientNet to align with the trading rules, providing a simplified user interface that circumvents the need for participants to be familiar with the more complex WQT rules.

6. Discussion and overview of water quality trading programs

To date, far more trading programs have evolved in the United States than in any other country. This is likely because of the successful U.S. SO_2 trading market clearly demonstrating the benefits of trading, the earlier occurrence, and recognition that nutrients are a key source of water quality impairment, and greater federal or national government support and guidance for WQT, e.g., the United States Environmental Protection Agency's (2003) water quality policy.

Because of the volume of trading programs coming on-line in the United States there has also been a move by states to develop state-wide trading rules (see Table 3) to facilitate the development of the individual watershed-based trading programs. The United States Environmental Protection Agency has also provided a number of tools to help with various aspects of the development of trading programs, e.g., the *Water Quality Trading Assessment Handbook* (2004), and the *Water Quality Trading Toolkit for Permit Writers* (2007). As more programs evolve in Canada, Australia, and New Zealand, the supporting tools for programs in these countries may also increase. There are increasing calls by regional authorities in New Zealand for national-level guidance for issues such as allocating watershed caps to individual sources.

One striking difference between New Zealand and other countries is the willingness in New Zealand to regulate agricultural nonpoint sources. Pastoral agriculture contributes approximately 44 percent of the manageable nitrogen load[17] in the Lake Taupo watershed (Environment Waikato, 2007). The high portion of the nutrient loads coming from agri-

[16] Under the Resource Management Act, a permitted activity may be carried out without the need for a resource consent (or permit) so long as it complies with any requirements, conditions and permissions specified in the Act. A controlled activity requires consent for that activity to be carried out.

[17] Undeveloped land contributes approximately 32 percent of the manageable nitrogen load, while point sources are 10 percent and forestry is 13 percent of the manageable load.

cultural sources is not unique to New Zealand, but to date New Zealand is the only country that has taken steps to regulate that sector. In the United States there appears to be a greater reticence to regulate the agricultural sector.

The use of trading ratios also varies between programs. The Lake Taupo Nitrogen Trading Program in New Zealand does not use any type of trading ratio, delivery ratios appear to be the most common form of trading ratio used in Australia, and most U.S. programs and the South Nation Total Phosphorus Management Program use some form of trading ratio. Despite trading ratios being relatively common components of a trading program, they have also been cited as a disincentive for trading. King and Kuch (2003) observed that high trading ratios of 3:1 or 4:1 meant point sources have often opted to undertake their own internal reduction efforts because the inflated credit costs from high trading ratios made it less attractive to purchase nonpoint-source credits or other point-source credits from other parts of the watershed.

In most instances, nonpoint-source loads are the largest contributor to nutrient pollution around the world (Millennium Ecosystem Assessment, 2005; Selman and Greenhalgh, 2009). While this is recognized in most programs, nonpoint sources are only involved as voluntary suppliers of nutrient credits. With the exception of the Lake Taupo Nitrogen Trading Program (and possibly the Murray-Darling Basin Salinity Credits Scheme and Grassland Area Farmers Tradeable Load Program), all active programs are focused on point-source dischargers, mostly wastewater treatment plants.

The types of markets (see Table 2) range from the very hands on bilateral trading to the more anonymous open-exchange type of market. We also see a shift to clearinghouses, exchanges, and third-party brokers in the more recent programs. This, we believe, has been in response to the high transaction costs experienced by the participants in earlier trading programs and the desire to simplify and streamline the trading process for participants.

Governments are also playing a large role in the establishment of trading programs, pilots, and demonstrations. As there is still an aspect of the unknown with WQT programs, governments are providing significant levels of funding for interested regional, state, and local governments, and other organizations, to undertake the design and engage in the stakeholder processes that typically accompany the development of a WQT program. In the United States, funding can be obtained through the U.S. Environment Protection Agency's Watershed Grants Program and the U.S. Department of Agriculture's Conservation Innovation Grants. Australian funding is also at the national level via the National Market Based Instruments Pilot Program. In New Zealand, the central government has made a "one-time" contribution[18] to efforts to meet the Lake Taupo water quality goals, but it is the Waikato Regional Council who has borne most of the cost for developing the regulation and trading program.

One of the more contentious issues for some programs was the allocation of a watershed cap to individual sources. This has been avoided in some programs which have opted to use bubble permits, where as long as the collective cap is not violated then all sources covered by the permit are considered to be in compliance.

7. Recommendations for advancing successful water quality trading programs

Because there are WQT programs in a number of countries around the world, much can be learned from their experiences that can then be used to develop markets that successfully reduce the cost of maintaining or improving the quality of our waterways.

Despite the inherent differences in the context and physical landscapes between programs that make programs "unique", there are many experiences and much knowledge from other watersheds that can be capitalized on. For instance, methodologies to estimate the reduction in nutrient losses from agricultural practices can be difficult and time-consuming to develop. In the United States this has often been done using Microsoft Excel™ (e.g., Williamette Partnership calculation tools) or web-based tools that incorporate nationally available algorithms (e.g., Revised Universal Soil Loss Equation, Nutrient Trading Tool). These are relatively straightforward to adapt to different watersheds. In New Zealand, AgResearch, a Crown Research Institute, has developed Overseer®, a nutrient-budgeting model, to facilitate the estimation of nitrogen and phosphorus losses from pastoral lands. CLUES[19], which models nitrogen and phosphorus loads in streams, is also national in scope and could easily be used by different New Zealand watersheds embark-

[18] The Central Government, Waikato Regional Council and Taupo District Council have contributed an equal share to establish the Lake Taupo Trust (NZD81 million) aimed at meeting the water quality goals established for Lake Taupo.

[19] www.niwa.co.nz/ncwr/wru/ma/2007-22/impacts

ing on WQT. Estimation algorithms may be more difficult to transfer between countries but they are most likely highly transferable within a country.

Trading infrastructure is another area that may have easily transferable material and tools. There should be little need to greatly modify marketplaces and registries between watersheds and countries. Using operational marketplaces such as NutrientNet can decrease the time and cost of implementing underpinning program infrastructure, allowing program developers to concentrate on more controversial and difficult areas.

One such area is stakeholder processes. These processes are crucial to the adoption of any trading program, and most programs highlight their importance. Material developed for communicating trading concepts to stakeholders can be "borrowed" from other programs. However, the success of the stakeholder process will frequently depend on the process employed and stakeholder personalities. The identification of a "trading champion" can be useful in this context. A high-level elected official (e.g., a Governor, head of environmental agency, council chairman) can help motivate other high-level officials during the early stages of developing a trading program, while a local "trading champion" can generate enthusiasm for trading at the grassroots level and help push a trading program forward.

Inadequate or poorly-enforced water quality regulations are the biggest hurdle to establishing robust WQT markets. Establishment and functionality of WQT markets are likely to increase as policymakers develop, implement, and enforce water quality regulations. Most trading programs currently rely on regulatory caps for a limited set of point-source discharges (e.g., wastewater treatment plants). Broadening the scope of trading programs should increase participation. For instance, in Chesapeake Bay, which is currently subject to a bay-wide TMDL, many states are considering regulations that would require new urban development to obtain nutrient offsets. Similarly, there have been discussions around trading policies for urban stormwater permitees. Other potential sources of demand in WQT markets include potential agricultural regulations, and concerns over the future supply of drinking water may also drive the development of innovative WQT programs.

Once a program is functioning, streamlining the actual trading process is important to reduce transaction costs. For instance, the development of standardized language in regulatory compliance documents, "model" contracts for sales, and mechanisms to facilitate an actual trade and the speed at which it can be finalized are all important for promoting trading activity.

Tied to implementation are systems that may help kick-start a trading program. Uncertainty about how trading works, fear of regulatory non-compliance, and the inherent distrust of many people for something new may mean trading is slow to start. Systems that develop trust and test the functionality of a new trading mechanism can be useful in this context. Reverse auctions and the establishment of trading banks are being explored to do this. If an initial pot of money is available or can be borrowed, then a trading bank can be established. The bank, through a reverse auction, can purchase the most cost effective credits from various sources in a watershed (Greenhalgh et al., 2007). These credits can then be re-sold to provide further liquidity for the bank or to repay the initial loan. For instance, the Pennsylvania Infrastructure Investment Authority (PENNVEST) implemented the Nutrient Credit Clearinghouse as a component of Pennsylvania's Nutrient Credit Trading Program to encourage the trading of nutrient credits. Regulated wastewater treatment plants, as well as developers and others, can purchase nutrient credits from PENNVEST, who in turn will purchase credits from credit generators and aggregators. Transactions occur through periodic credit auctions as well as through bilateral agreements (Pennsylvania Department of Environmental Protection, 2012).

Lastly, trading programs are only as successful as the water quality improvement they achieve. However, programs often overlook or underfund the extent of monitoring needed to gauge progress and manage the trading program adaptively. Progress towards watershed water quality goals needs to be monitored over the long term, as does trading activity so that, over time, the trading program improves its operation and management.

8. Concluding remarks

Water quality issues are on the rise -- since 1997 there has been a four-fold global increase in identified hypoxic zones (Selman et al., 2008; Diaz et., 2011) -- and governments will increasingly be looking for ways to deal with these problems. Consequently, the number of WQT programs has continued to grow and will most likely continue to do so. Trading complements regulation, providing flexibility for sources to meet their regulatory obligations at lower costs, making trading an attractive option for governments tasked with improving water quality.

To ensure the lessons learned by trading programs are shared more widely, programs need to make concerted efforts to document these lessons and provide the opportunity for others to access this information, for instance: websites dedicated to sharing information between trading programs; workshops for program developers and/or stakeholders that specifically target certain elements of a trading program (e.g., trading ratios and their use, nonpoint-source credit calculations, running effective stakeholder processes); the provision of simple, easy-to-understand explanatory material on what WQT is and how it affects stakeholders; and the development of material that explains the important elements of a trading program, where crucial decisions have to be made, and the steps necessary in designing such a program. In addition, the transparent reporting of progress towards water quality goals and program activity will further illustrate how trading programs have or have not helped watersheds meet their water quality goals.

Over time, the design of trading programs and the necessary infrastructure (e.g., marketplaces and trading registries) that supports them will become more consistent, and trading processes more streamlined, as programs and their participants learn better ways to design and implement WQT programs.

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