Water Quality Trading in the Lower Delaware River Basin:
A Resource for Practitioners

A Report to the William Penn Foundation
by the

Institute for Environmental Studies
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March 1, 2006

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Executive Summary

This document addresses technical and administrative issues related to the establishment of water quality trading (WQT) systems in the Lower Delaware River (LDR) Basin and is based on a series of workshops, public seminars, and analysis conducted in 2005. The report is designed for practitioners interested in developing WQT systems and provides a series of specific recommendations and steps to promote the development of WQT in the area.

Pollutant trading systems allow dischargers to obtain environmental protection in an economically-efficient manner by substituting, or trading, inexpensive controls at one location for expensive controls elsewhere. Although pollutant trading has been discussed for decades, there are few WQT systems operating in the United States and none have a long track record. Those that are in operation are limited in scope and were initiated by state, federal, or private funding. Nevertheless, WQT is expected to increase in the future and has already created incentives for dischargers to examine their operations and reduce their discharges beyond what conventional methods would have provided.

Nationally, trades involving nutrients and one-time point source (PS) to non-point source (NPS) offsets are the most common type of trades. Offsets designed to reduce nutrient inputs by converting agricultural lands to forests are viable in many situations in the region but will be more efficient in reducing water quality problems related to phosphorus than ammonia. Trades between PS are the easiest to design and monitor and are expected to be increasingly common. The most complex type of trading involves inter-pollutant trades between PS and NPS or NPS and NPS. These types of trades require detailed, site-specific technical analysis and are not expected to be widely used until the region has an established trading infrastructure that can design and monitor specific trades.

While WQT can play an important and economically efficient role in improving water quality, trading cannot be expected to solve many of the region's water quality problems. This is because many water quality problems are caused by the interaction of habitat alterations and sediment, bacteria, and nutrients derived from unregulated NPS. Since nutrients are also produced by PS, there is a potential to reduce nutrient pollution through PS-NPS trades. In contrast, sediment and certain types of bacteria are not readily amenable to trading because they are not produced by most regulated PS. While sediment and bacterial pollutant reductions from NPS can be achieved using Best Management Practices, there is little if any incentive for regulated PS dischargers to trade their regulated pollutants for unregulated pollutants unless complex inter-pollutant trades are allowed and proven feasible.

There do not appear to be any major legal or administrative impediments to establishing an active WQT program in the region. Moreover, the area is fortunate to have progressive leadership among government officials and NGOs that can promote innovative approaches like trading. The primary reason for the limited use of WQT has been the lack of incentives or direct benefits for dischargers. Moreover, water quality markets are not expected to develop without an external organization creating these incentives. The Total Maximum Daily Load (TMDL) is the total amount of pollutant a water body can assimilate without exceeding water quality goals. Enforcing watershed wide pollutant reductions to meet TMDL levels is expected to be the primary source of incentives that will promote WQT. Fortunately, the States and the EPA have been actively developing TMDL's in the region since the late 1990's. Nevertheless developing TMDL's is a relatively new and complex process that will require refinements before it they can be widely used to promote trading.

While the designing, monitoring, and evaluating WQT is technically feasible, it is challenging and each trade will require some level of individual technical analysis. By definition, WQT requires substituting pollution discharges at one location for another. However, to insure trades result in the same environmental benefits, site specific trading ratios (TR) must be calculated. Nationally, the use and calculation of TR varies considerable and it is recommended that normative procedures for developing TR be established for the region and that TR be included as an integral part of each TMDL. Because trading managers and TMDL developers will never have an a priori knowledge of all possible TR that will be needed, it is recommended that the simulation models used to develop specific TMDL's are made available to allow traders to evaluate potential trades. Moreover, both managers of trading systems and potential traders will need to run the water quality models used to establish TMDL's to evaluate the efficiency of specific trades. Therefore it is proposed that a necessary step in promoting trading is to establish a publicly assessable library of site specific TMDL's models and trading agreements.

In summary, this report finds that WQT has the potential to improve the region's water quality in an economically efficient manner. Nevertheless, developing effective trading systems is a complex and long-term process that will require a sustained effort by regional environmental organizations.

Chapter 1

An Overview of Water Quality Trading

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Introduction

It has been over 30 year since the passage of the 1972 Clean Water Act (CWA) and the United States is beginning a new era in water quality regulation. Although there have been significant improvements in the quality of the Nation's water bodies, and most of the Nation's largest dischargers are in compliance with current laws, 36% to 50% of the nation's surveyed river miles and lakes still do not meet their designated uses (Boyd 2000, EPA 2004). Furthermore, at least ½ of the pollutants found in the nation's water comes from relatively unregulated nonpoint sources (NPS). Therefore, even if all regulated point sources (PS) were in compliance with current laws there would still be significant water quality problems in many areas. To deal with these problems scholars, regulators and representatives of industry are looking for cost effective ways to improve water quality. Water Quality Trading (WQT) is one mechanism that is currently being widely discussed and considered. In general, trading systems allow dischargers to obtain the same level of environmental protection in an economically efficient manner by substituting, or trading, inexpensive controls at one location for expensive controls elsewhere (Solomon 2002).

Although pollution trading has been discussed for decades, few WQT systems are in operation, none have a long track record, and those that are in operation are often limited in scope. Nevertheless, several national, state, and local initiatives indicate that WQT will be increasingly used to meet water quality goals. This document addresses the feasibility of establishing water quality trading systems in the Lower Delaware River (LDR) basin. The primary goal of the effort is to identify technical, economic, legal, and administrative issues that influence the development and successful implementation of WQT systems in the region.

To address these issues with respect to the LDR, regional stakeholders and national experts were gathered in various venues in 2005 to discuss the issues. This report synthesizes these discussions and our additional analysis into a framework for developing and evaluating water-quality trading programs in the region. First, stakeholders, regulators and others that may be directly affected by water pollution and pollution trading in the region were identified and interviewed. A workshop of local stakeholders and regional experts was then held in January 2005 to discuss water quality trading in the region. An analysis of WQT projects and regional water quality issues was also undertaken along with a series of public seminars by national experts on trading during the Fall of 2005. This report synthesizes the information obtained in these activities, provides a detailed analysis of WQT, and presents recommendations for facilitating water quality trading in the region. The intent of the document is to provide detailed information needed by those who are involved with, or promoting trading in the region.

Historical Development of Water Quality Trading Systems

The restoration of the chemical, physical, and biological integrity of the nation's water resources is the aim of the Clean Water Act, and its precursor the Federal Water Pollution Control Act (FWPCA). The initial focus of both legislations was on using the Best Practical Treatment (BPT) and Best Available Treatment (BAT) to control major discharges and meet water quality standards. These major dischargers were generally selected on the basis on their size and toxicity of their discharges, although they typically represented only a small percentage of the total discharges entering the waterways. As a result of these efforts the biological oxygen demand from industrial sources and municipal sources decreased by 71% and 46% respectively between 1974 and 1981 (Boyd 2000), in spite of expanding economic activity and increasing population.

While traditional command and control type water pollution control strategies have improved the nation's water quality, the costs of environmental protection have risen and they have not been able to effectively deal with NPS pollution. Moreover, total spending for construction of water and waste water facilities increased from around $0.2B in 1960 to around $6B (1960 $) in 1982 (Portney and Stavins 2000). Additionally, the Environmental Protection Agency (EPA) expanded its budget and its staff from around $0.5B and 4,000 employees in 1970 to around $7B (1999 $) and 18,000 employees in 1999 (Rothenberg 2002). Some of this cost increase is related to the fact that initial efforts "picked the low hanging fruit" and that marginal costs of water treatment increase with increasing standards (Cropper and Oates 2000).

During the decades after the passage of the CWA, EPA recognized that water quality problems persisted and would require innovative strategies for resolution. Based upon the apparent success of the emissions trading associated with the Clean Air Act that is discussed below, WQT has been proposed. In 1996, EPA issued a draft framework which provided basic information for anyone interested in trading and signaled EPA's support for trading (EPA 1996). In the following years EPA learned from ongoing pilot projects. After more than a decade of development EPA presented the Final Water Quality Trading Policy on January 13, 2003 (EPA 2005a). The policy is designed to encourage voluntary watershed-based trading programs that will reduce CWA compliance costs. The policy encourages trading involving nutrients or sediments and supports cross-pollutant trading for oxygen-related pollutants when adequate information exists. The report also estimates that nationwide the flexible, market-based trading approaches to improving water quality could save $900 million dollars annually. These market-based approaches are also expected to create economic incentives to develop emerging technology that will help obtain a greater efficiency in improving the quality of the nation's waters (EPA 2001). A unique attribute of WQT is it's reliance on watershed-based cooperation and negotiated settlements, in contrast to the existing patchwork of various statutory and market incentive programs that were historically driven by short term single purpose objectives and conflict rather than consensus and long-term management (Deason et al 2001).

Emission Trading and the Clean Air Act

Although the concept of trading is relatively new to water pollution programs, pollution trading has been used successfully under the Clean Air Act (CAA) for over a decade. For a decade following the 1977 amendments to the CAA, Congress noted that attaining standards for sulfur dioxide (SO_2) emissions was both slow and expensive (Plater et al 1998). Congress also recognized that the National Ambient Air Quality Standards (NAAQS) for SO_2 only considered the local effects of emission and did not implicitly address acid rain, which results from the long-distance transport and transformation of SO_2. During the 1980s, Congress considered and subsequently rejected various proposals to combat acid rain until 1990 when they passed the Title IV Amendment of the CAA (Nash et al. 2001).

Title IV was the first large-scale environmental program that relied upon tradable permits to control pollution. It created a "cap", or upper level of SO_2 emissions and limited total emissions to one-half of the 1980 level (Schmalensee et al. 2000). Emitters of sulfur dioxide purchase allowances for the emissions from the EPA or other emitters. In the program, facilities with low reduction costs reduce more than their targets and sell allowances to facilities with high reduction costs. The participants are free to buy and sell allowances among themselves or at an annual auction that the EPA established. The first phase of the program lasted between 1995 and 1999, affected 263 sources from 110 electric utility plants, and 61 companies (Stavins 2000). The second phase started in 2000 and affects virtually all fossil fuel electric power plants in the country.

While some skeptics attribute successes of the program to forces other than trading, most scholars agree that the program is successful and that trading contributed to its success. Moreover, the program exceeded its emission targets and schedule and by 1996 all Phase I sources were compliant (Powers 1998, 157). Furthermore, nationwide emissions in 1995 and 1996 were 39% and 33% percent below the allowance levels. EPA also estimates that by 2020, the emissions will be 40% of the emissions that would occur without Title IV (Schmalensee et al. 2000).

As the program evolved the compliance costs were lower than both the proponents and the opponents initially expected. Initial predictions of compliance cost ranged from \$300 to \$1,000 per ton of SO_2 remove (Powers 1998). The initial prices of the allowances were consistent with these and ranged from \$265 to \$300 per ton in 1992 (Schmalensee et al 2000). However, once the program was established, the price decreased steadily to around \$100 per ton by 1996. In 2000 the price was approximately \$130 per ton. During the development of the program Congress and the Administration estimated that the annual compliance cost of the program would be \$42B and \$19B, respectively (Bailey 1998). After the program was established, EPA estimated that the actual annual compliance cost was only \$2B to \$3B (Percival 1997). Overall, they estimate that Title IV will produce an annual savings of \$12B to \$78B by 2010.

Analysis of the Title IV experience indicates several design principles that are relevant to water quality trading. First, pollution markets require the clear specification of property rights so dischargers can buy and sell pollution credits (Anderson and Leal 1998, Richards 2000). Second, Title IV used the market to attain a goal not to set the goal (Merrill 2000, Shapiro and Glickman 2000). Moreover, Congress capped the emission of SO_2 and allowed emitters to use market forces to find cost-effective mechanisms to achieve the cap. The "invisible hand" of market forces was not used to define the goal.

Third, trading systems are best for pollutants that are from defined PS and rapidly become well mixed in the ecosystem (Stavins 2000). Title IV allowed trading across the full geographic extent of the country because SO_2 emissions rapidly become relatively well mixed in the nation's atmosphere. Therefore, reductions at one point will ultimately affect large areas. In contrast, many water pollutants come from NPS and have mixing zones that are much smaller than mixing zones for air. Therefore, pollution trading systems for water should establish the geographic extent based upon the mixing of the pollutant in the system.

Fourth, the number of participants is a critical component of the design of the market (Wyman 2002). The first phase of Title IV had 61 participants from a range of industries that had a range of control costs (Stavins 2000). However, if the number and type of discharges is too small, the system may not have enough variation in the marginal cost of reduction to provide an incentive to trade. If the number and types of sources is too large, the information and communication barriers may be too great to overcome. Therefore, designers of water pollution trading systems should strive to create systems that are large enough to capture variations of marginal cost and benefit from decentralized-decision making, but are small enough to ensure that the barriers of information and communication are not too great.

The Title IV experience also indicates that a strong central organization that takes responsibility for monitoring, enforcement, conflict resolution, and brokerage of allowances or permits is needed. In Title IV, EPA performs these tasks (Stavins 2000).

Types of Water Quality Trading Systems

Although trading systems and other market-based pollution control mechanisms are being widely considered, there is no general consensus regarding the definitions of trading systems. Nevertheless, several classification systems have been developed. Shabman, Stephenson, and Boyd (2004) characterized trading systems by who has responsibility for allocation of the load and if the load has an upper level or cap (Table 1-1).

Table 1-1. Taxonomy of Trading Systems, from Shabman, Stephenson, and Boyd (2004)

	Buyer and Seller are Capped Sources	Buyer is a Capped Source. Seller is an Uncapped Source
Discharger Directed Allocation	Cap and Allowance Trades (CATs)	Credit Sales
Regulator Directed Allocation	Directed Trades	Offsets

In the discharger directed systems, dischargers determine how much they will discharge. In regulator directed systems, the regulators determine the allocation of the load. Within this classification, Cap and Allowance Trades involve transferable allowances whereby managers can distribute the load in a way that is cost effective for them but within the established cap. In these systems the allowance is a commodity that dischargers trade among themselves. Directed Trades involve a cap but not a tradable allowance. In these systems, regulators distribute the load in a way that maintains the cap. Credit Sales are load reductions achieved by uncapped sources. In these trades, uncapped dischargers voluntarily agree to trade with a capped source. In an Offset, regulators decide if a capped source can trade a reduction from an uncapped source.

These authors also argue that none of the existing systems are true "market-based" trading systems and are "simply an extension of the current permitting system" (Stephenson, Shabman, and Geyer 1999). They also suggest three features of effective trading systems:

- Discharger-driven redistribution of allowances under an established cap. Moreover, market forces are used to achieve a establish goal, not set the goal.
- Flexibility for dischargers to determine for themselves how to meet pollution control requirements.
- External compliance flexibility for dischargers – Dischargers must be free to shift their discharge reduction requirement to another party.

Woodward and Kaiser (2000) classified trading systems by the forum used to complete the trade. Four types of trading markets were identified: exchanges, bilateral negotiations, clearinghouses, and sole-source offsets.

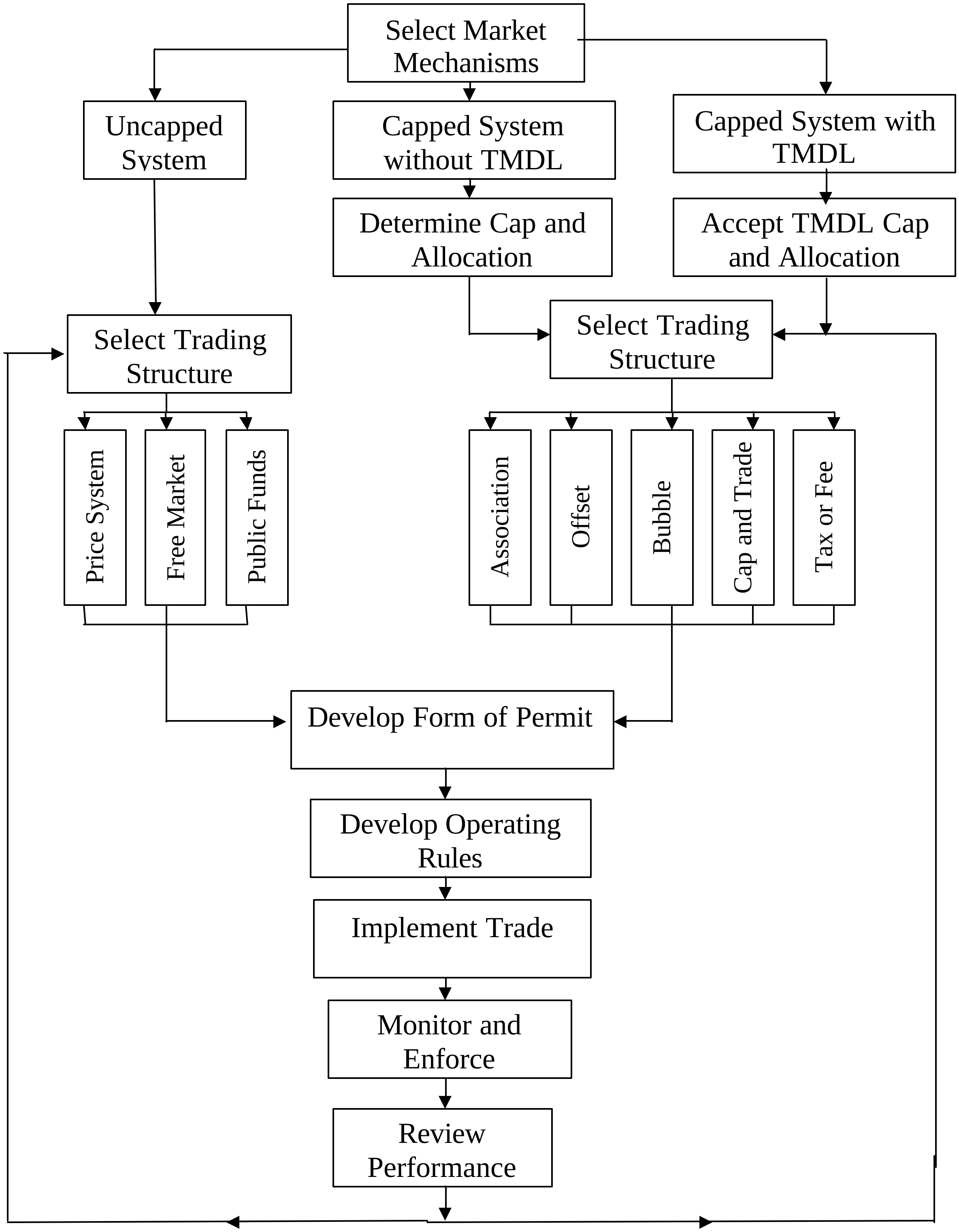
- *Exchanges* are open markets in which participants have accurate information about the price of a plentiful and uniform product. The Title IV program and the New York Stock Exchange are examples of exchanges.

- *Bilateral negotiations* are systems where buyers and sellers to exchange information and negotiate the terms of specific trades. The advantage of this type of system lies in its ability to accommodate non-uniform goods and unique circumstances. This is the one of the most common type of WQT markets and includes the Wisconsin's Fox River, the PS to PS trading of North Carolina's Tar Pamlico Basin, and Michigan's Kalamazoo program.

- *Clearinghouses* are systems that convert products of variable price and quality into a tradable product of uniform price and quality. Examples include the PS to NPS trading of North Carolina's Tar Pamlico Basin program.

- *Sole-source offsets* when a discharger is allowed to achieve water quality standards at one location by reducing pollution at another location. The Boulder Creek trading program is an example of this type of market.

Figure 1-1: Schematic of the development and types of trading systems



Nutrients are the most commonly traded water quality pollutant (Table 1-2). Moreover, 76 percent of the systems involved nutrients. A handful of other systems involve trading of BOD, sediment, and DO that are often related to nutrients. The most common type of existing trading programs involves a cap and use of NPS reductions as either offsets for PS expansions or in place of PS reductions. Fifteen programs, or 52 percent, fit this description.

Our review of trading systems has identified 3 stages of development and eight basic structures that can be used to classify WQT systems (Figure 1.1). In the first stage, developers of a WQT system must determine if trading will be based on a capped or uncapped system. The second stage involves developing the structure of the trading system and the procedures and rules for its operation and management. The final stage involves how the system measures success, penalize noncompliance and reward compliance. Regulatory review, modeling, and evaluation are involved in every stage of the process.

This framework recognizes three trading structures for uncapped systems and five structures for capped systems (Figure 1-1):

- *Tax or Fee Systems (TF)* – In these systems, regulators establish a tax or fee for discharge. Dischargers may emit pollutant at any level they determine is appropriate, but must pay a fee associated with the level of their discharge (e.g. $/ton of effluent discharged). The system is considered uncapped because regulators set the price and allow the quantity to adjust via the market. No examples of this type of system are known for water pollution control.

- *Free Market Purchase Systems (FMP)* –In these systems, stakeholders who are not dischargers purchase reductions from dischargers who do not have the incentive to reduce pollution. The system is uncapped because the price of the reduction determines the quantity of the reduction. A hypothetical example of this system is the resort downstream of a wastewater treatment plant (WWTP) that pays for extra water quality treatment to protect their resort.

- *Public Funds Purchase Systems (PFP)* – These systems are similar to the Free Market Purchase Systems except that public funds are used to purchase reductions. Moreover, a government or public agency pays a fee for reductions in excess of reductions that the law requires. The system is uncapped because the price of the reduction determines the quantity of the reduction. The Colorado River Basin Salinity Control Program uses this type of system. The Bureau of Reclamation, which manages the program, issues “Requests for Proposal” for projects that will reduce salinity in the river. They then select and fund the most cost effective proposal.

Five types of WQT systems are identified under capped conditions:

- *Associations (A)* – Associations are groups that broker or trade discharges to a water body that has an established pollution limit (e.g. cap). In practice, the associations purchase reductions from some dischargers and sell that reduction to other discharges. The resulting trading between dischargers with high and low marginal costs increases the cost efficiency of achieving the reduction. Examples of this type of system include The Lake Dillon Program, The Tar Pamlico Program, and The Long Island Sound Nitrogen Credit Exchange Program.

- *Offset Systems (O)* – In this type of system, regulators establish the maximum pollutant load that a water body may receive. Discharges in excess of that limit, including new discharges, require an offset of existing discharges. The mass of pollutant in the system is constant but the dischargers change. Examples of this type of system include The Boulder Creek Program and the Wayland Business Center Expansion.

- *Bubble Systems (B)* - This type of system is similar to the emissions trading program of the Clean Air Act. Regulators establish a cap but allow the dischargers to allocate the cap. The dischargers are free to allocate the cap in any combination they choose, but the total discharge within the "bubble" may not exceed the cap. Examples of this type of system include the Blue Plains Waste Water Treatment Plant Credit Creation Program, The Henry County Public Sewer Authority Program, and the NPDES permits for the Cargil and Ajinomto waste water treatment plants.

- *Cap and Trade Systems (CAT)* – This type of system involves the use of two different permits. The first permits require specific dischargers to satisfy the technology requirements of a NPDES permit. The second permit requires an additional reduction but does not specify the method to achieve that reduction. Participants are then free to buy and sell allowances or reductions. Dischargers with a high marginal cost for reduction buy permits or reductions from others while dischargers with low marginal costs will over control and sell their permits. Title IV is an example of this type of system and The Long Island Sound program resembles this type of system.

- *Tax or Fee Systems (TF)* – These systems are similar to the two types of Purchase Systems in uncapped water bodies except that these systems have an established cap. Regulators establish a cap and charge a fee for a discharge in excess of that cap. Regulators then use the proceeds from the fee to finance projects that will lower the pollution load in the waterway. They set the tax or fee at a level that ensures that they can finance projects that will offset the load form the dischargers that failed to achieve the cap. The Grasslands Area Tradable Load Program is an example of this type of system.

Table 1-2: Existing Water Quality Trading Programs. Sources Environomics 1999, Fisher-Vanden 2004, EPA 2005c

Name	Location	Pollutant	Year Est.	Type	Description
Bear Creek	CO	Phos.		A,O	PSs formed an Association to facilitate PS to PS offset
Boulder Creek	CO	Nutrients, pH, temp.	1990	O	A PS purchases NPS source improvements instead of making PS source improvements
Blue Plains WWTP Credit Creation	DC, VA	Nitrogen	2000	B	VA POTW pays DC POTW to expand treatment until VA POTW completes its expansion.
Cargil and Ajinomto Permit	IA	Ammonia, CBOD	1990	B	Regulators allowed two facilities to combine effluent under one permit.
Chatfield Lake	CO	Phos.	2000	O	PS buy offsets from NPS via a clearinghouse
Cherry Creek	CO	Phos.	1997	O	PS and NPSs trade phosphorus.
Colorado River Basin Salinity Control Program	CO	Salinity	1996	PFP	A Bureau issues RFPs for salinity reduction and purchases reductions via most cost-effective control project.
Fox Wolf Basin	WI	Phos.	2000	O	PS may purchase and NPS reductions. No trades have occurred.
Grassland Area Tradable Load Program	CA	Selenium	1998	TF	Drainage districts pay a fee or receive a rebate based upon achieving or not achieving their allotment.
Great Miami River Watershed Pilot Program	OH	Nutrients	2004	O	PSs may purchase upstream credits to comply with new water quality standards
Henry County Public Service Authority	VA	TDS	1998	B	Regulators allowed a POTW to transfer allocation to another POTW.
Iron and Steel Industry (Podar and Kashmanian 1998, p. 42)	IN, MD, MI	Industrial Pollutants	Unknown	B	Regulators allow interplant trading.
Kalamazoo Trading Pilot Program	MI	Phos.	1998	O	Regulators use grant funds to purchase NPS controls in agricultural watershed.
Lake Dillon	CO	Phos.	1984	O	PS and NPSs sell credits to an authority to offset phosphorus load from development
Long Island Sound Nitrogen Credit Exchange	CT, NY	Nutrients	2002	A	PS buy and sell allowances to an association to achieve their regulatory requirement.
Lower Boise River Effluent Trading Prog.	ID	Phos.	1997	O	PSs buy NPS reductions from a list of acceptable BMPs.
New York City Phos. Offset Program	NY	Phos.	1997	O	Regulators allow new POTW loads to offset with PS or NPS reductions.
Nuese River	NC	Nutrients	2003	A, TF	PSs issued individual and group permit. Group pays fine if group permit exceeded.
Passaic Valley Sewerage Commission	NJ	Heavy metals	1997	O	Regulators allowed industrial customers to buy and sell pretreatment requirements.
Piasa Creek Watershed Project	IL	Sediment	2001	O	PS creates sediment offset via land use change in place of capital upgrade
Pinnacle Foods (Shabman, Stephenson, and Boyd 2004)	DE	Nutrients	1999		Regulators required that a PS convert 35 acres of corn field to reed grass instead of PS load reduction.
Rahr Malting Permit	MN	Nutrients, BOD	1997	O	Regulators required that new PS offset new load with NPS reductions as part of NPDES permit.
Red Cedar River Program	WI	Phos.	1998	O	Regulators allows POTW to buy NPS reductions via BMPs.
Rock River Trading Program	WI	Phos.	1997	O	Regulators allow POTWs to buy NPS reductions via BMPs.
San Francisco Bay Mercury Offset	CA	Mercury	1999	O	Program requires that new sources find offsets.
Southern Minnesota Beet Sugar Cooperative	MN	Phos.	1999	O	Regulators required PS offset load via use of agricultural BMPs.
Tar-Pamlico	NC	Nutrients	1990	A, TF	PSs buy Agricultural BMP credits from an association if the PSs fail to meet discharge goal.
Trukee River Water Rights Offset Program	NV	Nutrients, DO, Solids	1999	O	Citizens and regulators purchased upstream water rights and converted land use to allow increase of load from POTW.
Wayland Business Center	MA	Phos.	1998	O	Regulators required that new PSs offset load by linking properties with faulty septic systems to WWTP.

Existing Water Quality Trading Systems

Several recent studies have compared WQT programs and initatives that are in various stages of development (Environomics 1999, Fisher-Vanden 2004, EPA 2005c). These different studies have identified nearly 50 programs, initiatives or proposals. Table 1-2 describes 29 existing programs in the United States that embody the name and spirit of WQT. The table only includes programs for which the development of a set of rules for trading is complete and accessible, regardless of whether trades have actually occurred.

Nutrients are the most commonly traded water quality pollutant (Table 1-2). Moreover, 76 percent of the systems involved nutrients. A handful of other systems involve trading of BOD, sediment, and DO that are often related to nutrients. The most common type of existing trading programs involves a cap and use of NPS reductions as either offsets for PS expansions or in place of PS reductions. Fifteen programs, or 52 percent, fit this description.

Only 14% of these programs have a group cap and a design that resembles the Title IV program for air quality trades. These programs, on Lake Dillon, Long-Island Sound, the Nuese and Tar-Pamlico rivers have group caps in addition to the technology requirement of an individual NPDES permit. In these systems the participants satisfy the requirements of their NPDES permit in a traditional way but have flexibility regarding how to satisfy the additional requirements of the group cap. Moreover, they are free to meet their portion of the group allowance by implementing their own reduction, buying a reduction from another member, or by buying NPS reductions.

Although all of the systems listed in Table 1-2 have established rules and procedures, only a few have actually completed multiple trades or agreements. Many trades were one-time offsets that are not considering further activity. Of the active programs, The Grassland Area Farmers Tradable Loads Program consummated nine trading agreements by February of 2000. The Trukee Water Rights Offset Program had completed thirty-three water rights contracts as of May 2004 (Fisher et al 2005). However, it is not clear whether either of these programs will see any activity in the future.

One of the most robust programs is the Long Island Sound Nitrogen Credit Exchange (Table 1-3). This system involves trades between waste water treatment plants (WWTP) that are also in the process of being upgraded to increase their capacity and decrease their nutrient discharges. Thus many of the trades will terminate or be modified when the older plants are upgraded. In the first and second year of the program, 97% of the plants participated and exchanged an average of 2.6 million dollars per year. One of the important lessons of this program is that participants of a single industry in the same geographic area can have marginal costs that are different enough to justify trading. Moreover, although all the participants operate similar WWTP, differences in the cost of real estate needed for plant expansion have been large enough to provide an incentive for trading (Johnson 2005). Differences in the cost of land preparation and remediation associated with plant expansion have also increased the marginal cost of reductions even though they are using the same technology. The net result has been that it is less expensive for rural plants to expand than urban plants. Thus they have expanded their treatment beyond their immediate needs and have been able to sell credits to WWTP in urban areas.

Table 1-3: Activity of the Long Island Sound Program. Source Connecticut Department of Environmental Protection 2002 and 2003

	2002	2003
Numbers of Buyers	38	40
Number of Sellers	39	37
% of active participants	97	97
Lbs of TN purchased	798,317	989,194
Value of purchase TN, US$	1,317,223	2,116,875
% of cap that was purchased	12	16
Lbs of Total Nitrogen sold	1,671,050	1,134,876
Value of sold Nitrogen, US$	2,757,323	2,428,636
% of TN cap traded	25	18

Relationship of Water Quality Trading and Total Maximum Daily Loads

The Total Maximum Daily Load (TMDL) is the total amount of pollutants that can be assimilated by a water body without causing water quality standards to be exceeded. TMDL's and the identification of impaired water bodies were originally included in the 1972 CWA as a way to provide an integrated, basin wide approach to water quality. However, because the initial focus of the CWA was on technology based "command and control", few TMDL's were developed. In the 1990's a series of lawsuits claimed that states had failed to identified impaired waters and calculate TMDL's according to the CWA. By the late 1990's TMDL's were being developed for many areas, including the LDR region (see chapter 2). Nationwide it is expected that over 30,000 TMDL allocations will be completed during the next 10-20 years (National Research Council 2001).

Because the TMDL measures the amount of pollutants that a water body can assimilate, they can also form the basis of wasteload allocation for dischargers and the pollutant caps used in WQT programs. Currently, the wasteload allocations derived from TMDL's are currently not mandatory in most areas or a formal component of the National Pollutant Discharge Elimination System (NPDES) permit system. Nevertheless, EPA hopes that local resource managers and stakeholders will work together in innovative and cost-effective ways to reduce discharges to the levels of the TMDL's (EPA 2005). It is also expected that the allocations developed by TMDL's will eventually be enforced. Therefore, determining how TMDL's are derived and how allocations are developed from them is currently a high priority for government water-quality managers and fundamental to developing WQT systems (see subsequent chapters).

Strengths and Weaknesses of Existing Trading Systems

Although many WQT programs are being developed, trading cannot yet be considered an effective tool for improving water quality because few programs have resulted in actual trades. Most that have been implemented are one time off-sets. Workshop discussions and literature reviews have identified several reasons for the slow development of dynamic WQT systems (Stephenson, Shabman, and Geyer 1999, Lacy 2000). These include:

- The statutory requirements of the CWA that require technology-based controls may be a barrier to establishing trades (Stephenson, Shabman, and Geyer 1999). Moreover, there is a general unwillingness of regulated dischargers to deviate from the technologies defined in the NPDES permit because they run the risk of being exposed to additional regulatory scrutiny and performance requirements. Fortunately, EPA's 2003 WQT Policy makes a commitment to adapting the NPDES permit system to facilitate more flexible solutions to reducing pollutant discharges.

- NPDES permits are not written in a way that facilitates trading. Moreover, permits in the same watershed cover different time periods and do not allow permit holders the flexibility to seek other methods to reduce their discharges by alternative methods. Fortunately, EPA is undergoing a large effort to train permit managers in trading and develop ways to modify traditional permits to promote trading.

- The zero-discharge goal may inhibit the use of trading because it reduces the incentive to trade discharges at one location with discharges at another (Stephenson, Shabman, and Geyer 1999).

- The slow development of the TMDL's has inhibited WQT by limiting the development of caps and the emphasis on watershed-based approaches (Lacy 2000). However, as a result of a series of lawsuits that forced their implementation, TMDL's have begun to be widely developed since the early 2000's (National Research Council 2001). Nevertheless, estimates indicate that there are over 21,000 individual river segments in the nation that are impaired and need TMDL's. Moreover, the there is a wide range in the focus of TMDL's and their ability to facilitate trading (see chapter 2).

- Lack of an incentive for participation in a trading program. Without a strong mandate to decrease pollutant levels, dischargers have no reason to join or facilitate the development of, trading systems.

Although WQT has been slow to establish and there have been relatively few actual trades, in some areas the process of developing WQT has already created measurable benefits to water quality. Moreover, discussions of trading systems has created incentive for dischargers to examine their discharge and reduce it beyond their expectations and beyond what the conventional command and control would provide. This has been shown in all three of the operating cap and trade systems (e.g. Connecticut, Tar-Pamlico and Nuese Rivers). In Connecticut, almost one-half of the dischargers found internal methods to reduce their discharge and have become sellers rather than buyers. Even the widely-referenced trading systems on the Tar-Pamlico and Nuese Rivers have not had to establish trades between dischargers to meet requirements. Again, the dischargers found internal methods to decrease their discharges and meet their caps without trading. This condition is in part due to point-source control costs that are lower than policy estimates predicted. (Stephenson, Shabman, and Boyd 2004).

Guidelines for Designing Water Quality Trading Systems

Establishing market and watershed based WQT systems and breaking away from the traditional command and control systems is a gradual process that can be expected to take years or decades. Nevertheless, there is ample evidence to suggest that their use will increase in the future. Moreover, over the past 5 years, state and national WQT policies have been adopted, TMDL's are rapidly being completed, the NPDES permit process is being modified, and the first programs have begun to demonstrate the potential success of the approach. While WQT is still in it's infancy, synthesis of the Title IV program and studies on the effectiveness of institutions designed to manage natural resources (Scott 1998, Ostrum 1990, Anderson and Leal 1998, Richards 2000, and Merrill 2000. suggest the following considerations should be used to develop successful trading systems:

- Pollution markets require the specification of property rights that allow dischargers to exchange pollution credits (Anderson and Leal 1998, Richards 2000). While the ultimate goal is to improve aquatic health and diversity, swimability, fishability, etc. actual trades must be based on measurable physical quantities that cause the impairment (e.g. nutrients, sediments, BOD in kg/ha/day). Therefore, defining tradable units with appropriate property rights is essential to developing tradable markets.

- Market mechanisms are instruments to attain a goal not a mechanism to set a goal (Merrill 2000, Shapiro and Glickman 2000).

- Pollutants that are well mixed and rapidly distributed in the ecosystem are good candidates for permit or allowance systems (Stavins 2000). Title IV allowed trading across the full geographic extent of the country because the air pollutants were well mixed across this geographic distance. The mixing zones for water are much smaller than mixing zones for air and must be explicitly defined when developing WQT systems. Therefore, clearly defining geographic boundaries, the size of market and stakeholder communities, and the importance of local conditions is critical to the success of WQT systems.

- The number of participants and the size of the stakeholder community is a critical to the design and success of WQT systems. If the market is too small, the participants may not need a market to achieve their goal (Wyman 2002). In addition, if the number of participants is too small or similar, they may not have enough variation in the marginal cost of reduction to provide the incentive for trading. A large number of participants ensure that the market price reflects the interests of multiple buyers and sellers and act to produce a market with sufficient incentive to trade. However, the market and stakeholder community cannot be too large to overcome information and communication barriers (Stavins 2000).

- A strong central organization should assist the operation of a trading system by taking responsibility for monitoring, enforcement, conflict resolution, and the brokerage of allowances or permits. All WQT systems should include appropriate penalties for non-compliance, procedures for conflict resolution, and mechanisms to insure the continual interaction between participants, regulators, and stakeholders.

- Systems that are transparent, simple, and adaptable have the best chance of success. Systems should also favor reversibility and provide means for rule changes.

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Chapter 2

Technical Aspects of Water Quality Trading Systems in the Lower Delaware Region

D. Curley and W. Shieh

Introduction

Numerous factors influence the water quality of a water body, including the natural and anthropogenic inputs, and the physical and biological processes that occur within the water body. Managing and improving water quality involves being able to quantify the spatial and temporal changes in water quality within a watershed. This is particularly important in water quality trading programs where understanding how pollutants travel through a watershed is essential to evaluating trades. This chapter discusses the technical aspects of modeling and monitoring that are required to establish and manage water quality trading systems.

Modeling

Selection of Models for Developing TMDL's and Trading Systems

The modeling that trading systems require is similar to the models that the TMDL program uses to predict water quality and determine allocations. The general form of the modeling combines a watershed loading model with a waterway model. Watershed loading models predict the amount of pollutants entering the water body, while waterway models predict the fate of the pollutants once they are in the water course. The simplest watershed loading models use statistical or empirical relationships between land use and loading rates. Complex methods involve physical-based deterministic equations that describe a water balance and the fate and transport of a pollutant that moves through a watershed. Steady state waterway models use constant values of input to predict water quality within a water course. Hydrodynamic models vary the inputs with time to predict the variation of concentration with time.

No model or combination of models is the best for all situations (EPA 1997). Factors that can influence the selection of a model include: the type of waterway, flow rate, environmental process of concern, availability of data, geographic extent of the water quality impairment, geographic extent of the watershed that feeds the impaired segment, temporal aspects of the impairment, and cost and availability of expertise. Table 2-1 and Table 2-2 summarize some of the existing models and methods that are available for the type of watershed analysis. Several of these models are available for download at www.epa.gov/ceam/publ/.

Water quality modeling for TMDL's and WQT can be both complex and expensive. For example, the estuary model for the Tar-Pamlico Nutrient Trading Program cost $400,000 to develop (Fisher-Vanden et al 2004). EPA estimates that the cost of development of 95 to 98% of all TMDLs will be between $6,000 and $154,000 (EPA 2001). These costs will vary according to the complexity of the watershed and the "efficiency" in combining the effort with the development of other TMDL's (Table 2-3). Given these costs, developing WQT systems on watersheds where TMDL's already exists will always be beneficial.

Table 2-1: Watershed Loading Models used for developing TMDLs and Water Quality Trading systems. Source: From the Compendium of Tools for Watershed Assessment and TMDL Development.

Low Level of Complexity	Medium Level of Complexity	High Level of Complexity
EPA Screening Method	SITE MAP	STORM
Simple Method	GWLF	ANSWERS
Regression Method	Urban Catchment Model	DR3M-QUAL
SLOSH-PHOSPH	Automated Q-ILLUDAS	SWRRBWQ
Watershed	AGNPS	SWMM
FHA Model	SLAMM	HSPF

Table 2-2: Waterway Models used for developing TMDLs and Water Quality Trading systems. From the Compendium of Tools for Watershed Assessment and TMDL Development

Hydrodynamic Models	Steady State Models
CE-QUAL	BATHTUB
CH3D-WES	DECAL
DYNTOX	EUTROMOD
DYNHYD 5	EXAMS II
EFDC	PHOSMOD
HSPF	QUAL2E
WASP	SMPTOX3
	Tidal Prism Model
	TOXMOD

Table 2-3: Estimated level of hourly effort and costs for TMDL Development. Adapted from *The National Costs to Develop TMDLs (Draft Report), EPA 841 D 01 004*, and assuming a hourly rate of 80$/hr.

	Low Complexity		Medium Complexity		High Complexity	
	Hours	US$	Hours	US$	Hours	US$
Low Efficiency	933	$74,630	1,798	$143,840	3,175	$254,000
Medium Efficiency	307	$24,560	739	$59,120	1,459	$116,720
High Efficiency	226	$18,080	435	$34,800	774	$61,920

Once TMDL's and reductions have been established, a second phase of modeling is needed to design a trading system on a specific watershed. While this modeling can build upon the existing modeling needed to develop TMDL's, it requires additional analysis and effort. The goal of this modeling is to determine the effect of a specific set of trades and evaluate various trading schemes within a watershed and in guiding the design of the overall trading system. This type of modeling can range from relatively simple calculations, to irrelative runs of existing TMDL models, to the solution of a network problem using linear, mixed integer, or nonlinear programming. To date most of this type of modeling has been based on relatively simple calculations or by modifying existing TMDL models. Nevertheless, optimal network solutions can be developed with a significant amount of accurate information about discharges in a waterway, as have been used to determine the optimum location of waste water treatment plants, water treatment plants, transportation facilities, solid waste facilities, and power plants (Revelle and McGarity 2001). Nevertheless a word of caution accompanies the use of this modeling. Markets and WQT rely upon flexible, decentralized decision making, instead of the centralized approached associated with watershed scale optimal network models. Therefore, while this type of modeling may be appropriate for specific cases and helpful to guide centralized decision making, it may not be appropriate for all WQT systems.

Trading Ratios

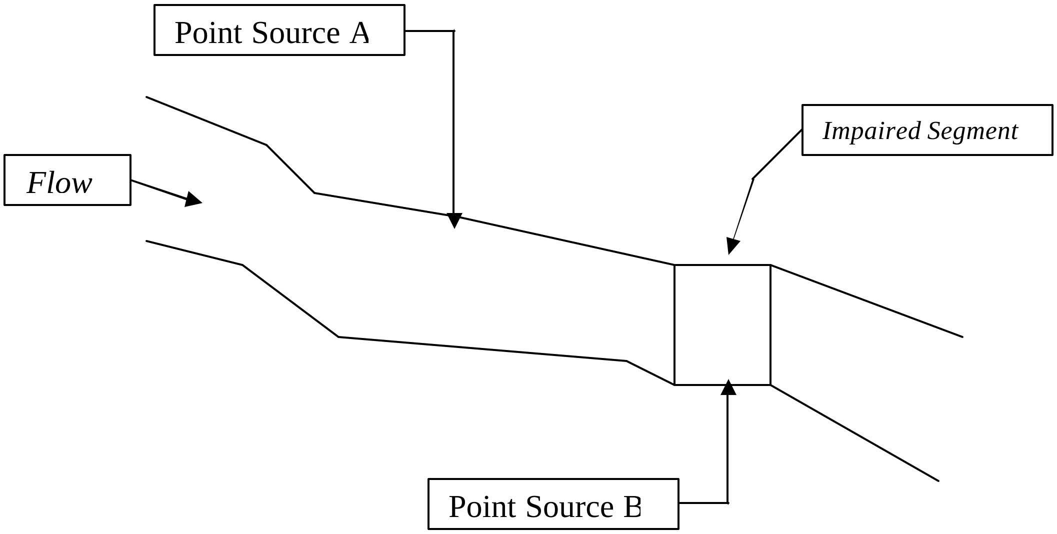
Equivalency of Discharges

The final phase of modeling in support of trading occurs during the design of the actual trade and the calculation of the equivalency of discharges. Discharges of the same pollutant and at the same rate, but at different locations may not have the same effect on water quality. If the pollutant is not conservative, it will decay and undergo transformation in the waterway and in the watershed during transit from the location of application on land to the nearest waterway and within the waterway. Additionally, some pollutant will experience removal via diversion of flow for other uses, like irrigation (i.e. advective removal).

In order to ensure that a trade is appropriate, participants must know the effect of trading different discharges will have on water quality. If traders do not have this information the trade may not achieve the water quality goal or will not be cost effective. For example, consider a situation in which facility A is upstream of the location of an impairment and in which facility B discharges directly into the impaired waterway (Figure 2-1). A one-unit reduction from facility A will not improve water quality at the impairment as much as a one-unit reduction from facility B. If regulators require a one-unit reduction from facility B and it chooses to buy that reduction from facility A, facility B must purchase more than one-unit to have the same environmental effect as its own one-unit reduction. A trade of one-unit for one-unit would fail to achieve the water quality that would occur in the absence of trading. Secondly, without knowledge of trading equlivances, a trade may achieve the water quality goal but will cost more than necessary. Consider the previous example; imagine that regulators impose a one-unit reduction on facility A and that facility A buys this reduction from facility B. The one-unit removal at location B is equivalent to more than one-unit at location A. This trade would result in an overcontrol at location B and an improvement in water quality relative to water quality that would occur in the absence of trading. But, this arrangement is not the most efficient arrangement. Facility A spends more than it needs to spend because it could buy less than one-unit from B and achieve the water quality goals.

The uncertainty of the actual reduction relative to the theoretical reduction is another concern in this phase of modeling. For example, imagine that a PS wishes to purchase a reduction from another PS or NPS via implementation of a BMP. All the sources discharge into the same segment of the waterway. The equivalency of the two PS is obvious. Traders who wish to ensure the equivalency of these sources would need only measure the outflow from the two sources. But, measurement of flow from NPS sources is very difficult and the effectiveness of the BMP is not certain (see sections below). Therefore, to ensure equivalency, traders must consider the uncertainty of the effectiveness of the BMP and the flow from the NPS.

Figure 2-1: Trading Ratio for Point Source to Point Source Trade



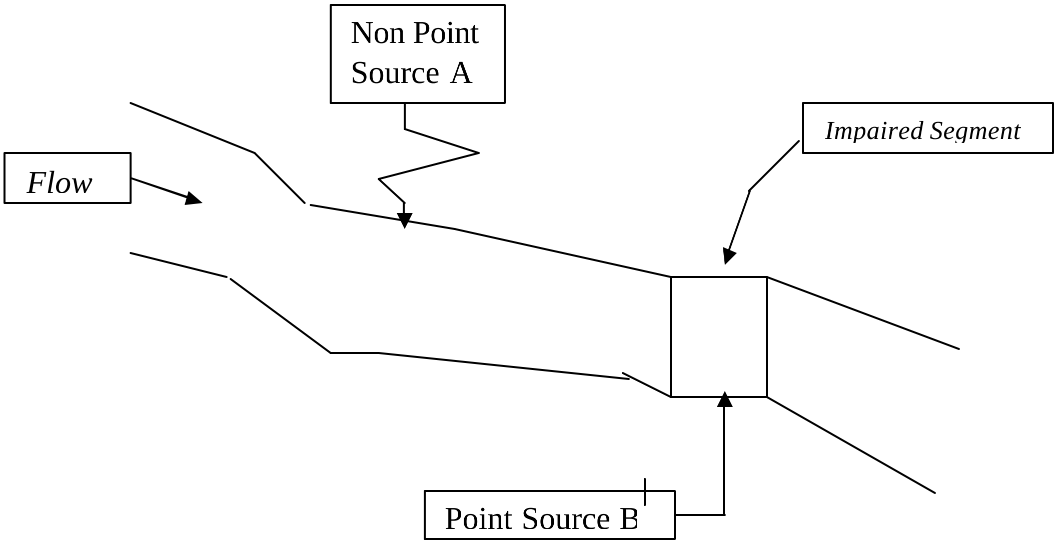
The previous examples demonstrate the traders must know the effect of transformation, decay, advective removal, and uncertainty to ensure equivalency. Trading systems must recognize this requirement and use a trading ratio to determine the equivalency of two discharges. One way to achieve this equivalency is to establish three ratios, one each for the water, the land, and the uncertainty of the trade. The final trading ratio is the product of these three ratios (Curley 2003).

> Waterway Location Ratio – The ratio that considers the effect of transformation, decay, and advective removal of a pollutant in a waterway and identifies the equivalency of discharges at prospective locations on a waterway relative to a baseline location on the waterway. The waterway location ratio identifies the equivalency between two discharges in a waterway.

Site Location Ratio – The ratio that considers the effect of transformation, decay, and advective removal of a pollutant during overland flow and identifies the equivalency of discharges at prospective locations on land in a watershed relative to a baseline location on the waterway. The site location ratio identifies the equivalency of a PS with a NPS or two NPS during flow overland.

Uncertainty Ratio – The ratio that considers the uncertainty of the effectiveness of BMP implementation, the uncertainty of the measurement of flow from NPS, and the uncertainty of decay, transformation and removal during transport of the pollutant. This ratio provides the margin of safety.

Figure 2-2: Trading Ratios for Point Source to Non Point Source Trades

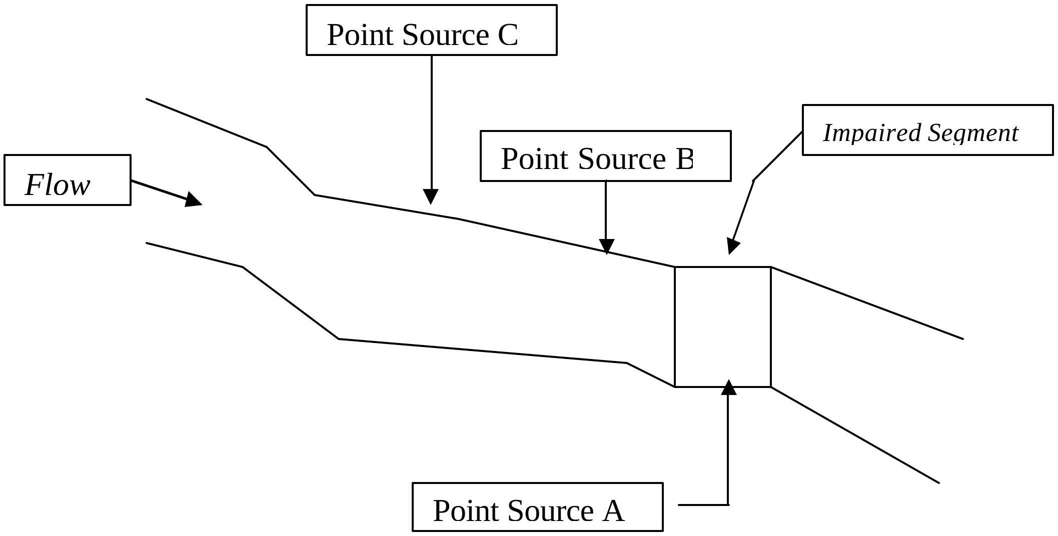


Trading ratios also need to be calculated for discharges from NPS (Figure 2-2). If a one-unit reduction at B has the same impact on water quality in the impaired segment as a one and one-half unit reduction in the un-impaired segment near A, the *waterway location ratio* for this trade would be 1.5. If a one-unit reduction at location A has the same environmental effect as a two unit onsite reduction of the NPS at A the *site location ratio* is 2.0. Finally, if regulators decide that they need a margin of safety of 20%, the uncertainty ratio would be 1.2. Therefore, the trading ratio between PS B and NPS A would be 3.6, or the product of its three ratios (1.5 x 2.0 x 1.2 = 3.6). Therefore, PS B must purchase a 3.6 unit reduction from NPS A to have the same effect on the waterway as a one-unit reduction at location B.

While most trading ratios are greater than 1, they need not be. For example, consider the reverse of the previous example in which NPS A wants to purchase a reduction from PS B. In this case the waterway location ratio and site location ratios would be the inverse of the previous values, or 0.66 and 0.5 respectively. The uncertainty ratio would be 1.0 because the regulators can measure the discharge from the PS with near certainty. Therefore, the trading ratio between NPS A and PS B would be 0.33 (0.66 x 0.5 = 0.33). Accordingly, NPS A can purchase a reduction of one-third of one unit from PS B and have the same environmental impact as a one-unit reduction at the on-site location of NPS A.

Trading ratios less than 1.0 are especially applicable for WQT systems that involve a large geographic area and discharges that are not directly released into the impaired segment. In some situations regulators may want to create incentives for dischargers who release pollutant far from the location of the impairment to purchase reductions from dischargers who directly release pollutant into the impairment. The trading program for the Long Island Sound provides an example of this situation. In this system a waterway location ratio accounts for the impact that location of the treatment plant has on water quality. Moreover, the equivalency factors makes nitrogen reductions closer to the hypoxic zones more valuable than reductions occurring further from these zones, encouraging plants with more detrimental discharges to remove nitrogen beyond their permit requirements and sell the credits (Fisher-Vanden et al 2004).

Figure 2-3 Trading Ratios for Multiple Sources



Sample Development of Trading Ratios

While no specific method of trading ratio development applies to all systems, the general form of the development should be the same for all systems. For systems with many PS, modelers can determine the equivalency of a unit load from each PS and a unit load at the impairment. For example, consider a waterway with three PS; PSA, PSB, and PSC (Figure 2-3). Assume that a reduction at B has one-half the impact as a reduction at A and a reduction at C has one-third the impact as a reduction at A. Trades involving PSA would use the trading ratio that defines the equivalency of a release into the impaired segment at PSA with the other sources. But, trades involving PSB and PSC would require another step. If PSB wanted to purchase a reduction from PSC, modelers would need to apply the trading ratio in series from PSB to PSA and then PSA to PSC. PSB would need to purchase two units to account for equivalency between PSB and PSA and 1/3 of a unit to account for equivalency between A and C. The resulting trading ratio is 0.66, the product of 2 and 1/3. TMDL modelers could perform a model run for unit loads at each PS and produce a matrix of trading ratios for the trading system (Table 2.5).

Table 2-5. Sample Matrix of Trading Ratios for Point Sources

	Sellers			
Buyers		PSA	PSB	PSC
	PSA	1	1/2	1/3
	PSB	2	1	2/3
	PSC	3	3/2	1

The development of a matrix of trading ratios for a system of PS is a manageable endeavor. First, the PS discharges have little uncertainty. Therefore, the trading ratio is a function of the decay, transformation, and advective removal in the waterway. Engineers can quantify this effect with ease and accuracy relative to the other aspects of modeling.

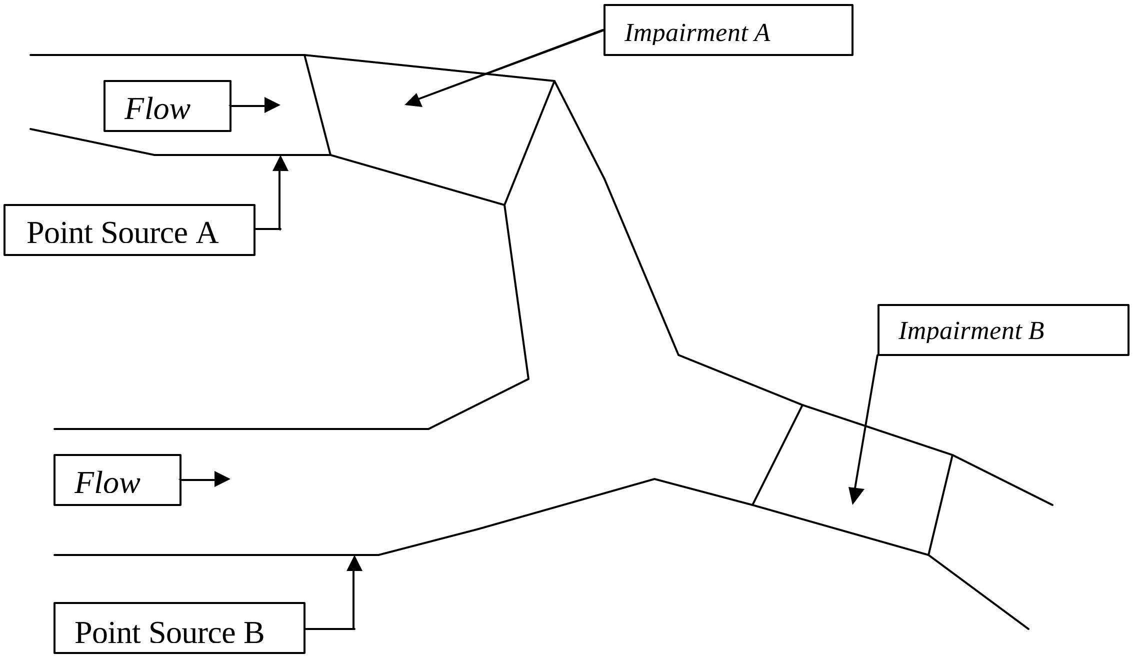
Second, the number of model runs that the system requires for determining trading ratio is manageable. A system with N prospective traders would require N x (N-1) trading ratios. For a trading system, like a system for low-flow TMDL on the Christina Watershed, only a handful of model runs are required because there are only a handful of PS. Furthermore, the hydrologic attributes of the waterway may create a system in which two PS buy from and sell to each other at reciprocal ratios (as shown in Table 2-5). If this condition holds, modelers need only perform one model run for each prospective PS trader. They can deduce all other values of trading ratio from these results.

Third, even if the system has a large geographic area and a large number of potential participants, modelers can take reasonable steps to simplify the development of trading ratios. Imagine a system with hundreds of prospective traders. It could require thousands of model runs to determine all of the trading ratios. This task may be problematic due to high cost and time requirements. Instead, modelers can divide the waterways in the basin into a manageable number of segments and perform an analysis for each stream segment. Application of this step can reduce the number of model runs from thousands or hundreds to hundreds or dozens.

While the determination of trading ratios is technically manageable, they can also be challenging. First, the specific ratios that the model runs determine apply only to the specific arrangement of loads that the model used to determine these ratios. If trading produced a significant redistribution of loads in the watershed, existing trading ratios would no longer define equivalency. Similarly, background changes could also change the ratios that the system requires for equivalency. System designers can account for these issues by applying a margin of safety or re-computing trading ratios with an appropriate periodicity. A logical time to reconfigure the trading ratios is during renewal of the permit.

The second issue of concern involves multiple impairments. Consider a watershed with two impairments and two dischargers. The dischargers are not on the same reach. One of the impairments is influenced by both discharges while the other impairment is influenced by only one discharger. Figure 2-4 shows this arrangement.

Figure 2-4: Schematic of trading ratios in a system with multiple impairments



PSA contributes to Impairment A and impairment B while PSB contributes only to impairment B. Trades between PSA and PSB are complex. If PSA buys a reduction from PSB, the reduction will benefit impairment B but not affect the impairment A. This trade is problematic because it over controls for impairment B and under controls for impairment A. Regulators intended that some portion of the reduction that they assigned to PSA would reduce the impairment in the vicinity of PSA. But, this trade fails to consider the local impairment in the vicinity of PSA. One potential solution to this problem is to divide the reduction requirement into a component for the local impairment and the downstream impairment. The system could allow only trades that limit flow into an impairment that is downstream of both dischargers. There are numerous permutations like this scenario. Each permutation is case specific and requires a unique solution and in no case will trades be allow that will causes a local violation of water quality standards.

The third issue involves the uncertainty of the reductions of the vast array of mechanisms for NPS control. The determination of a trading ratio for every possible mechanism of NPS reduction is not possible. The number of mechanisms and the unique effect that location has upon these mechanisms makes this task cumbersome. One solution to the problem is to produce a list of preapproved mechanisms with predefined uncertainty. Dischargers who wish to purchase NPS reductions may choose from the list for which regulators have previously determined the value of uncertainty for each mechanism. The Lower Boise River program provides an example of this type of system where traders choose from a preapproved list of BMPs (Fisher-Vanden et al 2004). The Cheaspeake Bay program is also developing and maintaining a similar list that can be used to evaluate BMPs

Table 2-6 Estimated Cost of Development of Trading Ratios for the Low-Flow TMDL for the an average sized basin in the Lower Delaware River Basin

Approximate costs, 2005$			
Description	Labor (hrs)	Rate ($/hr)	Cost ($)
Premodeling Analysis	30	150	4,500
Modeling	40	150	6,000
Post Modeling Analysis	30	150	4,500
Total	100	N/A	15,000

Cost of Developing Trading Ratios

The ability of a trading system to achieve the reductions it desires depends heavily upon appropriate identification and use of trading ratios. Nevertheless, the complexity and cost of developing trading ratios can be barriers to the establishment of trading systems. One way to overcome this barrier is to use the existing model which regulators used for development of the TMDL. This condition will solve the complexity problem by using the expertise of the TMDL modelers and will solve the cost problem by eliminating the cost for development of the basic model. There would still be cost associated with running the model to develop specific trading ratios. We estimate that the cost of developing trading ratios for a trading system in a watershed similar to the Christina Watershed would be approximately $15,000 (Table 2-6).

Trading Ratios for Existing Trading Systems

A survey of existing trading systems shows the range of considerations WQT systems use in developing trading ratios (Table 2-7). Seventeen of the twenty eight systems (61%) that we identified in Table 1-1 apply a trading ratio. Typical values range from 1.1:1 to 3:1. However, most of these systems assign a single trading ratio for all trades and do not consider geographic or environmental differences in calculating the trading ratio. In general, economic, environmental, geographic, and qualitative considerations guide the selection of trading ratios (Table 2-8). Environmental and geographic considerations involve implicit considerations of the spatial influence on the transformation, decay, and advective removal of the pollutant. Qualitative considerations consider the overall interactions of economic, environmental, or geographic conditions. Economic considerations typically involve the difference between the marginal cost of reduction for the participants. For example, the Wayland Business Center, applied a ratio of 3:1. The ratio was not based upon the physics of pollutant transport but upon the economics of the alternatives of pollution control (EPA 1998). Regulators recognized that the cost of the NPS controls that the developer proposed to offset new PS discharges was considerably less than the benefit that the developer would receive for the development. Consequently, they required a trading ratio of 3:1.

The Lower Boise River Trading Program uses a mass-balance model of physical transport to identify trading ratio (IDEQ 2003). The model considers five components of trading ratio:

- The site of the non-point discharge
- The transport in the small waterways that drain the watershed
- The transport in the main waterway
- The uncertainty of BMP
- The effectiveness of the BMP

The final trading ratio is a product of these five components and comes from a pre-established formula. The model considers only the advective removal of the pollutant via irrigation diversions. It assigns a value of 0.6, 0.8, or 1.0 for the site location ratio depending upon the particulars of the site. It uses a formula to identify the physical removal depending upon the location of the discharge in the small waterways that drain the watershed and upon the location in the main waterway.

The Rock River Trading program also considers the effect of location and uncertainty. For trades involving NPS, it assigns a trading ratio that is higher than the ratio for trades involving only PS. Furthermore, it requires an additional 12.5% removal if the seller and the buyer are not in the same watershed or if the traders are further than 20 miles apart from each other.

Lessons Learned from Existing Trading Systems

A review of the current use of trading ratios indicates that WQT systems should establish and publish the values of acceptable trading ratios. In the Title IV program all participants know that they have a 1:1 trading ratio. In the Long Island Sound Program modelers identified geographic zones with equal equivalency ratios during the design of the system. These ratios are part of the General Permit so that each participant knows the effect of their discharge relative to other dischargers (CTDEP 2004, Appendix B). This condition precludes the use of a complex engineering analysis during consideration or approval of individual trades.

The use of trading zones, predefined trading formulas, and predefined safety factors can also simplify the development and application of trading ratios. Although each discharge has a unique effect on water quality and consequently, a unique trading ratio, developing trading ratios for every location or discharger can be costly, especially when the watershed is large and there are many dischargers. The use of zones (like the Long Island Sound program) or simple formulas (like the Rock River program or Lower Boise River program) may solve this problem in certain situations.

Table 2-7: Trading Ratios for Existing Water Quality Trading Programs

Name	**Trading Ratio**	**Type of Trade**	**Notes**
Bear Creek	1:1	PS-PS	
Boulder Creek	1:1	PS-NPS	Stakeholders did not directly consider T.R.s but indirectly considered it by selection of BMPs.
Blue Plains WWTP Credit Creation	1:1	PS-PS	
Cargil and Ajinomto Permit	1:1	PS-PS	
Chatfield Lake	2:1	PS-PS or PS-NPS	
Cherry Creek	1:1	PS-NPS	
Colorado River Basin Salinity Control Program	N/A	N/A	The program solicits proposals to reduce salinity so that ratios for equivalency are not required.
Fox Wolf Basin	2:1 – 10:1	PS-PS or PS-NPS	The T.R. is based upon the cost of the reduction of the traders not physical transport of the pollutant(Fisher-Vanden et al 2004, p. 271)
Grassland Area Tradable Load Program	1:1	NPS-NPS	There is no need for a T.R. because dischargers have a single discharge location and high certainty of load.
Great Miami River Watershed Pilot Program	1:1 – 3:1	PS-NPS	The T.R. is based upon the water quality of the segment into which the discharge occurs.
Henry County Public Service Authority	1:1	PS-PS	
Iron and Steel Industry	1:1	PS-PS	
Kalamazoo Trading Pilot Program	1.1:1 – 4:1	PS-NPS	Trading ratios are for uncertainty and environmental improvement. They can also address seasonality and distance.
Lake Dillon	1:1 – 2:1	PS-NPS or NPS-NPS	Trades between NPS use a T.R. of 1:1 and trades between non point sources use a T.R. of 2:1.
Long Island Sound Nitrogen Credit Exchange	1:1 – 7.7:1	PS-PS	The trading ratio. considers the location at which the load enters the watershed and the watershed enters the sound. (CTDEP, 2000, p. 29)
Lower Bosie River Effluent Trading Prog.	Vary	PS-NPS	Ratios will vary according to a formula. No trades have occurred so trading ratios are not known.
New York City Phos. Offset Program	3:1	PS-PS or PS-NPS	All trades are within the same basin.
Nuese River	2:1	PS-NPS	The trading ratio. is embedded in the offset because new dischargers must pay 200% of the projected cost of the non-point source reduction
Passaic Valley Sewerage Commission	1.2:1	PS-PS	Trades are PS to PS only. T.R. is for a net environmental benefit.
Piasa Creek Watershed Project	2:1	PS-NPS	Modelers showed that 1.5:1 was sufficient for conservation. 2:1 ratio is for environmental improvement.
Pinnacle Foods	1:1	PS-NPS	Modeling showed that the NPS offsets would achieve water quality goal.
Rahr Malting Permit	2:1 – 10:1	PS-NPS	Trading ratios are discounted for location, distance, and MOS.
Red Cedar River Program	2:1	PS-NPS	Trading ratio is for net environmental improvement.
Rock River Trading Program	1.1:1 – 3.6:1	PS-PS or PS-NPS	The system established ratios that are higher for NPSs than for PSs. It also includes a 12.5% increase for traders that are not in the same watershed or more than 20 miles apart.
Southern Minnesota Beet Sugar Cooperative	2.6:1	PS-NPS	T.R. includes 1:1 for the offset, 1:1 for environmental improvement and 0.6:1 for MOS.
Tar-Pamlico	2.1:1	PS-NPS	The T.R. is embedded in the offset because new dischargers must pay 200% of the projected cost of the non-point source reduction and it also includes an MOS and administrative costs.
Trukee River Water Rights Offset Program	1:1	PS-PS or PS-NPS	The extent of the NPS reduction is defined by the magnitude of the water quality improvement.
Wayland Business Center	3:1	PS-NPS	The low relative cost of NPS controls enabled regulators to require this ratio.

Table 2-8: Considerations for the Development of Trading Ratios

	Economic	Environmental	Geographic	Qualitative
Chatfield Lake				**X**
Fox Wolf Basin	**X**			
Great Miami River Watershed Pilot Program			**X**	
Kalamazoo Trading Pilot Program		**X**	**X**	**X**
Lake Dillon				**X**
Long Island Sound Nitrogen Exchange			**X**	
Lower Bosie River Effluent Trading Prog.			**X**	
New York City Phos. Offset Program				**X**
Nuese River	**X**			
Passaic Valley Sewerage Commission		**X**		
Piasa Creek Watershed Project			**X**	**X**
Pinnacle Foods			**X**	
Rahr Malting Permit			**X**	**X**
Red Cedar River Program		**X**		
Rock River Trading Program			**X**	**X**
Southern Minnesota Beet Sugar Cooperative		**X**		**X**
Tar-Pamlico	**X**			**X**
Wayland Business Center	**X**			
Percent of Total	**22**	**22**	**44**	**50**

Best Management Practices

Description, Effectiveness and Cost

Best Management Practices are procedures that land or plant managers can use to reduce the amount of pollutants that are exported from a given site. Trading systems that involve NPSs typically involve a NPS implementing a BMP to reduce discharges beyond the level that regulations require. Best Management practices can be separated into those used for urban (Table 2-9) and agricultural land uses (Table 2-10). They can be further separated into structural and non-structural BMP's.

Each BMP has a unique effectiveness and uncertainty that must be quantified before the operator can sell the credit to the PS. The ability of BMP's to reduce the amount of pollutant that is discharged into a water body depends on the type of BMP and local site conditions. Nationwide, BMP's are expected have removal efficiencies of 15 to 100% (Tables 2-11 and 2-12). Their costs also vary considerable and all need some long-term maintenance (Tables 2-13 and 2-14).

Table 2-9: Common Urban Best Management Practices

Type	Description
Structural	
Wetlands	Facilities with base flow and wetland species
Infiltration Systems	Pits, vaults, trenches, basins, porous concrete, etc.
Filtration Systems	Bioretention systems, placement of filtration media, rain gardens.etc.
Swales	Grass filter strips, vegetated channels, etc.
Ponds	Above or below ground detention basins, vaults, retention basins, roof top collection systems, etc.
Proprietary Equip.	Vendor supplied equipment like separators, filters, etc.
Physical Improvements	Pavement modificationl, CSO disconnection, disconnection of direct discharges to waterway, level spreaders, etc.
Non Structural	
House Keeping	Commercial, residential and industrial land use practices (i.e. household or automotive hazardous waste disposal programs)
Material Control	Material prohibitions, use requirements, disposal alternatives, etc. (i.e. pesticide plans, fertilizer plans, animal waste plans)
Street Sweeping	Cleaning programs for roads, highways, and parking lots (i.e. street sweeping, basin cleaning, or road maintenance)
Education	Educational and outreach programs (i.e. storm drain stenciling or lawn management instruction)
Regulation	Zoning, ordinances, enforcement (i.e. illicit discharge elimination, paving restrictions, setbacks, low impact development zoning)

Table 2-10: Common Agriculture and Animal Feed Operation BMPs (Cestti et al. 2003)

Type	Description
Structural	
Terraces	Embankments, across the slope of a field, that capture runoff and reduce erosion.
Diversions	The collection of runoff before it enters a crop area and routing of the runoff away from a crop area.
Grassed Wwaterways	A broad shallow channel with perennial vegetation that transports runoff.
Animal Waste Storage	Physical facilities that hold waste until farmers can apply it on land during conditions that are suitable for environmental protection.
Trees, Vegetation, or Riparian Buffers	Trees, shrubs, and vegetation that are adjacent to a waterway and that reduce the impact of non-point source pollution.
Grazing Control Plans	Physical structures like fencing that protect sensitive areas from grazing or watering.
Waste Management Structures	Physical features like roofs, curbs, gutters, pavement, etc. that improve the environmental control of existing facilities.
Non Structural	
Nutrient Management Plans	A site specific plan that specifies the use of nutrients to minimize harmful environmental effects and optimize farm profits.
Conservation Tillage Systems	A tillage system that leaves a crop residue to protect against erosion. It includes no-till, ridge till, and mulch till.
Crop Rotation Pans	A system that reduces fertilizer demand by rotating crops to achieve a natural fertilization and pest control.
Strip Cropping	A technique that uses different crops in the same plot to improve the biological stability of the system.
Cover Cropping	A technique that grows a crop, during an off season, not for harvest but to protect topsoil or improve the output of future crops.
Waste Management Plans	A comprehensive plan that combines structural and non structural BMPs into a single system.

Table 2-11: Typical Pollutant Removal from Urban BMPs EPA 1999

BMP Type	Percentage (%)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Basins	30-65	15-45	15-45	<30	15-45
Retention Basins	50-80	30-65	30-65	<30	50-80
Constructed Wetlands	50-80	<30	15-45	<30	50-80
Infiltration basins	50-80	50-80	50-80	65-100	50-80
Infiltration Trenches	50-80	50-80	15-45	65-100	50-80
Porous Pavement	65-100	65-100	30-65	65-100	65-100
Grassed Swales	30-65	15-45	15-45	<30	15-45
Vegetated Filter Strips	50-80	50-80	50-80	<30	30-65
Surface sand Filters	50-80	<30	50-80	<30	50-80
Other Media Filters	65-100	15-45	<30	<30	50-80

Table 2-12: Percentage Removal of Agriculture and Animal Feed Operation BMPs (Cestti et al 2003).

BMP Type	Total Nitrogen	Total Phosphorus
Filter Strip	20	15
Terrace Systems	70	30
Diversion Systems	90	70
Reduced Tillage Systems	55	45
Nutrient Management Plans	15	35

Table 2-13: Cost of Urban BMPs EPA 1999)

BMP Type	Typical Construction Capital Cost ($/ cf of water)	Typical Annual Maintenance Cost (% of capital cost)
Retention Basin	0.50-1.00	<1
Wetland	0.60-1.25	3-6
Infiltration Trench	4.00	5-20
Infiltration Basin	1.30	1-10
Sand Filter	3.00-6.00	11-13
Bioretention	5.30	5-7
Grass Swale	0.5	5-7
Filter Strips	0.00-1.30	320/acre

Table 2-14 Cost of Agriculture and Animal Feed Operations BMPs from Cestti et al 2003,

Practice	Nutrient Removal ($/kg of N)	Sediment Removal ($/ton)
Conservation Tillage	4	4
Cropland Protection	4	4
Strip Cropping	8	8
Vegetative Cover	12	13
Terrace	16	17
Diversion	15	16
Waterway	20	24
Critical Area Planning	22	23
Sediment and Water Control	29	38
Stream Protection	22	28
Grazing Land Protection	37	58

Application of BMPs in Water Quality Trading Systems

A pre-approved list of acceptable BMP's and their associated TR is essential for developing WQT. However, these lists and the information provided in this document are for planning purposes only and not without complications or problems. Specifically, the site-specific performance of BMP requires that they be designed and monitored at a fairly site-specific level. A recent review of the effectiveness of BMP's (US EPA 2002b) provides additional advice for the designers of trading systems:

- The pollutant removal capability of any BMPs is site specific. Therefore, designers of trading systems should cautiously apply average values to their application.

- The Cost to benefit ratios of BMPs are site specific. Local conditions not only affect the pollutant removal capability of a BMP but also the construction and operating cost.

- Some BMPs, especially non structural BMPs, are difficult to monitor and there are no widely-accepted definitions or techniques for evaluating their performance. Therefore, site specific monitoring plans are often needed and appropriate.

- The effectiveness of BMP's that rely on reducing pollutant exports will decrease with time. Therefore, specific time limits need to be established when BMP's are used for trading.

An additional issue that arises with NPS trades is whether the credit is given for the input or export of the pollutant (Shortle and Ambler 2001). With input credits, regulators assign a credit value for practices that reduce or eliminate the application (e.g. inputs) of chemicals, fertilizers, of other pollutants. Export credits are based on the reduction in pollutants leaving a specific area. The administration, monitoring, and enforcement for input credits is relatively straight forward. The evaluation of export credits relies on quantifying the transport of pollution from the landscape. Moreover, calculating the change in pollution inputs from a new wetland, a new traffic pattern, or land cover change is more difficult than quantifying the reduction of pollutant load by reducing the application of a chemical, fertilizer, flow, etc. Therefore, the value of input or export credits is case specific and will have to be evaluated for each situation. Table 2-15 provides a list of useful websites that contains information about BMPs.

Table 2-15: Web Sites for Information on Best Management Practices

Description	Site Address
ASCE BMP Database	http://www.bmpdatabase.org
MD Stormwater Design Manual	http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp
EPA Management Measures for NPS	http://www.epa.gov/owow/nps/urbanmn/index.html
EPA Summary of Urban Storm Water BMPs	http://www.epa.gov/ost/stormwater
EPA Urban Stormwater BMP Monitoring	http://www.epa.gov/waterscience/stormwater/montcomplete.pdf
PA Stormwater BMP Manual	http://www.dep.state.pa.us/deq/subject/advcoun/stormwater/stormwatercomm.htm
Villanova Urban Stormwater Partnership	http://www.villanova.edu/vusp

Compliance

Compliance Mechanisms for Existing Trading Systems

Once established and operation, WQT require monitoring and compliance. Transparent monitoring and the applications of appropriate penalties are essential to the success of these endeavors (Ostrum 1990, Scott 1998). Existing WQT systems use four mechanisms for ensuring compliance; 1) discharge monitoring, 2) stream monitoring, 3) physical inspection, and 4) private contracts (Table 2-11). Discharge monitoring involves the continuous monitoring of the effluent stream. Trades involving PS can use the monitoring results of the NPDES permit to assist with the verification of compliance. Stream monitoring involves sampling the waterway. Some trading systems require sampling of the waterway to determine if a trade achieved its objective. Physical inspection involves site visits to verify the conditions of a facility. Some trading systems include physical inspections by regulators or by one of the parties in the trade. This mechanism is applicable for trades between PS and NPS that involve BMPs. Some trading systems use an outside contractor to monitor the responsibilities of the parties in a trade. All but one of the known WQT systems involves PS that have NPDES permits that require continuous monitoring, maintenance of records, and periodic reporting (Moya 2001).

Stream monitoring is used in approximately 21 percent of the trading systems (Table 2-16). While this type of monitoring has the advantage that it is focused on the aquatic resources that are the aim of protection, the cause and extent of impairment can be difficult to determine from sampling. Additionally, this type of sampling can be expensive and can require specific expertise. Approximately 39 percent of the systems use physical inspection to ensure that the construction and operation of the facility is consistent with the conditions of the trade. In 28 percent of the systems, private contractors are used to monitor compliance. All of these involve PS to NPS trades.

Penalties for Noncompliance

The vast majority of the WQT systems do not specify a penalty for non compliance. However, because these systems involve a permit, legal action from EPA becomes the default penalty. Other systems assign a fee for failing to achieve the intention of the trade. The Grasslands Area Tradable Load program, the Neuse River program, and the Tar-Pamlico program assign a fee for failure. The Blue Plains Credit creation program withdraws state funds if the state determines that the participants did not comply.

Several programs use a “carrot” in place of or in addition to the “stick” approach to compliance. The Grasslands Area Tradable Load program redistributes the fees it collects from non compliers to the complying participants. Another “carrot” for successful participation is foregoing the opportunity cost of noncompliance or nonparticipation. The Kalamazoo Trading Pilot program specifies the refund of payments if the parties do not perform as per the contract. The Long Island Sound Program requires that participants that do not achieve the individual requirement forego a credit payment, instead paying the system-wide aggregate marginal cost of reduction.

Table 2-16: Compliance for Existing Water Quality Trading Programs

Name	**Discharge Monitoring**	**Stream Monitoring**	**Physical Inspection**	**Private Contract**	**Type**	**Penalty and Notes**
Bear Creek	**X**				PS-PS	Legal action. Failure of PSs to satisfy the discharge limit is a violation of NPDES Permit.
Boulder Creek	**X**	**X**	**X**	**X**	PS-NPS	Legal action. Regulators inspect the physical facilities and monitor water quality .
Blue Plains WWTP Credit Creation	**X**				PS-PS	Legal action and withdraw of state funds.
Cargil and Ajinomto Permit	**X**				PS-PS	Legal action. The Cargill facility agreed to accept the effluent from the Ajinomoto facility.
Chatfield Lake	**X**	**X**			PS-PS or PS-NPS	Legal action. The credits are incorporated in the NPDES Permit.
Cherry Creek	**X**		**X**		PS-NPS	Legal action. Point sources are accountable for non-point source reduction.
Colorado River Basin Salinity Control Program			**X**	**X**	N/A	Legal action. Each project is an agreement with a contractor who provides the reduction.
Fox Wolf Basin	**X**				PS-PS or PS-NPS	
Grassland Area Tradable Load Program	**X**				NPS-NPS	Trades are retroactive, based upon monitoring, and involve a fee and rebate policy.
Great Miami River Watershed Pilot Program	**X**	**X**	**X**	**X**	PS-NPS	Legal action. PS and NPS develop an agreement. 5%-10% of sites are inspected.
Henry County Public Service Authority	**X**				PS-PS	Legal action. The proposed trade involved permit modification.
Iron and Steel Industry	**X**				PS-PS	Legal action.
Kalamazoo Trading Pilot Program	**X**	**X**	**X**	**X**	PS-NPS	Legal action and refund. Money is refunded if the parties to the agreement fail to perform.
Lake Dillon	**X**		**X**		PS-NPS or NPS-NPS	Legal action. NPDES Permit reflects NPS controls.
Long Island Sound Nitrogen Credit Exchange	**X**				PS-PS	Legal action. Failure is a violation of group permit. Payments are for participation.
Lower Bosie River Effluent Trading Prog.	**X**		**X**	**X**	PS-NPS	Legal action. PS is liable and sign PC with NPS.
New York City Phos. Offset Program	**X**	**X**			PS-PS or PS-NPS	Legal action. Each offset must have a contingency plan for failure. Reductions calculated by inlet and outlet sampling of BMP.
Nuese River	**X**				PS-NPS	Legal action, fee, or rebate. The association pays fee for group failure.
Passaic Valley Sewerage Commission	**X**				PS-PS	Legal action. Trade transfers legal responsibility from one permit to another permit.
Piasa Creek Watershed Project	**X**	**X**			PS-NPS	Legal action. Not-for-profit organizations samples waterway.
Pinnacle Foods	**X**				PS-NPS	Legal action. Offsets are written into NPDES permit.
Rahr Malting Permit	**X**		**X**	**X**	PS-NPS	Legal action. PS inspects BMPs, signs contract with NPS, and maintains liability.
Red Cedar River Program	**X**		**X**		PS-NPS	Payment is received only after implementation is verified.
Rock River Trading Program	**X**			**X**	PS-PS or PS-NPS	Legal action. Trade is assumed to meet environmental goal.
Southern Minnesota Beet Sugar Cooperative	**X**		**X**	**X**	PS-NPS	Legal action. PS maintains responsibility for NPS reductions.
Tar-Pamlico	**X**		**X**		PS-NPS	Legal action and fee. State assumes responsibility for verification of BMPs.
Trukee River Water Rights Offset Program	**X**				PS-PS or PS-NPS	Legal action. Permits state that no discharger can be penalized for discharge of another.
Wayland Business Center	**X**				PS-NPS	Legal action. Offsets are written into the permit. PS retains liability for NPS reductions.

Lessons Learned from Existing Trading Systems

Legal action is the ultimate mechanisms for ensuring compliance. However, the reliance upon legal action for enforcement may be a barrier to the widespread use of trading because legal action is not transparent. NPDES permit violations can cost $10,000 to $25,000 per day (Fisher-Vanden et al 2004). Additionally, the CWA allows for the payments of actual damages, punitive damages, and attorney's fees (O'Leary 2003). These penalties have much uncertainty. In contrast, Title IV provides transparent penalties. At any time, participants know the cost of compliance (the market price of an allowance) and the cost of non compliance ($2000 per day). The availability of this information makes the choice of compliance the obvious and better alternative to non compliance.

Additionally, legal action often has an "all-or-nothing" character (Noll 1989). This characteristic introduces uncertain liability for the participants. This condition is especially problematic for small dischargers, like many in existing trading systems, who do not have the financial capability to assume the open ended risk of participation in a trading system. These participants may choose conventional methods of environmental control instead of market mechanisms because of the relative certainty and well-defined liability of conventional methods. Litigation may also be expensive relative to other mechanisms for regulation, preventing claims and allowing violators to proceed without regulation (Horan and Shortle 2001).

Several studies indicate that the uncertain liability of the participants is a barrier to the widespread use of trading. Horan (2001) states that in most PS-NPS systems, trades transfer the responsibility for reduction but not the liability and that the failure to transfer the liability is an important barrier to the trade. Woodward and Kaiser (2000) indicate that responsibility and liability are the primary concern when a trade fails and that this condition raises transaction costs. Some existing or proposed trading systems identify liability as a barrier to the use of trading. In Colorado, liability was one of the issues that prevented the use of trading to clean up an abandoned mine. The Fox-Wolf program in Wisconsin has not had any trades, in part because PS are reluctant to trade due of high uncertainty and transaction cost (Fisher-Vanden et al 2004).

One solution to the liability issue is to clearly establish the penalty. The Neuse River program, Tar-Pamlico program, and the Long Island Sound program use this method. For the Neuse River program and the Tar-Pamlico program, if the association or a member exceeds the individual allocation then the association or the member purchases credits by paying an offset fee that the association previously defined (Fisher-Vanden et al 2004). This fee is approximately twice the cost of least cost effective BMP. Once the purchase is made, the state assumes the responsibility for monitoring and verification of the BMP. For the Long Island Sound program, participants who discharge more than their allotment must also purchase credits at a rate the state previously defined (Fisher-Vanden et al 2004). If they fail to make the purchase, they are subject to traditional enforcement mechanisms. For each of these systems, the participants know the penalty for failure to achieve their reduction. In this regard, these systems are similar to Title IV and consistent with the theory that values transparency.

Summary of Chapter 2

The modeling for establishing and monitoring WQT is complex and should be closely linked with the modeling of the TMDL program. The development and use of TR is critical to the success WQT and is dependent on economics, environmental improvement, geography, and qualitative judgment. Economic considerations are important when one party in a trade has a considerably lower marginal removal cost than the other party. This condition may provide an opportunity for high-relative trading ratios that can reduce uncertainty. Environmental improvements are a consideration when regulators wish to retire an amount of load with each trade. Developers may choose to use this type of trading ratio to reduce the resistance to the implementation of trading. Geography is the most important factor for trading ratio. It includes three components; land delivery, water delivery, and uncertainty. Developers of trading systems should consider these components and basic trading ratios should be modeled with and included in TMDL's. The consideration does not necessarily need to involve a robust technical analysis of each component and simplification is often appropriate. The use of TR zones, pre-approved ratios, and pre-approved BMP's efficiencies are appropriate, but need to be continually evaluated.

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Chapter 3

Water Quality Issues Relevant to Water Quality Trading in the Lower Delaware Region

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Introduction

This chapter reviews major water quality issues in the lower Delaware River region in relation to market based water quality pollutant trading schemes. The first section of the chapter covers the local TMDL's process and compares local TMDL's to those that have been used in watersheds where WQT has been established. The second section uses the TMDL of the Christina watershed of the Lower Delaware as a case study to understand the detailed information needed to establish water quality trading schemes in the region.

General Water Quality Considerations

Like the rest of the nation, the focus of water quality management in the Lower Delaware Region has shifted over the past two decades from PS discharges (end-of-pipe) to NPS problems, primarily sediments and nutrients from urban and agricultural sources (Delaware River Basin Commission 2004). Of the impaired freshwater bodies in the region, 97% are streams, creeks or rivers (http://oaspub.epa.gov/waters/state_rept.control?p_state=PA). Over 156 impaired segments have been listed in the Pennsylvania region of the Lower Delaware River. In Pennsylvania, abandoned mine drainage, agriculture, and urban runoff are the three largest causes of these impairments. In the LDR, industrial discharges, urban runoff, and agriculture are the major causes of impairments. In some highly urbanized basins, like the Wissahickon Creek, urban storm runoff and municipal PS are the dominant causes of impairments (Wissahickon TMDL 2003). In most other watersheds impairments result from a mixture of industrial and municipal PS and agricultural and urban NPS. Regardless of the source of the pollutant, habitat alteration, siltation, pathogens, metals, nutrients, pH and DO are the most common impairments to freshwater aquatic life. Fish consumption from streams is also limited by PCB's, mercury, chlordane, and dioxin. Pathogens, metals, and total dissolved solids are also responsible for drinking water impairments.

Total Maximum Daily Loads in the Lower Delaware River Region

TMDL's represent the total amount of a pollutant that can be assimilated by a stream without exceeding water quality standards (see Chapter 1). The pollutant allocations resulting from the TMDL process represent the amount of pollutant that can be discharged into a waterway from each source. As noted in Chapter 1, TMDL's are an essential component for establishing WQT systems. Therefore, how TMDL's are determined, reviewed, and adopted is an essential component to the establishment of WQT systems in the region.

Sediment, nutrients, and habitat alterations are the primary causes of water quality impairments in the area and the major focus of local TMDL's. Except for a few quarries or abandoned sites, sediment does not typically come from PS. Instead, most sediment is generated from NPS including agriculture, construction sites, and stream bank erosion associated with channel widening in response to urbanization. In contrast, nutrients are derived from both PS and NPS. Acid mine drainage is another major source of water quality impairment in the greater Mid-Atlantic region. While off-sets or WQT maybe possible in certain situations, the similarity in abatement costs between acid mine polluters and the unique chemistry of acid mine drainage suggests that acid mine drainage problems are not readily amenable to trading. Because they are not common in the LDR they are not considered in this analysis.

Although the development of TMDL's is relatively recent in the LDR, both EPA and the state governments in the region have active programs for their development. By 2004, TMDL's were approved for 1212 stream segments in Pennsylvania (http://oaspub.epa.gov/waters/state_rept.control?p_state=PA) and 100 segments in Delaware (http://oaspub.epa.gov/waters/state_rept.control?p_state=DE). By the end of 2005, the State of Pennsylvania expects to complete TMDL on an additional 33 non acid mine drainage water bodies (Pennsylvania Bureau of Water Supply and Wastewater Management 2004). The State of Delaware expects an additional 15 TMDL's will be completed by the end of 2006.

Table 3-1. Summary of 130 recently completed TMDL's in the Lower Delaware River Basin region. Several watersheds have more than one TMDL. Complied from an analysis of approved TMDL's listed at http://www.epa.gov/reg3wapd/tmdl/index.htm

Water Quality Pollutant	*Number of TMDL's*	*% TMDL*
Total Phosphorus	58	44.6
Sediment	22	16.9
Total Nitrogen	13	10
Metals	12	9.2
Bacteria	9	6.9
Dissolved Oxygen	8	6.2
Multiple Nutrients	5	3.8
Specific Chemicals	3	2.3
Total number of TMDL's	130	100

All of the EPA-sponsored TMDL's that have been developed for the Lower Delaware region have been completed since 2003. In this study 130 TMDL's from the region were reviewed and compared (Table 3-1). Sediments and/or nutrients were the focus of 75% of the TMDL's. The majority of the TMDL's were done on streams (62%) or lakes (35%) and consider both storm and low flow conditions. Total phosphorus was the dominant focus pollutant in both streams (35%) and lakes (61%). While 87% of the TMDL's were focused on single pollutants (e.g. nitrogen, PCB's etc.), 13% were focused on bacteria and dissolved oxygen that are influenced by multiple biophysical processes.

All of the TMDL's for lakes and estuaries and 95% of those for streams were calculated using spatially explicit water quality models (Table 3-2). However, no individual water quality model was used in the majority of the TMDL's. The reference watershed approach without modeling was used in 5% of the stream TMDL's. The most common water quality models used to estimate TMDL's for streams were variations of WASP and GWLF (see chapter 3 for a discussion of various models).

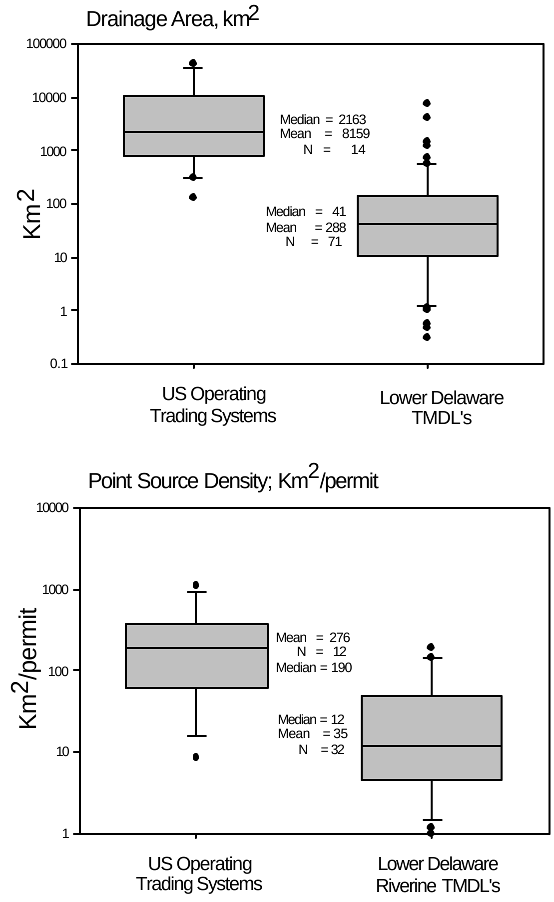
Table 3-2. Water quality models used to calculate TMDL's for streams in the Lower Delaware Region

	# of TMDL's	% of TMDL's
Models	61	78.2
Models and reference watersheds	13	16.7
Reference watersheds	4	5.1
WASP model	21	28
Reckhow model	11	15
GWLF or AVGWLF	17	23
Other models	25	34

TMDL's in the LDR region have been developed for watersheds ranging from 1.5 to over 17,000 km^2 (Figure. 3- 1). On average the regional water bodies with TMDL's had nearly 7 NPDES permits within their boundaries. In general, the TMDL's of the LDR cover smaller areas than the watersheds that contain established trading systems. The PS density (e.g. km^2/NPDES permit) is also lower in the Lower Delaware watersheds than in watersheds with operating WQT systems. This higher density reflects the urban and industrial nature of the LDR compared to the relatively rural watersheds with existing trading programs. It also indicates that there should be ample opportunities for trading in the region

On average, the TMDL's in the Lower Delaware River Basin indicate that a 58% reduction in the current input of pollutants is needed to achieve water quality standards. Moreover, lakes will require a 62% reduction while streams will require a 54% reduction in current inputs to meet their designated use (Figure 3-2). These reductions are generally higher for metals and nutrients than sediments.

Figure 3-1. Drainage area and point source density of watersheds with operating trading systems and TMDL's that have been developed in the Lower Delaware River region.

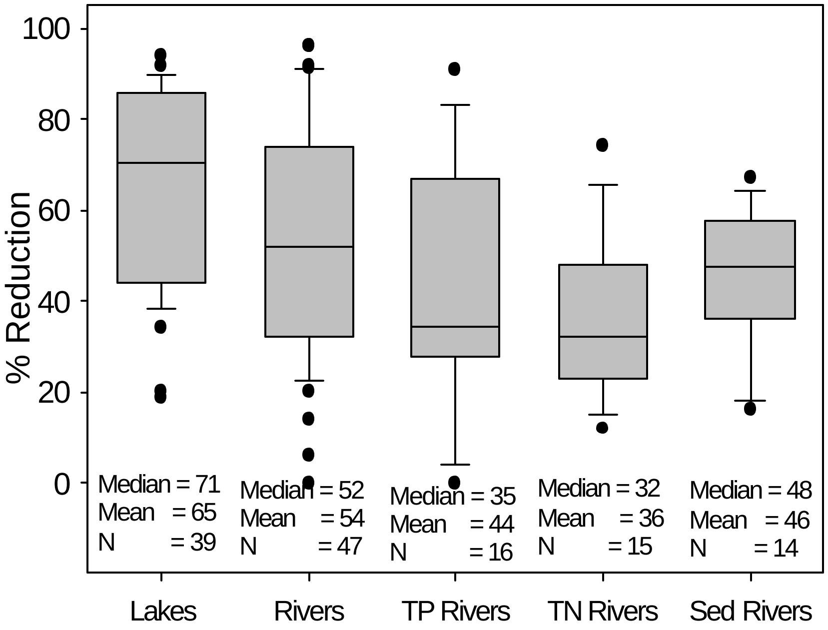


Reduction allocation strategies

On average, the TMDL's in the Lower Delaware River Basin indicate that a 58% reduction in the current input of pollutants is needed to achieve water quality goals (Figure 3-2). How these reductions are distributed between polluters is critical to the achieving water quality goals in an equitable, legally defensible, and economically efficient manner. Unfortunately, far less than half of the 130 regional TMDL's reviewed in this study explicitly stated how the reductions are distributed among dischargers. Less that 10% of the TMDL's describe the details of the allocation strategy used to distribute the reductions.

For the TMDL's that do state how the reductions are allocated between dischargers, a size based equal marginal percent removal (EMPR) allocation strategy is the most commonly used method. In this strategy, all dischargers modeled in the TMDL are reduced by equal percentages and the water quality model is run in a reiterative fashion until the WQS are met. Thus the marginal rate of removal for all affected dischargers is the same but the absolute quantity removed depends on the size of the discharge. Site specific allocations of NPS reductions are not implicitly considered in the most of the TMDL's. It is also common to combine and model all small PS one source and not consider them in the final allocation of the reductions. Thus the final reductions are typically distributed among large point-sources. Furthermore, there is little if any consistency between TMDL's as to what sources are considered for reductions (e.g. large and small PS, NPS sources etc.) and what rules are used to distribute the reductions between the selected sources. Because, the final allocations provide the incentive to trade, the lack of guidelines for determining how reductions are distributed among sources is considered a potential barrier to the establishment of WQT systems in the region (see Chapter 5).

Figure 3-2 Percent reductions in pollutants recommended by TMDL's in the from the Lower Delaware River Region, where TP = total phosphorus, TN = total Nitrogen, and SED = sediment



The Christina Watershed Case Study

From colonial times to the present, the Christina watershed has been vital to the region (Figure 3-3). Because the basin has had an long history of community involvement and technical study, it has often been considered to be one the first basin's in the region where water quality trades can be established. Trades between PS, PS and NPS, upstream and downstream users, and even trades that involve hydromodifications and dam releases have been envisioned for the basin.

Today the watershed drains three states and provides up to 100 million gallons of public drinking water per day (Kauffman et al 2003). Since the 1960's there have been extensive efforts to improve the water quality of the basin. While there have been many measurable improvements, 39 river segments are still considered impaired by low levels of dissolved oxygen (DO) (Figure 3). The inputs of nutrients from both PS and NPS are considered to be the root causes these impairments.

This section briefly summarizes the current state of the water quality in the basin and provides background information needed to evaluate the use of water quality trades. The Hydrodynamic and Water Quality Model of the Christina River Basin (EPA 2000), the Christina Watershed Restoration Action Strategy (Kauffman et al 2003), and the low and high flow TMDL's for the Christina River Basin (EPA 2004a and b) provided much of the information used in this brief summary.

Physical Geography

The Christina Watershed drains 545 square miles and parts of three states before it enters into the Delaware River. Seventy percent of the watershed is in Chester County, Pennsylvania. Almost 30% of the watershed is in New Castle County Delaware and a small portion is within Cecil County, Maryland.

The Christina River, Brandywine Creek, Red Clay Creek, and White Clay Creek are the major waterways within the basin. Six water supply reservoirs are also located within the basin. The East Branch White Clay Creek has been designated as having water of "Exceptional Value" by Pennsylvania. The lower segments of all the streams are considered impaired by low DO levels (Figure 3-2.). Nonpoint sources were identified as contributing to 98% of the impaired segments (Kauffman et al 2003). Point sources were considered to impact 28% of the total impaired miles.

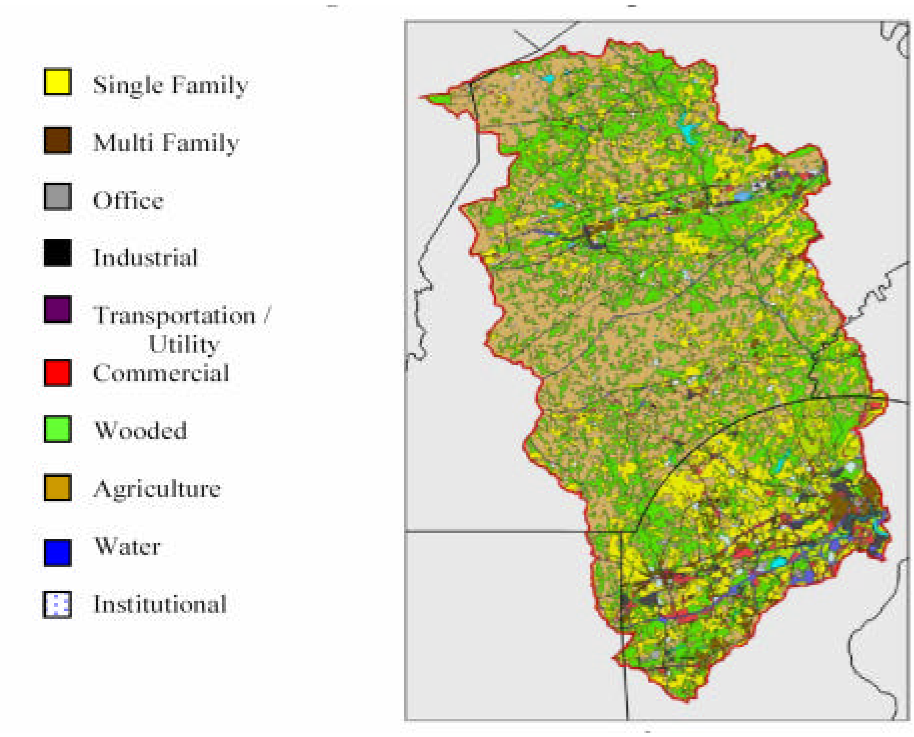
Like many watersheds in the LDR region, the Christina is a suburbanizing watershed that has lost 15% of its open land to development since 1970 (Kauffman et al 2003). Today urban and suburban land uses occupy 34% of the basin (Table 3-3). Agriculture land uses occupy 31%. In the State of Delaware most of the urban area is concentrated around Wilmington and Newark. In Pennsylvania, urban land use occurs in West Chester, Downingtown, Kennett Square and a host of smaller communities. In general, most of the urban areas and superfund sites are in the southern portion of the basin, while single-family suburban land-use is spread throughout the basin (Figure 3-3).

Table 3-3 – Land Use Summary of the Christina Watershed

Land Use	DE and MD (Sq. Miles)	PA (Sq. Miles)	Total (Sq. Miles)	% of Total Area
Urban and Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Land	21	5	26	5
Wooded	37	123	160	28
Water or Other	3	3	6	2
Total	166	399	565	100

Source: www.epa.gov/reg3wapd/christina/pdf/tmdl_christina.pdf.

Figure 3-3. Land use in the Christina Watershed (Kauffman et al 2003)



Institutional framework and stakeholders

Because the basin drains 3 states, 5 counties and over 60 townships, numerous institutions are actively involved in managing the water quality of the basin. Watershed stewardship is also provided through at least 8 non-profit organizations and the Delaware River Basin Commission (DRBC). This commission is an interstate agency with the authority to establish water quality standards (WQS) and regulate pollution activities within the Delaware River Basin. Since 1961 the Chester County Water Resource Authority (CCWRA) has also been active in land use acquisition and planning for floodcontrol and water supply (USGS 1998). Since 1969 the U.S. Geological Survey has had a cooperative water-resource investigation program with the CCWRA that measures and describes the water resources of the county. In 1993 EPA and the DRBC created the Christina Basin Water Quality Management Committee (CBWQMC) to address watershed scale water quality problems. This committee represents a variety of stakeholders including conservation districts, planning commissions, and nature societies. One outcome of these efforts is that a great deal of high quality hydrologic and water quality data is available for the basin.

The CWA requires that water from the upstream state meet the WQS of the downstream state at the state line. Since 1991 the DRBC has agreed to mediate interstate water management issues of the Christina. In 1993, Pennsylvania, Delaware, EPA, and DRBC reached an agreement to produce TMDL allocations for the Christina River basin by late 1999. The final low-flow TMDL was released in 2004 and is focused on loads of nutrients and dissolved oxygen (EPA 2004a Christina Low Flow TMDL). The target of this TMDL is to attain and maintain applicable DO water criteria at low flow conditions. A related, but separate TMDL's for sediment and bacteria under high flow conditions was completed in April of 2005.

Sources of water quality degradation

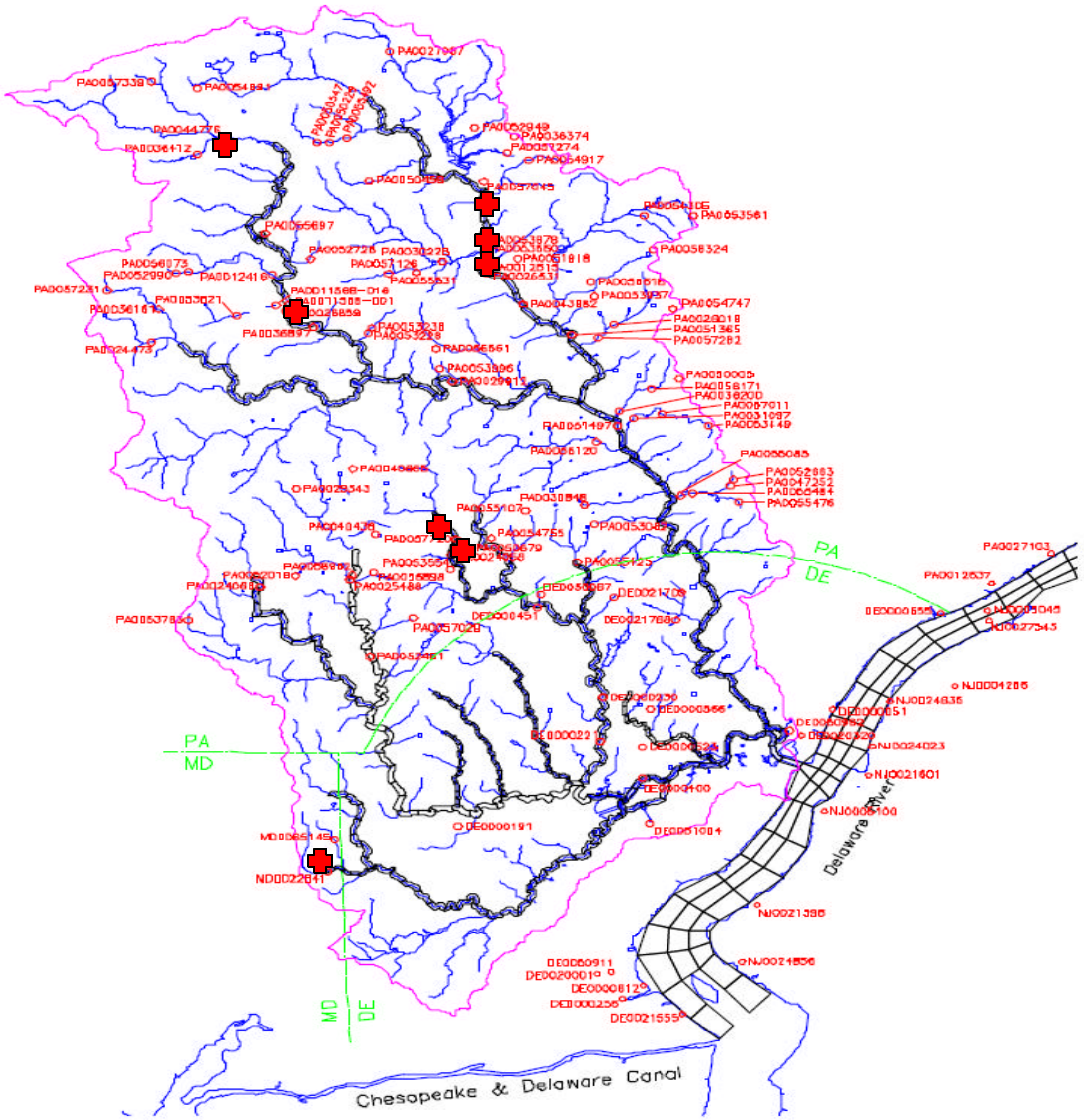
Sources of pollutants and water quality degradation within the basin include industrial and municipal PS, agriculture, superfund sites, and hydromodifications (EPA 2004a). Over the entire basin, 43% of the impaired segments are considered impaired by either PS or Superfund sites. In Pennsylvania, nearly all of the PS that are causing impairments are municipal.

In 2004 the watershed had 104 dischargers with NPDES permits (Figure 3-4). The flows of the dischargers range from 500 gpd to 7 mgd. Of these NPDES permitted PS, 88% are considered to be small (< 0.25 mgd). Seven facilities are not located within the actual watershed but discharge more than 10 mgd directly into the Delaware River near its confluence with the Christina. Because of the tidal conditions at the confluence, these facilities do influence the water quality of the lower tidal Christina and were considered in the low flow TMDL analysis.

Non-point sources of water quality degradation include agriculture, combined sewer overflows, and urban runoff. Agriculture is responsibility for 53% of the annual total suspended sediment load within the basin and is considered the major source of impairment in 12 of 15 impaired segments in Pennsylvania (EPA 2004b).

In the Pennsylvania area of the watershed six stream segments are listed as having bacterial impairments (EPA 2004b, Christina high flow TMDL). In the Delaware drainage, 19 water bodies are listed as impaired by bacteria. Pennsylvania uses fecal coliform bacteria as an indicator whereas Delaware uses enterococcus bacteria. Fecal coliform are primarily found in intestinal tracts of mammals and birds while enterococci are normally found in warm-blooded animals and are considered an indicator of human sewage. Both bacteria can cause swimming related illnesses.

Figure 3-4: Location of NPDES Discharges in Christina Basin. The locations of those NPDES permits that are recommended for reductions in the 2004 Low flow TMDL are marked with large crosses. Source EPA 2004b



The TMDL estimates for the Christina watershed

Two TMDL's, one based on high flow conditions and one on low flow conditions, have been developed for the Christina watershed. The low flow TMDL, does not implicitly consider NPS and is focused on the impacts of nitrogen and phosphorus from NPDES permit holders (EPA 2004a). In contrast, the high flow TMDL explicitly includes NPS of bacteria and sediment (EPA 2004b). High flow contributions of nutrients are not explicitly considered in the allocations of either analysis. Attaining adequate dissolved oxygen levels is the major goal of both TMDL's.

The Christina Low flow TMDL was one of the first to be completed in the Lower Delaware River basin. The target of this TMDL is to attain and maintain applicable DO levels at low flow conditions (Table 3-4). Because of the complex bio-physical interactions that influence DO levels (Figure 3-5), the low flow TMDL specifically addresses PS load allocations for total phosphorus, total nitrogen, ammonia-nitrogen, and Carbonaceous Biochemical Oxygen Demand (CBOD). In the analysis, the 10th percentile concentrations during the 7Q10 low-flow period were assumed to represent low flow NPS contributions (EPA 2004a). No shading of the stream due to vegetation canopy or cloudiness was incorporated into model. Thus the model is based on maximum photosynthetic activity. Stream water temps were also set to historic highs and the month of August was used in developing allocation scenarios. This time period was selected as the most representative of when critical water quality conditions are expected to occur.

Figure 3-5. Interrelationships of major kinetic processes that influences dissolved oxygen in surface water bodies. EPA 2004a

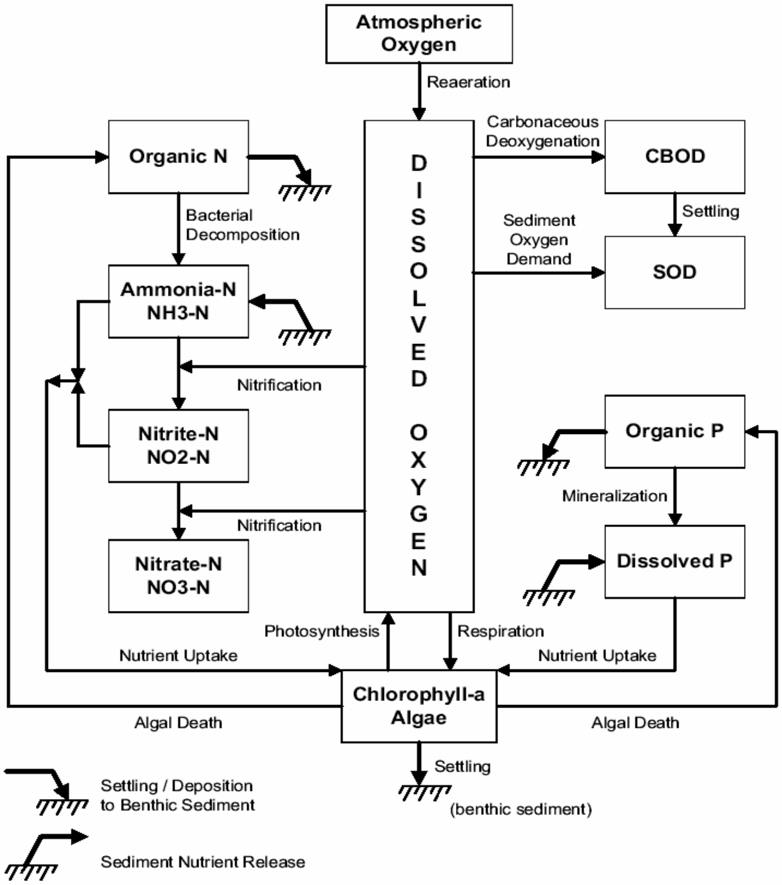


Table 3-4. Christina TMDL target limits for Dissolved Oxygen that are recommended by the 2004 Low Flow TMDL of the Christina Basin (EPA 2004a).

Parameter	Target Limit	Reference
Daily Average DO, freshwater, Pennsylvania	5.0 mg/l	Pennsylvania Water Quality Standards
Daily Average DO, freshwater, Delaware	5.5 mg/l	Delaware Water Quality Standards
DO at any time, Maryland	5.0 mg/l	Maryland Water Quality Standards
Minimum DO, freshwater	4.0 mg/l	Pennsylvania and Delaware Water Quality Standards

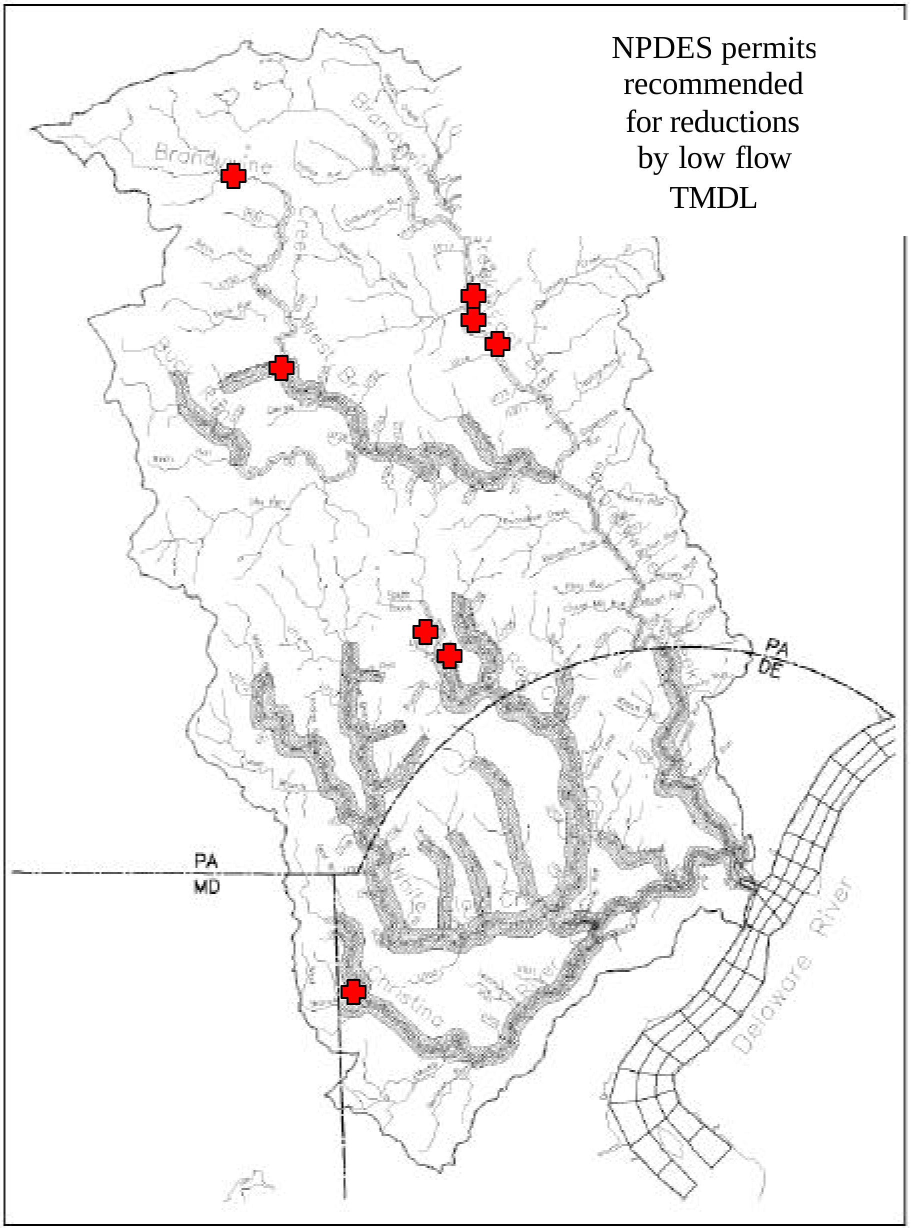
The Christina high flow TMDL is focused on sediment and bacteria from point and NPS, including storm water and storm sewage systems. The TMDL's target endpoint for bacteria was selected to maintain recreational contact use during both swimming and non-swimming seasons. In this analysis the main PS were municipal separate storm sewer systems (MS4s). Within the basin, there are 40 MS4-NPDES permits. Nonpoint sources of sediment and bacteria that were considered include septic systems, agriculture, wildlife, and domestic pets. The sediment endpoint was determined by using the reference watershed method and ranges between 0.09 to 1.04 tons/acre/yr.

Both the high-flow TMDL and the low-flow TMDL's for the Christina Watershed used the EFDC model to simulate conditions in the waterway. However, each TMDLs used a different watershed loading model. Inputs for the low-flow TMDL were estimated from the product of the flow rate for each subwatershed and a characteristic concentration for the particular contaminant. These concentrations were based on a combination of STORET data and field observations at monitoring stations. The high-flow TMDL used a combination of HSPF and SWMM to develop the input loads (EPA 2005). HSPF was used to develop the loads from point and nonpoint sources. SWMM was used to identify loads from combined sewer overflows (CSOs) from the city of Wilmington. All of these modeling efforts were based on data characterized as "extensive and high-quality". Model calibration and validation was confirmed by EPA by showing that the model was able to simulate the locations of the impaired stream.

The allocation of TMDL based reductions

The EMPR allocation strategy was used in allocating the reductions required in the low flow TMDL analysis. In this strategy all point-source dischargers are reduced by equal percentages in reiterative model runs until WQS are met. Thus the marginal rate of removal for all affected dischargers is the same but the absolute quantity removed maybe different. In the Christina basin the EMPR strategy was applied in multiple levels of analysis (EPA 2004a).

Figure 3-5. Impaired Stream segments in the Christina Basin and location of the NPDES permits that are recommended for reduction by the 2004 Low Flow TMDL of the Christina Basin (EPA 2004a).



NPDES permits recommended for reductions by low flow TMDL

Figure 1-2. 303(d) waters listed for nutrients, low DO (NPS and PS as cause)

The first level of analysis involved analyzing each NPDES PS individually to determine the baseline levels of treatment necessary to achieve WQS for daily average and daily minimum DO. In this analysis all of the small (< 0.25 mgd) NPDES permits were combined and modeled as one distributed source. This modeling effort indicated that combined, and thus individually, these 87 small NPDES sources do not create violations of DO standards. Multiple model runs were then made in which the NPDES discharges are added one-at-a-time based on the size of their CBOD load. This modeling indicated that WQS for DO were not met in the East Branch of the Brandywine creek, West Branch of the Brandywine, West Branch Red Clay Creek, and in the tidal portion of the river. The allocation procedure was then implemented by running the water quality model in an iterative fashion where CBOD, NH3-N, and TP were reduced in 5% intervals for all the NPDES dischargers upstream of the farthest downstream DO violations. In the final level of analysis, dischargers outside the basin that influence the tidal portions of the Christina were included in the model and the allocations were fine tuned in 1% increments until no violations were found. Summaries of the resulting allocations by watershed are included in Table 3-5.

Table 3-5: Summary of proposed allocations and reductions by subwatershed of the Christina that are recommended by the 2004 Low Flow TMDL of the Christina Basin (EPA 2004a).

Watershed		CBOD5 allociation	CBOD6 reduction	NH3-N allociation	NH3-N reduction	TP allociation	TP reduction
Units		lb/day	lb/day	lb/day	Lb/day	lb/day	lb/day
Brandywine		1710	436	299	59	198	65
Christina		76	0	14	26	6	0
Red Clay		271	77	24	9	88	57
White Clay		143	0	19	0	16	0
Total		2200	513	356	94	308	122
Units		lb/day	lb/day	lb/day	lb/day	lb/day	lb/day

Overall, the 2004 low-flow TMDL recommended that eight facilities, seven in Pennsylvania and one in Maryland, have their NPDES permits modified to reduce the quantity of pollutants they can discharge. Three of the eight facilities were private companies. The remaining permits were discharging municipal waste. These 8 PS were distributed in 4 of the basins subwatersheds (Figure 3-2). Within each of these watersheds there are other NPDES permit holders whose permits were not recommended for modification. In some subbasins the combined discharge from theses permit holders is less than the reduction recommended from the others. In other instances the combined discharges from excluded dischargers is greater than the needed reduction. For example, in the West Branch of the Brandywine, the combined total phosphorus allocation of the 16 NPDES permit holders who are not recommended for permit modifications (12.91 lb/day) is less than the total TP reduction (17.88 lb/day) that is recommended from the other two dischargers. However, the combined CBOD5 allocation (176.83 lb/day) of the 16 NPDES permit holders who were not recommended for a reduction is greater than the recommended reduction from the two dischargers (117.46 lb/day) who were recommended for a reduction. Because these 16 permits are not recommended for modification, they have little incentive to develop or trade reductions.

The allocations for the Christina High Flow TMDL were also made using successive model runs in which land uses, meteorological conditions, and kinematic parameters remained the same. Unfortunately, the modeling report does not explicitly state how the "loads from various sources were adjusted" when allocating bacterial loads

(EPA 2004b). For the reductions of CSO the EFDC model was used by changing "the enterococci concentrations in the model input file". Unfortunately, how these changes were made and distributed across the CSO was not explicit in the modeling report. Nevertheless, the High-flow TMDL indicates that bacteria loadings reductions from 29 to 93% are needed. Sediment reductions ranged between 15.7 and 70.6%. All of the sediment reductions are in PA streams. No segments within Delaware are listed as having sediment impairments. This disparity reflects the different methods that the states use in defining water quality impairments.

Opportunities for Water Quality Trading in the Christina Watershed

Although the Christina Watershed has approved TMDL's and adequate institutional support, there have been no WQT to date. Our discussions with NPDES permit holders indicate that their first approach will be to undertake internal reductions before partaking in trading. While none are currently considering trading, they generally consider it as a viable future option. Fortunately, trading opportunities exist and can be expected to be carefully evaluated once adequate incentives exist. These opportunities include PS-PS trades, PS-NPS trades using BMP's, stream channel restoration and habitat improvement, dam releases, and land conversions.

While there are 104 PS permits within the basin, only 8 were recommended for trading under the Christina low flow TMDL's. Of those recommended for reductions, two were private companies. The remaining 75 percent were municipalities. Trades between the private companies and municipality PS are possible and should be explored. However, because the total discharges from the private companies are small compared to the municipal dischargers, trades between public and private PS will not be sufficient to meet the basins water quality goals.

While trades between these PS, and specifically between adjacent PS, are the simplest to develop and monitor, they may not be possible in the Christina basin. Moreover, although there are several clusters of PS that are recommended for reductions, because these clusters are mostly municipal dischargers from similar urbanizing communities that use similar technologies and have similar property values, their differences in abatement costs may not be large enough to warrant long-term trading relationships. Therefore, off-sets within individual municipalities or trades between municipalities and private NPS are the most likely type of exchanges in the near future. Offsets within a municipality may include nutrient or sediment reduction trades between MS4s discharges and WWTP. However, because the High Flow TMDL that includes MS4s discharges is focused on sediment and bacteria, while the Low Flow TMDL that includes NPDES permits is focused on nutrients and DO, there are few incentives for the dischargers to trade, even between themselves. Any trades that are established will need to establish multi-pollutant trading ratios.

While opportunities for PS-PS trades maybe limited, there are ample opportunities for nutrient reduction trades between PS and NPS. Specific projects may include the implementation of agricultural BMP's and the establishment of riparian buffers above and beyond what is required to meet regional nutrient management budgeting requirements (Pennsylvania DEP 2005). Stream channel restorations and the release of water from dams during summer low flow periods are additional practices that should be considered. Adequate dam releases can increase water flow and reaeration during critical periods. Likewise, habitat and channel restorations can also mitigate low flow dissolved oxygen levels and increase the nutrient assimilatory capacity of the channels.

Converting agricultural lands to forest is an additional type of trade that can be considered. Given that the difference in annual TP loads between agricultural and forested lands in the watershed is simulated at 4.6 lb/ac/yr (Senior and Koerkle 2003 Table 26), a conversion of approximately 9% of the basin's non-mushroom agriculture land into forest could reduce TP loads by the amount designated in the low flow TMDL (e.g. 122 lb/day). In contrast, to meet the TMDL based reductions in ammonia, approximately 78 percent of the basin's non-mushroom agriculture would have to be converted to forest. While the actual amount of agricultural to forest conversion that would be needed depends on the location and conditions of the lands, these simple calculation indicate that while trades based on establishing agricultural BMP's or converting agriculture to forests maybe a viable option for reducing TP, these land use conversions are not likely to solve the ammonia problem. The large measured and modeled differences in nutrient exports between mushroom based agriculture and non-mushroom agriculture also indicate that mushroom based agriculture may have the greatest potential for reducing nutrient exports via trading. Moreover, because the nutrient exports from mushroom farms appears to be 3 to 5 times that of other types of agriculture (Senior and Koerkle 2003, Tables 24 and 26), effective BMP's on these farms may result in greater nutrient reductions, larger trading ratios, and more viable trades.

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Appendix 1: Comparison of EPA sponsored TMDL's completed in the recent lower Delaware River basin region by Fall 2005.

Watershed Name	Drainage area km2	Pollutants	%Reduction Required	Approach	Reference Watershed/Model	NPDES ermits
Brush Run	25.9	TP	15%	watershed/model		
Brush Run		Sediment	67%	watershed/model	GWLF	
Christina River High Flow	1463.3	Bacteria	by stream	model	HSPF,XP_SWMM,EFDC	122
Christina River High Flow		Sediment	by stream	reference watershed	NA	
Christina River Low Flow		CBOD5	by stream	model	EFDC	122
Christina River Low Flow		DO	by stream	model	EFDC	
Christina River Low Flow		NH3-N	by stream	model	EFDC	
Christina River Low Flow		TN	by stream	model	EFDC	
Christina River Low Flow		TP	by stream	model	EFDC	
Deep, Beach, Elizabeth	39.9	Nutrient		model	GWLF	
Deep, Beach, Elizabeth		Sediment		watershed/model	GWLF	
Delaware River Estuary PCB	17546.6	PCB	99.80%	model	TOX15,DYNHYD5	142
Glanraffan Creek	1.5	Metals	90%	model	Monte Carlo Simulation (@Risk^2)	1
Glanraffan Creek		Suspended soilds	90%	model	Monte Carlo Simulation (@Risk^2)	1
Lake Ontelaunee	497.3	Nutrients	87%	model	GWLF	10
Lake Ontelaunee		Suspended Solids	87%	model	GWLF	10
L.Wallenpaupack (Draft)	567.2	Mercury	40%	model	AVGWLF, BASINSIM GWLF, LAKE2K	14
L.Wallenpaupack (Draft)		Nutrients	40%	model	AVGWLF, BASINSIM GWLF, LAKE2K	14
L.Wallenpaupack (Draft)		Suspended	40%	model	AVGWLF, BASINSIM GWLF, LAKE2K	14
Litiz Run TMDL	44.0	Turbidity, S. Solids	43%	reference watershed/model	Catasauqua Watershed (NY), AVGWFL	6
Marsh Run and McCarthy Run TMDL	17.6	Sediment	56%	reference watershed/model	Pine Creek (PA), Elkhorn Run (PA), AVGWFL	1
Skippack Creek	309.0	Nutrients	74%	model	AVGWLF	11
Skippack Creek		Sediments	20%	reference watershed	East Branch Perkiomen (PA)	
Mill Creek	8.8	Phosphorus	27%	model	AVGWLF	
Mill Creek TMDL		Sediments	52%	reference watershed	Little Conestoga Creek	1
Waltz Creek	55.4	Metals	50%	model	AVGWLF, LDC	
Waltz Creek		Sediment	57%	reference watershed/model	East Fork Martin's Creek (PA), AVGWLF	1
Wissahickon Creek	165.8	Nutrient	by stream	model	EFDC, WASP/EUTRO	
Wissahickon Creek		Sediment	by stream t	reference watershed	Ironworks Creek (PA)	19
Wyomissing Creek	40.7	Sediment	40%	reference watershed/model	Big Hollow Watershed,AVGWLF	9
Average	1484.5		56.6			29.3
Median	49.7		52.0			10.0

Chapter 4
Administration and Management of Water Quality Trading Systems

Stanley L Laskowski and Kimberly Abbott

Introduction

There is a paucity of fully-functioning water quality trading systems in the US. This is despite numerous efforts by creative environmental professionals to establish such programs. The reason for so few programs may be due to several factors, including the high transaction cost (e.g. the time and money needed to set up the programs), judgments made regarding the feasibility of implementing a program once all costs/benefits are understood, and/or the failure to resolve the administrative, management, and other issues before implementing a program. This suggests that careful early planning should be undertaken in establishing any trading program. This planning should include an assessment of the administrative processes involved. A thorough examination of these key issues will help ensure the success of the program or, in some cases, provide an early warning to the decision makers that a program is not feasible.

In researching this Chapter the authors interviewed over a dozen environmental professionals. The recent publication, the "Water Quality Trading and Offset Initiatives in the US: A Comprehensive Survey" was used extensively and provided a wonderful listing of efforts around the country (Breetz et al 2004). Websites for many of the leading water quality trading programs and from organizations in the Delaware Valley were consulted to gather additional background information. Information was also received from training provided by the US Environmental Protection Agency Region 3 Office, from a meeting with EPA water professionals, and from presentations sponsored by the University of Pennsylvania's Institute for Environmental Studies.

This Chapter presents the findings related to the administrative and management issues and offers recommendations for establishing WQT systems in the LDR and the Christina River Basin. The issues addressed include organizational structure, types of skills needed, staffing levels, funding and budget. Issues involved with incentives for trading, and finding trading opportunities are also included.

Organizational Structure and Staffing of Water Quality Trading Systems

Analysis of existing water quality data bases (Breetz et al. 2004) indicates that it is often an administrative organization that facilitates trades. This can be a governmental, non-governmental, or other organization. The need for, and type of, organization needed to administer a trading program depends on factors such as the size, type, and complexity of the trading program. In choosing between organizations such as a local watershed authority and watershed association, the program designers should take many things into consideration, including regulatory authority, existing resources and the sentiments of non-point dischargers who may not have experience with water quality management programs. For some smaller watersheds, existing local watershed authorities or watershed organizations may be the appropriate administrative organization. For larger, more complex trading programs, governmental organizations may be preferable. In some situations, notably the Grassland Area Farmers (CA), Long Island Sound (CT), and the Passiac Valley Sewerage programs, the need for an administrative organization has been eliminated as the trades are conducted directly with the government agencies.

Since the main stem of the Delaware River could potentially involve an interstate trading situation, either an agency with interstate authority or a process involving all the needed agencies (and stakeholders) would be necessary. There is no major interstate water quality trading program that covers an area comparable in size and nature to the LDR Basin (eg. a large, tidal, multi-state system with an existing complex governance structure). The Long Island Sound Program covers a area that is similar in size to the LDR but its trading program currently includes only dischargers from the State of Connecticut (Johnson 2005). The organizational structure will be different for a situation where all trades would occur between sources in one state (intrastate trades) versus the LDR situation where the potential trading partners are located in different states (interstate trades). Since there is a potential for interstate trades in the LDR the administrative organization should have broad representation from Delaware, Pennsylvania, and New Jersey.

In either interstate or intrastate programs it is essential to involve all pertinent permitting agencies and interested stakeholders in some way. For example, to the extent that permits under the NPDES are involved in trading programs (this is usually the case), the permitting authority has usually been involved in an active way. In the LDR, all three states (Delaware, Pennsylvania, and New Jersey) have been delegated the authority to administer the NPDES permit, compliance, and enforcement program. The EPA maintains a role of “overseeing” the administration of the state-administered NPDES programs in order to ensure consistency with national standards and policies. The DRBC also has authorities to be considered in any trading scenario. Evaluations of the strengths of organization relative to trading are provided in the last section of this chapter.

- In addition to designating or designing an administrative organization, for a trading program to be successful, it is essential to build trust with key interested stakeholders. These stakeholders typically included groups such as the regulated community, elected and career government officials at all levels, environmental groups (mostly at the local level but sometimes at the national level), and civic organizations. The timing of the stakeholder involvement is also important. The process of establishing a trading program should be as transparent as possible, involving potential stakeholders at the earliest possible time. Since there are many complex issues to address before it is determined if trading is appropriate for a watershed, and since many stakeholders may be interested but may also have time constraints, it is important for leaders to find effective ways to communicate. Nationwide, the traditional methods of mailings, internet sites, and newspaper articles have all used by various leaders involved in trading. However, meeting early and often with potentially-impacted parties is viewed to be especially important in establishing the trust needed to be successful in the long run.

The types of skills needed to administer a trading program are similar to those needed to manage the typical environmental program. The following are some of the skills needed and examples of why these skills are important:

- Legal. Although there are no legal barriers to establishing an overall trading program in the LDR Basin, legal advice will be needed in implementing specific trades and trading systems, especially if such trades do not fit neatly into the routine regulatory framework.
- Environmental, technical, and economic skills to determine if a trade makes sense from both an environmental and economic perspective.
- Administrative to handle any contracting issues.
- Data management to monitor trades for compliance, and to track environmental trends.
- Communication to build teams and keep participants involved in the process.
- Evaluation to determine the success of the program.

These skills can be, and often are, available from the staff in existing agencies, environmental/civic groups, or academia. They can also be available from consultants who are becoming more aware and involved in trading issues. It is recommended that existing staff from government, NGOs, academia, and others be used to determine if opportunities exist for trading and to develop a framework for trading before any permanent staff are hired solely to administer a trading program.

Participants and Communications

In addition to ensuring that the correct skills are available, it is also important to involve the correct organizations and individuals. The exact groups to target for inclusion will be determined by the situation in the specific watershed. However, the following types of organizations/individuals are typically involved and should be considered in establishing a trading program: local/state/ and federal permit writers; water quality planners; local dischargers; environmental groups; and political/civic leaders. Leadership by government officials, both political and career, is important in setting the tone for a creative trading situation. “Buy-in” by the planners, permit writers, and environmental groups is essential. Of course, the dischargers potentially involved in trades need to see that they would realize sufficient cost savings for them to spend the time needed to work through the process. A partial listing of critical groups to include in the LDR Basin is included the last section of this Chapter. In order to promote inclusiveness the process of developing a water quality trading process should be as transparent as possible.

Throughout the process the messengers may be as important as the message. Therefore, it is most desirable to spend time providing the facts to those who most often communicate with the ultimate local decision makers. These may include local elected officials, sewage treatment plant operator associations, farm organizations, and local Chambers of Commerce. For example, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), county soil and water conservation districts, agricultural extensions at universities, and watershed organizations are some of the existing and effective channels of communications with farmers.

Sources of Funding

Funding for existing trading programs has come from a variety of sources including state grants, Clean Water Act section 319 funds, private grants/funds, and in-kind services. For example, Cherry Creek (CO), Piasa Creek (IL) and Kalamazoo (MI) all use unspecified state and federal grants to finance trading activities. Chatfield (CO) has received a Clean Lakes grant, and Long Island Sound (CT) and Great Miami River (OH) depend on capital improvement money from the State Revolving Loan fund. Grants from the Environmental Protection Agency (EPA) have funded watershed studies, modeling and other research in Charles River in Massachusetts and Red Cedar River in Wisconsin.

Private sources of funding should also be explored. Point sources seeking adjusted effluent limitations contribute significant amounts, ranging from thousands to millions of dollars. These funds are usually for offset projects. Illinois-American Water Company, in Piasa Creek, will contribute millions of dollars over the 10-year program. American National Power (ANP) in Charles River (MA) contributed $1.3 million to fund water-flow projects.(Breetz et al 2004). The Kalamazoo Demonstration Project (MI) received $25,000 from a paper company. Rahr Malting (MN) and Southern Minnesota Beet Sugar Cooperative established $275,000 and $300,000 funds respectively to pay for phosphorus offsets. Finally, the Tar-Pamlico Discharge Association paid a total of $700,000 for a trading ‘trial run’. Some of this money was also used to pay for a full-time employee to facilitate trading.

Many program stakeholders tap the “in-kind” expertise and resources of other agencies and organizations to defray expensive research and administrative duties or help with pollution reduction. Volunteers are also used in some cases. Chatfield Reservoir (CO) uses in-kind services from agencies such as the Army Corps of Engineers and the local botanical garden. The Nitrogen Credit Advisory Board (NCAB), composed of representatives for the buyers and sellers, helps to track credit exchange for the Long Island Sound program, free of charge. The United State Geological Survey (USGS) assists on the flow modeling for Charles River (MA) and the NRCS ‘partnered with the Kalamazoo project’ to perform field work. The Barron County Land Conservation Department took on a bulk of the administrative work to make trading more cost-effective in the Red Cedar River (WI).

Some programs raise funds through application fees, dues and/or through credit sales. The Chatfield Reservoir program charges a $100 ‘Application’ fee to PS applying for a higher effluent limitation, and administrative costs are also built in credit prices. User fees and credit sales pay for a portion of Cherry Creek’s $1.4 million budget (2003), while ten percent of the trading costs in the Tar-Pamlico go towards administrative expenses. Cherry Creek and Chatfield Reservoir in Colorado also augment revenues through property taxes and fundraisers.

In the LDR Basin and the Christina River Basin all the above types of funding should be considered. The diversity of funding approaches that have been used suggests that there may be different funding approaches that could be used within the LDR Basin depending on the individual characteristics of the trade (ie. parties involved, specific interests of potential funders, etc). Managers in the LDR Basin and the Christina River Basin have an impressive record of attracting state (eg. Growing Greener) and federal (eg. Section 319) funds and should use these experiences to seek funds for high-priority trades.

Management Costs

The budget needed to administer a trading program varies considerably. Reliable figures regarding staffing levels were difficult to find. The national air trading program is managed centrally by a few dozen people (Personal communication with Bob Rose, EPA 2004). However, water trading, being more localized, is different. These programs must be managed at a smaller scale. Although information is scarce, anecdotal information provides the following insights:

- Point source- to- point source trades appear to have the least amount of duties that need to be performed by an administrative organization and therefore less associated cost.
- The Long Island Sound program (CT) is managed by approximately five people who work part time on the program. In all a total of two person work-years is used to manage the program (Gary Johnson 2004).
- Russell Clayshulte of the Chatfield Reservoir program estimates that the equivalent of one full-time employee's (FTE) time, approximately $38,000/yr is spent communicating with Colorado's Water Quality Control Division, generating annual reports, and organizing historical documents (Russell Clayshulte 2005)
- Tar-Pamlico and Neuse River (NC) are also clearinghouses with significant overhead. Administrative duties include reviewing load reports, collecting monitoring data, reviewing numbers and keeping track of administrative costs. The Division of Water Quality, which administers the program, was granted $150,000 to fund one staff position for the program, and 10% of the cost of a credit goes toward ongoing administrative costs.
- Great Rivers Land Trust (GRLT) in Piasa Creek (IL) is a third-party broker responsible for generating sediment reductions at NPS in order to fill (a) contractual agreement' (Breetz et al 2004). As part of the agreement, GRLT provides monthly, quarterly and annual monitoring reports; along with other duties, this is the equivalent of one FTE and about 15% of each project's cost.

Incentives for Trading

The decision to initiate a trading program is often driven by regulatory programs. A review of the programs listed in the Water Quality Trading Initiatives and Offsets Survey (Breetz et al 2004) indicates that, of approximately fourteen water quality trading initiatives found to be working on guidelines or who had a framework for trading in place (as of August, 2004), the main incentive for at least eleven of the programs has been to comply with regulatory requirements that were associated with TMDL or NPDES permit limits. For example, the TMDL for nitrogen was the driver in the Long Island Sound

Program. The review also found that at least six programs incorporate offsets to enlarge or add another wastewater treatment plant to the watershed. A handful of PS explored, and in some cases implemented, the use of offsets to defer costly pollution controls and/or upgrades. Lack of regulatory pressures sometimes results in no trades. For example, PS in Chatfield Reservoir (CO) have been meeting the limits for years without trading (although the framework is in place), and only recently needed credits due to upgrades (Breetz et al 2004). In watersheds with no TMDL, there may be less incentive to trade. In the Fox-Wolf Basin (WI), dischargers have applied for and received temporary alternative permit limits based on financial hardship (Breetz et al 2004).

Occasionally, trading is just not economically feasible. In situations where extremely large reductions are required, the installation of site specific pollution controls may be more cost effective than trading. At least six of the programs in the Water Quality Trading and Offset Initiatives survey did just that. The Grassland Area Farmers (CA), Neuse River Basin (NC) and Tar-Pamlico Basin (NC) are all group-compliance programs where one member was able to make capital improvements that significantly lowered the group's discharge below the limit. A concrete framework for the Fox-Wolf Basin (WI) and Red Cedar River (WI) trading programs never materialized due to uncertain state trading guidelines and lack of support from local conservation districts (Breetz et al 2004). According to the Water Quality Trading and Offset Initiatives survey, PS wanting to trade in the Fox-Wolf Basin would be responsible for developing their own framework and bearing all of the administrative costs. In the Red Cedar River Basin, the administrative costs for a trading program would be nearly equal to the costs for BMP implementation without the help of the local Land Conservation district (Breetz et al 2004).

Other Considerations for Successful Water Quality Trading Systems

Based on discussions with many environmental professionals, the following recommendations can be made regarding the initiation of a trading process. First, if a TMDL must be developed for a stream, it is advisable to defer the implementation of a trading program until after the TMDL has been finalized. This provides more certainty to the trading negotiations and allows for the more efficient use of time and resources. Second, given the complexities of developing a trading program, it is generally advisable to start with simple trades. For example, if possible, a trade between two PS of pollution would be more desirable than a trade between two NPS in the early stages of a trading program. Likewise, starting with one traditional pollutant (eg. a nutrient), would also be advisable if the specifics of the situation allow this.

Although regulatory requirements are often the driving force in establishing a trading program, other elements are deemed to be desirable. These include having one or more key leaders familiar with the basic concepts of trading, and having those in critical decision-making positions (eg. state permit writers) being receptive to the concepts of trading. Having key executives, especially government officials, actively seeking progressive solutions to water quality problems is also very helpful. In this regard, both the LDR Basin and the Christina River Basin are fortunate. The environmental leaders in each of the three states, in DRBC, in EPA, and in the Christina River Basin have a history of progressive environmental management and several of these leaders have been vocal in their support for actively evaluating the feasibility of trading program. Although trading opportunities can initially be identified by a number of sources (eg. the dischargers, local officials, NGOs), it is important to the eventual success of the program to have active support from the governmental decision makers.

Finding Trading Opportunities

Identifying potential trading opportunities has involved several different types of organizations and stakeholders, including:

Administrative or regulatory organization: Some NPS offsets are identified through an administrative organization or regulatory/government agency rather than the PS. Great Rivers Land Trust in Piasa Creek (IL) is the local watershed association and the organization responsible for finding sediment reduction projects. The Kalamazoo (MI) demonstration project Steering Committee chose to identify projects using aerial photos and topographic maps and the Great Miami River Pilot program (OH) used local soil and resource conservation agencies to select NPS sites.

Point sources: A significant number of PS find their own trades. Members of group-compliance permits are especially likely to find trades with other members. The Grassland Area Farmers (CA) and Southern Minnesota Beet Sugar Cooperative (MN) trade primarily among themselves since bigger entities can cost-effectively reduce on behalf of their smaller counterparts. Individual PS to PS source trading initiatives, including Passaic Valley Pretreatment (NJ), Bear Creek (CO) and Henry County (VA), also feature trades identified by PS. The Lower Boise (ID) program is unique since PS find their own trades, but with NPS instead of PS.

Municipalities: Municipalities occasionally identify NPS offsets for PS. This is especially true where WWTPs want to expand or add a new facility in an area that is fully allocated. The municipalities of Boulder Creek (CO), Wayland Business Center (MA), Falmouth WWTP (MA), Red Cedar (WI) and most likely Rock River (WI) have or will identify offset projects so a PS can receive a greater discharge allowance.

Hybrid methods: Some trading initiatives permit both PS and ‘other’ organizations to find trades/offsets. The Tar-Pamlico and Neuse River programs in North Carolina and the Chatfield Reservoir and Cherry Creek programs in Colorado encourage PS to find their own trades, but also fund NPS offsets through a special fund or clearinghouse. In the Charles River (MA), the local watershed association negotiates offset contracts with the PS, but the city identifies landowners to participate in offset projects. Rahr Malting (MN) and Long Island Sound (CT) programs have their own unique ways of facilitating offsets. Rahr Malting’s NPS offsets were found through a ‘network’ of various organizations and individuals. The State of Connecticut doesn’t ‘find’ offsets for PS dischargers; it merely calculates who has reduced enough to sell credits and who is in need of credits and settles the balance accordingly.

Once trades are identified they must be approved and tracked. Four examples were found where the administrative organization is a regulatory agency that also has the power to approve trades. Chatfield Reservoir, Cherry Creek (CO) and the Neuse and Tar-Pamlico (NC) programs are all administered by their state environmental management organizations. Each of the agencies tracks as well as approves offset credits, acting as a clearinghouse and in some cases acting as the 'middle man' between buyer and seller (Breetz et al 2004). In Lower Boise, PS who engage in pre-defined NPS offsets do not have to obtain an individual approval. Because of this, the Idaho Clean Water Cooperative only has to track the trade credits, provided the trading partners participated correctly in the process.

Compliance Monitoring and Enforcement of Trades

After the trading program has been established and the trades have been documented, the trades must be monitored for compliance and effectiveness. An examination of existing programs (Breetz et al. 2004) indicates that monitoring duties vary greatly in scope and expense from program to program. NPDES permit holders are required to self-monitor. Non-point source monitoring (in stream and at BMP sites) is typically done by the administrative organization, the PS pursuing the trade, or not at all. At least six administrative organizations oversee or perform monitoring themselves. Cost estimates for monitoring range from $58,000/year (Chatfield Reservoir, CO) to about $400,000 - $600,000/year (Great Miami, OH). Some initiatives have relied on other agencies such as the USGS and local universities to monitor to help offset costs. Programs with no monitoring cited cost as the primary factor.

The penalty for not complying with the requirements of the trading agreement depends on the specifics of the trading agreement. In the Long Island Sound Program the "penalty" is the payment to the fund for any loading discharged in excess of the allocation. Alternatively, if the discharge is less than the allocation, the fund pays the discharger.

Evaluation of Trading Programs

In addition to the cost reductions realized by the trades, measures for success vary from program to program. However, the most commonly cited benchmark is a measurable reduction in pollution discharges. The most important measure in the Long Island Sound (CT) program is nitrogen reduction and corresponding improvement in dissolved oxygen (Paul Stacey 2005). For the Tar-Pamlico, the reduction in nutrients (45% nitrogen and 60% phosphorus since 1990) and the corresponding increase in flows (30%) is considered a success (Rich Gannon 2005). Great Rivers Land Trust in Piasa Creek (IL) calculates total tons of sediment removed to date and compares that to the reduction schedule as its way to gauge progress. Another common benchmark is establishing the feasibility of trading based on conditions in the watershed. Passaic Valley Sewerage Commissioners knew they had reached this goal when small PS were able to meet adjusted trading requirements, and enough reductions were made to sell credits (Andy Caltagirone 2005). According to Scott Van de Mark, Director of Special Projects, the Conestoga River trading initiative will be a 'success' if the recently established framework makes trading economically feasible (Scott Van de Mark 2005). Other measures include community participation, acceptance by farmers, and the number of volunteers involved.

Communications, transparency of the processes, and active involvement of interested stakeholders, all appear to be critical factors in the success of any trading program, especially in larger programs. It should be recognized that it generally can take several years for the trading concept to be accepted and implemented, and that sometimes, for various reasons (technical, financial, etc) a trading program may not be implemented despite everyone's best efforts. Nevertheless, a evaluation process should be established "up front" during the planning stage and before any trading program is implemented. This will ensure that all participants know what is expected of them before the process begins. The process should indicate who will do the evaluation, what criteria will be used, and how the information will be disseminated to interested parties. In order to promote credibility, it is also recommended that the evaluators be lead by an independent third party with involvement by the major stakeholders in the process. The lead evaluators should have knowledge of the principles of trading, the requirements of the underlying legal authorities and water quality control programs. The evaluation criteria should include compliance with the specific conditions of the trading agreement, review of the financial records, and an analysis stream quality changes that may have resulted from the trades.

Selection of an Organization to Administer Trading Programs

Having a central organization help establish, manage, and evaluate WQT systems is essential to their success (see Chapters 1, 2, 3 and 4). Having one lead organization will help ensure that there is consistency between trades within the basin, that there is a single contact point for parties interested in initiating a trade, and that financial and contractual issues are properly handled. A central organization can also provide other services, such as providing training, tracking the success of various trading efforts (including trading models used, trading ratios/credits for best management practices, etc), and maintaining a data base of trades and trading technology used in the area.

The following criteria are proposed for selecting an organization to administer a trading program in the LDR region.

- Organizational Infrastructure and Interest-- does the organization have a history of accomplishment, an understanding of the local environmental, economic, and cultural considerations, demonstrated interest in trading programs, and a culture of innovativeness and team building? Does the organization have sufficient interest in administering the trading program? Will it be able to provide the focus needed?
- Funding -- Does the organization have sufficient funding to administer the program? Does it have a sufficient infrastructure to handle funding in a responsible way?
- Staffing and experience--Does the organization have experience in trading and related areas? Does it have sufficient staff to administer the program? Does it have sufficient expertise in key areas (e.g. environmental science, environmental regulations, management, economics, and law)? Does staff have the expertise needed to oversee contractors that could fill certain needs?

- Scale--Is the geographic area covered by the organization compatible with areas where potential trades will be made?
- Local Network--Does the organization have a history of positive relationships with various stakeholders in the area where the trading program will be established?
- Working Relationships with Regulators--- Does the organization have a good working relationship with key governmental organizations such as EPA and the state environmental programs?

Using the criteria listed above the following is an assessment of some of the key agencies that are potentially involved in WQT in the LDR Basin.

The US Environmental Protection Agency (EPA)

EPA has a Regional Office (Region 3) located in Philadelphia. This office has federal jurisdiction over parts of the LDR basin that drains Pennsylvania and Delaware. Areas that drain New Jersey are under the federal jurisdiction of EPA Region 2, located in New York City. In general EPA:

- has the legal authorities needed to implement a WQT program
- has a strong interest in promoting WQT
- has split jurisdiction for the Basin between Region 2 and Region 3
- could bring national assistance to the program
- has the organization to handle financial, economic, or legal issues that may arise
- elsewhere has been in a support role rather than having the role of the administrating WQT programs
- has a large staff skilled in issues relating to trading

Summary: EPA has supported market-based programs in the past and the current Administration continues to make these programs a priority. EPA is more interested in giving strong support to others who would administer the program. Their support and leadership is very important to getting a program started and sustained.

State Agencies

Each state has its own capabilities and interests. As a whole, they can be characterized as follows. Each state has:

- The staff skills needed for a trading program or could obtain them through a contractor
- The legal authority to implement trades within their state boundaries but these authorities may have difficulties with interstate issues.
- Sufficient organizational capabilities to handle financial, economic, or legal issues
- Strong local contacts in their respective state but usually not in the other states
- A delegated NPDES permit program, the responsibility for the development of TMDLs, and primary responsibilities for other programs relating to water quality

- A history of trying new and innovative approaches to environmental management

Summary: States are essential participants and a WQT program cannot be implemented without the full support of the affected state. For each state, the transaction costs may be high on interstate trades. If interested, each state could implement a WQT program for trades confined to their state.

Delaware River Basin Commission (DRBC)

DRBC was established in 1961 under the Delaware River Basin Compact. It is governed by governors from the four basin states (Pennsylvania, New Jersey, Delaware and New York) and a federal representative appointed by the President of the United States (www.state.nj.us/drbc). The DRBC has:

- The legal authority needed to implement a trading program
- Interstate responsibilities and a history of success on interstate issues
- Knowledge of many of the key players in the Basin
- Staff/ expertise on which to build a trading program
- An interest in promoting innovative solutions in the Basin
- A structure that can handle the financial, technical, legal, and administrative issues related to a trading program
- The ability to promote teamwork and consistency among the states

Summary: DRBC should be involved in any trading program in the LDR Basin that deals with interstate issues. It should also be involved in issues relating to consistency between the states.

Delaware Estuary Program (DELEP)

DELEP was established as part of the National Estuary Program in 1988 (www.delep.org) and has a steering committee of officials from the three states, two EPA Regions, and the Partnership for the Delaware Estuary. DELEP seeks cooperation between all involved in the Estuary to promote environmental protection and economic improvements. DELEP has:

- A mandate to promote cooperative solutions
- A vision for interstate education, coordination, and cooperation
- An extensive network of contacts in the Estuary
- A staff limited both in size and the expertise needed for trading
- A geographic area of responsibility consistent with the LDR Basin

Summary: DELEP should have a key role in trades effecting the estuary, especially in the areas of education and forming cooperative partnerships

Other potential organizations

There are many other organizations in the LDR Basin who could be instrumental in promoting water quality trading. The following list, while not intended to be exhaustive, represents a sampling of some of the key organizations.

- Delaware River Port Authority—The DRPA "invests in the economic growth of Southeastern Pennsylvania and Southern New Jersey" (www.drpa.org) and can promote the trading concepts with its members.
- Delaware River and Bay Authority – DRBA, created by Compact in 1962, promotes transportation links between Delaware and four counties in NJ. It also promotes economic development in the region (www.drba.net/about/about).
- Delaware Valley Regional Planning Commission—DVRPC, created in 1965, "provides continuing, comprehensive, and coordinated planning" in five Pennsylvania counties and four New Jersey counties (www.dvrpc.org). They are directed by an 18-member Board and have over 100 full-time employees who work on a broad spectrum of planning issues, including environment, transportation, housing, land use, and air quality.
- Other state agencies – Each state has other governmental organizations that relate to the environment. These include organizations that deal with natural resources, recreation, and farming to name a few.
- US Army Corps of Engineers --- USACE is involved in many engineering and technical projects involving navigation, the environment, and other issues. Their Philadelphia District has responsibility for the Delaware River Basin (www.nap.usace.army.mil).
- National Park Service, US Fish and Wildlife Service, USGS, and other federal agencies also may have important roles to play depending on how a trading program is structured.

In addition to government agencies there are many other organizations that can play important leadership role in developing water quality trading programs in the LDR Basin. These include:

- Watershed Associations and Environmental Groups—there are numerous groups in each state who throughout the years have been very influential in promoting innovative ways to protect the environment. These groups have demonstrated leadership, extensive local knowledge, expertise, and interest in finding solutions that will protect water quality in a cost-effective way. These organizations should be especially valuable in identifying local off-set opportunities. In the Christina River Basin there have been many active organizations such as the Brandywine Valley Association (www.brandywinewatershed.org). Depending on the area covered by a trading program, the appropriate groups should be involved as full partners at the earliest possible time.
- Colleges and Universities—The LDR Basin has one of the highest concentrations of institutions of higher education in the US. These organizations offer an extraordinary range of expertise needed to advance multi-disciplinary efforts such as water quality trading. They also offer the opportunity to train the current and future leaders in progressive ideas in environmental management. Some colleges and universities also have extensive experience in specific watersheds. For

example, the University of Delaware has done extensive work and has been involved in many partnerships on both the Delaware River and the Christina Basin (www.wr.udel.edu/cb).
- Foundations—these organizations have traditionally provided vision and leadership with environmental problems in the LDR Basin. They can continue to be catalysts for change by promoting innovative management solutions. For example, foundations could provide seed money to initiate the first trades in the LDR Basin/Christina River Basin.

In summary, there are many organizations who have expressed an interest in water quality trading programs and many others that may also be interested in playing a role. The DRBC and the states have special standing in this regard. DRBC has a unique role in the LDR Basin as a convener and a consensus builder, and is recognized as a leader on interstate issues, such as the development of the initial low-flow TMDL for the Christina River (http://www.epa.gov/reg3wapd/christina/pdf/execsumm.pdf). Therefore it is recommended that DRBC, working with the states and EPA, take a lead in promoting WQT in the region.

Summary of Chapter 4

The following conclusions can be reached regarding the administrative and management aspects of establishing water quality trading programs in the LDR Basin and the Christina River Basin:

- The LDR region is fortunate to have progressive leadership among government officials and NGOs. Many of these leaders have expressed interest in innovative environmental management and specifically in the concepts of trading.
- Governmental organizations in the environmental field have a history of cooperation and team-building in the basins. The Delaware River Basin Commission plays a unique role as a consensus builder in the Delaware River Basin. NGOs and municipal and industrial leaders have, in the past, been willing and capable of adopting cost-effective solutions to environmental problems.
- There do not appear to be any major legal or administrative impediments to establishing a water quality trading program in the LDR
- Water quality trading can be one innovative way to reach water quality goals in a cost-effective way. It is not a panacea and may be appropriate in only a limited number of situations. It should be viewed as one "tool" in the toolbox of the water quality manager. The tool may not be used as often as others but, under the appropriate conditions (eg, environmental, economic, political), it may result in both significant cost savings and water quality improvements.
- The establishment of a trading program should be expected to take several years, especially in a large basin like the LDR Basin. Those interested in promoting a trading program should plan to be involved in a long term process. There could be significant "transaction costs" in establishing a program. These costs include organizing meetings with key stakeholders to discuss the concepts, educating the interested parties, and conducting initial technical evaluations to identify the best

opportunities for trading. Existing staff and funding should be used in the early stages of establishing a trading program. As the feasibility and size of the program is understood, specific needs can be identified.

The following specific recommendations are made in order to take the next steps in determining the feasibility of establishing a water quality trading program:

- Building on the existing interests of the organizations involved, EPA (Regions 2 and 3), DRBC, the states of Delaware, Pennsylvania, and New Jersey should sign an agreement to promote water quality training in the LDR Basin and issue a press release telling of their intent to promote these ideas. A nationally-recognized NGO, with trading experience, should also be invited to sign this agreement. The agreement should announce the intent of these organizations to work together to identify priority opportunities for trading throughout the LDR Basin within 18 months.
- Use existing governmental organizations, processes, staffing, and funding and the capabilities of others (eg. local watershed associations, academia, foundations, and industry) to take the next steps. DRBC and the states should chair a meeting of key stakeholders to delineate responsibilities of major organizations using the proposal set forth in this report as a starting point for those discussions
- Using the technical findings of this report, the state officials, DRBC, EPA, and the local stakeholders should decide the degree to which trading is appropriate at this time in the Christina River Basin . This will give some of the key players experience in the trading deliberations and will inform their decisions on future efforts. These deliberations should be documented in a way that can be used to train others on trading issues. The development of workbooks and video documentation should be considered.
- The states, DRBC, and EPA should continue to find opportunities to educate potential stakeholders in the concepts of trading. The “train the trainer” concept should be used with national and local experts training the key stakeholders. Of particular importance is the training of state/federal planners, watershed managers, and permit writers and key NGOs from the LDR Basin and the Christina River Basin. Interested university and college professors should also be included and utilized to provide training to larger audiences and their students. This training should also be documented by video for broader dissemination.
- To the extent possible, the first trades should be as simple. They should not be implemented until needed TMDLs are approved. They should be PS to PS or perhaps one PS to one NPS. They should also be limited to one pollutant (nutrients are suggested as the first priority). Trading decisions should be memorialized by including the conditions in the NPDES permit, if possible, and the NPDES program should be used to monitor compliance.

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Chapter 5

Conclusions and Recommendations

The TMDL's that have been developed in the LDR region indicate that, on average, there needs to be a 58% reduction in pollutant discharges to meet the region's water quality goals. How to meet these reductions is challenging. Despite the lack of widespread use, there is ample evidence to suggest that water quality trading can help meet water quality goals in an economical way. Furthermore, the high density of different PS in the region, the variety of different land uses, and strong institutional structures indicate that WQT can be successful in the region. Nevertheless, developing effective trading systems is a complex and long-term process that will require incentives and a sustained effort by regional environmental organizations. This chapter reviews the types and costs of WQT trading systems that can be expected in the region and summarizes the specific recommendations mentioned in the previous chapters.

The Cost of Establishing and Managing Trading programs

Because only a few WQT systems have been established nationwide, and most of those have received outside funding, the actual costs of developing and maintaining trading programs is unknown and will be site specific. Nevertheless, a rough estimate of the cost of a median size WQT system in the region can be estimated from the information in Chapters 2 and 4 of this report. These first-order estimates indicate that the administrative costs of establishing and maintaining a trading system in the region are on the order of 150,000 to 200,000 dollars per year and are comparable to those of operating WQT systems elsewhere in the country (Breetz et al 2004 and Chapter 4). These estimates are considered conservative and assume a 20 year, renewable program. In addition, they do not include the costs of implementing reductions and further assume that the region has established TMDL programs and regional trading protocols.

Potential of WQT to meet regional water quality goals

Given the need for dischargers to have incentives to trade, it is expected that most trades will be developed in association with NPDES permit modifications that are designed to meet TMDL derived allocations. Nationally, trades involving nutrients and one-time PS-NPS offsets are the most commonly used trades. This type of trading, or simple PS to PS trades, are expected to be the dominate type of trade in the region in the near future. Actual trades maybe offsite agreements between municipal discharges (e.g. water treatment plants trading with storm water discharges), or between NPDES permit holders and agricultural NPS. While site specific TR and BMP's credits will need to be developed (Chapter 2), it is expected that the initial trades will be based on average values developed by the Chesapeake Bay Program (Pennsylvania DEP 2005).

Point-source to point-source trading is expected to be the second most common type of trade in the region. While this type of trade is the easiest to develop and monitor (Chapter 2), its use is expected to be limited because most of the PS that need to reduce their discharges are rapidly urbanizing municipalities that face similar pollution abatement costs (Chapter 3). The most complex type of trading involves multiple NPS and inter-pollutant trades. While reducing NPS pollution is essential to meet the regions water quality goals, developing NPS-NPS trades requires considerable specialized analysis. These types of trades are not expected until the region has an established trading infrastructure and strong incentives for NPS to reduce their pollution.

While WQT can play an important and economically efficient role in improving the regions water quality, trading cannot be expected to solve all of the regions water quality problems. This is because many of the regions water quality problems are caused by sediment, bacteria, and nutrients from unregulated NPS. Since nutrients are also produced by PS, there is a potential to reduce nutrient pollution through PS-NPS trades and WQT maybe effective in these situations. In contrast, sediment and bacteria are not readily amenable to trading because they are not produced by PS that have a regulatory incentive to trade. Instead most sediment and bacteria originate from unregulated agricultural NPS or temporary construction projects. While sediment reduction from NPS can be achieved using BMP's, there is little if any incentive for dischargers with NPDES permits to trade sediment reductions unless complex inter-pollutant PS-NPS trades are developed.

Specific conclusions and recommendations for developing WQT systems in LDR Basin

The successful development and implementation of WQT trading in the region will require strong institutional commitments and modifications in the way that water quality permits and the TMDL's are developed. Recommendations for each of these components are discussed below.

Water Quality Permits

The primary reason for the limited use of WQT has been the lack of incentives for dischargers. Moreover, water quality markets have not developed and are not expected to develop without an external organization creating incentives. Enforcing the TMDL based pollutant reductions is considered to be the most likely source of these incentives. Integrating the permit renewal process with the TMDL's allocations is the most likely mechanism for creating these incentives. Therefore to promote the establishment of WQT in the regions it is recommended that:

- EPA and State agencies work toward incorporating the allocations derived from the TMDL process into NPDES permits. Without the equitable incentives to reduce loads, trades will be limited to a limited number of site specific one-time offsets.

- To facilitate exchanges between traders, all NPDES permits within a watershed should be on the same renewal sequence. Fortunately, the EPA Region 3 and the states are moving in this direction.

- The NPDES permit renewal process needs to be flexible enough to allow dischargers to determine if they want to use a technology control or purchase a reduction to achieve an imposed cap. This requires that regulators and permit holders acknowledge that trading is a viable option and that they have the ability to evaluate various trading options during the renewal process.

Total Maximum Daily Loads

The TMDL process is closely linked to the establishment of WQT. While all of the states in the region are actively developing TMDL's, the process is relatively new and not yet conductive to trading. Our analysis suggests that the following actions should be taken when developing TMDL's to facilitate trading in the region:

- When ever possible, TMDL analysis should explicitly, and jointly, consider both point and non-point sources, high and low flow conditions, and present and future conditions of the watershed. This will insure that all of the pollutant sources are adequately evaluated and that the TMDL analysis is flexible enough to meet future demands.

- A variety of water quality models are currently being used to develop TMDL's in the region. While it is appropriate to use different models in different situations, some regional consistency and quality control is needed if the TMDL's are going to be enforced and subject to legal and technical scrutiny. Therefore, it is suggested that regional guide lines and quality assurance procedures are established to guide the development of future TMDL's.

- The water quality models that are the basis for calculating TMDL's are essential to evaluating trades and need to be made available to potential traders. Moreover, both managers of trading systems and potential traders need to run established TMDL models to evaluate the efficiency of proposed trades. Therefore it is proposed that a necessary step in promoting trading is to establish a mechanism by which the TMDL models are available for the WQT process. This maybe done through contractual agreements with the developers of the TMDL models or by establishing a library of TMDL's models in a local institution that can oversee their use. The local institutions that may facilitate such a library are EPA or DRBC.

- Because low DO is a widespread problem in the region, reducing low dissolved oxygen is typically the desired end-point for many impaired stream segments and is the focus of many of the regions TMDL's. However, DO is influenced by complex of interrelated physical-biological processes that cannot be directly traded. Therefore while the end-points of the TMDL analysis may be DO levels, the reductions recommended by the TMDL's process should be based on easily quantifiable water pollutants (e.g. nitrogen, phosphorus, sediment etc.).

Pollutant reduction allocation strategies

TMDL's determine the total amount of pollutant a water body can assimilate without exceeding water quality goals. How the pollutant reductions needed to meet those goals are allocated between discharges is essential to providing the incentives needed for trading. Unfortunately there is little consistency or transparency in determining how reductions are allocated (see Chapter 3). This analysis suggests that the following actions regarding pollutant allocation should be taken to facilitate trading in the region:

- While some of the regions TMDL's explicitly indicate how reductions are distributed among discharges, most do not. Therefore, it is recommended that TMDL explicitly explain how the reductions are distributed among dischargers and that specific guidelines are developed for allocating pollution reductions in the region.

- Size-based equal marginal percent removal allocation strategy is currently the most commonly used method to distribute TMDL based reductions across PS. While it has the advantages of being a relatively simple approach, it's effectiveness and equity depends on number of point and non-point sources that are included in analysis. Unfortunately, most of the regions EMPR allocations exclude small PS and NPS and allocate the required reductions on a subset of major PS. Furthermore, there is little consistency between TMDL's on what sources are excluded or included. These exclusions not only raise questions of equity, they also limit the numbers of potential traders. Therefore it is recommended that regional guidelines be developed for implementing EMPR in TMDL's

Trading ratios and Best Management Practices

By definition, WQT requires substituting pollution discharges at one location for another. However, to insure trades result in the same environmental benefits, trading ratios and the effectiveness of BMPs need to be established. Unfortunately most of the existing WQT systems do not explicitly consider the spatial distribution of trades and use a generalized trading ratio between 1 or 2. Fortunately the Chesapeake Bay program is developing efficiencies of standard BMPs that can be used as guidelines. Nevertheless, TR and BMPs need to be analyzed and monitored on a site specific basis. Our analysis suggests the following recommendations need to be implemented to promote trading in the region:

- Relevant institutions in the LDR should develop regional standards for assessing the pollutant reductions produced by Best Management Practices. These standards can be based on existing efforts by the Chesapeake Bay program and the Pollution Reduction Impact Comparison Tool (PRedICT) developed by PENN State University (Evans et al 2003). Similar models are needed for evaluating potential WQT in the region and should be developed and adopted.

- It is recommended that normative procedures for developing TR be developing for the region and be included as an integral part of each TMDL's (Chapter 2, Marshall 1999). Trading managers and TMDL developers will never have an a priori knowledge of all the possible TR that traders may need within a basin. Therefore, it is also recommended that the simulation models used to develop specific TMDL's are made available to allow potential traders to develop site specific TR. However, TMDL's should also include generalized TR for BMP's and major impaired reaches that will allow potential traders to conduct preliminary evaluations to determine if a potential trade warrants further analysis.

- Most, if not all, of the Best Management Practices that are currently considered in WQT involve modifying upland and riparian land use practices. However, dam releases during low flow periods and stream channel restorations can also be used to improve impaired water bodies. Guidelines for these practices should be developed and made available to potential traders.

- While inter-pollutant trading of water pollutants is technically and scientifically possible, they are very complicated due to the complex and site specific chemical transformations that need to be evaluated. While an eventual goal should be to build TMDL models and trading systems that allow inter-pollutant trading, these types of trades are not recommended in the present time unless detailed site specific studies and analysis are made.

Administration and Management

Trading is an evolving and continual process that relies on effective management and trust between all parties. To date the most successful programs work to "keep it simple" and have focused on the simplest trades. Nevertheless, trading is inherently a complex and dynamic process that requires institutional leadership, memory and flexibility to be effective. Fortunately the region has strong institutions committed to establishing trading in the region. To further enhance WQT in the region, it is recommended that the following be considered:

- Although individual states have or are in the process of developing trading policies and programs, there is no regional trading policy or guidelines. Nevertheless, many water bodies and problems are regional. Therefore it is recommended that DRBC, the EPA regions, and the states develop a regional trading and TMDL policy. This policy should determine how TMDL's and trades will be evaluated. Regional guidelines for monitoring the effectiveness of specific trades should also be developed. The regional policy should also address how TMDL models can be made available for potential traders and how non-compliance and the failure of well intended but technically inadequate trades will be addressed.

- Following or concurrent with the establishment of a regional trading policy, regional agencies should sign an agreement to promote water quality trading in the LDRB and identify priority impairments where trading can expedited through the establishment of enforceable caps based on established TMDL's

- Because trading is an evolving process, educating and communicating between key players is essential to long-term success. Annual or periodic trading symposium should be established to insure the region is informed about the state-of-the-art knowledge on the technical and legal aspects of trades.

- A regional repository of specific information on individual trades and TMDL's models should be established and made publicly available to promote the establishment and improvement of trades.

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Abbreviations used in this report

BAT	Best Available Treatment
BPT	Best Practical Treatment
CAA	Clean Air Act
CAT	Cap and Allowance Trades
CBOD	Carbonaceous Biochemical Oxygen Demand
CBWQMC	Christina Basin Water Quality Management Committee
CCWRA	Chester County Water Resource Authority
CTDEP	Connecticut Department of Environmental Protection
CWA	Clean Waters Act
DELEP	Delaware Estuary Program
DO	Dissolved Oxygen
DRBA	Delaware River and Bay Authority
DRBC	Delaware River Basin Commission
DRPA	Delaware River Port Authority
DVRPC	Delaware River Regional Planning Commission
EMPR	Equal Marginal Percent Removal
EPA	Environmental Protection Agency
FMP	Free Market Purchase Systems
FWPCA	Federal Water Pollution Control Act
LDR	Lower Delaware River
MS4s	Municipal separate storm sewer systems
NAAQS	National Ambient Air Quality Standards
NCAB	Nitrogen Credit Advisory Board
NPS	Non Point Source
NPS-NPS	Non Point Source-Non Point Source Trades
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PFP	Public Funds Purchase Systems
PS	Point Source Trades
PS-PS	Point Source to Point Source Trades
PS-NPS	Point Source-Non-Point Source Trades
TF	Tax or Fee Systems
TMDL	Total Maximum Daily Load
TMDL	Total Maximum Daily Load
USACE	US Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United State Geological Survey
WLA	Waste load Allocation
WQS	Water Quality Standards
WQT	Water Quality Trading
WWTP	Wastewater Treatment Plant