Chanathip Pharino

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Sustainable Water Quality Management Policy

The Role of Trading: The U.S. Experience

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Sustainable Water Quality Management Policy

The Role of Trading: The U.S. Experience

by

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PREFACE

After the success of the Acid Rain Program, pollution trading became a more acceptable policy in dealing with pollution problems. Trading of pollution credits and allowances helps to achieve environmental goals faster and more cost-effectively. Although for the past 20 years water pollution trading had been in effect for as long as air pollution trading, many water quality trading programs – as compared to air pollution trading programs – lack success in the implementation of trading. The motivation factor for my work came from an interest in learning and understanding what the differences were that culminated in different levels of success being achieved between water pollution trading programs and air pollution trading programs. Moreover, another incentive was not only to understand what the role of trading should be for managing water quality, but also how to better improve the water quality trading programs in order to become successful.

This book focuses on the examination of problems existing within a market-based system for water pollution control policy in the United States, and provides essential information for introducing market-based instruments for water quality management, presents general situations where trading may or may not work, and offers a recommendation for those interested in developing new water trading programs as a suitable option for solving localized water pollution, for fine-tuning the system after implementation, and for overcoming trading obstacles.

The book is divided into 5 chapters. Chapter 1 explains the background of water pollution, evolution, and performance of the current water pollution control regulation. Chapter 2 presents detailed information on how to develop a trading program and important elements which include the current theory and related empirical studies essential for pollution trading function. Chapter 3 presents the systematic analysis, with focus on current experiences, of all water quality trading programs in the United States. Chapter 4 explains how specific water quality trading programs proved to be successfully implemented, and discussions about how their unique characteristics led to each program's success. Chapter 5 provides recommendations for the roles of trading and essential elements for a water quality trading program to promote successful trading in the future.

I would like to thank all of those who supported me in writing this book. I am especially indebted to the AGS, especially Professor David H. Marks for his unconditional support and encouragement from the initial start to completion of my book, Dr. Denny Ellerman and Dr. Eric Adams for their intellectual advice and expertise, and the Martin Family Foundation Society of Fellows for Sustainability. I sincerely appreciate the individuals from USEPA, World Resource Institute, and the State Agency who took the time to share their experiences and insightful information, and Joanne Kauffman, Nathalie Jacobs, Anneke Pot, and Jolanda Karada for their help with the final publishing process. Last but not least, I would like to express my deepest gratitude to The Royal Thai Government, to my friends Jacqueline and Timothy Donoghue, and especially to Attasit Korchaiyapruk, and my parents Surachat and Chongchit Pharino for their unconditional love and confidence in me.

October 2006
Chanathip Pharino

Chapter 1
BACKGROUND

Introduction

There are two major mechanisms currently use to manage water quality; a direct regulation (or command-and-control mechanism) and a market-based mechanism. Command-and-control type policy is predominant and preferred by regulators after the passage of the Clean Water Act (CWA) in 1972. Major point sources are controlled under command-and-control regulation. However, agriculture and other non-point sources have largely escaped direct regulation (Ribaudo 1999). Traditional command-and-control regulation does not appear to be able to meet the challenges of the water pollution problems that result from nonpoint source pollution. The failure to extend pollution controls to nonpoint sources increases the costs of water quality protection by precluding efficient allocation of control between point and nonpoint sources (Milliman 1982; Davies and Mazurek 1997; Freeman 2000).

Water pollution can be difficult and complicated to manage efficiently; mainly because water is public goods serving many beneficial uses; and also due to the nature of water which is affected by many factors; e.g. sources, types of pollutants, waste collections and treatment systems. With beneficial uses for different classes of waters and localized nature of water pollution, it is difficult to determine the optimum level of cleaning water that is economically achievable for each water body. In the past, a lot of attention on water pollution control was placed only on how to clean the water without considering costs (Davies and Mazurek 1998). Based on economic theory, the way we clean our water is not really efficient and cost-effective (Vig and Kraft 2000; Tietenberg 2004; Rosenbaum 2005). Currently, increased experience in market-based policy particularly in controlling air pollution indicates that it has a good potential for improving water quality cost-effectively and can help face new challenges in water quality management (Stephenson et al. 1999; Rousseau 2001; Tietenberg 2003b).

Recently, there has been an increase in applying market-based mechanism in controlling water pollution, particularly for a tradable permit system. A number of water trading programs have been installed in the US; however, the water quality markets are not functioning well nor do they have active trades. Successful implementations of other pollution trading programs particularly that of SO_2, cannot help us wondering what the difficulties of the implementation of water pollution trading are. The use of trading as a regulatory instrument to control air pollution is increasing. The air tradable permit program – the SO_2 program – stimulated more aggressive pollution prevention behavior that resulted in lower compliance costs than the credit trading program (Ellerman et al. 2000). Will this practice occur with regards to water pollution control?

This chapter is divided into two parts. Part A describes how water quality and water pollution are defined, and on which principles and parameters are used in the measurements of water quality. Additionally, a history and evolution of the existing water pollution control system and regulation in the US is presented to help understand why current water quality management is ineffective. This basic principle will lead us to have an idea of the problems existing in the current pollution control system, to know where to increase efficiency of water quality control and what would need to be done. At the end of this chapter, definition and experience of water quality trading systems are explained in comparison to the air trading system, and why the air trading program is far more advanced than the water trading program is also presented.

1.1 Definition of Water Quality and Water Pollution

1.1.1 Water Quality

Water Quality reflects the composition of water as affected by natural causes and man's cultural activities, expressed in term of measurable quantities and related intended water use (Novotny and Olem 1994). For scientific and legal purposes the following definition of water quality is most often used: "*Water quality is the ability of a water body to support all appropriate beneficial uses*" (Novotny and Olem 1994).

Within a water body, there could be more than one designated use (USEPA). For instance, water suitable for drinking can be used for irrigation, but water used for irrigation would not meet drinking water guidelines. The quality of water appropriate for recreational purposes differs from that used for industrial processes. The quality of water needed for drinking, recreation, fishing, and aquatic habitat is higher than that required for transportation or agriculture.

Water quality is a relative term which makes water quality goals and means to achieve the end results are sometimes very difficult to be efficiently implemented. The definition of water quality is not objective, but is instead socially defined depending on the desired use of water. The Clean Water Act defines water quality in terms of designated beneficial uses with numeric and narrative criteria that support each use; i.e. drinking water supply, primary contact recreations, and aquatic life support (USEPA 1994a, b). Different uses require different standards of water quality (Revenga et al. 2000). For example, water used for hydropower generation, industrial purposes, and transportation does not require such high standards of purity for recreation, drinking, and habitat for aquatic organism (Novotny and Olem 1994). The regulators need to take into considerations of costs and benefits when setting up a standard according to various beneficial uses.

1.1.2 Water Pollution

Water pollution can be defined into several definitions. One is as a change in the physical, chemical, radiological, or biological quality of the water caused by man or due to man's activities that is injurious to existing, intended, or potential uses of the water (Novotny and Olem 1994). Another is as damage to the services provided by the water caused by the disposal of residuals from production or consumption activities causing the emissions of materials into the water that can reduce its service (Milliman 1982). Some human activities and land uses that can contribute to degraded water quality include: deforestation/development/construction, urbanization/industrialization, agricultural operations (largely via runoff from non-point sources), municipal or industrial wastewater discharges, artificial channelization or habitat alteration.

1.1.3 Water Pollution System

Many factors control the health of the water. Once pollutants are discharged into receiving water (e.g. surface water, ground water), degree of damages to water quality depend on assimilative capacity of the water, sources of pollutants (point sources *versus* nonpoint sources), types of pollutant (flow pollutant *versus* stock pollutant), and the amount of pollutants accumulated in the waterbody. Each factor is discussed as follows:

1.1.3.1 *Pollution Sources*

There are two main sources of water pollution: *point sources* and *nonpoint sources*. *Point sources* (PS) discharge from a defined route, such as a pipe from sewage treatment plants, municipal storm water collection systems, and industrial facilities such as power plants. Municipal and industrial wastewater discharges are the primary contributors to point sources in the US. *Nonpoint sources* (NPS), on the contrary, have diffuse discharges that enter a river or lake as runoff from a wide geographic area; e.g., runoff from agricultural fields, roads and parking lots. Pollution from nonpoint sources includes fertilizer and pesticide/herbicide runoff from agricultural fields and golf courses, siltation from agriculture and logging, acidic drainage from mine tailings, the deposition of pollutants from the atmosphere, and bacteria from livestock and faulty septic systems. Nonpoint source is the leading cause of water quality impairment. Nonpoint sources problems are becoming more important particularly BOD and nutrients because nonpoint sources are not fully responsible for cleaning pollution. Overall, more than one-third of the stream miles in the US appear to be affected by nonpoint pollution (USEPA 2000). Table 1.1 ranks the top five pollutant sources causing water quality impairments from National Water Quality Inventory 2000. The most frequently reported source of pollution that is impairing water quality in rivers, streams, lakes and ponds was agriculture (60% of impaired river miles, 30% of lake acres).

Nonpoint pollution is especially troublesome for several reasons. Its origin is elusive. The nonpoint pollution typically enters water bodies over a large area and the loads are not constant through time but vary with natural events such as temperature, precipitation and wind. Pollution from nonpoint sources is harder to control and measure accurately than discharges from point sources. Additionally, there are many categories of NPS which require different control strategies.

Controlling nonpoint pollution is technically and economically challenging because technological solutions are rarely available. In addition, many state governments, fearful of damaging a major component of the state economy, are reluctant to do more than encourage farmers to voluntarily seek ways to limit their pollution runoff (Rosenbaum 2005). Major national efforts are clearly required to address this non-point pollution. It is expected by USEPA that the greatest future gain in water pollution control will come from NPS.

1.1.3.2 *Pollutants*

Pollutants differ in how easily they can be assimilated in terms of the absorptive capacity of the environment. A pollutant that is assimilated slowly is called a *stock*

Table 1.1 **Leading sources of pollutants causing water quality impairment.**

Pollutant Source	Rivers and Streams	Lake, Ponds, and Reservoirs	Estuaries and Bays	Ocean Shoreline	Great Lakes Shoreline
Agriculture	1	1	5		3
Atmospheric deposition		5	4		4
Contaminated sediment					1
Forestry	5				
Habitat modifications	3				5
Hydrologic modifications	2	2			
Industrial discharges			3		
Land disposal				3	
Municipal point sources			1	5	
Nonpoint sources		4		2	
Septic tanks				4	
Urban runoff/storm sewers	4	3	2	1	2

Source: Water quality condition in the US: a profile from the 2000 National Water Quality Inventory

pollutant. Examples of stock pollutants include heavy metals, persistent synthetic chemicals and nondegradable materials. Pollutants that are assimilated quickly are called *flow pollutants*. Examples of flow pollutants are organic wastes, which will be attacked and broken down by bacteria in water into less harmful inorganic components, thermal pollution (dumping hot water into water bodies lowers dissolved oxygen), and bacteria and virus (from domestic and animal wastes, meat packing wastes).

Moreover, types of substances causing water pollution fall broadly into six categories, (1) Microbiological, (2) Chemical, (3) Oxygen-depleting substances, (4) Nutrients, (5) Suspended matters and (6) Thermal pollution. As specified under the Clean Water Act, *conventional pollutants* include suspended solids, fecal coli form bacteria, biochemical oxygen demand, pH, and oil and grease. Table 1.2 ranks the top five pollutants for impairing water quality in rivers, lakes, estuaries, ocean and great lakes shorelines. Overall, EPA found that the three pollutants most often associated with impaired water were solids (i.e., suspended solids, siltation, and total dissolved solids), pathogens, and nutrients.

Table 1.2 Pollutants most often associated with impairment.

Pollutant	Rivers and Streams	Lake, Ponds, and Reservoirs	Estuaries and Bays	Ocean Shoreline	Great Lakes Shoreline
Habitat alterations	3				
Metals		2	1		
Nutrients	5	1			2
Oil and grease				5	
Oxygen-depleting substances	4	5	3	2	5
Pathogens (bacteria)	1		4	1	3
Pesticides			2		
Priority toxic organic chemicals			5		1
Siltation (sedimentation)	2	3			4
Suspended solids				4	
Total dissolved solids		4			
Turbidity				3	

Source: Water quality condition in the US: a profile from the 2000 National Water Quality Inventory

1.1.4 Water Quality Indicators

Since there is no single, universal parameter that adequately describes surface water quality, investigators typically use several indicators related to sanitary quality, ability to sustain aquatic life, ecosystem productivity and aesthetics. Monitoring the physical, chemical and biological markers of a particular water source provides a means to determine the overall quality of the source water without directly monitoring the infinite number of potential toxicants that may be present. The following properties are included: dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, alkalinity, total and fecal coliform levels, chlorophyll-a (chla), light transparency, turbidity, nutrients (nitrogen and phosphorus), and temperature. The significance of these properties are briefly explained by AUEPA (2005) as follows, more technical information found in Metcalf and Eddy (1991).

Dissolved oxygen (DO) supports life functions of most aquatic organisms. DO is considered a key indicator of overall water quality. *Biochemical oxygen demand* (BOD) is used as a measure of organic wasteload strength. The *pH* of a water sample is a measure of its acidity. *Alkalinity* is a measure of the acid-neutralizing (that is, buffering) capacity of a water. *Total and fecal coliforms* measure sanitary quality in terms of bacterial counts within a given sample volume. High fecal coliform levels indicate the presence of feces in a waterway and, perhaps, the presence of other more dangerous pathogens. Major *nutrients* in the subject waterways include various species of *nitrogen and phosphorus*. *Ammonia*, an inorganic form of nitrogen, is an oxygen consumer and an indicator of water health. Organic nitrogen hydrolyses to ammonia. Un-ionised ammonia is toxic to various aquatic species and is regulated. The sum of ammonia plus organic nitrogen is another indicator, Total Kjeldahl Nitrogen (TKN). *Phosphorus* is the key nutrient regulating algal growth. Another important indicator of water quality is the amount of solids in the water column – both dissolved (filterable) solids and not dissolved (suspended) solids. *Turbidity and water temperature* are physical properties of natural waters that often affect water quality. *Turbidity* is a condition of reduced water clarity resulting from the presence of suspended solids in the water column, including silts, clays, industrial wastes, sewage, plankton and other suspended organic matter. *Water temperature* is a measure of the heat content. Since the solubility of DO decreases with increasing water temperature, high water temperatures limit the availability of DO for aquatic life. *Ecological indicators* are sometimes used to assess overall water quality and health. Such indicators focus on abundance and diversity of aquatic organisms such as algae, aquatic plants, benthic macroinvertebrates and fish.

1.2 Water Quality Regulation and Policy Reviews

This section reviews prior attempts/experiences for resolving water pollution problems. This review, in effect, helped in understanding the lack of progress and problems that existed within the current regulatory and political process before a focus turned more towards market-based policy.

1.2.1 Brief History and Evolution of Water Pollution Policy in the US

In the US, very little attention was paid to water quality until such notorious events such as the Ohio's Cuyahoga River catching on fire in 1969. The Cuyahoga fire, in fact, helped spark the rise of environmental movements (more information "The Cuyahoga River Fire: June 22, 1969" at *http://www.cwru.edu/artsci/engl/marling/60s/pages/richoux/index.html*). Responding to these concerns, Congress passed a major revision to the federal water pollution control policy in 1972 (FWPCA-72), later called the Clean Water Act (CWA) (Freeman 2000). The CWA established a national goal for water pollution policy: the attainment of fishable and swimmable waters by July 1, 1983, and the elimination of all discharges of pollutants into navigable water by 1985. In the last decades, federal law and policy have been strengthened several times to achieve these goals. Freeman summarized the key features of federal laws dealing with water pollution-control policy, as explained in Table 1.3 (Freeman 2000).

The main sections of the CWA (described below) established programs for reducing pollution from both point sources and nonpoint sources (Davies and Mazurek 1998; Shortle and Abler 2001).

Section 402 of the CWA established the National Pollutant Discharge Elimination Program (NPDES) permit to control pollution from point sources dischargers. Each point sources discharger must obtain a discharge permit before it can discharge into surface water. The permit requires point source dischargers to comply with technology-based controls (uniform USEPA-established standards of treatment that apply to certain industries and municipal sewage treatment facilities) or water quality-based controls that invoke state numeric and narrative water quality standards (Moreau 1995). More information about the standards are reviewed in *http://www.epa.gov/waterscience/standards/handbook/* and *http://cfpub.epa.gov/npdes*. Currently, over 500,000 discharge sources are subject to NPDES permits (USEPA 1998b). Besides the NPDES programs, the National Pretreatment Program is designed to reduce the amount of pollutants discharged into municipal sewer systems by industry and other non-domestic wastewater sources. The program prevents pollutants from being introduced into the Publicly Owned Treatment Works (POTWs) that may interfere with plant operations and may pass through untreated while improving opportunities for the POTWs to reuse wastewater and sludges that are generated.

Section 303(d) requires states to identify those waters which cannot meet the water quality standards to develop total maximum daily loads (TMDLs). A determination of TMDL is an analysis of all sources of pollutants to a water body to calculate the maximum pollutant load a water body can receive without violating water quality standards. Regulators establish wasteload allocation (WLA) for point sources and load allocations (LA) for nonpoint sources and natural sources and margin of safety to ensure achievement of water quality goals (USEPA 1997).

Section 309 of the CWA established the nonpoint sources control programs for addressing polluted runoff from land surfaces. It consists of a national program that is implemented by the states with federal approval and assistance. All states currently have USEPA-approved management programs. The states are free to choose the policy instruments contained in the management plans. Most states are relying on voluntary approaches that emphasize education, technical assistance and economic incentives (Shortle and Abler 2001).

***Table 1.3* Federal water pollution control laws.**

Title and year of enactment	**Key provisions**
The Refuse Act, 1899	*Goals*: Protection of navigation *Means*: Barred discharge or deposit of refuse matter in navigable waters without permit *Federal vs. state responsibility*: Federal permits and enforcement *Financing of municipal sewage treatment*: None
Water Pollution Control Act, 1948	*Goals*: Encouragement of water pollution control *Means*: Authority for federal research and investigation *Federal vs. state responsibility*: Left to state and local government *Financing of municipal sewage treatment*: Authorized federal loans for construction, but no funds were appropriated
Water Pollution Control Act Amendments, 1956	*Goals*: Authorized states to establish water quality criteria *Means*: Federally sponsored enforcement conferences to negotiate clean up plans *Federal vs. state responsibility*: Federal discretionary responsibility to initiate enforcement conferences for interstate waters *Financing of municipal sewage treatment*: Authorized federal grants to cover up to 55% of construction costs
Water Quality Act, 1965	*Goals*: Attainment of ambient water quality standards required to be established by states *Means*: State-established implementation plans placing limits on discharges from individual sources *Federal vs. state responsibility*: State responsibility for setting standards, developing implementation plans, and enforcement; federal oversight through approval and strengthened enforcement conference procedures *Financing of municipal sewage treatment*: No significant change
Federal Water Pollution Control Act, 1972	*Goals*: fishable and swimmable waters *Means*: Enforcement of technology-based effluent standards on individual dischargers *Federal vs. state responsibility*: Federal responsibility for establishing effluent limits for categories of sources, and for issuing and enforcing terms of permits to individual discharges; state option to take over responsibility for permit and enforcement *Financing of municipal sewage treatment*: Federal share increased to 75% and total authorization substantially increased ($18 billion over 3 years)

Table 1.3 **(Continued)**

Title and year of enactment	**Key provisions**
Clean Water Act, 1977	*Goals*: Postponed some deadlines established in the 1972 act; increased control of toxic pollutants *Means*: No significant changes *Federal vs. state responsibility*: No significant changes *Financing of municipal sewage treatment*: No significant changes (authorizations for an additional $25.5 billion in federal grants over 6 years)
Municipal Wastewater Treatment Construction Grant Amendments, 1981	*Financing of municipal sewage treatment*: Reduced federal share to 55%, changed allocation priorities, and lowered authorizations to $2.4 billion per year for 4 years
Water Quality Act, 1987	*Goals*: Further postponement of deadlines for technology-based effluent standards *Financing of municipal sewage treatment*: Transition from federal grants to contributions to state revolving load funds

Sources: Freeman III 2000 (table 6.1). Public Policies for Environmental Protection © 2000 RFF Press.

Section 208 calls for the development and implementation of area-wide waste treatment management plans. Section 208 makes explicit reference to nonpoint sources and also authorizes federal grants to share in the cost of developing area-wide management plans, administered through the Soil Conservation Service of the Department of Agriculture, that would cover up to 50% of the cost to rural land owners for implementing and maintaining "*best management practices*" to control nonpoint-source pollution (Freeman 2000).

The Coastal Zone Act Reauthorization Amendments (CZARA) is a second federal statute that directly addresses non-point sources pollution. It establishes a coastal nonpoint source pollution control. The programs are administered by the National Oceanic and Atmospheric Administration (NOAA). Under CZARA, state coastal nonpoint source programs must provide for the implementation of best management practices specified by USEPA with national technical guidance (Shortle and Abler 2001).

Shortle and Abler (2001) explained that the Clean Water Act and CZARA focus primarily on surface water. *Section 102* of the CWA encourages groundwater protection. The CWA provides a framework for states to develop their own

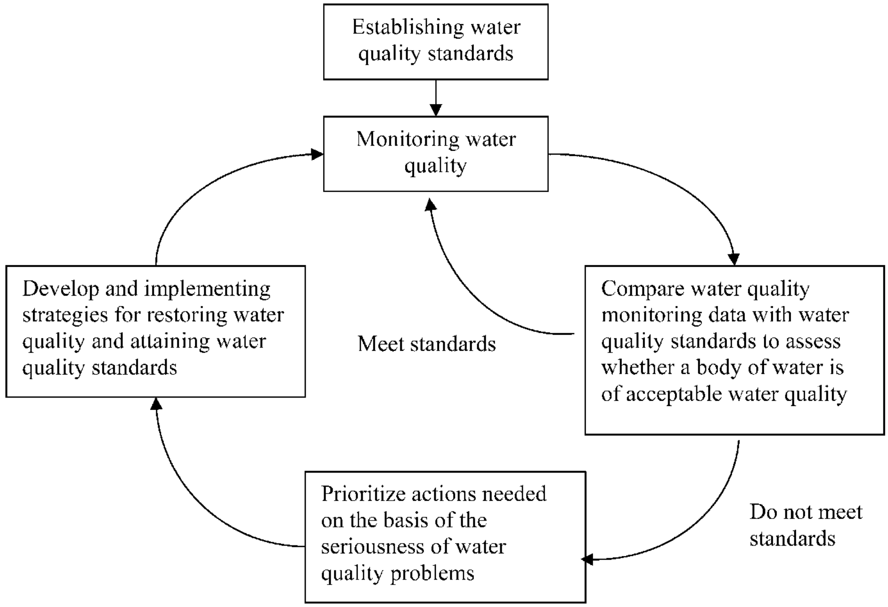


Figure 1.1 **Process of managing water quality. Source: USGAO 2000.**

programs for reducing, eliminating and preventing groundwater contamination, rather than specifying or requiring specific actions to be taken (Shortle and Abler 2001).

As shown in Figure 1.1, monitoring water quality is a key activity for implementing the CWA. The CWA requires states to set standards for the levels of quality that are needed for bodies of water so that they support their intended uses. States report to the EPA on the condition of their waters every two years. States also identify waters for which existing pollution controls are not stringent enough to enable them to meet applicable standards, and then place these waters on their TMDL lists with suggested implementation strategies. Forty-five states reported lack of resources being a key limitation for fully assessing their waters for making more progress on improving water quality (USGAO 2000a, b).

Table 1.4 **Waters that support designated uses on the 2000 National Water Quality Inventory.**

	River and streams (miles)	**Lakes, ponds, and reservoirs (million acres)**	**Estuaries (square miles)**
Fully supporting	55% (463,441)	46% (7.9)	47% (13,439)
Threatened	10% (85,544)	9% (1.6)	9% (2,766)
Good but impaired	35% (291,263)	45% (7.9)	44% (12,482)
Percentage of total water assessed	23% (840,402/3,662,255)	42% (17.4/41.6)	32% (28,687/90,465)

Source: USEPA Nation Water Quality Inventory Report 2000 (in percent of area or length assessed).

1.2.2 Progress and Challenges for the Trading Approach

Over the past decades, the approach in the CWA has been greater control of water pollution from PS under the NPDES programs than from NPS under voluntary approach. The success of the programs is measured by the large number of improvements in the US. The proportions that fully support the designated uses are in the range of 47–55% (see Table 1.4). Waters that are safe for fishing and swimming have doubled. The number of US populations served by sewage treatment facilities has doubled (USEPA 1998). BOD loading to POTWs (influent loading) and BOD removal efficiency increased significantly (Stoddard et al. 2002).

The traditional focus on point sources, however, is becoming less effective in eliminating major threats to water quality that are increasingly being attributed to nonpoint sources (Freeman 1994; Davies and Mazurek 1997). The current institutional structure for protecting water quality in the US is weighed heavily towards dealing with pollution from point sources, particularly at the federal level. The key mechanisms for attainting water quality objectives under the CWA are the establishment and enforcement of technology-based effluent standards. These standards are quantitative limits imposed on all dischargers where quantities are determined based on what can be done with available technology, rather than on what needs to be done to achieve ambient water quality standards or to balance costs and benefits (Freeman 2000). On the contrary, responsibility for nonpoint source pollution control has been given to the states, largely addressed through voluntary incentives that support best management practices and land-use changes through education, technical assistance, financing and research provided by USEPA and USDA and state programs (Shortle and Abler 2001).

A consequence of the different approaches taken for point and nonpoint source pollution is that gains in water quality have come at a higher cost than if both sources had been treated more evenly (Freeman 2000). Additional evidence of inefficiencies in the CWA comes from comparisons of marginal pollutant removal costs between point sources and nonpoint sources. Nationally, allowing point sources at 470 sites to reduce treatment costs by enabling them to purchase nutrient reductions from nonpoint sources in a point-nonpoint trading program would save dischargers between $611 million and $5.6 billion (USEPA 1994a, b). Evidently, a water quality goal at these sites can be achieved at a lower cost by reducing nonpoint source dischargers rather than point source dischargers.

In the future, water pollution management will require serious attention for improving the treatment efficiency because of resource/budget problems. The underlying trends that generate these needs include: (1) increase in nonpoint source pollution problem, (2) increasingly stringent federal requirements to improve water quality and drinking water safety, (3) increasing unit costs of attaining these requirements using more complex technology due to the concern of toxic pollutants, (4) increasing use of chemicals and energy, and (5) increasing the cost of replacing aging and failing water distribution systems and wastewater collection systems (WIN 2000).

Therefore, decentralization of water pollution control policy (i.e. water trading policy) will significantly help with increasing efficiency in controlling point sources and nonpoint sources. Trading can potentially increase efficiency in water pollution management; i.e. trading can help limit upstream discharges as a mean of deferring renewals or avoiding expanded treatment capacity. The coordinated implementation programs in watershed management will provide the greatest opportunities for cost-effective control of all sources affecting water quality; e.g. promoting trading pollution credits between point sources and nonpoint sources.

1.3 Introduction to Water Quality Trading

1.3.1 Description

Water quality trading or effluent trading is an innovative approach for achieving water quality goals more efficiently. Trading is based on the fact that sources in a watershed can face very different costs to control the same pollutant. Trading programs allow facilities facing higher pollution control costs to meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall expense.

A tradable permit system starts by selecting water quality objectives and establishing the total amount of permitted pollution equaling the maximum allowable load cap that will assure the water quality objective is met. At the initial start, all identifiable dischargers will receive the permits to discharge a certain amount of pollution based on some rules set by the government agency. From then on, dischargers can voluntarily reallocate their pollution control responsibility in the market by buying and selling their permits which would reduce the amount of a problem pollutant elsewhere in the watershed. For example, if polluter A can achieve an equivalent amount of reduction at a lower cost than polluter B, polluter B can pay polluter A to reduce its discharge. By buying such permits from polluter A, polluter B can then increase its discharges without installing additional abatement technologies. However, polluter A would need to control its discharges to a lower level than would otherwise be required, to be at least the equivalent of the amount purchased by polluter B. Polluter A also generates income by selling permits to polluter B. Trading allows both polluters to achieve an overall level of reduction at a less expensive cost. The government agency, however, would have to monitor emissions to ensure that they were conforming to the discharge permits.

Experience to date with water quality trading indicates a number of economic, environmental and social benefits. Economic benefits can include: allowing dischargers to take advantage of different marginal costs of treatment and efficiencies that vary from source to source; reducing the overall costs of achieving water quality objectives in a watershed; and providing the means to manage growth while protecting the environment. Environmental benefits can include: achieving water quality objectives more quickly; encouraging further adoption of pollution prevention and innovative technologies; engaging more nonpoint sources in solving water quality problems; and providing collateral benefits such as improved habitat and ecosystem protection. From a social standpoint, trading efforts have helped promote productive communication among watershed stakeholders and have helped to create incentives for water quality improvement activity from a full range of dischargers (Hoag and Hughes-Popp 1997; Jarvie and Solomon 1998; Kraemer et al. 2003).

1.3.2 Incomplete Experience of Effluent Trading in the US

Pollution trading in the US started in 1974 with air quality. A key program of emission trading is the Acid Rain Program which achieved exceptional success compared with other applications. The Acid Rain Program employs a system of tradable SO_2 emission allowances to reduce the abatement costs while still meeting environmental goals. Experience with an allowance system has been proven to be the superior economic and environmental performance of the market-based instruments (Ellerman et al. 2000; Ellerman 2003). Schmalensee et al. evaluated the program comprehensively and the most current ex post evaluation of the program by Ellerman provided several lessons to be learned from the Acid Rain Program. In addition, Stavin discussed the experience from the program in the broader views (Schmalensee et al. 2000; Stavins 2000; Ellerman 2004).

After the success of the Acid Rain Program, the US policy makers have now shown renewed interest on water quality trading as a potential policy expecting the same success as found in air trading policy. In 1996, the USEPA released a draft of a framework to encourage and facilitate development of watershed-based effluent trading programs. Based on pilot projects and research, in 2003, the USEPA released its final Water Quality Trading Policy identifying general provisions necessary for creating credible watershed-based trading programs. The policy provides regulatory and technical guidance to states and other local governments for developing and implementing trading programs.

To date, a number of water trading programs have been installed in the US. However, the water quality markets are not functioning well or have been largely stagnated. For example, the earliest application of water pollution trading was the Fox River program in Wisconsin in 1981 (O'Neil et al. 1983). It was not until 1995 that a successful trade was complete (Jarvie and Solomon 1998). The most common forms of water quality trading to date includes point source-point source, and point source-nonpoint source trades. Nonpoint sources (e.g. agriculture) generally have much lower marginal abatement costs for common pollutants such as nutrients and sediments. Therefore, trading between point sources and nonpoint sources should yield the highest cost-savings. However, there are several market challenges in point sources-nonpoint sources trading and other types of trading. More details about barriers of the trading are discussed in the following chapters.

1.3.3 Comparison between Air and Water Trading

Regarding the different performances between air and water trading, the main factors causing these differences are important to investigate. Since water and air are similar in nature of media and are controlled with a similar regulatory structure, why then is water quality trading not as successful as air quality trading? Shabman et al. (2002) explicitly compared trading experiences in the air and the water by elaborating on the distinctions between allowance markets, credit trading and command-and-control. They pointed out program design and institutional setting as having significant effects on the behavior and performance of the trading programs. Adler (1999) argued that the legal differences in the CAA and the CWA explain much of the differential levels of success for emission trading programs in the air and the water.

Adler explained that mainly, the CWA does not establish a strong connection on achievement of ambient water quality goals and lacks of explicit regulatory requirements as compared to the CAA, but rather focuses on the use of technology-based performance standards. Approaches used to control pollution from NPS for water and mobile sources for air are different. Nonpoint source credit offsets are a unique approach to control water pollution. Whereas, mobile sources emitting air pollution face a number of regulatory requirements (e.g. catalytic converters and fuel quality) under the CAA. Air emission trading program, as opposed to nonpoint source credit offsets, do not allow trades between mobile and stationary source or between regulated and unregulated sources.

The relative ineffectiveness of water pollution trading programs can be traced to physical and institutional of the water pollution problems. Table 1.5 presents the comparisons between the nature of water pollution and air pollution which can result in different trading performances between water trading program and the Acid Rain Program. Water pollutants are nonuniformly dispersed over a wide area, unlike many air pollutants. Characteristics of water pollutants are non-uniformly dispersed; flow downhill within a single watershed and concentration changes over time. Unlike many air pollutants often drift over into a rather large region. Water pollution problems are confined to a watershed, therefore, the number of potential participants in an effluent trading is quite restricted. Consequently, polluters have limited ability to find suitable trades and the markets are typically smaller in size (Woodward 2003). The transaction costs due to search information and negotiation processes are high in water trading programs. This is because the water trading program often involves nonpoint source pollution. There are three main problems when a trading program includes NPS; monitoring and enforcement costs are quite high; predictions of load are likely be expensive or imprecise; and legal conflicts may arise between the estimated pollution reduction achieved through the trading program and the actual reductions required by the CWA (Ribaudo et al. 1999).

Table 1.5 **Observations and comparison between nature of air and water pollution.**

Factors	**Air**	**Water**
Regulation	The CAA: Mandatory to reduce SO_2	The CWA: 1. mandatory to reduce pollution from point source, voluntary from nonpoint source; 2. Technology-based standard is an obstacle in achieving WQ goals cost-effectively
Source of pollution	Homogeneous, identifiable sources (SO_2: Power Plants), majority of polluters for SO_2 emission are responsible for the treatment	Heterogeneous, many different types of industries discharge, many different pollutants (single or multiple) only identifiable sources are controlled
Nonpoint sources	(1) Small amount of SO_2 emission from NPS source; (2) NPS (i.e. cars) can move to different areas depending on transportation	(1) Relatively large amount of water pollution from NPS; (2) amount of pollution is difficult to be identified and quantified.
Transport of pollutants	– Airshed is larger than watershed; – Air pollutants are dispersed multi-directionally by wind; – No one move air from system.	– Watershed size is relatively smaller – Water pollutants always flow into the lowest level (downstream) uni-directionally – Water can be withdrawn from river by human to use in different purpose
Easy to be monitored	Reliable equipments installed, reliable monitoring	Only point source can be monitored accurately. Nonpoint sources pollution use indirect monitoring method e.g. based on predicted load
Alternative: Available Advance Technology	Change the material to use low sulfur coal, scrubber	Prevent pollution in the first place, redesign production process, use less water (pollution prevention)
Mass balance in airshed or watershed (SO_2 vs. nutrient), transformation	Less complex mass balance: SO_2 is a stock pollutant, slowly assimilated	Complex mass balance, e.g. Nitrogen (4 major species, org N, ammonia, nitrite, nitrate,) and highly assimilated by bacteria and nutrients are uptake by aquatic organism

According to current experiences with water trading, some of the water quality trading programs are well-functioning; e.g., the Tar-Pamlico Program and the Long Island Sound Trading Program. Emission trading for other air pollutants may not always be as successful as SO_2 trading which has an exceptional success rate for example; NOx and VOC emission. The SO_2 trading program successfully reduces aggregate SO_2 emission because most of SO_2 emission came from large stationary sources. NO_x emission trading programs among stationary sources are successful as trading programs. However, they are probably less successful in dealing with the environmental problem because NO_x emissions from mobile and small sources constitute a large proportion of total emission and these latter sources are not as effectively controlled. The difference is extent to which the trading program covers all sources contribution to the environmental problem. The NPS problem in water quality is similar in many respects to that of mobile and small sources for air quality problems, such as ozone, for which difficult-to-control sources are significant contributors.

Therefore, what gives rise to a different level of success in air trading and water trading are dependent on the nature of the pollution (completely mixed, disperse and heterogeneity), sources of pollution (mobile *versus* from the stack, density of identifiable *versus* unidentifiable sources), the majority of sources contributing to the environmental problem, and program design (credit trading *versus* cap-and-trade). It may be that the issues of the fluid nature of air and water are not really the key to the different performances found between air and water trading programs. The existing arrangement of a political and institutional system and permit program implementation and design features may be considerably more relevant to the success of the program.

Chapter 2
CONCEPT, FRAMEWORK AND CONSIDERATIONS FOR WATER QUALITY TRADING

Introduction

Today, tradable permit systems are increasing in importance and acceptance by the regulators, and the regulated, to manage various environmental problems (Vig and Kraft 2000; Harrington et al. 2004; OECD 2004). After Coase proposed the basic foundation underlying tradable permits on external costs (Coase 1960), and the later development of the concept and use of marketable permit system elaborated by Crocker on controlling air pollution and Dales on regulating water use (Crocker 1966; Dales 1968), the theoretical reasons why trading of pollution rights should be superior to the direct regulation became well known (Stavins 2000; Ellerman 2003; Tietenberg 2004). Hahn et al and Tietenberg made a review and evaluation of several attempts to introduce market-based instruments into environmental regulation and were optimistic about the applications (Tietenberg 1985, 1990; Hahn and Hester 1989; Hahn 1989). In applying transferable permits to water problems, the earlier experiment conducted in the Fox River was studied by O'Neil et al. (1983). Water pollution trading may be referred to as effluent trading or water quality trading (WQT). Within the past decade, interest in investigating the application of tradable permits in water quality trading has increased.

The basic concepts, the fundamental elements, and the mechanics of how trading operates are presented in three sections of this chapter, which will lay the essential foundation for establishing a WQT program. The first section explains concepts about tradable permit system for water quality trading including definition and classification, permit lifetime, allocation strategy and tradable permit schemes. The second section describes significant elements (legal, economic and technical) required for establishing the water quality trading program. The third section discusses issues affecting the program's performance which a program designer needs to take into consideration when developing a program.

2.1 Concept about Tradable Permit Systems

2.1.1 Definition and Classification

The most general use of a tradable permit defined by Ellerman (2005) is as "a transferable right to a common pool resource". The definition of a tradable permit for the environmental application is "a transferable right to emit a substance that can create pollution" to a common pool resource; i.e. air and water (Ellerman 2005). The author pointed out that the tradable permit for pollution trading is different from the conventional permit implemented in command-and-control regulation in that it is transferable and may not define specific conditions to operate, set standards, or prescribe specific technologies to limit discharges.

Contents of permits and conditions of user rights for resource usage may have a significant effect on trading program performance. Tietenberg argued that the permit should at least provide some security to the permit holders, while still making it clear that it is not a property right (Tietenberg 2000). The crucial features for tradable permit systems are: (1) Entitlement – legally protected entitlement of discharge to a specified limit, (2) Transferability – right to convey all or part of the entitlement to others, and (3) Enforceability – right to protect the entitlement and ensure compliance of the terms of transfer (Tietenberg 2003a, b). Tietenberg (2003a, b, chapter 4) provided concise discussion of the importance of well-defined property right to a tradable permit system. The entitlement, transferability and enforceability must be established through governmental actions.

2.1.2 Type of Tradable Permit

Kraemer et al. (2003) categorized tradable permit systems related to water into three major types based on fields of application. (1) *Tradable water abstraction rights* are used to manage the water resource mainly within the agricultural sector. Concerns mainly relate to inadequacy of steam flow. Trading water abstraction rights can be exchanged in volumetric terms. (2) *Tradable permits to water-based resources* are applied in fisheries or in the potential energy of water. (3) *Tradable discharge permits* or tradable water pollution rights are used for the protection of surface water quality.

Table 2.1 **Pollutant characteristics and permit denomination.**

Permit type	**Spatial characteristics**	**Temporal characteristics**	**Permit denomination**	**Example**
Flow	Uniformly mixed	Assimilative	Rate	Volatile organic compounds (air, water)
Flow	Nonuniformly mixed	Assimilative	Concentration	SO_2 (air) Nutrients (water)
Stock	Uniformly mixed	Accumulative	Quantity	CO_2 (air)
Stock	Nonuniformly mixed	Accumulative	Deposition	Heavy metals (air, water)

Source: Sorrell and Skea (1999) (adapted from table 1.1, chapter 1). Pollution for Sale © 1999 Edward Elgar Pulbishing Ltd.

The focus of this book is on *tradable discharge permits*. Tradable discharge permits can be further divided into two general categories by Sorrell and Skea (1999); *flow permits* and *stock permits*. A flow permit refers either to a rate measure where the time dimension is explicit (e.g. lbs/hour), or to a concentration measure where the time dimension is incorporated into the averaging period (e.g. hourly average ppm). In contrast, stock permits refer simply to total quantities, such as tons of emissions.

Flow permits and stock permits accommodate the spatial and temporal dimensions. In the spatial dimension, uniformly mixed and nonuniformly mixed pollutants can be distinguished by whether pollutant concentration is independent of the location of the sources (Tietenberg 1985). Source location is matters for nonuniformly mixed pollutant. In the temporal dimension, the pollutants can be separated into pollutants that accumulate in the environment and those that are assimilated (Tietenberg 1985). Combining these spatial and temporal considerations leads to a general classification of permit denomination, summarized in Table 2.1 (Sorrell and Skea 1999). A major point is that a trading scheme becomes much more viable if the pollutant can be treated as uniformly mixed. In this situation, the trading scheme can be based on emission permits for individual sources that can trade with each other regardless of their location. In contrast, for nonuniformly mixed pollutants, the freedom to trade is constrained. In this instance, the theoretical solution is to denominate permits in terms of pollutant concentrations at particular location (Sorrell and Skea 1999).

2.1.3 Permit Lifetime

Permit lifetime may either be finite, where the right of use expires at the end of a specified period, or indefinite, where no termination date is defined. Either type may be made contingent upon review and renewal by the regulators (Rousseau 2001). Permits with a short duration, would allow the regulator more flexibility in adapting the program to new information concerning abatement technologies or water quality. Long-term permits, however, would allow dischargers to plan capital investments with less uncertainty and might allow improved cost efficiency in water management (Rousseau 2001). Rousseau suggested that regulators might build a margin of safety into the baseline load since permit banking can lead to some variation in pollution over time.

2.1.4 Allocation Strategy

There are a number of allocation strategies for tradable permits. To choose the proper method, regulators need to consider several issues; i.e., allocation frequency, reference period, preserving the cap, or incorporating new sources (USEPA 2003a, c, d). Permit allocation may either be *once-off* at the initiation of a scheme or *periodic* at regular intervals over the duration of the scheme. Updating allocations periodically can influence future compliance activities of the discharger due to an incentive to obtain more allowance. Periodic distribution is most appropriate for stock permits and allows declining pollution to be more easily targeted. For example, a source could be allocated a single permit to emit *N* tons/year of pollution, which would then be valid for a specified period of time. Alternatively, it could be allocated *N* stock permits each year, with each permit worth 1 ton of pollution.

It is important to emphasize that instead of allocating credits or permits, Beder (2001) proposed the "share" concept to deal with the problem of revising baseline levels or allowances over time. Each discharger will receive their shares of allowed discharge in proportion to total pollution per time period. Their shares can be bought and sold. The share would be owned forever, but the volumes/amount of pollution allowed could vary (Beder 2001). The share concept has a great applicability to be adjustable to the future loads and allowable permits.

The commonly used methods for distributing tradable discharge permits are auction or grandfathering. Under the auction approach, the source purchases the permit from their governments at the market-clearing price. Regulators need to decide on how to distribute the auction revenues and permits. Under the grandfathering approach, the permit is distributed to each source based on some allocation rule (typically historical use). Firms that polluted more in the past would have larger shares. Under grandfathering, existing sources only have to purchase any additional permits they may need over and above the initial allocation (as opposed to purchasing all permits in an auction market) (Tietenberg 2000). Primarily, pollution permits are distributed through a grandfathering method.

Although the auction method has advantages over grandfathering, in that it can generate revenues and give a price signal to the market which can facilitate trading, firms would have to pay additional costs for permits at the auction. Stavins (1995) argued that the grandfathering rules allocation tend to predominate. Grandfathering may increase the likelihood of adopting the trading policy (particularly from the existing sources) and would be the easiest strategy for the regulator to implement. Only a transferable permit system that allocates permits free of charge to sources on the basis of their historic emission rate would guarantee that existing sources would be no worse off than they would under a command-and-control system imposing the same degree of control (Tietenberg 1995). However, the free distribution system imposes a bias against new sources, in the sense that their financial burden is greater than that of an existing source, even if the two sources install the same control devices. This new source bias has hindered the introduction of new facilities and new technologies that embody the latest innovations (Tietenberg 2003a, b).

2.1.5 Tradable Permit Schemes

Ellerman (2005) classified the tradable permit systems into three forms: (1) credit trading, (2) averaging and (3) allowance trading, clearly explained the classification with examples. Table 2.2 compares features of each form of tradable permits with the conventional permit (which will be discussed in the following sections). The degree to which a trading program shifts management responsibility of pollution control from the regulator to the discharger primarily distinguishes the systems (Shabman et al. 2002). Shabman et al. pointed out that a trading program where regulators have authority and responsibility for approving where and when a trade can occur will be called *credit trading*. The authors argue that a credit trading system (regulator-directed trades) is not a typical market but rather a market-like system. An *allowance market* is a true market system where dischargers make their own decision on how they will meet pollution control obligations including trading arrangement.

2.1.5.1 *Credit Trading System*

In a *credit trading system*, the regulators have to set an emission baseline as a benchmark for measuring trading performance. Usually, the baseline is determined

Table 2.2 **Type of tradable permit schemes.**

Permit Scheme	**Distinctive Feature**	**Limitation/Example**
Conventional Permit	The regulatory authority identifies the pollution control technologies that are available and affordable for each pollutant source. The technology then is used to establish a maximum allowable rate of pollutant discharges. Permits cannot be transferred.	– Regulators ensure that ambient environmental goals are not violated by manipulating and revising technology-based permit limits rather than identifying a mass load cap. – *Example: the NPDES permit for controlling water pollution from point source dischargers.*
Credit Trading	Certification of credits (more than required to meet the conditions of its permit) can be transferred. Regulator-approved-trades ensure that a facility will not receive credit for what it would have done anyway.	– High transaction cost associated with certification may outweigh the cost saving. – *Example: The US federal offset programs control water pollution from nonpoint source in PS-NPS trading.*
Averaging	Automatic credit trading, firms that do better than required in their permits automatically receive credits even if the firm would have reduced emission anyway.	– Total amount of pollution has not been capped and may escalate due to economic growth. – Regulatory burden is to set up standards as a baseline and need to be revised regularly. – *Example: The mobile source emissions program in the US.*
Allowance Trading (Cap-and-trade)	Optimal quantity of pollution is specified by regulators instead of emission standards.	– Intensive resources and funding is required at the beginning of the program to set up an acceptable quantity of emission, allocate allowances and consider limits to spatial and temporal trading. – *Example: The Acid Rain Program.*

Source: Adapted from Ellerman (2005).

by references to traditional technology-based standards (Tietenberg 2000). Credits are generated when polluters reduce discharge below the baseline set by regulators. The reduction credits have to be certified by the regulatory agency, before or after the fact (Ellerman 2005).

In an *averaging system*, firms that do better than required in their permits automatically receive credits without being certified by the regulatory agency (Ellerman 2005). Ellerman described that averaging is automatic credit trading. Credit and automatic credit trading programs place severe restrictions on the exchange process. Dischargers face limited ability to decide how pollution will be controlled while dischargers may have better information to initiate credit creation for their firms. For these reasons, Shabman et al. (2002) argued that credit trading is an extension of conventional command-and-control regulation that keeps firm-level abatement decisions in the hand of the regulators. Dewees notes that credit trading systems are not typically designed to create low cost systems of decentralized exchange, but rather depend on a case-by-case amendment to the permit issued in the traditional regulatory process (Dewees 2001).

2.1.5.2 *Allowance Trading System*

An *allowance system* is also known as a *cap-and-trade*. The system contains a mandatory cap on discharges and individual allowances to participating sources. Firms are required to surrender a permit for every unit of discharge in allowance trading without any mandate to meet a specific standard (Ellerman 2005). The cap is established by the regulator to limit effluent load from all sources to achieve certain environmental objectives. Ellerman (2005) pointed out that "the cap is frequently set at a level that would be achieved if some best technology were to be required by all … or at a level that is presumed to be a step in the direction of reducing emissions to some ultimate goal." In the US, caps can be set for individual watersheds through the TMDL process.

A prespecified number of allowances are allocated to the dischargers. Dischargers are granted authority to make their own pollution control decisions, and there must be a program to readily and reliably monitor discharges. The initial allocations are not necessarily based on traditional technology-based standards. Typically the number of issued allowances declines over time. Therefore, the aggregate reductions implied by the cap-and-trade allocations can exceed those achievable by standards based on currently known technologies (Tietenberg 2000).

2.1.5.3 *Allowance versus Credit: Open versus Closed System*

Allowance versus Credit

It is necessary to differentiate between pollution *allowance* and pollution reduction *credit* since these terms are important to pollution trading programs structure and performance. The essential feature of a credit is that it is given either for over-compliance with some pre-existing regulatory requirement or for reductions below business-as-usual discharges from uncontrolled sources (such as NPS in water). In both cases, credit is given for reductions which would not have occurred but for the possibility of transferring the reduction obligation form the buyer to the seller of the credit. The key point is that a reduction is created at a specific source for use in meeting some regulatory obligation at another source. *In contrast, there is no "creation" of source-specific reductions in an allowance system.* Permits are distributed in some manner to sources as tradable rights to discharge a certain quantity and those rights can be exchanged among the recipients of these allowances. The allocation of the permits may correspond to an assumed application of some control standard, but there is no requirement on specific sources to meet that standard. Therefore, over-compliance loses much of the meaning it has in a credit system. One might refer to the seller of allowances as one that has over-complied with the standard implicit in the initial allocation of permits, but the standard is theoretical only and has no practical force upon the specific source, as is the case in a conventional regulatory system (Ellerman 2006).

Allowances set a cap on aggregate emissions that cannot be eroded by economic growth. This characteristic is not shared by either technology-based, source-specific emission standards, or by an emission credit system that is linked to technology-based standards. Credit trading did not prevent pollution growth resulting from economic growth since new firms were given the same baselines as existing firms. There is no control over the aggregate emission from all sources; therefore, total pollution will escalate unless some additional constraints are built into the system. For example, a constraint requires new or expanding sources made up for all emission increases by acquiring sufficient credits from existing polluters (known as "offset") (Sorrell and Skea 1999; Tietenberg 2000).

The two approaches have the different implications for the extent and timing of regulatory involvement (Ellerman 2005). Credit trading depends upon the existence of a previously determined set of regulatory standards, but allowance-based trading does not. Allowance schemes may require a great deal of investment at the inception of the scheme, but relatively little oversight during operation. In contrast, credit schemes require less initial design work, but the regulator must be involved in certifying individual trades. Allowance schemes represent a purer form of emission trading, but credit schemes may be easier to implement (Ellerman 2005). For this reason, credit trading is more preferable to an allowance system by the regulator in water pollution trading.

Open versus Closed System

The relation between credit and allowance systems and open and closed systems is approximately at best. It is true that allowance systems have an explicit absolute limit on emissions form some predefined set of sources, whereas the regulatory system in which credit may be earned typically do not. Thus, one might think of the allowance system as closed and the credit system as open, but this is confusing different attributes. For example, the trading of credits in a conventional regulatory system implies some level of total emissions within the relevant time period that is unchanged if the additionality requirement is met by the source earning the credit. One might think of this counterfactual level of total emissions as an assumed or implicit cap. Alternatively, an allowance system may be open in that either credit earned outside the system may be used or uncontrolled sources "opt-in" to the system. In both of these cases, the initially specified cap is increased by the credits injected into the system or by the allowances issued to opt-in sources. But, note in both of these cases the scope of the program, that is, the number of sources has also increased. One could say as well that the absolute cap remains closed but has been adjusted to reflect the inclusion of more sources (Ellerman 2006).

The terms, open and closed, which are used occasionally in the literature, refer mainly to the ability to generate credits. "Open market" systems allow the generation and use of credits for compliance with implicitly "closed" conventional, prescriptive systems that would not allow such flexibility. This is nothing more than the introduction of cost-reducing credit trading into an otherwise prescriptive system. Unfortunately, several experiments in these so-called "open-market" systems were badly compromised by being too lax on the requirement to demonstrate additionality. As noted above, allowance systems may be "open" in allowing opt-ins or credits as the case may be. One might think of them as "closed" if such mechanisms were not included. As alternative, frequently encountered expression is an "off-system" credit. In the case of water quality management, open systems hold the greatest interest in facilitating the inclusion of off-system, nonpoint sources, whether the underlying controls are conventional prescriptive regulation or a decentralized allowance cap-and-trade mechanism for point sources (Ellerman 2006).

2.2 Framework for Establishing WQT Systems

There are several elements, agents, and entities contributing to the development and implementation of effluent trading. Benkovic and Kruger provide a delightful discussion about the specific prerequisites for a pollution trading program (Benkovic and Kruger 2001). The reading by OECD (2001) provides detailed information on the overall design and implementation of a tradable permit in environmental management. The study of the OECD discussed extensively the principal issues that arise when designing a tradable permit system. The USEPA (2003a, b, c, d) provides the framework for watershed-based trading as generic guidelines for establishing a trading program. The WQT framework has been reviewed several times in 1996, 1999 and 2000. Detailed information about the final water quality trading policy (2003) from USEPA Office of Water is available at *http://www.epa.gov/owow/ watershed/trading/finalpolicy2003.html*. More step-by-step details conducting an analysis with examples for determining the viability of watershed scale trading is referred to in the WQT handbook by USEPA 2004. Outstanding issues that should be considered for the introduction of tradable permits for water pollution and relevant theory are discussed in detail by Kraemer et al. (2003).

The following sections explain specific elements of a water trading program, which are required but not necessarily limited to, to be credible and successful as suggested in several of the trading frameworks (USEPA Draft Framework, Chesapeake Bay Program Fundamental Principles and Guideline, National Wildlife Foundation 1999, Idaho Trading Guidance, Michigan Rules, Colorado Pollutant Trading Policy, Tar-Pamlico Trading Program, Connecticut DEP (Long Island Sound), and an Effluent Trading Policy Review for Texas). Each of the elements described below are adopted from guidelines in these frameworks and becomes potential problems in water trading programs unless they are appropriately designed. Elements in designing a WQT Program may be roughly divided into three groups: legal elements, economic elements and technical elements.

2.2.1 Legal Elements

Element 1: *Trading must be consistent with the statutory requirements and water quality standards outlined in the CWA and other federal laws*

Element 2: *A trading program must have clearly defined goals and objectives*. Goals outline the vision and rationale for the program, and the objective serves as the qualitative and quantitative measures by which to evaluate the program and judge the merits of individual trades within it.

Element 3: *Trading and transactions may be developed within any authorizing framework*. The TMDL process appears to be the preferred method of the USEPA for addressing nonattainment watersheds and it may offer the greatest opportunities for effluent trading.

Element 4: *A program must establish trade approval and administration to oversee the trading program at local, watershed, and state levels*. Establishment of a central coordinating office is an important step to determine costs and set prices, baselines, trading ratio, trade facilitation. Accountability and assessment of progress is a critical component that needs to be established.

Element 5: *Enforcement and eligibility mechanisms must exist to ensure trading performance*, including monitoring and periodic program evaluation. The five types of provisions must be considered within the design of trading enforcement mechanisms: (1) anti-backsliding, (2) anti-degradation, (3) agency and trading partner monitoring, (4) trading partner liability for noncompliance, and (5) citizen enforcement provision.

Element 6: *The regulatory agency must actively encourage effluent trading through information and education programs*. Agency-sponsored or encouraged-demonstration programs and training seminars on how to develop and structure trades will be crucial aspects for developing a viable program.

Element 7: *Public participation should be encouraged at all stages in the evaluation and implementation of the program*. Stakeholders' dissatisfaction may delay or impede the implementation and execution of trading programs.

2.2.2 Economic Elements

Element 1: *The benefits from trading programs will be realized only when there is a significant difference in unit costs of abatement between sources*; otherwise if all sources in a watershed face approximately the same cost of load reduction, there will be little incentive to trade and a program will likely fail.

Element 2: *Trading procedure should be taken to reduce transaction costs*. Trading will be encouraged to the extent that an agency can reduce transaction costs through actions such as providing more information to traders, acting as a broker, or paying for monitoring and enforcement activities.

Element 3: *Trading should apply to point sources and nonpoint sources*. The full benefits of effluent trading will be realized when trades are made between point and nonpoint sources. The distribution of baseline abatement responsibilities should be fair to all market participants.

2.2.3 Technical Elements

Element 1: *Trading should be restricted to pollutants that are biologically degradable and assimilable* such as nitrogen, phosphorus, and organic carbon. However, pollutants that are accumulative within the ecosystem (metals, some organics) are potential toxicants and not appropriate to trade.

Element 2: *Trading boundaries should coincide with watershed or watershed segment*, so that the impact and improvement to water quality through the trades are measurable. Reducing a pollutant loading rate in one watershed by increasing it in another is not consistent with the concept of integrated watershed management.

Element 3: *Adequate technical- and economic-related information is needed to define a clear rule* including defining units of trade, creation and duration of credit, determining eligibility; participant eligibility, and trade eligibility (type of pollutants, water quality standards, regulatory limitation, eligibility of funds, eligibility of reduction credit, and pollution reduction mechanisms).

Element 4: *Credits available for sale must represent a real improvement in water quality* or must at the very least offset the pollution load for which it is substituting. Establishing baseline loads for all sources is critical.

2.3 Considerations in Establishing Tradable Permit Schemes

The three requirements for an effective trading system are defining pollution, allocating pollution rights and measuring emissions (Ellerman 2005). A government agency plays a significant role in setting a discharge limit and assigning responsibility for effluent control to create demand for a water quality market (Stephenson and Shabman 1996). Mainly, the establishment of an effluent trading program requires a structure of reduction in goals, trading mechanisms, understanding marginal treatment costs of different technologies, clearly defined rules of compliance measurement, monitoring performance and penalties. This section outlines and presents some of the major technical, economic, legal and regulatory issues that need to be taken into account for developing an effluent trading program.

2.3.1 Legal and Institutional Consideration

2.3.1.1 *Responsibility of Government Agency*

The process of designing and introducing a tradable permit system requires regulatory and institutional reform of an existing functioning water pollution control system already in place to facilitate the introduction of a tradable permit system (OECD 2001). There are some key elements in regulatory and institutional reforms, as suggested by OECD (2001), including:

- A shift from regulations focused on technology choice to the formulation of physical constraints, such as ambient water quality standards that are more in line with environmental objectives and offer greater flexibility in the choice of means to achieve compliance.
- A shift from environmental standards expressed in terms of unit and concentration value to those expressed as absolute/mass values (ceiling or quotas by period).
- Assignment of responsibility for verifying policy implementation to independent administrative authorities whose long-term mission is to ensure compliance with regulations and to develop transfer activity and fair transactions.

Market development requires a shift in regulator responsibilities (Stephenson et al. 1999). Stephenson explained that in an allowance market, the regulator serves the role of a market designer who creates the condition for decentralized decision making and an officer who monitors and enforces the rules concerning the disposal of wastes into the water. This regulatory allocation requirement encounters a number of difficult and serious questions. For example: How much of the acceptable load (and conversely, the need for pollution reductions) should be allocated among various sources of pollution, and according to what principles? How much allocation should be made for a margin of safety, and how much for future growth? Water quality trading programs need cooperation between federal, state and local efforts.

An appropriate definition and assignment of a property right has to incorporate all polluters into the permit system in order to establish a functioning trading system. Particularly, when regulators want to manage pollution from nonpoint sources using a permit system, Young and Karkoski suggest that regulators may need to re-define nonpoint source as a large collection of small, independent, and controllable sources rather than a diffuse, uncontrollable, and unmonitored source, or define it based on capacity of operations/types of firms or size of activity to be able to assign their responsibilities (Young and Karkoski 2000).

Multi-party watershed permits is another potential challenge in addressing nonpoint sources, as parties are potentially subjected to the permit by including synchronization of permit issuance across a watershed of multiple parties, which allows coordinated monitoring, assessment and characterization, prioritization, planning and implementation. This type of permit will lower transaction costs and integrate a large number of sources with different marginal control cost to create potential trading situations within a watershed.

Many trading programs face institutional obstacles particularly with regulator-approved trade (King and Kuch 2003). Moreover, the CWA undermines the incentives and opportunities to trade credits because of limited choices of control options (Stephenson and Shabman 2001). Boyd et al. (2003) pointed out that trading between regulated point sources is inhibited by regulatory provisions that reduce the incentive to trade; e.g., trades cannot be used to comply with technology-based standards. The authors argued that in the credit trading, sources must "over-comply" to have credits to sell but doing so presents regulatory risks. First, the Clean Water Act (CWA) has anti-backsliding provisions to ensure that water quality will be sustained. Over-complying sources that return at a later date to more normal levels of compliance may run afoul of this provision. Second, over-compliance signals to the regulator that greater levels of control can be attained cost-effectively. This can lead to a future increase in stringency of the standards. In either case, the CWA provisions undermine the incentive to over-comply, and thereby also undermine the trades (Boyd et al. 2003).

2.3.1.2 *Enforcement and Monitoring*

Key to success of the tradable permit program requires adequate monitoring, reporting, and strong enforcement to ensure that the pollution abatement goals are achieved. There are two distinct problems in monitoring and enforcement which are (1) equivalency and (2) measurement. The equivalency is applicable to all trading and the measurement problem is unique to NPSs. For example, a simpler case regarding to the equivalency is a PS/PS trading. In this case, the assumption about the conventional, no-tradable permit system is very important. If one can assume that the conventional regulatory system is designed for the environmental problem in such a way that different control levels are imposed on sources in relation to their relative contributions to the underlying environmental problem, then it is hard to imagine how a trading system can achieve the same environmental results at lower cost. It could do so only if the differing valuations of the damages and the resulting differing controls were replicated in comparable transfer ratios for trades between those sources. Otherwise, a 1:1 trading ratio will always involve a trade-off of environmental effectiveness and cost-savings. For instance, if the conventional system imposes a uniform control requirement on all sources regardless of their relative contributions to the environmental problem, then it is easier to see how trading can reduce costs without also reducing environmental effectiveness. In fact, it may be possible to improve environmental effectiveness if it is easier to introduce an appropriate trading ratio than it is to impose different controls on different sources (Ellerman 2006).

Measurement NPS pollution is a major problem in trading. Nature of nonpoint sources pollution makes credits measurement hardly to be done with accuracy at reasonable costs. There are several concerns in enforcing and monitoring trades involved in nonpoint sources, including (1) baseline of pollutant discharges, (2) pollution reduction attributable to Best Management Practices (BMPs), (3) verification of BMPs installation and maintenance and (4) monitoring frequency and credit assessment. The ability of an administrative agency is needed to quantify and then verify over time how the amounts of nonpoint sources are affecting the program's effectiveness. Additionally, it is critical to know which party (the agency or the sources) must prove that a source is incompliance or out of compliance, and who will track the monitoring for a trade involving NPSs. For example might be the requirement to inspect equipment or practice to be sure that they are in force.

The choice of monitoring strategy is based on the pollutant to be tracked, the cost of conducting the monitoring, and the level of accuracy acceptable to agencies and stakeholders. Monitoring baseline and controlled nonpoint sources is particularly difficult due to the site-specific weather-related nature of discharges. Direct and indirect monitoring strategies have been developed to determine baselines and to verify the pollutant quantities over time. The indirect methods of modeling which rely on information from disparate sources and estimate of overall nonpoint source discharge loads to the receiving water, dominate the observed program monitoring method.

Measurement and enforcement are presumed not to be problems between trading among point sources. Because discharges from point sources can be measured and the regulation or permit surrender requirements effectively enforced. However, PS/NPS trading would involve all the equivalency and measurement problems. For example, many agricultural pollutants arrive via dispersed and unobservable transport mechanisms, whether through runoff, groundwater leaching, or the atmosphere. Therefore, it is difficult to predict with certainty the amount of discharge reduction (or production of credits) the implementation of BMPs will produce at the point in the watershed where credits are measured. The problem is then to establish eligible BMPs that can be observed (and therefore enforced) and which can be reasonable assumed to result in real reductions of the relevant discharges. Generally, credits that are granted to nonpoint sources are based on verifiable BMPs and predicted reduction of changes in management, rather than being based on actual measured load. Therefore, establishment of a trading ratio between PS/NPS is usually estimated with a discount in its effectiveness due to potential uncertainty in the data and other management factors.

Responsibility and liability are the primary enforcement concerns with trading programs. The programs should clearly state which conditions make a trade fail. If a trade fails, who is responsible for remediation and who is liable. Enforcement process could be in the form of permit-based enforcement by the CWA or by contract (either by a bilateral or multilateral party). Traditionally, enforcement is usually unidirectional: from the regulator to the regulated. Whereas, contract enforcement flows are multidirectional involving the buyer and the seller with the legal support of the courts. Liability must be assigned to either the buyer or the seller.

Buyer liability refers to tradable permits for which the validity or usability of the permit is uncertain and the buyer bears the risk that the permit might not be acceptable. These system simply differing prices corresponding to the risk associated with different permits. Seller liability refers to rules in which the seller guarantees the validity of the permit sold and where the buyer has legal recourse against the seller if the permit is not accepted by the regulatory authority. Nearly all workable systems establish seller liability. A system of buyer liability creates incentives for monitoring and assuring that the necessary pollution reductions are achieved. Buyers must take precaution before buying credits, particularly form NPS. When buyer liability prevails, buyer would pay less for permits with uncertain monitoring and therefore not be any more motivated to assure the reduction than with a seller liability rule. Equivalently, sellers are paid more for permit with better monitoring and better chances of acceptance (Ellerman 2006).

The ability of a measurement system to produce information to support trading depends upon how well the system is designed. The information cycle, describing the continuous process from specifying information needs, strategy to collect data, and data analysis, provides a quantitative means of connecting monitoring system design and operations for water management (Timmerman 2000). Implementation of a tradable permit program needs two kinds of data monitoring. Periodic data on the environmental condition and data to monitor compliance are needed for evaluating the effectiveness of the program. Monitoring compliance with the program requires data on the identity of permit holders, amount of permits owned by each owner, and permit transfers (Woodward and Kaiser 2002). It will be very helpful to input all data into a centralized computer system that is accessible by eligible users on a real-time basis, so that users can search for the potential trading partners within the program.

2.3.1.3 *Penalties for Noncompliance*

To guarantee a successful implementation, regulators need to enforce a set of sanctions for noncompliance. Stringent penalties for noncompliance are required for a well- functioning trading program. The penalties should be sufficiently high and determined based on the nature and severity of the violation. The appropriate penalties will be an incentive for compliance (USEPA 2003a, b, c, d).

The form of penalties could be notice of violation, civil action, excess emission offsets, financial penalties or criminal penalties (jail sentences and revocation of discharge permit). Often predetermined administrative fines can be imposed by the enforcing agency itself for minor or routine noncompliance. More serious noncompliance could then trigger civil penalties. Criminal penalties should be reserved for falsification of official reports as being the most serious violation (Tietenberg 2000).

2.3.2 Economic Consideration

This section will discuss several economic factors affecting the success and efficiency of effluent trading; including driver for trading, size of the market, type of trading, type of market, transaction costs, administrative costs, trading ratio and other concerns.

2.3.2.1 *Driver for Trading*

The leading drivers for WQT market are TMDLs. TMDL allocates pollution wasteloads to all polluters within the watershed. The difference between marginal costs of treatments between PS and NPS are the major incentives for trading. For a pre-TMDL trading (a watershed where a TMDL is not yet established), “nonpoint source baselines are the levels of pollutant loads associated with existing land uses and management practice and point source baselines are defined by their NPDES permit or other effluent limitations" (USEPA 1998a, b, c, d). For watersheds with a TMDL in place, trading should be consistent with the assumptions and requirements upon which the TMDL is established. Powers (2002) examined the issues of pollution trading as a possible mechanism for implementing TMDLs. TMDLs, which are legally required, can be critical for establishing a foundation upon which a trading program can be built (Powers 2002).

Many existing water pollution trading programs do not appear to be particularly effective, and often times do not operate within the context of a TMDL. Some concerns frequently cited by current program administrators are that the TMDL process is lengthy and expensive. The important observation is that the ability to develop an effective TMDL is subject to the availability of funds, and influenced by the interests of the groups involved in its creation (Stephenson and Shabman 2001). It is crucial for regulators to address these conditions.

2.3.2.2 *Size of Trading Market*

To have a functioning market for tradable discharge permits, enough market participants should exist. Therefore, the number and size of pollutant sources participating in a trading program affects the success of trading. King and Kuch (2003) pointed out that the necessary condition for a trading program to be successful is to attract the willingness to buy and sell from the dischargers. The determinants of demand and supply of nutrient trading and potential effects to WQT markets in the US studied by King and Kuch, including waste treatment requirements, waste discharge restrictions, enforcement policies, level of fine and charges, TMDLs allocations, marginal costs of reducing discharges, liability for credit buyers and sellers, etc.

To have viable trades, the trading systems need to involve many traders (credit generators and credit buyers). There should be many pollutant sources affecting the same parameters (e.g. nitrogen, phosphorus, BOD) within the same watershed. The sources must have different abatement cost curves so that benefits from trades are possible. Demand for trading will be driven by the degree to which dischargers perceive there will be potential cost-saving from purchasing credits rather than from installing control (King and Kuch 2003).

It is critical to have a large number of buyers and sellers for a competitive long-run and equilibrium price that will minimize abatement costs and yet distribute emission among sources at various locations to meet certain water quality standards. If too few sources are involved in the trading, the trading can be difficult and there may not be enough of a difference in the marginal cost of reduction to make trading worthwhile. The limited number of participants may result in fewer trades and there will be less information available regarding prices paid for abatement credits. In contrast, with a larger number of participants, high transaction costs and uncertainty are related to diversity of sources and activities (Jarvie and Solomon 1998).

2.3.2.3 *Type of Trading*

In the WQT programs, the regulator must choose the type of trading allowed. Characteristics of pollution sources (i.e. point sources/nonpoint sources) are used to design types of trading allowed and eligibility of participants in the programs (USEPA 2003a, b, c). USEPA grouped trading into 5 types (USEPA 1996).

1. *PS/PS* – a point source trades with other point sources on the same water body that can reduce more pollution than required at lower abatement costs instead of upgrading its own treatment.
2. *Intra-plant* – a point source allocates pollutant discharges among its outlets to a river in a cost-effective manner. Combined permitted discharge in trading has to comply with the requirements to meet applicable water quality standards.
3. *Pretreatment* – a POTW arranges for indirect dischargers that send waste to the POTW to reduce the amount of pollution beyond required reduction from its facility before discharging to achieve water quality goal more cost-effectively.
4. *PS/NPS* – a point source arranges for nonpoint source discharges control instead of upgrading its own treatment.
5. *NPS/NPS* – instead of installing or upgrading its own control, nonpoint sources arrange for more cost-effective control of other nonpoint sources.

2.3.2.4 *Type of Markets*

USEPA (2004) recommended the water quality trading market have essential functions including

- Defining and executing the trading process (i.e. negotiating a transaction, accounting for water quality equivalence, completing appropriate paper work, reviewing and approving trades, monitoring and verifying reductions, reporting to regulatory agencies, auditing reported information, and taking enforcement actions).

- Communication between buyers and sellers, and providing information to the public and other stakeholders (encouraging electronic publication of information of boundary of watershed and trading areas, discharge sources involved, quantity of credit generated and used, market price).
- Assuring compliance with the CWA and relevant state and local requirements (predominantly relying on NPDES and TMDL).

Woodward and Kaiser (2002) categorized the principle types of water quality trading (WQT) markets into four main types and these categories are not mutually exclusive:

1. *Bilateral Negotiation*. Credit buyers and sellers directly negotiate the agreement of each trade. Currently, bilateral negotiations are the most common structure of WQT markets. Despite relatively high transaction costs associated with searching for the information, negotiation and enforcement, the advantage of this system is that it accommodates trading of nonuniform goods.
2. *Third Party Broker*. The third-party brokers facilitate trades for buyers and sellers who are unfamiliar with the trading programs. The brokers can reduce transactions costs in finding trading partners. However, the brokerage fee may increase the transaction costs. The government agency can act as a broker to bring together buyers and sellers and play an active role in providing information to market participants.
3. *Clearinghouse*. The clearinghouse generates uniform credits from water quality projects with variable prices and quality. Without direct negotiation between buyers and sellers, the clearinghouse sets the prices for the credits which then help reduce the search and information costs.
4. *Exchange*. A requirement of this system is the uniformity of the credits generated by the sellers which allows for an open information structure, a market-clearing price for transaction between buyers and sellers.

2.3.2.5 *Transaction Costs*

Transaction cost is one of the most important issues to be considered in effluent trading programs. Montero (1997) notes that the presence of transaction costs and uncertainty can lead to cost inefficiencies in the markets depending on initial allocation of the permits, or on the baseline level established (Montero 1997). Stavins (1995) categorized transaction costs in pollution trading based on three potential sources: (1) search information about the needs, and potentially available credits; of buyers and sellers, (2) bargaining and decision making including time, fee for brokerage, legal service, and (3) monitoring and enforcement associated with the completion of the trade. Stavins (1995) argued that search and information costs should be improved somewhat in markets with relatively large numbers of potential trading sources. A large number of trading participants can then mean more frequent transactions, more generated information, and thereby reducing uncertainty (Stavins 1995).

A primary source of transaction costs is governmental oversight and management of trading. Hahn and Hester (1989) identified three means by which government intervention can contribute to an increase in transaction costs: (1) a high degree of regulator oversight of individual trades, (2) a large number of levels of bureaucracy at which a trade must be reviewed, and (3) expenditure required to obtain adequate information necessary to establish property rights for trading.

Rules for a statewide effluent trading program in Michigan are proposed to reduce transaction costs by the establishment and maintenance of a Water Quality Trading Registry. The information in the registry, including the name and location of the sources, the pollutant-specific quantity of credits, a brief description of sources and methods to generate discharges or loading reductions, is made available to the public through an electronic bulletin board which would be updated daily. Such a bulletin board would reduce the transaction costs involved in search and information.

Effective enforcement requires accurate and consistent measurement of pollution. Establishment of proper levels of fines can encourage compliance and prevent pollution damage. Administrative costs can be lower, if the regulator sets up a system in such a way that burden of proof is shifted to the firm or dischargers. For example, a nonpoint source discharger needs a verification of BMPs installation in order to receive a certification for credit generation. Another example is the continuous emission monitoring (CEM) systems used in the Acid Rain Program. The systems have allowed the government to easily monitor and enforce emission restriction in accordance with the permits. Any units that exceed emissions allowed by its permit pay a $2,000 per ton penalty (Stavins 2000).

2.3.2.6 *Trading Ratios*

A trading ratio is the number of units of pollution reduction a source must purchase to receive credit for one unit load reduction (USEPA 1996). King and Kuch (2003) mention that trading ratios are used not only to achieve environmental goals via trade, but also to equalize the inherent risks (expected increase or decrease in discharges). Hoag and Hughes-Popp (1997) pointed out that a trading ratio can have a negative impact on the success of a tradable discharge permit program. Higher trading ratios increase the cost of achieving regulatory compliance through trading. Higher trading ratios reduce the economic values of a credit and make it more cost-effective for point sources to treat their discharges on-site rather than by buying credits (Hoag and Hughes-Popp 1997).

The location of the polluters should take into consideration while setting up a trading-ratio. Hung and Shaw (2005) explored a trading-ratio system (TRS) of tradable discharge permits for water pollution control by incorporating location effect into the tradable discharge permit for nonuniformly mixed pollutants in water. In their study, the researchers proposed that the TRS is a model trading system for water pollution control which meets the predetermined standards of environmental quality at minimum abatement costs. Main characteristics in the trading-ratio system in their study are (1) the zonal effluent cap is set by taking into account the water pollutant loads transferred from the upstream zones; (2) the trading ratios are set equal to the exogenous transfer coefficients among zones; and (3) permits are freely tradable among dischargers according to the trading ratios. The specific characteristic of water pollutants which always flow to the lowest level unidirectionally allows the authority to set an effluent cap for different zones in order to make the trading ratios equal to exogenous transfer coefficient among zones. Polluters who want to increase their effluents will need to buy the zonal tradable discharge permit of the same zone, or upstream zones, to offset their increase. It is not necessary to buy tradable discharge permits from all zones that are affected by their effluents (Hung and Shaw 2005).

Setting up the exact trading ratios is quite difficult because of uncertainty; e.g., run-off from nonpoint sources varies with the weather, which then complicates the establishment of trading ratios that would equate point and nonpoint sources (USEPA 1996). Horan (2001) considers an economically optimal point/nonpoint trading ratio that is adjusted to encourage more nonpoint controls. In actual trading programs, ratios are adjusted in response to nonpoint uncertainties (Horan 2001). In theory, permit numbers and trading ratio must be chosen simultaneously to achieve economic efficiency. However, in practice, program managers only have control over trading ratio – not the number of permits (Horan and Shortle 2005). Other additional factors of the optimal choice of trading ratio include the impact of agri-environmental and other farm payments (Horan et al. 2004).

2.3.2.7 *Banking and Borrowing*

Emission banking and borrowing allows firms to move emissions between time periods as well as between sources. The term "banking" means saving emissions in one period for use in later periods and "borrowing" means using more emissions than current standards allow in one period and by paying back those emissions in the future (Rousseau 2001).

There are some concerns as to whether the trading program should allow banking and borrowing despite significant economic potential gain and incentives to generate reduction credits. First, there is the possibility of temporal clustering of emissions, and second, there is a concern that borrowing is very hard to enforce over time. Imposing sanctions for noncompliance can be difficult. Another concern is that the reduction goals may be overachieved in one period while underachieved in another (Tietenberg 2000). Moreover, dischargers have a certain risk of not being able to use their banked credits in the future when the cap needs to be tightened. Therefore, in order to encourage generating reduction credit in advance, regulators will need to, right from the beginning, set clear trading rules as to what will eventually happen with the banked credits (Kraemer and Banholzer 1999).

2.3.2.8 *Other Potential Economic Related Problems*

Market Power and Competition

Concerns about market power happen when either the permits or the products of effluent trading participants are concentrated in the hands of relatively few participants. Malueg (1990) found that if firms participate in noncompetitive product markets, then permit trading might reduce social welfare (Malueg 1990). Tietenberg (1985) argued that overall environmental quality may not be affected by market power since, by design, permit markets hold the aggregate level of pollution constant. Even though the market power may not affect aggregate pollution, the concern is that localized concentration of pollutants may rise. Regulatory agencies must consider the market power and competition problem which could lead to market distortion and failure, and then take necessary action to correct it.

Moral Hazard

In the case of water quality trading, particularly with credit trading, pollution sources may increase or inflate their current pollution levels in order to sell the reduction credits in the future. For example, land owners could change their practices to increase their pollution loads for the purpose of obtaining credits that can be sold later. Baseline measures must be set in a way that eliminates this problem (Fossett et al. 1999).

Free Riding

Free riders may enjoy the benefits from the step of control taken by others but decide not to take any action (Tietenberg 2003a). For example, within the same watershed, where one source upstream installs the control and benefit transfer to the downstream users who may not need to control pollution from their properties in order to meet the discharge limit.

2.3.3 Environmental Consideration

2.3.3.1 *Water Pollution Problems: Relevant Factors*

The effect of pollution on ambient quality is a function of location and geography, timing of discharge, the location of other dischargers, and the stochastic elements due to weather and other factors. There are three fundamental entities that form the problem: a pollution source, a physical system, and a traded pollutant.

First, *source characteristics* play a role in determining whether tradable permits should include point sources and nonpoint sources in the program. There must be enough sources (scope and diversity of sources) to warrant trading (USEPA 2004). The sources of pollution need to be identifiable, therefore the credit will be verifiable and trading rules can be enforced. It is important that the permit authorization be expressed quantitatively to reflect the activity. When pollution or damage is the inevitable consequence of a given activity, or pollution is illusive, the trading program may not be effective in controlling pollution, nor have smaller advantages gained from using the tradable permit system.

Second, a physical system, the *characteristics of the watershed* may impose specific constraints linkage between temporal and spatial flexibility. For example, certain areas/segments in the watershed contain ecosystems of special ecological values; therefore it is difficult and less obvious to allow permits of certain activity that will affect the vulnerable ecosystem due to the complexity of measurement and lack of the acceptable equivalencies (USEPA 2004). According to the characteristics of a watershed (i.e. composed of a number of rivers and sub-basins), an appropriate boundary for setting zones to determine a cap is difficult to establish. Insufficient knowledge of the behavior and changes in the pollution load of the water system within a local zone and across zones can lead to technical obstacles for trading.

Third, *pollutant characteristics* are important variables in the tradable permit system in the design of responsibility for effluent control and setting discharge limits for trading schemes. The WQT assessment handbook explains the approach for analyzing the stability of trading a particular pollutant in a particular watershed to be able to serve as a valid commodity. There are four key factors related to inherent pollutant characteristics, watershed conditions, and the compliance regime (USEPA 2004):

1. *Type/Form*: a pollutant should be identified in a common form; e.g. trading soluble phosphorus for nonsoluble forms might not be allowed. If different types of pollutants are traded (e.g. total phosphorus and oxygen demand), the translation ratio must be applied to have an equivalent effect on water quality.

2. *Impact*: the water impact of trading has to be equivalent or better than the pollutant reduction without trading at the location where a pollutant reduction is made and where the reduction is purchased.

3. *Timing*: Pollution reduction targets should align among trading partners. Purchased reduction should be produced during the same time period that a buyer is required to produce them.

4. *Quantity*: The amount of demand for credit and supply for excess reductions should be aligned.

2.3.3.2 *Technical Considerations*

For an effective implementation, it is important that regulators have enough technical information to be able to designate a number of permits for pollution activities and ambient water quality. Modeling transport of pollution in the water is complicated but important for (1) defining the caps and permits which adequately address water quality, and (2) monitoring trading performance. Water quality modeling would be required to simulate various locational patterns of discharges and the outcomes of different zonal boundaries and temporal patterns. In addition, the zonal definitions in terms of maintaining ambient quality standards may have to be qualified in terms of the requirements of a competitive market. The size and configuration of discharge permit regions will also affect the number and size of potential market participants and market equilibrium. Importantly, the regulators should consider whether or not to allow exchange of permits across zones that may increase trading opportunities but also have potential to create “hot spots”.

The random variability of hydrologic variables and stream flow pollutants create difficulty in modeling water quality with certainty. Beck (1987) reviewed the uncertainty in the water quality modeling and concluded that many of the larger, more complex water quality models can easily generate predictions with little or no confidence (Beck 1987). Reckhow suggested the use of simple models for thorough uncertainty analysis (Reckhow 1994). It is important that uncertainties associated with each component of the effluent trading process be assessed. Potential mechanisms to reduce these uncertainties should be identified and incorporated into the trading framework.

Since nonpoint sources typically do not face discharge control requirements, there is no apparent reference level of discharge (baseline) from which to calculate effluent reductions. Moreover, the quantity and quality of the runoff tends to be intermittent and can be difficult to model and predict. It may be difficult to establish meaningful wasteload allocations for nonpoint sources. The method choice for control of polluted runoff is generally a best management practice approach rather than technology-based treatment systems. It is more difficult to monitor or predict the effectiveness of best management practices on reducing the discharge of pollutants into waterways, and therefore, more difficult for an authority to determine with certainty that the requirements it places on nonpoint sources will meet a wasteload allocation requirement (USEPA 1998a, d).

2.3.3.3 *Hot Spot*

For trades of nonuniformly-mixed pollutants, emission location matters as it could potentially create "hot spots" problems. Hot spots refer to local pockets of intense pollution (Wolman 2003). The formation of hot spots may result from more clustering than permitted of emissions in vulnerable areas. Hot spots can occur with or without effluent trading. However, there is great concern that poorly managed trading systems can worsen this problem.

Trades that create hot spots – localized areas with unacceptable high levels of pollutants – must be avoided. USEPA (2004) suggests various approaches which are being used by trading programs to avoid unacceptable localized impacts. One is to exercise some control over how the permits are used by applying permit limitations to cap the number of credits used in an area susceptible to localized impacts to avoid transferring pollutant loadings to sensitive parts of the watershed.

Other approaches include limiting the direction of trades, e.g., upstream *versus* downstream, and imposing discharger-specific limits for pollutants that could cause localized concerns.

Chapter 3
OVERVIEW OF OBSERVATIONS IN WATER QUALITY TRADING

Introduction

After the first American effluent trading schemes arose in the 1980s; the development of effluent trading schemes has been increased, with the Fox River Program in 1981, the Lake Dillon Program in 1982 and the Tar-Pamlico River Basin Program in 1986. A small number of new effluent trading programs arose in the early to mid-nineties. It has only been within the past five-to-ten years that such programs have begun to increase. More recently, trading programs have increased in popularity under an increased (and explicit) regulatory flexibility on the part of the EPA, as laid out in the 1996 Effluent Trading in Watersheds Policy, the 2003 Water Quality Trading Policy. There are approximately 47 effluent trading programs in operation and in developmental stages in the US today (Morgan and Wolverton 2005).

An overview of water quality trading programs in the US is presented in this chapter. A summary table listing these programs in details is provided in Appendix A. Individual factors affecting the functions of the trading systems are explained as well in the chapter. Main factors controlling the success of water quality trading programs are discussed in detail both qualitatively and quantitatively when possible. These factors include (1) program structures, (2) pollutants, (3) market structures, (4) size of watershed, (5) number of participants, and (6) trading ratios. Furthermore, the observations derived from trading programs including temporal issues (banking and borrowing), number of trading occurred, transaction costs, and amount of cost-saving, are studied and explained in detail. In Chapter 4, experiences drawn from major case studies or trading programs, are presented and discussed to better understand the function of water trading before and after implementation of the programs.

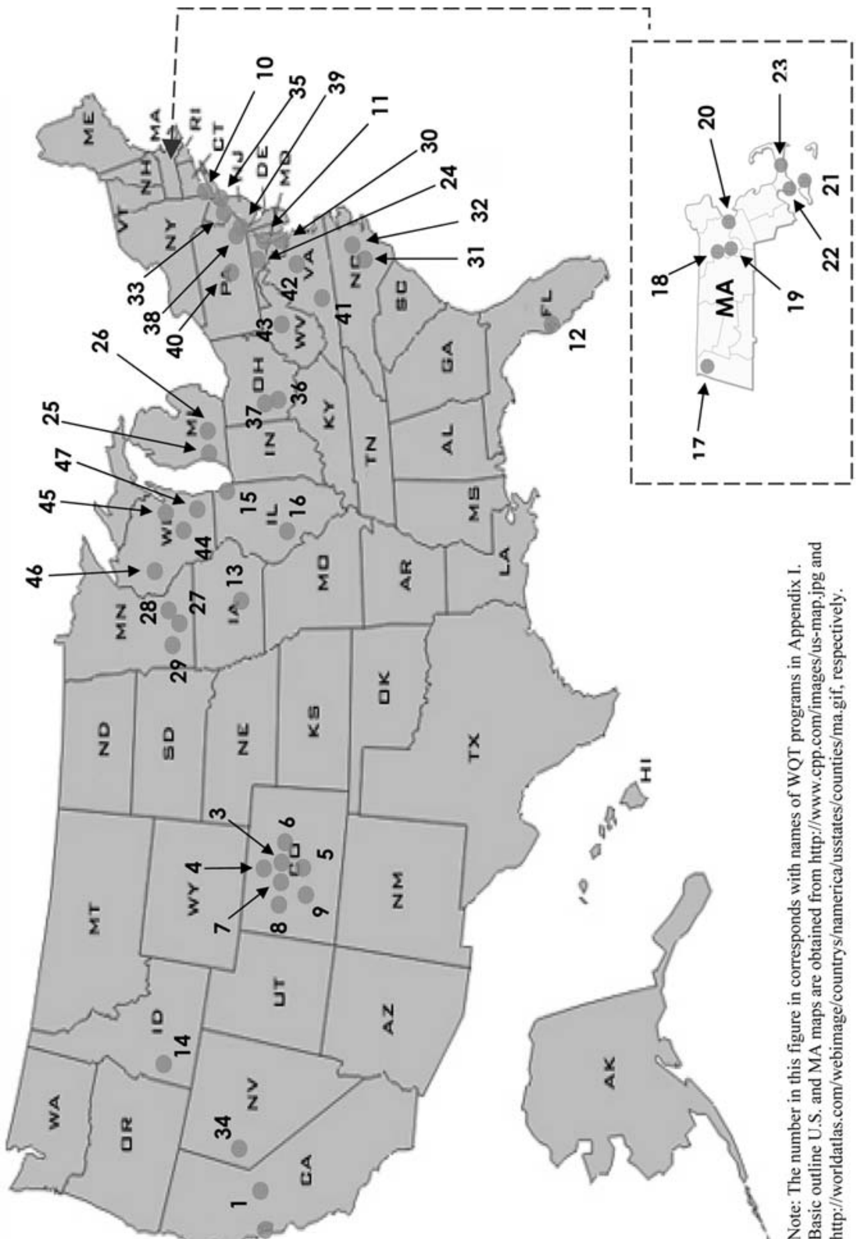
3.1 Overview of Water Trading Programs in the US

Economists for decades have been promoting water quality trading because of potentially higher benefits and flexibilities for the long term. There are several trading programs already implemented with slightly different program settings depending on environmental problems, physical characteristics of the areas, and legal conditions. Only a few of the trading programs are considered to be successful after long time implementation, while the majority of other programs are either inactive or have failed in the aspect of trading. The better understanding the important factors and their effects on the successes and failures of the programs in both theoretical and practical aspects helps the programs progress.

Several researches comprehensively investigate individual WQT program separately. Morgan and Wolverton (2005) presented the most recent comprehensive overview of the WQT programs in the US. The authors suggest that the success of the WQT program does not appear to be driven by any one factor. This chapter presents further analysis on how each individual factor affected the success of trading programs and the degree of significance of each factor. A current situation of water quality trading programs in the US demonstrated in this chapter is adopted from a systematic overview by Morgan and Wolverton to further analyze the relationship to the WQT programs success, factor by factor.

The following sections demonstrated an overview of all activities and current situations of WQT program in the US. A summary table is presented in Appendix A. Current information about water quality trading programs is based on data collected from several sources and databases (Podar 1999; USEPA 2003a, b, c, d, 2004; Breetz et al. 2004) which are excellent and complete databases with all relevant data including program background, trade structure, outcomes and program information and references. More detailed information should be referred to the original sources (Podar 1999; USEPA 2003a, b, c, d, 2004; Breetz et al. 2004).

According to Morgan and Wolverton (2005), within 20 US states 47 water quality trading programs are presently implemented and/or are in developing stages. Figure 3.1 demonstrates the approximate location of current water quality trading programs within the US. These programs can be further divided into (a) 19 ongoing trading programs (b) 8 offset agreements and (c) 20 proposals and small projects in developing stages under feasibility studies. Among these programs, nutrients (nitrogen and phosphorus) are the most commonly traded pollutants. The sizes of watersheds vary significantly from small to very large.



Note: The number in this figure in corresponds with names of WQT programs in Appendix I. Basic outline U.S. and MA maps are obtained from http://www.cpp.com/images/us-map.jpg and http://worldatlas.com/webimage/countrys/namerica/usstates/counties/ma.gif, respectively.

Figure 3.1 **Map of current water quality trading programs in the US.**

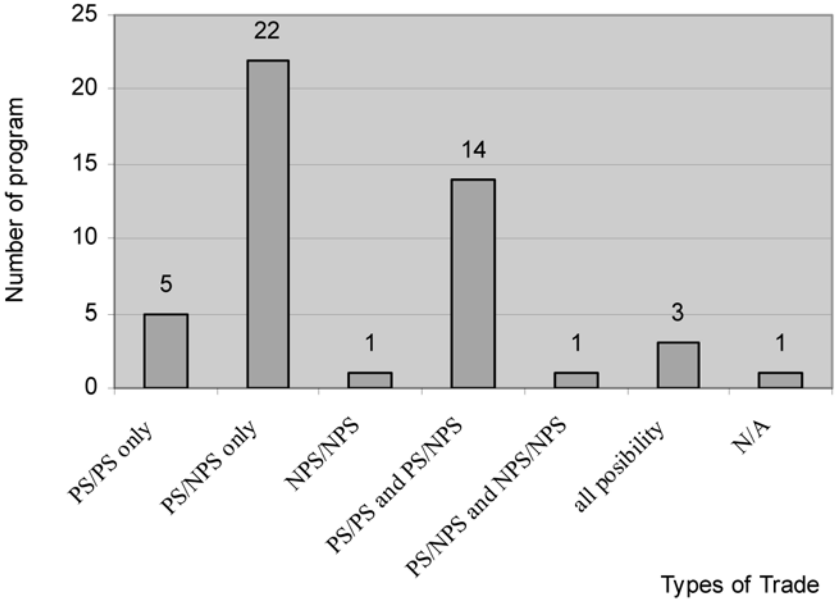


Figure 3.2 **Type of trading and number of programs.**

More importantly, details of the trading framework (i.e. market structures, trading ratios) also differ broadly among programs (Morgan and Wolverton 2005). Each factor affects the program performance differently as discussed in the details in the following section.

3.1.1 Program Structures

Structures of trading programs can vary significantly based on criteria used to set up the program. Several criteria are currently implemented to categorize program structure such as type of participants, authorization mechanism for trading, and design framework.

Program structures, based on types of polluters participating in the programs, are (1) point/point source type trading, (2) point/nonpoint source type trading, and (3) nonpoint/nonpoint source type trading. The most common type of trading in the US occurs between point sources and nonpoint sources, as shown in Figure 3.2.

Of the in total 47 programs, 22 programs involve trading between point sources and nonpoint sources. There are 5 programs where trades occur between point sources only. Only one program involves trading between nonpoint sources.

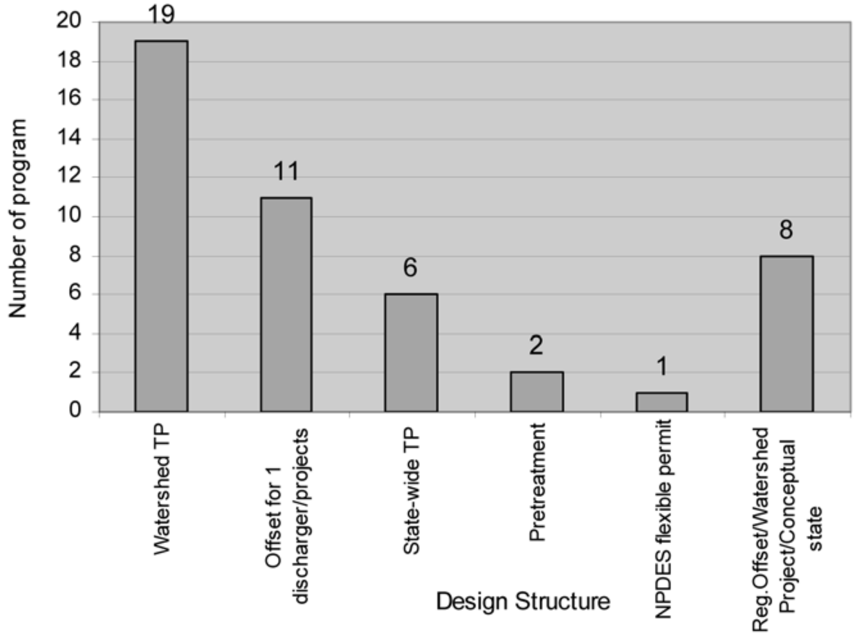


Figure 3.3 **Design structure *versus* number of programs.**

Fourteen programs allow trading between both PS/PS trading and PS/NPS trading. It is quite reasonable that PS/NPS trading is the most common structure because the difference in marginal costs of treatment between point sources and nonpoint sources are greater incentives for polluters because of the potential for higher benefits gained from trading.

Another common criterion is based on who has the authority to make a decision as to whether or not a trade can occur. Using this criterion, trading programs can generally be separated into three structures; i.e. (1) a credit trading program, (2) a cap-and-trade program, (3) a one-time or ongoing offset program. Specific criterion commonly used sometimes is interchangeable depending on the local conditions of the watershed.

The structures of trading can also be categorized based on design framework of the program; e.g. whether they are watershed tradable permits, offsets, NPDES flexible permit, pretreatment trading or statewide trading policies. Figure 3.3 displays the types of structures of trading programs in the US. However, some of these programs are not actually implemented but are in developing stages or pilot projects. The next section discusses each trading structure in more detail.

3.1.1.1 *Tradable Permits*

Watershed tradable permit programs within the same watershed are the most predominant structure of trading. Among these 19 out of 47 programs, there may be a credit trading program or a cap-and-trade program. The majority of trading programs in the US are credit type trading programs where the polluters obtain credits if pollution reduction is below a certain baseline set by the regulators. The polluters need approval from the regulators to adjust the pollution permits when the decisions are being made to trade. The cap-and-trade type trading program, which is more similar to a real market mechanism, is found in a small number of water quality trading programs. Within this type of structure, regulators need an estimate of the total amount of pollutants to allocate the allowances based on the desired amounts of discharge allowed. As long as the polluters have enough permits to cover amounts of their discharges, the buyers and sellers can directly trade their allowances without the regulators being involved in the negotiation and change of permit titles.

An example of the water program, which is the closest to the cap-and-trade type structure, is the Long Island Sound Program with the General Permit System. The point sources in this program have individual permits in proportion to their discharges in order to meet a collective nitrogen cap. The point sources can buy and sell their credits directly to the Nitrogen Credit Exchange Program which facilitates trading among the polluters. Another program example is the Tar-Pamlico Trading program. In this program, the regulator handed out permits to a group of polluters. The group then set up an internal trading agreement to meet the pollution limit without the regulators being involved. However, the regulators set a penalty if the polluters exceed the given limits. The program can also be categorized as a tax-exceedence structure (this will be discussed in Chapter 4). The last example is the Grassland Area Farmers trading program. In this program, the state of California sets up selenium limits to seven irrigation districts which discharge into the same watershed. Each district has authority to set up management rules with farmers located in their districts to keep the selenium under the permits and where trading only occurs between irrigation districts. No direct trading between farmers is allowed.

The majority of the programs are not a cap-and-trade type, except for the Long Island Sound Program, the Grassland Area Farmers Program, and the Tar-Pamlico Program. All the water quality trading programs use the grandfathering method to allocate permits to either individual polluters or to a group of polluters in the program. There is no auction mechanism used in the water trading program for permit allocation. Legal liability and penalties are determined under the NPDES or WWTP permit limits, unless specified individually; i.e. with offset agreement. In the majority of cases, point sources are held responsible for obtaining and verifying the nonpoint source credits generated.

3.1.1.2 *Offsets*

The second most common type of trading structure is the offset, being either a one-time agreement or an ongoing offset. Offset structure occurs primarily in the areas where the watershed has limited assimilative capacity and where firms need to increase their discharges permit for future business expansion or to meet new regulatory requirements. Therefore, polluters have to make an arrangement case-by-case with other polluters in the near-by areas to offset their discharges. In most cases, the offsets only occur when the need for expansion exists. Moreover, there is a sole-source offset where no money is actually transferred (no actual trading) to other parties and the polluters take action offsite to offset its own increase in discharge (Morgan and Wolverton 2005).

The offset structures rely significantly on state policies. There are eight programs which are one-time offset agreements occurring in four states; 1 offset in CO, 4 offsets in MA, 1 offset in IL, and 2 offsets in MN. Only Colorado has state trading policies in place. The others have no standard framework under which the trading agreements take place (Morgan and Wolverton 2005).

All of the offset agreements are undertaken by point sources to reduce nonpoint sources pollution in the watershed. In most cases, offsets have been generated as a condition of the renewal of a NPDES or WWTP permit which requires a plant to improve water quality through offsets or upgrades; for example, the Edgartown WWTP (MA), the Special Minerals (MA), and the Rahr Malting Co. (MN) programs. Most offsets have been negotiated to reduce discharges in one pollutant while allowing increases of the same pollutant elsewhere. The exception is Rahr Malting Co. agreement, which pertains to offsets across three possible pollutants (BOD, phosphorus and nitrogen) (Fang and Ester 2003).

3.1.1.3 *NPDES Flexible Permit*

One program categorized as a NPDES flexible permit is the Cargill and Ajinomoto trading (IA) (Podar 1999). NPDES flexible permit is slightly different from an offset in that in this program structure the regulators agree to adjust the permit according to agreement among firms to lower the limits. Cargill and Ajinomoto are neighboring industrial plants discharging into the same water body (the Des Moines River) where the stream does not have the capacity to accept new discharges but Ajinomoto wants to expand its plant capacity. The state of Iowa arranged for two plants to jointly meet the effluent limit. The Cargill plant agreed to accept and treat Ajinomoto's effluent stream and Ajinomoto helped Cargill with its nutrient control to meet its limit (Podar 1999). This particular case can also be viewed as an informal offset agreement among two firms.

3.1.1.4 *Pretreatment Trading*

There are two pretreatment trading programs, (1) Passaic Valley Sewerage Commission Effluent Trading Program (NJ), and (2) Illinois Pretreatment Trading Program (IL). The Public Owned Treatment Works (POTW) aims to reduce the overall level of metals from the sludge. Both programs trade multiple metals. The shared characteristic of these pretreatment trading programs is that a POTW sets local limits and trading as an alternative for indirect dischargers who send their wastes to the POTW to cost-effectively meet the limit. Since different factories discharge different types and amounts of waste, the POTW set a limit on the levels of metals as a baseline for indirect discharges to trade among them if their discharges are above or below the baseline (USEPA 1998a, c).

3.1.1.5 *Statewide Trading Policy*

Morgan and Wolverton (2005) pointed out that there are six states and regions developing a statewide trading policy and implementing a pilot study, including Maryland, Michigan, Pennsylvania, Virginia, West Virginia, and Wisconsin. In all cases, the policies address trading among point-point source and point-nonpoint sources. Only Maryland, Michigan and Wisconsin consider trading between nonpoint sources. All trades are allowed only within the same watershed. Most of the policies prefer the clearinghouse structure or bilateral negotiation. Not all policies allow banking even though the benefits of cost-saving in trading from banking can be significant. Only Virginia and Michigan allow banking but with different terms of use (Morgan and Wolverton 2005).

3.1.2 Pollutants

A wide variety of water pollutants were recently traded in the trading programs. These pollutants include nutrients (both nitrogen(N) and phosphorus (P)), N only, P only, ammonia, BOD, COD, pH, selenium, water flow, temperature, TSS, and heavy metals. Two major pollutants that will become significant water pollutants, and play major roles in trading, are nutrients and BOD. Because marginal costs of NPS for nutrients and BOD control are lower than that of PS, there is a higher potential benefits gained via trading.

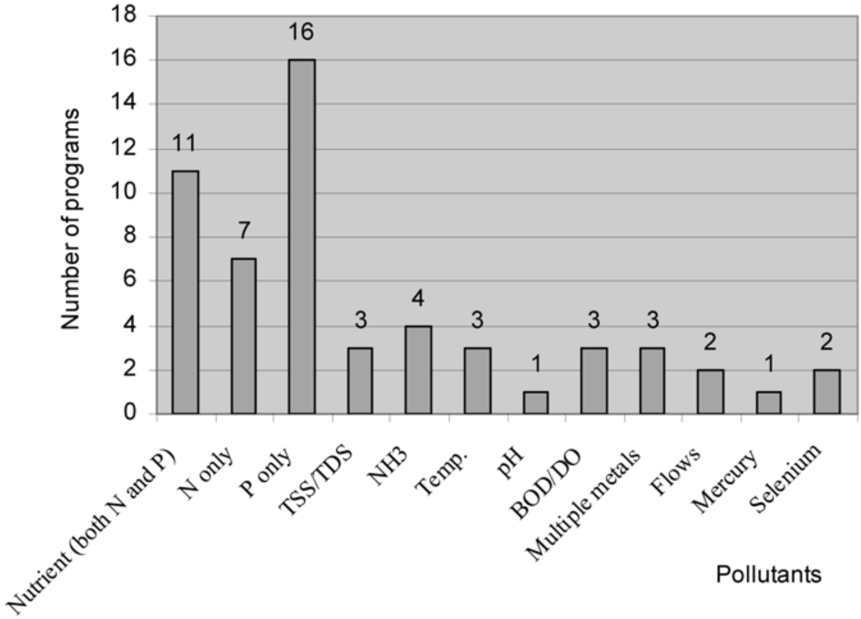


Figure 3.4 **Pollutants and number of programs.**

Figure 3.4 shows pollutants traded and numbers of programs trading each pollutant. Phosphorus is the most common pollutant in trading within 26 programs. The second common pollutant traded is nitrogen, which occurs in 17 programs. There are 11 programs in which both P and N are traded in the same program. Phosphorus and nitrogen, which can affect the level of oxygen in water if high concentrations of them are present in the water body, are essential nutrients for plants and algae. However, nutrients cannot cause an acute impact to human health as that of when heavy metal is accumulated; therefore, trading nutrients is gaining increased acceptability and becoming the major traded pollutant.

Nineteen programs (as listed in Table 3.1) allow trading of more than one pollutant in the program. Twenty eight programs only allow one type of pollutant to be traded. Most of the water trading programs trade only for the same water pollutant. With the exception of for Rahr Malting Co., the program also allows cross-trading between different pollutants. It sets up offset ratios 2:1 in general, for cross parameter ratios 8:1 for CBOD:P and 4:1 for CBOD:N (Podar 1999; Fang and Ester 2003).

Nutrient trading is implemented in either a tradable permit system or an offset type. On the other hand, temperature, TSS, pH and mercury are found

***Table 3.1* Number of programs allowing trading of more than one pollutant in the same program.**

Pollutants in the program	Number of programs
N, P	11
Multiple metals	2
NH_3, BOD/DO	1
P, BOD/DO	1
Water flow, N, P, TSS, Temp	1
N, P, TSS, NH_3	1
CBOD, P, N, SS, NH_3, Acid, Metals	1
NH_3, Temp, pH	1

to be implemented or proposed frequently in an offset type trading program. In addition, some pollutants mentioned in the discussion here are already in developing state or in pre-approval process to be traded but no actual trading structure have yet been developed; for example, the mercury offset program in San Francisco Bay.

3.1.3 Market Structure

Market structures refer to a market's standard for obtaining information and exchanging rights. Woodward and Kaiser (2002) separated pollution trading markets into four main structures: exchanges, a third party broker, bilateral negotiations, and clearinghouses. An exchange is characterized by its open information where offers are publicly available and products are uniform, for example the SO_2 market. Bilateral negotiation is common where there are a wide variety of sellers from which a buyer might choose, and where the goods are heterogeneous. Bilateral negotiations require substantial interactions between the buyers and the sellers to exchange information and negotiate the terms of trade for each transaction. The transaction costs for this mechanism are generally high. Bilateral negotiation is the most common structure for the water quality trading market; e.g. the Fox River Program, the Tar-Pamlico Trading Program (NC), and the Kalamazoo Program (MI). This structure is particularly common in programs that seek to include NPS polluters. A third party broker is usually a broker using bilateral negotiation to identify potential parties interested in buying or selling credits.

Woodward explained that in a clearinghouse, the state or some other entities pays for pollution reductions and then sells generated credits at a fixed-price to polluters. Buyers and sellers do not interact directly. A clearinghouse works best when the impacts of pollution discharges are similar enough to allow for the transfer of rights between a large number of buyers and sellers in the watershed. A water quality clearinghouse differs from a broker in a bilateral market in that it eliminates all contractual or regulatory links between buyers and sellers. The benefit of water quality clearinghouses is its ability to create a uniformed good for final sale, and is able to reduce transaction cost in the market. The PS/NPS trading program in the Tar-Pamlico Trading Program and the Nitrogen Credit Exchange Program in the Long Island Sound Trading Program are good examples of a clearinghouse structure.

Finally, another structure that actually does not involve trading at all is a sole source offset where a source is allowed to meet water quality standard at one point if pollution is reduced elsewhere, either on-site or by carrying out pollution reduction activities off-site (Woodward and Kaiser 2002). Many water quality trading programs are a sole source offset including; Rahr Malting Co. (MN), Southern Minnesota Beet Sugar Cooperative Plant Permit (MN), Falmouth WWTP (MA) and Boulder Creek Trading Program (CO).

A market structure may evolve over time in response to changes from information received regarding the market, legal restrictions, and market size to reduce transaction costs. The market structures are not necessarily mutually exclusive. Sole source offsets can remain part of any trading program. A gradual evolution from bilateral negotiation to an exchange or clearinghouse might then occur. The choices made regarding authorization, monitoring and enforcement help to determine a market structure as they establish which structures are feasible and which ones will influence the transaction costs that will occur under those structures. The market tends to use the structures that minimize transaction costs (Woodward and Kaiser 2002).

As shown in Figure 3.5, out of a total of 47 programs, bilateral and clearinghouse structures are the relatively most common use. Additionally, eight programs are implementing more than one market structure within the same program which is the most common practice currently found in trading programs. N/A in the graph means that the market structure of the program is under development. At the beginning of any trading program, it may be more beneficial to allow the implementation of more than one approach. One mechanism may work better than another given different situations or if it is for a long term. The mechanism which does not function will later disappear. Only three programs are third-party brokers (i.e. Clear Creek (CO), Charles River (MA), and Great

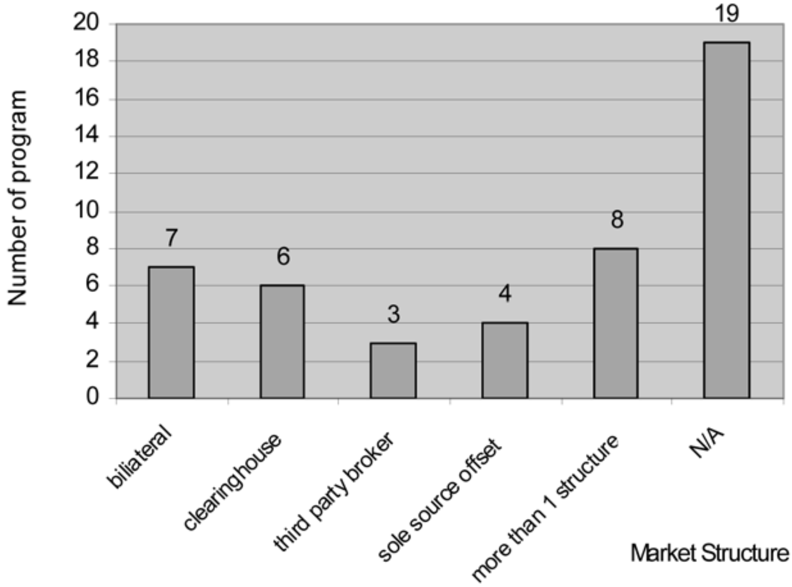


Figure 3.5 **Market structure *versus* number of programs.**

Miami River Watershed Trading Pilot Program (OH)). This is possibly due to the small amount, or none, of the benefits gained from being a broker in the water quality trading market, and the high transaction costs of the localized nature of water pollution problem.

3.1.4 Size of the Watershed

The size of a watershed covered by each trading program varies significantly. The size of the program presented here is categorized based on the approximated areas of the watershed. Watershed areas, in acres, range from small (area < 100,000), medium (100,000 < area < 1,000,000), to large (area > 1,000,000). Theoretically, the larger the size of the market (watershed area, number of participants), the higher potential for trades occur. While the size of a watershed may be a significant factor, other factors can sometimes become more significant in precluding trading activities. There are many trading programs covering large watershed areas that had no, or minimal, trade occurring in the program. For example, the Minnesota River Nutrient Trading program which covered 10.9 million acres had no single trade occurring in the program. In contrast, in some smaller watershed areas, i.e. the Lake Dillon Trading Program, which has 3,200 acres, was successful with a

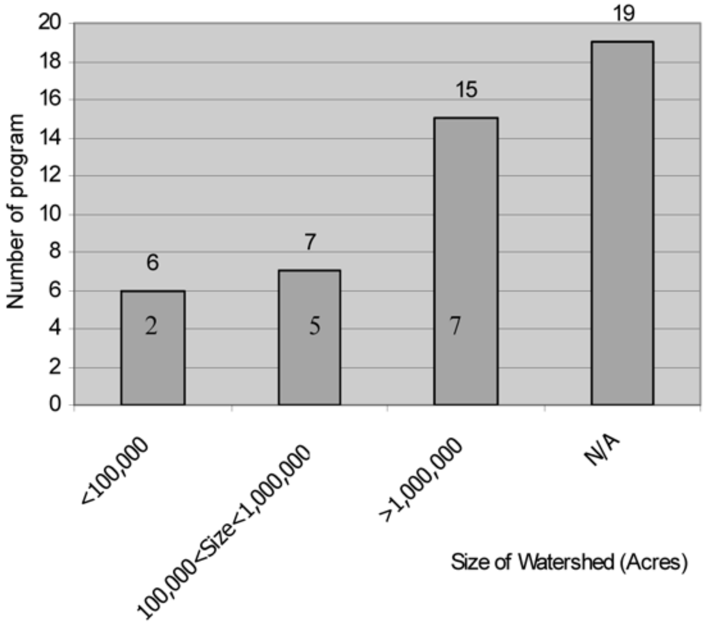


Figure 3.6 **Areas of watershed and number of programs.**

number of the active trading activities and had significant cost-saving (Woodward 2003).

Figure 3.6 displays the number of the programs located in each watershed-size category. The majority of the watershed areas of trading programs are in the large category. It is difficult to know whether or not the program size affects the program's success. The analysis of the big picture regarding the size of programs, and numbers of programs with active trading occurring in each category, might be more interesting. The numbers of the programs of trades occurring within each size category are indicated in Figure 3.6. In the small-size watersheds, there are 2 out of 6 programs where trades occurred. In the medium-size watershed, trading occurred in 5 out of 7 programs. In the large-size watershed, there are 7 programs out of 15 programs where trades occurred. A simple comparison in terms of the ratio of number of programs with active trading activities to the total number of programs in each category, the medium-size programs are the most successful in numbers of programs with active trading. This comparison is not based on number of trades (or transactions) but rather based on the number of programs which trading occurred or did not occur at all. In the large-size programs, other factors may significantly affect trading incentives. These include

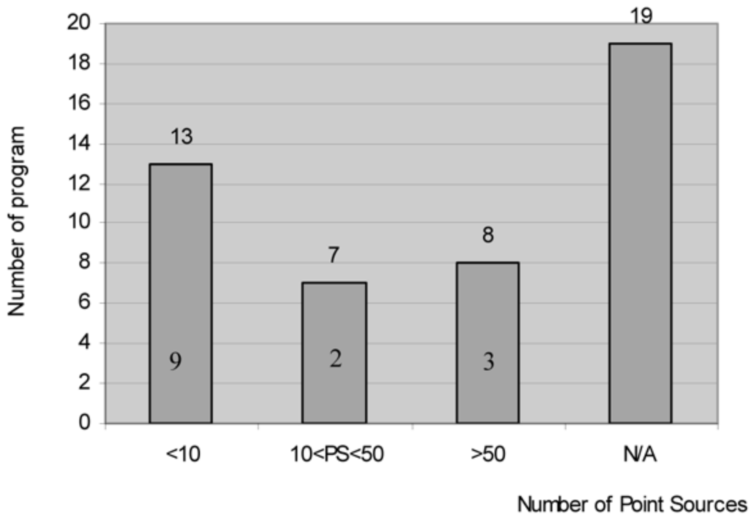


Figure 3.7 **Number of programs and number of point sources within each program.**

higher transaction costs and administrative costs. Monitoring and enforcing the rules becomes more difficult and resource-intensive, with no establishment of TMDL.

At this point, it is really unclear which size of a trading program has the most significant affects to trading activities i.e. whether the larger is actually better than the smaller watershed in terms of trading. However, the size of the trading programs should be considered with other factors in determining the program's success. Other factors mainly consist of the program design, market structures, and the characteristics of pollution sources contributing to the pollution problem in the watershed.

3.1.5 Number of Participants in a Trading Program

Characteristics of trading participants (e.g. numbers and types of pollution sources) in the programs can significantly affect trading achievement. Limited numbers of point sources in the watershed may negatively affect the success of the program. Theoretically, it is easier to trade among point sources because identification of reduction credits and monitoring can be done with accuracy.

It is found that number of point sources participate in the program randomly affect number of active trades occurred in the program. Based on data available, as shown in Figure 3.7, the majority of the trading programs, 13 out of 47 programs in the US, have number of participants with less than 10 point sources in the program. The numbers in the programs which have active trading in each category are shown within the bar. For example, 9 programs out of 13 programs, that have less than ten point sources participating in the programs, have the highest number of active trading programs. Among seven programs that have point sources between 10 and 50 point sources, two programs have active trading. Only three programs out of eight programs, that have point sources participants of more than 50, have active trading.

Generally, it is expected that the larger number of point sources in the programs, the higher potential of success (i.e. active trading activities) because of the greater chances in finding trading partners and gaining benefits via trading. In this case, the focus is whether or not there are trading activities occurring at all in each program. The focus is not about the number of trades which occurred in each program. And what happened in water quality trading programs disproves the presumption. There are water quality trading programs which include a large number of point sources in the programs, however no/or a few trading occurred in the program. For example, in the Minnesota River Nutrient Trading Study, even though there are 212 point sources participating in the trading program, the program has no trading activities (Breetz et al. 2004).

There are also many other factors involved in these programs that might prevent trade activities from occurring. One of these factors is the number of nonpoint sources in the WQT programs. The remaining pollution problem from NPS runoff is still left out of the mandatory reduction requirements. The lower marginal cost in treating the pollution from nonpoint sources is a significant factor to support trading with nonpoint sources. However, a problem in trading with nonpoint sources is in the difficulty of monitoring NPS pollution. The costs of monitoring and identifying trading partners could be higher than the benefits gained from trading.

The majority of sources contributing to the pollution are key to active trades by allowing all sources contributing to pollution the ability to search for available credits. In the last decade, the majority of current programs included nonpoint sources in the program. All current active trading involves trading between point source and nonpoint sources. For example, Lake Dillon (CO), Red Cedar River (WI) and more programs predominantly offset their credits from nonpoint sources. However, it is difficult to systematically compare affects of nonpoint source participation among the trading programs. This is due to the large number of nonpoint sources involved in the programs, the differences in characteristics of nonpoint sources among the programs, and the difficulty in the identification of nonpoint source pollution.

3.1.6 Trading Ratios

Trading ratios are the ratio between the numbers of credits from sellers to the numbers of credits eligible for buyers to meet the permit requirement. The ratios vary significantly from program to program. The most common trading ratio for programs that are trading nutrient between point and nonpoint sources is 2:1. The ratio between point sources trading is 1:1 (Morgan and Wolverton 2005).

Trading ratios are applied to serve several purposes. First, the ratios serve to manage uncertainty associated with the effectiveness of nonpoint source controls. Second, the ratios account for the difference in locations of the sources in the watershed to prevent hot spots and to ensure the equivalency of the potential environmental impact between different locations. For example, the Long Island Sound sets up an equivalency factor where the credits generated from reductions closer to the problem zone (mouth of the estuary) is more valuable than the credits generated further from the zone. Finally, they are used to ensure water quality improvement from trading. In the Passaic Valley Sewerage Commissioners Pretreatment Trading Project, the trading ratio is set to be 5:4 so that 20% of the credits is retired to ensure the reduction of overall heavy metal loadings.

In addition to setting trading ratios to reduce the uncertainty in nonpoint source trading, the Grassland Area Farmers Tradable Load Program manages the uncertainty by making trading retroactive. The trades of selenium credits occur after the BMP installation by measuring water quality instead of the prediction of effectiveness of BMP (Young and Karkoski 2000).

3.2 Observations Derived from Trading Programs

There are several other interesting phenomenon and issues which can be derived from the studies of the current trading programs. The following discussions are the observations about temporal issues (banking and borrowing), number of trades in each program, transaction costs, and cost savings.

3.2.1 Banking and Borrowing

Emission banking and borrowing allows firms to move pollutants between time periods as well as between sources. The term "banking" means saving emissions in one period for use in later periods, and "borrowing" means using more emissions than current standards allow in one period and paying back those emissions in the future (Rousseau 2001). Few water quality trading programs allow banking. A program allowing or approving "borrowing" in water quality trading rules is not found.

For example, in the Tar-Pamlico, the Association may choose to make a payment in anticipation of a future cap exceedence and to bank credit toward that exceedence. The Association accumulated $343,960 in advance offset payment for 11,860 kg N reduction credit (NCDENR 1994). The Association can use the credits to offset any loading above their cap for a 10-year period from 1995. However, the banked credits never were redeemed. Currently, in the beginning of Phase III of the program, the NC Division of Water Quality is working on resolving the issues regarding the longevity of the banked credits and the rate at which banked credits can be redeemed (EMC 2005). In addition, in statewide trading policies established within 6 states, Morgan and Wolverton point out that only two allow for banking. Michigan allows banking for up to five years. Virginia allows banking for one year for a point source's own use (Morgan and Wolverton 2005).

3.2.2 Number of Trades Occurring in Each Program

A well-known behavior of water quality trading programs in the US is, unfortunately, the lack of trading activities, as shown in Figure 3.8. There are about 28 out of 47 programs where no trade occurs. In 19 programs, trading occurred only once or more than once. 12 programs had trading occurring only one time. The market structure for the majority of these active trading programs is one-time offset (11 out of 12 programs).

The most successful programs in terms of the number of trades, which have more than 10 trades (collectively), are the following four programs (Breetz et al. 2004).

1. The Grassland Area Farmers Tradable Loads had 39 trades over a two-year period (1998–2000). These trades occurred over 9 agreements, 38 in 1998, 1 in 1999, and 0 after.

2. Long Island Sound had 63 trades over a two-year period (2002–2004), 38 in 2002 and 25 in 2003.

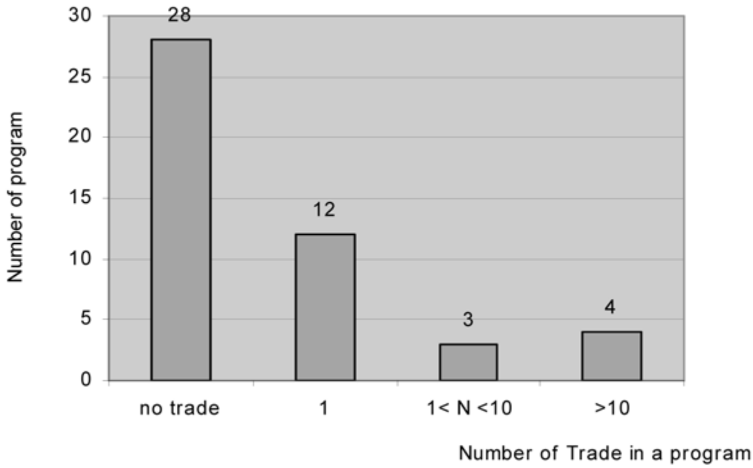


Figure 3.8 **Numbers of trades *versus* number of programs.**

3. Truckee River Quality Settlement Agreement had 33 trades over an eight-year period (1996–2004), 17 trades before 2001 and 16 trades after 2001.

4. The Red Cedar River had 22 trades each year since 2001.

Indicator for the success of a trading program should be considered both environmental and economic aspects. For example, the Tar-Pamlico trading program meets the collective limits without trading. Moreover, nutrient levels in the watershed are steadily decreasing over time despite steady increases inflow. In this program, the Association of point source dischargers in the program pays an advanced fee to start up the trading program, and the states use the money to fund nonpoint source BMPs and other activities to improve water quality management. The point sources gain flexibility in pollution management, received credits for future use and achieved a significant amount of savings compared to a traditional command-and-control mechanism.

The total amount of a particular pollutant traded varies widely across programs. For example, in the Chatfield Reservoir program, the amount of phosphorus traded in the program was very small (only 2 lbs). In contrast, in the Long Island Sound, the amount of nitrogen traded was 2.7 million lbs in 2003. The Red Cedar River program has about 5,000 lbs of phosphorus credit traded annually. The larger amount of pollutant traded is probably due to the larger size of the program (Breetz et al. 2004; Morgan and Wolverton 2005).

There is no standard price, or price range per credits, across programs. The price also depends on market structures; i.e. bilateral negotiation, clearinghouse, broker or offset. The price of credits for the same pollutant varies significantly for different market structures (bilateral, broker and offset). In general, programs with a clearinghouse structure set a fixed price per unit of pollutant before any trading occurred. For example, in the Grassland Area Farmer, the price or fee for selenium credits was set for both a monthly and annual rate, approximately $40/lb monthly and $100/lb annually.

In the Tar-Pamlico program, the offset rates for nitrogen credit in Phase I was $56/lb. The offset rate was reduced to $29/lb in phase II because more information and accuracy in measurements became available. In contrast, the price of nitrogen credit in the Long Island program is less expensive than the price of that in the Tar-Pamlico program. In the Long Island Trading Program, the price for nitrogen credit is $1.65/lb (2002) and $2.14/lb (2003). Both programs market structure is the clearinghouse. However, it was noted that the differences were due to there being more participants in both point sources and nonpoint sources in the Long Island Sound than there were in the Tar-Pamlico. The area of watershed in the Long Island (3.5 million acres) is also larger than that of the Tar-Pamlico (2.88 million acres). In the Long Island Program, the agency uses federal funding to buy excess credits from all point sources. Moreover, point sources are major sources of nutrient pollution in Long Island Sound. On the other hand, in the Tar-Pamlico, the price of credit is actually a fee that sources have to pay if they exceed the cap which will be used to fund nonpoint source BMPs. These factors affect the price of the credits differently.

3.2.3 Transaction Costs

Costs associated with different trading programs vary significantly due to a lack of consistent data. Morgan and Wolverton 2005 pointed out that the data about costs in trading programs are derived from a variety of sources that vary in estimation, quality and completeness. It is difficult to accurately discuss the transaction costs and cost savings issues within different programs. Generally, there are three main types of transaction costs: search and information, bargaining and decision, and monitoring and enforcement including costs associated with transportation and set up (Stavins 1995). Transaction costs may be one time costs associated with initiating a market, or may be present in each trade. The administrative costs involved in monitoring and enforcing trades vary considerably across trading programs. High administrative costs are due to (1) high monitoring costs especially with nonpoint sources monitoring, (2) extensive review of application for trading, and (3) oversight and inspection costs for nonpoint sources BMPs implementation.

Transaction costs differ substantially across different trading programs, partly due to differences in market structures. For instance, a clearinghouse typically has substantially lower transaction costs because buyers and sellers only need to interact with the intermediary and face a fixed price that is not subjected to negotiation transaction costs. However, for bilateral negotiation, the transaction costs are usually quite high because buyers and sellers need to pay for processing fees associated with information searching and data gathering, negotiations and actual contract development (Woodward and Kaiser 2002).

The monitoring process usually results in significant cost especially in the monitoring of nonpoint source controls. Each program uses different strategies to monitor the nonpoint source pollution, ranging from no monitoring to verification of all BMPs used to generate credits. For example, Lower Boise and Red Cedar verify and monitor all BMPs. The Tar-Pamlico programs inspect only 5–10% of BMP credits. Instead of verifying BMPs, the Grassland Area Farmers program monitors selenium loads. The Kalamazoo program and Cherry Creek program monitor water quality to determine the effectiveness of non-point source controls (Morgan and Wolverton 2005).

Several mechanisms developed in trading programs are found to have lower transaction costs and administrative costs (Morgan and Wolverton 2005). For example:

- A trade arranged at regular meetings can reduce the costs for information searches needed to identify sources of credits. In the Bear Creek Program (CO) during annual meetings and during the Grassland Area Farmers Tradable Load Program (CA) at monthly meetings, all traders attend and negotiate potential trades.

- States assume most transaction costs; therefore, there is no transaction fee for trading programs; for example, in the Long Island Sound (CT) and the Neuse River Basin (NC).

- States become a mediator of trading between point sources and nonpoint sources; for example the state establishes a cost-share fund to minimize transaction costs. As in Tar-Pamlico Basin (NC), the polluters make an advanced payment to the state agency to generate credits. The agency then uses that money as funding for nonpoint sources.

- Using the existing federal monitoring system to lower the transaction costs; i.e. in the Grassland Area Farmers program.

- Low levels of oversight for nonpoint source implementation help reduce transaction costs; for example in the Tar-Pamlico program, only 5–10% of nonpoint source contracts were inspected each year. However, the program needs to make sure that violations do not occur and water quality goal is achieved.

- Shifting of costs from government to point sources can lower the administrative cost. For example, in the Low Boise River (ID), the state requires point sources to conduct most of the identification of sources and evaluation.

On the other hand, high transaction costs are generally due to extensive application, application fee, and a long approval process. For example, the Cherry Creek Program (CO) requires a $2,500 application fee which it attributes to high transaction costs. Negotiation process can also be a time-consuming process and requires a lot of resources especially when there is minimal/no guidance. For example, the Passaic Valley Sewerage Commission Pretreatment Trading (NJ) and the Fox-Wolf Basin (WI) are programs requiring high transaction costs due to the negotiation process. Moreover, feasibility studies can add significantly to transaction costs as is evidenced in the case of Rock River (WI).

Bilateral negotiations typically have higher transaction costs while clearinghouse market structures typically have lower transaction costs (Woodward and Kaiser 2002). There are some exceptions where there was an indication of other factors being involved that had significant effects on transaction costs. For example, the Grassland Area Farmers Tradable Loads arrange all their trades during monthly meetings when all irrigation districts are in attendance. Therefore, transaction costs with bilateral negotiations are quite low. The Kalamazoo River program, despite the clearinghouse market structure, requires a significant amount of information as part of the application process and it has a long approval process which results in higher transaction costs.

3.2.4 Cost Savings

Estimated amount of cost saved via trading varies considerably across trading programs. It is difficult to discuss the cost-savings between programs because amounts of cost savings are estimated based on different baselines (program background) and the variation in sources and estimation methods. Some programs may report or estimate the amount of cost-savings over a definite period of time. For example, the Long Island Sound Trading program is expected to save about $200 million over 15 years. Another example is the Lake Dillon Trading program which estimates amount of savings to be approximately $1.5 million for an offset for 1 discharger. Whereas, Michigan Water Quality Rule Development is expected to save $10–20/lb of P reduced. Tampa Bay Cooperative

Nitrogen Management only estimates a cost-saving from trading qualitatively as an avoided cost of TMDL implementation. Table 3.2 below summarizes available information about estimated cost-savings in water quality trading programs already implemented.

Table 3.2 **Approximated amounts of cost-savings from water trading programs within the US.**

	Name of program	State	Cost-saving
1	Grassland Area Farmers Tradable Loads Program	CA	Many trades exchanged in-kind of service. Cost saving is difficult to be estimated, ~$14,320 changed hand during the first five years
2	Bear Creek Trading Program	CO	Forest Hills saved the cost of system replacement over $1.2 million, instead it has to pay ~$5,000 per year for offsetting discharges
3	Boulder Creek Trading Program	CO	The City saved $3–7 million by deferring full nitrification modification, although it needed to upgrade its WWTP
4	Cherry Creek Trading Program	CO	NPS projects (pond retrofit) can generate credits worth $456,000, with the cost of the project $400,000
5	Clear Creek Trading Program	CO	The ASARCO agreed to pay a clean up cost of ~$50,000
6	Lake Dillon Trading Program	CO	Trading could reduce an estimate cost of maintaining WQ of over $1.5 million annually by about a half
7	Long Island Sound Trading Program	CT	Nearly $200 million over 15 years
8	Blue Plains WWTP Credit Creation	DC, VA	With the same money to reduce 1 million lb of N in 2 years, result of trading can reduce 6 million lb in 2 years
9	Tampa Bay Cooperative Nitrogen Management	FL	The consortium's action may help avoid TMLD costs and legal and administrative costs
10	Cargill and Ajinomoto Plants Permit Flexibility	IA	N/A, Offset trading between two neighboring industrial plants meets effluent limits jointly

Table 3.2 **(Continued)**

	Name of program	State	Cost-saving
11	Lower Boise River Effluent Trading Demonstration Project	ID	Expected cost-savings are \$10–158/lb of P reduced
12	Illinois Pretreatment Trading Program	IL	~\$6.9 million if able to trade federal categorical pretreatment limits
13	Piasa Creek Watershed Project	IL	~\$3.25 million, Illinois American Water Company avoided capital, operation and maintenance costs associated with lagoon and landfill system
14	Specialty Minerals, Inc. in Town of Adams	MA	Avoid estimated capital cost of \$300,000 and reduced amount of money that company has to pay to the Town
15	Town of Acton POTW	MA	Acton residents save ~\$2.25 million annually
16	Wayland Business Center Treatment Plant Permit	MA	~\$937,000
17	Michigan Water Quality Trading Rules	MI	Saving \$10–20/lb of P reduced
18	Minnesota River Nutrient Trading Study	MN	Saving \$18/lb for PS alone, to \$4–5/lb for the combination of subsidies for NPS BMP
19	Rahr Malting Permit	MN	Savings in WWT costs and avoid uncertainty regarding industrial user fees to POTW
20	Chesapeake Bay Nutrient Trading Program	MULTI-STATES	Depending on each state's trading rules
21	Neuse River Nutrient Sensitive Water Management Strategy	NC	Estimated cost of control \$25–30/lb but the offset rate is \$11/lb
22	Tar-Pamlico Nutrient Reduction Trading Program	NC	The offset rate is at \$29/lb while cost for at-the-plant control were estimated to be \$55–65/lb
23	Passaic Valley Sewerage Commission Effluent Trading Program	NJ	N/A, Buyers are able to avoid non-compliance fines, whereas sellers generate revenues from sale of excess reductions

Table 3.2 **(Continued)**

	Name of program	State	Cost-saving
24	New York City Watershed Phosphorus Offset Pilot Programs	NY	N/A, A pilot program to allow new or expanding WWTP to obtain offsets
25	Great Miami River Watershed Water Quality Trading Pilot Program	OH	\$314–384 millions over 20 years period
26	Pennsylvania Water-Based Trading Simulations	PA	These water meet all applicable standards and no TMDL is planned
27	Fox-Wolf Basin Watershed Pilot Trading Program	WI	Expected cost-savings are \$47/lb of P reduced
28	Red Cedar River Pilot Trading Program	WI	The trading saved Cumberland approximately \$15,000 in 1998

Reference: Data in this table mainly are extracted from Austin (2001), Breetz et al. (2004), Kerr et al. (2000), Podar (1999), Young and Karkoski (2000), Jarvie and Solomon (1998), Woodward (2003), NCAB (2003), Fang and Ester (2003), NCDENR (1994, 1998), Gannon (2003), CTDEP (2003), and USEPA (2003a, b, c, d). For more details, please refer to Appendix A-3.

Chapter 4
POTENTIAL ROLE OF TRADING IN WATER AREA

Introduction

Important factors affecting performance of current water quality trading in the US, including effects of each factor on trading activities in general, are presented in the previous chapter. This chapter aims to present the potential roles of trading based on experience with the current trading programs. The specific focus is on the performance from a number of selected trading programs which are active and successfully implemented. These programs are considered successful based on two objectives of the trading roles of as to whether or not they achieve a desired water quality cheaper (cost-effectiveness) and/or faster (in a desirable duration), listed in Table 4.1.

4.1 A Specific Role of Trading

This section discusses the experience and specific role of water quality trading from eight water quality trading programs.

4.1.1 Grassland Area Farmers Trading Program (CA)

The program is the first NPS-NPS-type trading program (Young and Karkoski 2000). The quantitative limits of selenium have been imposed on a regional consortium of farm districts. The mass-based caps of selenium, which were allocated to seven irrigation districts in the program, control the total quantity of selenium that is allowed into the San Joaquin river. The amount of selenium is

Table 4.1 **WQT programs with unique characteristics led to programs' success.**

Name of program	Characteristics of program	
Grassland Area Farmers Program	Cap-and-trade + Fee and Rebate	NPS/NPS
Tar-Pamlico Program	Cap-and-trade + Tax exceedence	PS/NPS, PS/PS
Lake Dillon Program	Credit trading	PS/NPS
Rahr Malting Co. Program	Offset for one discharger	PS/NPS
Long Island Sound Program	Cap-and-trade	PS/PS, PS/NPS
Passaic Valley Sewage Commission Program	Credit trading (Pretreatment Trading)	PS/PS
Truckee River Water Quality Settlement Agreement	Credit trading or offset	PS/NPS
Chesapeake Bay Program	State-wide trading policy	All possibilities

curbed, independent on the volume of discharge, as compared to concentration-based limits and technology-based limits. Trading in the program is a cap-and-trade-like trading with a fee and rebate system. The difference in a program from the traditional cap-and-trade system is that the farmers are not allowed to trade directly. Trading only occurs among irrigation districts.

The primary role of trading in the program is to decentralize pollution control decisions from the California Regional Water Quality Board to seven locally-controlled irrigation districts to Grassland Area farmers. The program is overseen by the Bureau of Reclamation, and the Department of Interior. Accountability for the programs is a unique agreement between groups of farmers locally-organized to the districts and between the districts and the Bureau of Reclamation. The number of polluters are not identified in the program but there is a clear arrangement between each district to control its nonpoint sources. Locally organized nonpoint sources management, by districts, significantly reduces transaction costs in trading identification and negotiation processes.

The districts play two major roles involving trading in the program. The first role is as a trader between districts, since direct trading between farmers is not permitted. The second role is as a regulator to locally manage farmers within their districts to maintain selenium concentration under the cap. Each district has flexibility to implement its own methods for complying with the district selenium load allocation; which then would considerably increase pollution control efficiency. Several mechanisms are implemented to control discharge including direct incentives and mandatory requirements for farmers to suit its needs; e.g., tiered water pricing, low interest loans, recycling of drainage water and workshop.

The continued use of the drain is the greatest incentive for farmers in the programs (Young and Karkoski 2000). The program sets a strict penalty which is the cut off of use of the drain after 20% exceedence. Trade agreements are for either monthly or annual allowances with no banking allowed. The transaction costs of the trade are considered to be low, despite the bilateral negotiation implemented between the traders in the program. Under regularly schedule meetings and simple arrangements among the districts, the transaction cost is kept low since the trade negotiation can be done during a scheduled monthly meeting between the drainage districts. Also, there is no trading ratio in the program which is uncomplicated for trade amongst districts.

The sump monitoring system is a key component in the trading of this program (Young and Karkoski 2000). The monitoring system provides farmers, districts, and the advisory committee with weekly updates. The farm drainage in the Grassland Drainage Basin is collected into a series of pipes and canals and bypassed to the federal San Luis Drain to the San Joaquin River. The measurement of the selenium loading can then be accurately measured at the drainage pumps. The government agency of this program measures selenium concentration, instead of the BMPs effectiveness as in other programs. These factors increase efficiency in controlling selenium loadings.

Moreover, the unique feature contributing to the success of the program is the incentive fee and rebate system (Kerr et al. 2000). The farmers must pay a fee for any discharges above the regional selenium cap, which is based on the percentage of the fee attributed to exceed its district-level load allocation. The fee increases over time as the cap is reduced over the life span of the project. No fee is paid if the group, as a whole, remains below the regional cap. On the other hand, the rebate fee acts as a form of automatic trading between districts, and addresses inequalities of incentive fees for districts remaining below their allocation.

Since the program started in 1995, the selenium load was steadily decreased each year except for the wet year of 1998 (Kerr et al. 2000). Moreover, the trading is found to be less costly than paying for a penalty fee. Farmers have decreased selenium loading, as well as water usage, through initiatives such as increasing recirculation of drainage water, or installing more efficient irrigation equipment with low interest loans. Each farmer chooses to implement the method which is suitable for their individual farming conditions.

4.1.2 Tar-Pamlico Trading Program (NC)

In the Tar-Pamlico Trading Program, the regulators set annual mass-based caps of nutrients allowable for point sources, replacing the concentration-based monthly limits. However, the regulators did not give out the definite number of permits as absolute tradable rights. The point sources do not receive individual allocation, but instead they arrange to meet the pollution cap under a group agreement. A group cap agreement is made among 15 WWTPs (called the Association) and the state of North Carolina. The members of the Association do not directly trade their allowances but rather use an internal agreement to keep the discharge level below the collective cap. Moreover, the Association has to pay an exceedence fee if they exceed the allocated cap. The program performs like a hybrid system between a cap-and-trade-like and a tax exceedence system (Gannon 2003).

The program allows trading between PS/PS and PS/NPS. The market operates as a clearinghouse because the state agency breaks the connection between point sources and nonpoint sources and sets a uniform price for nitrogen credits. If the Association exceeds the nutrient cap, it can pay the investment for future credits to the state cost-sharing program. The credits can be banked and redeemed within 10 years. This feature provides benefits to both the members of the Association and to the government agency. As an example at the start of the program, the Association was required to make an advanced payment and received credits to use as an offset for any future exceedence load. The agency used the money to support the projects to improve water quality management including NPS's BMP, and modeling systems (NCDENR 2001).

Allocating the permit to a group of polluters deregulates the pollution control decision from the regulators to the Association. Point sources are allowed to use any treatment technology needed to meet a group cap for nitrogen and phosphorus. The Association, therefore, sets an internal agreement among the members to control nutrient level under the group cap. This is known by the member of the Association as the penalty-reserve procedure. The penalty-reserve system in the Tar-Pamlico works by keeping records of the actual nitrogen loadings of each member. The procedure is used internally by the Association to ensure that all members incorporate biological nutrient removal system (BNR) when they expand. While facilities exceed their allotted portion of the cap, they accrue penalties. The Association has not required the facilities to make a formal payment. The penalty amounts are tracked each year and held in "reserve". To offset any penalty accrued, all members must reduce loading below their cap during the next year. When the members want to increase the capacity of their operation system, they need to install biological nutrient removal (BNR). The members can then "buy back" their accrued penalties without any money ever changing hands (Kerr et al. 2000).

A clearinghouse structure set up by the state as a NPS cost-share fund helps keep transaction costs low because it reduces the cost of identifying the traders in the programs. Moreover, an internal trading agreement among the members of the Association provides each firm flexibly to adjust their pollution control level to meet their individual business needs. This system helps members of the Association save significant amounts of money while still operating under the permit without actual money being transferred (Kerr et al. 2000).

Several methods are used to help reduce administrative costs of the program. First, the monitoring system in the program is designed to be collective-to-collective trading. End-of-pipe mass loads are totaled based on effluent monitoring at all facilities. The Association has to pay a preset fee rate, if the cap is exceeded. Point sources do weekly samplings and annual reporting to the NC Department of Environmental Management. Second, the regulator inspects at least 5% of BMPs that generate NPS credits but not all of BMPs are inspected. NPS reductions are assumed based on research values regarding BMPs effectiveness. There is no in-stream monitoring next to the agricultural field (Breetz et al. 2004).

The program focuses on incremental progress by establishing goals for specific time frames of the program's Phases I, II, and III. With specific achievable goals given for each phase, relevant parties are encouraged to participate in the initiation. For example, in Phase I (1991–1994), point sources had to meet a collective and declining cap which was not considered to be very stringent. Nonpoint source participation was on a voluntary basis. Therefore, there was a lack of trading activity in this phase. In Phase II (1995–2004), the collective cap changed from declining to be a steady cap. The program also set nonpoint source reduction requirements. Phase III maintains the steady cap principle and targets 30% nutrient reduction from agricultural nonpoint source control (Breetz et al. 2004).

With trading implementation, the Association significantly reduces nutrient loading despite a steady increase in flows. It cost less than it would have if it had applied uniformed technology-based standards (Gannon 2003). The trading played significant roles in decentralizing pollution control decisions from regulators to the regulated, transferring funds from point sources to nonpoint sources and increasing the efficiency and reduction of pollution control cost. The start-up money and the internal agreement among the members of the Association were the key to the success of the program. The regulator used an advanced payment system required at the initial start of the program to reduce nonpoint source pollution. For the polluters, the trading provided the flexibility to meet the pollution limits in a cost-effective manner compared to the traditional command-and-control approach.

4.1.3 Lake Dillon Trading Program (CO)

Even though the Lake Dillon Trading Program started in 1982, no trading occurred until 1999 (Woodward 2003). The long-time absence in trading is partly due to a limited number of point sources in the program (4 WWTPs). Moreover, the strict rules imposed made trading no longer an interesting option for PSs and precluded any trading activities. In this program, the point-point sources trading and the banking of nonpoint source credits for the future use were not allowed. Even though, some upgraded point sources reduced phosphorus levels far below the cap, the program did not allow banking and trading between point sources. Only a point/nonpoint trading is allowed and the point sources are liable for all trades. Point sources are held in violation of its NPDES limits if nonpoint sources are not in compliance.

An incentive for trading credits was from the needs for business expansion of the Copper Mountain Ski Resort. The expansion was expected to lead to violation of Copper Mountain's NPDES permit, even after upgrading the plant. The demand for offset phosphorus credits for the Copper Mountain Ski Resort is the main drive for trading in this program (Woodward 2003). The structure of the program is a point source/nonpoint source type trading with a trading ratio is 2:1.

The market structure in this program is a bilateral negotiation. The bilateral negotiation may create high transaction costs for the buyers in general. However, the transaction cost in the program is not too high because the uniformity of nonpoint sources is mainly the private septic system of homeowners. This helps the point source to more easily identify the trading partners. Also, one credit of phosphorus per home connecting to the sewage pipeline of the service system has made a credit system identification and measurement easier to enforce (Woodward 2003).

The role of trading offers a firm cost-effective solution to meet the regulatory requirement. Trading allows an alternative for economic growth to occur in the area with limited assimilative capacity. With this program, the Copper Mountain Ski Resort was able to expand its business. Trading reduced the cost of water pollution management, provided a cost-saving for the company and allowed funds for a private septic system to be connected to the treatment system. Trading in this case increased efficiency of pollution control in the area as it created an incentive for owners of private septic systems to connect to a central treatment facility.

4.1.4 Rahr Malting Company Trading Project (MN)

Started in 1997, the reasons for creating the trading project were Rahr Malting Company's intention to build its own wastewater treatment plant (WWTP) to expand its production while at the same time reducing wastewater treatment costs and meeting the total minimum daily load (TMDL) established by the EPA. The Rahr Malting Company set up a mandatory trust fund, devoted to the trading project in order to achieve the required nutrient load reduction (Fang and Ester 2003). The trust fund is a unique feature of the Rahr Malting Company trading project in comparison to other water pollution trading projects, in that the permit specifies that a minimum amount of the trust fund is required to assure the financial viability of the trading project.

The trading structure is under the NPDES permit framework. The Rahr Malting Company bore the burden of identifying nonpoint source trading partners and ensuring the proper functioning of pollutant reduction measures. A bilateral negotiation is the trading communication between the Rahr Malting Company and nonpoint sources to offset the CBOD reduction credits so that the company can construct a new water treatment plant. The program sets cross-pollution trading ratios to allow trading between different pollutants (phosphorus and nitrogen) for CBODs credits, 1:8 (phosphorus: CBOD) and 1:4 (nitrogen: CBOD). The program also applied a 2:1 ratio to account for the uncertainty of point/nonpoint source trading (Breetz et al. 2004).

The role of trading in this program is to allow the company to save more money by operating its newly-owned treatment plant. There was no waste load allocation available for the proposed new discharge of 150 lb of CBOD in the watershed area. Also even the best available technology proposed could not achieve zero discharge. The regulators use trading as a mechanism to maintain pollution level in the area, by requiring an offset from a new source to allow for construction of a new treatment plant to achieve cost-effective pollution control. However, as compared to that in a cap-and-trade program, the offset trading scheme does not have any mechanisms which could create incentives or regulatory requirements for PSs and NPSs to further reduce pollution in the long term.

4.1.5 Long Island Sound Nitrogen Trading Program (CT)

The main driver for trading in this program is the establishment of a total maximum daily load (TMDL). The TMDL requires the state of Connecticut

(CT) and New York (NY), by 2014, to attain a 58.5% collective reduction of nitrogen loads from all sources from an established baseline (NCAB 2003).

The success of the Long Island Sound Nitrogen Trading Program comes from the development and passage of Public Act 01-180, codified in the Connecticut General Statutes in Section 22a-521 through 527 (CTDEP 2003). The statute established a Nitrogen Credit Exchange (NCE) overseen by a Nitrogen Credit Advisory Board (NAB), and authorized issuance of a Nitrogen General Permit (NGP). The NCE, the NAB and the NGP collectively are the foundation of the success of the trading program (CGA 2001).

The General Permit forms the backbone of the trading program by setting all sewage treatment plants under a single permit (Breetz et al. 2004). There are 79 wastewater treatment plants participating in the General Permit. The treatment plants are major sources of nitrogen loading in the Long Island Sound and a 64% reduction goal was set for sewage treatment plants in CT. The General Permit replaced the need for separate and complex permits for each individual treatment plant for nitrogen requirements. Since the majority of pollution is from point sources, the program therefore does not rely on NPS reduction. The TMDL only sets a 10% nonpoint source reduction goal. This is a unique characteristic of the program.

General Permits set annual nitrogen limits for each WWTP below its TMDL waste load allocation to ensure TMDL compliance (Breetz et al. 2004). The system generates significant demands for trading because the limit is decreasing every year. Facilities that discharge lesser total nitrogen than their permits allow receive nitrogen reduction credits. The facilities having advanced technology can generate credits from an excess of pollution reduction. The credits are bought and sold through the NCE each year.

Unlike other water trading programs, the structure of the program is cap-and-trade. The total amount of pollution is capped. The permit is allocated to the polluters, proportional to their discharges. The reduction cap is reduced until the final goals are achieved. Under this permit, facilities can purchase or sell nitrogen credits annually based on each facility's performance with respect to their annual limit. The market structure of trading in this program is a clearinghouse where buyers and sellers trade all excess credit generated through the Nitrogen Credit Exchange (NCE) program run by the Nation Credit Advisory Board (NCAB).

The NCAB sets up an equivalency factor to account for the location of the treatment plants and their varied impact on the hypotoxic zone. The state also reserves the right to revoke or modify a point source authorization under the General Permit for reasons necessary to protect human health and the environment (CGA 2001).

The NCE facilitates trading and helps reduce transaction costs. Since the NCE will buy all the excess credits generated, this helps to ensure future decision making for the firms. The General Permit can reduce administrative costs since any additional application process involved in trading is not required in addition to the procedures under the General Permit. The role of nitrogen trading in this program is identified as a cost-effective mechanism to reach an aggregate goal for wastewater treatment plants in CT.

In this program, the treatment plants may need to upgrade in the future in order to meet the steady decreasing cap. The Clean Water Fund – funding for an upgrade of nitrogen removal construction – is necessary for certain water treatment plants. Therefore, trading allows more flexibility and efficient use of the Fund.

4.1.6 Passaic Valley Sewerage Commissioners (PVSC) Pretreatment Trading Project (NJ)

This project is one of the pretreatment trading programs that have an active trade. It is one of the few programs that use trading to lower levels of heavy metals (Cadmium, Copper, Lead, Mercury, Nickel, and Zinc) to meet an excepted quality of sludge. The trading framework is not related to TMDL. The unique driver is from the need for public-owned treatment work (POTW) to be able to meet sludge requirements. PVSC sets a pretreatment local limit for its indirect dischargers to achieve an exceptional quality of sludge. The PVSC established metals limits for its industrial users, tighter than technology-based standards, in order to improve the quality of the POTW sludge (USEPA 1998c).

A market structure is a bilateral negotiation among indirect dischargers that send wastes to the same POTW. There is no nonpoint sources involved in the trading. The program is credit-type trading where the POTW approves the trades and adjusts the permit limits of the trading partners. The trading ratio of 5:4 is to make sure that the trade will help improve water quality as 20% of credits from each trade will be retired. One partner will not be penalized if the other partner violates the permit level set under the trade (USEPA 1998c).

The role of trading in this program is to provide flexibility for the indirect dischargers to reduce the aggregate amount of pollution at the POTW in a cost-effective manner. Limited numbers of trading occurred in the program. The POTW should require more stringent standards or expensive fees, so that indirect dischargers will be forced to find cheaper alternatives to improve water quality, either by an upgrade or by trading. Moreover, the POTW could distribute discharge information to facilitate trading and reduce transaction costs.

4.1.7 The Truckee River Water Quality Settlement Agreement and Truckee Meadows Wastewater Reclamation Facility Permit (NV)

A TMDL in the Truckee River is a regulatory driver for the trading program. The TMDL is in place for total nitrogen, total dissolved solids and dissolved phosphorus in order to control dissolved oxygen in the Truckee River. The Reno-Sparks Joint Wastewater Treatment Facility (Truckee Meadows Water Reclamation Facility, TMWRF) sought to increase its discharge to the River. The municipalities had to develop a creative solution to both expand the plant and comply with the TMDL. Three possibilities of water quality trading are being explored to authorize increased discharge at the TMWRF: water rights purchases and flow augmentation, point/nonpoint sources trading for agricultural best management practices and septic conversions, and point/point trading with two other wastewater treatment plants (Breetz et al. 2004).

The program is the first and only program involved in water right trading. A water rights agreement that involves some elements of pollutant trading allows the treatment facility to increase its discharge while still assuring attainment of water quality standards during the dry (low flow) season. The local communities and the federal government are sharing the costs of purchasing upstream water rights. The purchases will both: (1) reduce nonpoint nutrient loads by precluding the use of the water for agricultural purposes; and (2) mitigate the impact of increased POTW loading by increasing the river's flow during the dry season (Breetz et al. 2004).

The Truckee River is the only program that allows trading water rights for the purpose of improving water quality. The role of trading in the program is a mechanism which allows the polluter to meet the TMDL cost-effectively when there is no better option. Given the low river flows in the Truckee River and the difficulty of increased treatment, it recognized that flow augmentation provided the greatest and most cost effective benefits. Even though, trading water rights is likely to be a dilution of pollution which is in fact not a preferred solution.

By May 2004, 33 water rights contracts, comprising 4,197 acre feet of water, were signed. The trading program is the foundation for acquiring water rights on a larger scale. It is, however, still under observation as to whether or not increased flow will lead to a revised TMDL and higher WLA (Breetz et al. 2004).

The water rights in this program are purchased through brokers. Water right trading does not fit any category of types of trades; however a point/nonpoint trade may be the most fitting category (Podar 1999). Trading is not an offset or a direct trading as the facility will not receive a higher wasteload allocation in exchange for increasing instream flow. There is no trading ratio use. Explicit trading ratios were not calculated, since the offset is not as straightforward as allowing an additional amount of discharge for each unit of additional flow in the water. The amount of water rights to be purchased is expected to offset the effects of increased loadings from the treatment plant. TMWRF will face the same WLA until the additional flow leads to a revised TMDL as the TMDL sets nitrogen, phosphorus, and TDS limits by mass – not by concentration. The higher flows will increase assimilative capacity and thus enable the river to carry a higher nutrient load, which would then lead to an increased TMDL and wasteload allocation (Breetz et al. 2004).

The structure of point/point trading and point/nonpoint trading in the program is a bilateral negotiation. These two kinds of trading have less potential for trading than that of purchasing water rights. In point/point trading, only two other wastewater treatment plants are potential traders. Moreover, they also face stringent requirements and will not be able to reduce nitrogen loading enough to trade. In addition, point/nonpoint trades are more promising but the trading rules are still under development (Breetz et al. 2004).

4.1.8 Chesapeake Bay Nutrient Trading Program (VA, MD, PA and Washington DC)

The Chesapeake Bay Program has developed voluntary nutrient trading guidelines for its member jurisdictions (VA, MD, PA and Washington DC). The Chesapeake Bay Program set Bay-wide collective nutrient caps in 2000 and state and basin allocations in 2003, and at that time each state agreed to establish Tributary Strategies to meet their goals (Chesapeake Bay Program 2001). The role of trading in this program is to have the option of implementing a cost-effective method to achieve nutrient reduction goals and tributary strategy before implementing the TMDL solution if the goals are not met by 2010.

The guidelines are voluntary and each jurisdiction is responsible for determining an individual trading policy, establishing a mechanism for certifying and registering credits, creating a central coordinating office for tracking trades, and developing a system of monitoring and evaluating performance. Interstate trading within a single watershed may become a possibility in the future, but trading will likely proceed within each state first (Chesapeake Bay Program 2001).

The guidelines outline potential trading between both point/point sources and point/nonpoint sources. Point sources will be responsible for self-monitoring and reporting on a monthly basis, while nonpoint sources must monitor on a seasonal basis. Nonpoint sources monitoring should include an annual on-site inspection to ensure that BMPs are functioning properly (Chesapeake Bay Program 2001).

Under the self-monitoring mechanism, there may be a reduction in administrative costs.

The market structure may be bilateral or clearinghouse; however, it is not finalized. The guidelines state that the buyer should ultimately be responsible for complying with its permit and ensuring that adequate credits are delivered. Depending on the contract, a seller may be required to pay penalties, return the money obtained from trading, or lose state certification for trades if credits are not delivered as committed. Therefore, with a clearinghouse, it will be more suitable and large enough to pool credits for liability (Breetz et al. 2004).

Eligibility for trading will be defined by individual state rules, and therefore it is not possible to conclusively state the number of potential trading parties. However, one of the mechanisms for trade identification and communication – an online trading registry – developed by the World Resource Institute is called NutrientNet. This website provides information about availability and demands for credits which could help to reduce transaction costs from trading.

It is a big challenge to develop bay-wide trading guidance in order to balance the interests of such a diverse set of stakeholders. No trades have occurred in the Chesapeake Bay, nor have any Bay-states developed state-wide trading regulations. Maryland considered developing state rules; however, recent legislation requiring POTWs to apply limits of technology standards may undermine the economic incentives for trading. Pennsylvania established a pilot trading program for the Conestoga River (Breetz et al. 2004).

4.2 Important Barriers Hindering the Role of Trading

Roles of trading in water quality management are not fully utilized due to barriers related to regulation, nature of water pollution and economic issues. Understanding these obstacles are very important parts for identifying roles of trading which will lead to future improvement of the functions and success of the trading program. The barriers or factors that hinder the success of water quality trading are described below.

4.2.1 Regulatory Related Barriers

4.2.1.1 *A Lack of Optimal Drivers from the Regulators*

Regulatory requirements generate demands for credits which then drive trading functions. TMDL set a realistic and enforceable framework for trading because it takes account of all potential polluters the ability to be able to protect water quality with a margin of safety and with a detailed implementation plan. The trading mechanism very much depends on actual TMDL implementation plans requiring load reductions and BMPs. Currently, many states do not establish a TMDL because of lack of funding. Setting up a TMDL is a costly and time consuming process. However, with no TMDL, a nonconcrete framework for trading is created. The delay associated with the establishment of TMDL is a definite obstacle for trading programs.

It is very challenging for regulators to set an optimal level of pollution reduction goal to generate trading because if the reduction permit is too loose or too stringent, it could discourage trading. The environmental group makes comments about caps in that they are usually set too loose in many trading programs, even in programs where trading has occurred. The initial allocation can also cause a lack of trade. As in Cherry Creek (CO), the initial allocations were very generous. Therefore, sources can easily meet limits without trading. On the other hand, with too stringent reduction goals, it can result in pressuring the firm to upgrade their treatment facility rather than trade since an upgrading POTW operation system could significantly reduce the operating costs and discharge concentration despite high capital costs. Many cases, including Chatfield Reservoir (CO), Tar-Pamlico Basin (NC), Neuse River Basin (NC) and Lake Dillon (CO), are in question regarding the stringency of pollution limit causing a lack of trade.

Only when proper regulatory requirements are set up by the regulators, an additional increase in trading activity will happen and participants will then be more willing to get involved with the trades. The initiatives and programs set by governmental agencies are sometimes counter-productive for incentives to trade. For example, the farmers in the Minnesota Watershed Trading are reluctant to participate in trading programs because there are no significant differences between traditional cost-share programs and trading payments. The farmers are unwilling to make voluntary changes that may later become mandatory and as a result become targeted as polluters. This was found to be a major obstacle in the Minnesota Watershed Trading.

Other water quality management initiatives can also make trading unnecessary and/or easier to meet limits without trading; for example, in the Grassland Area Farmers Tradable Loads Program, CA. Even though several trades were planned, there has not been done one since 2000 because of one drainage district that implemented a drainage recycling project which sufficiently reduced the regional selenium loading to the point where there was no need for trading (Breetz et al. 2004). Another example is Lake Dillon (CO) where methods are available to inexpensively reduce phosphorus without the need for trading between point sources.

4.2.1.2 *A Lack of Central Facilitation to Support Traders*

Lowering expenses of trading are a major incentive to participate in trading. In order to create incentives for trade, either the costs have to be lower than other mechanisms or there has to be some sort of reward from trading to create incentives to trade. What happened in most cases is that overhead costs related to trading were higher than benefits to the firms; for example, costs associated with identifying buyers and sellers. Also, the uncertainty about trading approval from the regulators sometimes makes an overhead cost difficult to justify. In many programs, there are no central facilities to assist trading; e.g., a clearinghouse can significantly help facilitate trading.

Without a central facilitation to guarantee eligibility of credits generated is rewarded, or to provide information about potential buyers, polluters are thus discouraged to spend efforts to generate extra credits for trading, especially those who may have limited funding and knowledge about trading. For example, NPSs are often not able to neither invest in future sales nor have the ability to look for buyers to sell their credits. This uncertainty limits their motives to engage in nonpoint source projects.

A good example of a central system is NutrientNet, an online-trading registry that provides a simple way for buyers and sellers to connect (Faeth 2000). NutrientNet makes trading relatively easy for both point sources and nonpoint sources to estimate their remediation costs using standard, consistent methods, and to make the records of trade readily accessible. NutrientNet has been developed for two watersheds: the Kalamazoo watershed (in Michigan) and the Potomac watershed (in Maryland, Virginia, West Virginia, Pennsylvania and District of Columbia).

A few programs actually create a reward system whereby polluters who could treat pollution below the requirement would receive cash or rebates. For example, the Grassland Area Farmers trading program has the fee-rebate system which encourages polluters to reduce pollution based on their actual ability. They have to either pay a fee if their pollution exceeds the limits, or they would receive a rebate from the program if their pollution is below their limits. This system creates an incentive to gain benefits without additional costs associated with finding sources that need to purchase credits. Another example of central facilitation supporting trading activity is the Long Island program where regulators guarantee to buy all the credits generated even if there are no demands for credits. In this program, the regulators spend federal funds to buy extra credits and ensure that participants can at least partly recover the overhead costs associated with the actual set up.

4.2.1.3 *Uncertainty and Disincentives Associated with Trading Rules*

Many trading programs are not able to reach a consensus for establishing trading guidelines because too many parties are involved in the programs. These guidelines would include; for example, the standard credit estimation methods, credibility of nonpoint source load reduction and liability after trading. The lack of definitive trading guidelines creates reluctance, misperception, and hesitation for point sources trading and for other participants to join the trades.

Trading rules can sometimes be major barriers limiting the trading activities; for example, in the Lake Dillon Program. The Lake Dillon program prohibits point sources from trading surplus pollution allowances; and has no provisions that allow banking of nonpoint source credits for future sale. Together the strict features diminish the incentives for point sources to further decrease phosphorus beyond the level that the regulatory requires. The regulators in the program believe that the right to pollute is not a commodity that can be freely traded between polluters. If a source needs to increase its discharge, it must compensate the public (in this case through nonpoint source reductions) rather than compensate other sources (Woodward 2003). This particular point of view of the regulators inhibits the potential trading activity among point sources.

The credit denomination creates an inconvenient status for trading. The majority of trading programs are a credit trading system where the permit is not set up as units of pollutants which can be directly traded as in a cap-and-trade type program. As a result, credit trading system requires long approval processes which would make a trading process slower and drive up transaction costs. For example, trading under the current NPDES permit, without central facilitation from the governmental agency, indirectly forces the firms to negotiate bilaterally. This increases the transaction costs and creates an inconvenience and uncertainty for trading as it is unclear whether or not the regulator will approve the trading.

The other most common barrier found in many trading programs is the lack of clear legal rules and enforcement. Complication arises from the controversy surrounding potential changes in standards and the trading rule liability which leads to limited incentives for participating in trading; e.g. some are concerned about anti-backsliding requirements which will not allow an existing permit to be modified or reissued with lesser stringent effluent limitations, standards, or conditions than those already imposed.

Currently, point sources face more stringent requirements than nonpoint sources. Nonpoint sources controls are still voluntary. More and more pressure is being put on point sources which can lead to upgrade their system rather than buy credits due to uncertainty of a future regulation. Moreover, the USEPA still requires technology-based standards be developed on an industry-by-industry basis and does not allow categorical pretreatment loading allowance to be traded. This creates no incentive for pretreatment trading between indirect dischargers because the federal categorical limit is more stringent than local limits. This barrier resulted in a lack of trading in the Illinois Pretreatment Trading Program, IL, for example.

4.2.2 Economic Related Barriers

4.2.2.1 *Problem with High Transaction Costs*

Transaction costs and administrative costs can preclude trading if they are too high. It is therefore essential to keep the costs low by providing an easy means for market participants to find each other and to identify what they have to sell or need to buy. Many trading programs face higher transaction costs related to trader identification (e.g., to reach farmers is a difficult task requiring intensive effort which thus leads to a higher cost) and trading approval process (e.g. the Cherry Creek Program requires $2,500 for application fee). This problem can be linked to insufficient information and means of communication provided by the government.

4.2.2.2 *Information Related to Trading*

Available information related to trading is sometimes difficult to obtain and can also become costly. This is partly due to businesses not wanting to share much of their information. This needed information is important for firms to decide whether or not to trade. The absence of trading may be attributable to a lack of distribution of related information. For example, it is sometimes difficult to obtain favorable pricing for small quantity trades because overhead costs for retrieving the information can be significant. Moreover, cost of pollution treatment is different across different areas, industries, and size of the treatment plant which makes it harder to justify a suitable price. Moreover, the uncertainty related to nonpoint sources credits monitoring and estimation, associated with the cost of reduction depending on types of BMPs, significantly increases the cost of obtaining reliable information needed for trading.

An example of unavailable information of trade resulting in limited trade is the Passaic Valley Commission Pretreatment Trading Program, NJ. The program's staff reported that examining discharge monitoring data from a publicly owned treatment work (POTW) is a time-intensive process. It is found to be a significant barrier for potential traders in pursuing trading options. The suggested solution to this problem is that since the POTW is more familiar with compliance history of many facilities, the POTW could play the role in identifying potential buyers and sellers. The POTW can then actively promote the availability of trading and help buyers and sellers to more readily identify themselves.

A potential solution is to assume a more active role in brokering or promoting trade by the governmental agency. For example, in the Long Island Program, a government agency set up a clearinghouse as a trading market. Price of credits was set and publicly announced so that firms could obtain information about selling and buying credit in order to decide whether or not trading would be a less expensive alternative. A clearinghouse system can solve problems related to uncertainties of price negotiation, lack of information about trading and transaction costs.

4.2.2.3 *Lack of Funding*

Funding available from the State can affect trading activity. Because a project development is expensive and resource-intensive, many programs are delayed due to deficient funding and insufficient staffing to run the program. For example, in Blue Plain WWTP, VA, point source was looking for trading as a temporary alternative while waiting for State Funding to upgrade their system. The state no longer made funding available; and thus, the trading program has not yet developed.

In the Long Island Sound Program, the point sources are looking for trading as a temporary alternative while they wait to receive federal support for upgrading their system. Continued funding from the Clean Water Fund to support the infrastructure upgrade of nitrogen removal is important for the progress of the program. Upgrades to municipal treatment plants require stable, multi-year funding. As noted in a report by NCAB in September 2003, the projected demand for the Clean Water Fund to support construction projects was more than the amount projected to be available (NCAB 2003).

One of the major drivers for water trading comes from economic needs of expansion of the business. Therefore, business hardship or change of business operation is found to cause lack of trades. For example, in the Henry County Public Service Authority/City of Martinsville, VA, the textile plant that contributed 95% of total waste to the river went out of business thus making trading no longer necessary. Puyallup River, WA, is another example of absence of business demand which caused a lack of trading activities. Originally, there was a plan to modify permits for two PSs to allow for trading of BOD, but no trading occurred due to changing economic needs of the PSs.

4.2.3 Technical and Environmental Related Barriers

4.2.3.1 *Characteristics of Watersheds and Polluters*

Size of trading programs or areas covered by the programs sometimes can preclude trading. There may be few or not any potential trading partners within a small hydro-geographical area due to a limited number of sources in each water body. However, lack of trade did not always result in a small-sized trading program. Within a very large area, the cost of finding partners may outweigh the benefits gained from trading. This has happened to many large-sized trading programs where no trading occurred; for example, the Minnesota River Nutrient Trading program.

Lack of diversity among pollution sources can also become a trading barrier as evidenced with the first trading program in Fox River. Majority of point sources in the program are doing a similar type of business (paper industry). They already compete in business; and as a result, they have no incentive to share information about their operation nor are they motivated to help other companies.

However, diversity between point sources and nonpoint sources may be less important if the majority of the sources are participating in the trading. For example, in the Long Island Trading Program, the program is successful in a number of trades because 79 WWTPs, which are major polluters in the watershed, participate in the program. All of the point sources are controlled under the same cap. Another example is the Grassland Area Farmers Tradable Load Program. Even though the majority of the polluters are agricultural nonpoint sources, all sources are identified and controlled by the irrigation districts. Trading occurred among districts and was successful in helping to lower levels of pollution in the area. These examples demonstrate that the success of trading was primarily due to the majority of polluters who are participating in the program under proper implementation.

Recently, statewide trading policies were implemented in many states. These policies are expected to help increase the potential for trading. It would be more beneficial if trading within different watersheds were allowed; however, only trading within the same watershed will be allowed. It is difficult to access the success of the statewide policies as most of the states are still in the development stage and some are only conducting pilot studies.

4.2.3.2 *Difficulty with Monitoring*

Setting up reliable means for estimating and monitoring credits from nonpoint sources is difficult especially in keeping it at a lower cost. Therefore, processes of verifying credits usually increase the cost of trading. In addition, there is a complicated issue of defining the appropriate and accurate trading ratios, especially in cross-parameter trading. For example, where some of the BMPs – particularly the fencing and tree planting – were not initially successful; estimating credits became difficult to assess. More consistent and accurate mechanisms documenting reductions from BMPs are needed before trading for agricultural nonpoint sources can significantly expand.

An example of a potentially good solution for the problems of an estimation method can be found in the Lake Dillon program. The program set up an indirect measurement for credits by establishing a simplified credit calculation method whereby one homeowner connected to a sewage pipeline is accounted for as one credit. Another example of a good solution of nonpoint source estimation method is the Grassland Area Farmers Tradable Load Program. In this program, the staff measures selenium concentration in the water collected from each farm, instead of measuring BMPs effectiveness. This mechanism increases accuracy and eliminates the uncertainty related to NPS credit measurement.

4.2.3.3 *Uncertainty of Fate and Transport for Water Quality Improvement*

One barrier which may put a constraint on trading and limit the potential for trading is that most trading programs do not allow downstream trading due to the accumulative nature of water pollutants. Most trading programs only allow upstream trading where the sellers are located upstream of the buyers. However, the conditions of trading should be based on other factors rather than just on upstream trading alone; i.e. whether the trading occurred in target areas, near regions where there were water quality problems already in existence or not. If not, perhaps downstream trading should be allowed if this would provide cost savings to both parties and where the effect on the environment would be minimal. A solution to the problem may be for the program to set a trading ratio with a multiplying factor depending on conditions of water and locations of sources to prevent the hot spot problems, as implemented in the Red Cedar River Nutrient

Trading Pilot Program and the Lower Boise River Effluent Trading Demonstration Project.

4.3 Generic Roles of Water Quality Trading

The previous section presented the analysis of specific roles of water quality trading and barriers hindering the trading roles within several water trading programs. Each successful trading program had a clear focus for creating and implementing trades. This following section will focus on the common roles of water quality trading. Roles of water quality trading can serve as a guideline for initiating or implementing a trading program. Trading in the US can be described in five major roles which are as follows:

(1) Putting the focus of pollution control back to the overall water quality rather than on controlling technology

Trading plays a major role in decentralizing pollution control decisions from the federal to a local regulator, or to the polluters. Trading shifts the water pollution control focus away from traditional technology-based standards and gears it towards water quality standards. The regulators focus on whether the water quality goal is met. The polluters can then use any technology and can also trade with others as long as they stay under the limit of their discharge permit. Instead of focusing on the use of specific technology to control the pollution, the emphasis is on adapting the water quality standards to manage the pollution. This allows regulators to improve the performance of the overall outcome of water quality without forcing the polluters to use a specific technology. The firms then reap benefits in terms of flexibility to use any technology suitable for their company situation and also from meeting specific requirements from the government.

The regulators set the water quality goal and make decisions on the amount of pollution allowed in certain areas. The pollution allowances will be allocated to the authorities; e.g., districts or polluters in those areas will decide on how to control the pollution based on their individual performance. There are several examples that implement this strategy including the Long Island Sound program, the Tar-Pamlico Program, and the Grassland Area Farmers program. Details of implementation of each program can be slightly different but the major goal of each is to adapt the water quality goals (absolute total amount of pollution capped) as a new gauge.

(2) Setting the rules to facilitate independent pollution control decision (trading among participants)

In pollution control regulation, regulators set a specific requirement to control polluters and to protect the environment. Similar to the command-and-control type policy, trading mechanisms require specific rules set by the regulators as a driving tool to control water quality efficiently. Setting appropriate trading structures and rules are important because different program structures (i.e. cap-and-trade or credit trading) and different implementations (i.e. market structure, trading ratio, etc.) can achieve different levels of success. Unlike the command-and-control, trading mechanisms do not set the requirements regarding the use of specific treatment technology; instead it allows participants to reach the pollution goals via trading with others. The ultimate role of the regulator will be to set up and enforce trading rules and the maximum amount of pollution allowed, and monitor the performance of the system. On a short term, regulators can act as an intermediate agency to help promote water quality trading and help reduce costs associated with trading in the early stages of the program.

A good example of regulators setting the rules to help facilitate trades is the Long Island Sound Trading Program. The regulators set the General Permit, a framework for trading, according to the total amount of nitrogen allowed, and allocate permits to point sources in proportion to their discharge levels. The pollution control decision is then up to the polluters to meet the requirements by buying or selling credit based on their performance. The regulators facilitate the trading by setting up a nutrient exchange market for polluters to buy and sell their credits. Another example is the Tar-Pamlico program. The regulator delegates a group permit to a group of point sources without getting involved in their pollution control decision as long as they meet the permit requirement. Also, in the Grassland Area Farmers Program, the state of CA allocates the pollution permits for irrigation districts. Each district implements their own strategies to locally manage the selenium suitable for the farmers in their immediate areas.

(3) Reducing overall operating costs of water quality control

Trading is used as a mechanism to reduce the aggregate cost of a pollution control policy. In the program where the aggregate level of pollution can be capped, the regulator only needs to adjust the amount of pollutant allowed to improve water quality. With this mechanism, the regulator can then effectively spend more money for monitoring and enforcing the rules to meet water quality goals instead of having to revise ineffective technology-based standards. Trading can eliminate problems related to setting up technology-based standards for different types of sources. The problem with asymmetric information would be eliminated as the government will have adequate information to set up water quality goals. Focusing on water quality standards can also help facilitate a water quality trading program which would place the effort on managing and controlling the actual amount of pollution, rather than being on the technology required to be used in the treatment.

Trading stimulates incentive for the polluters to reduce the cost of pollution abatement. The Lake Dillon, the Tar-Pamlico, and the Long Island Sound trading programs meet stringent water quality standards and have demonstrated cost-savings via trading. Moreover, trading can serve as an indirect source of funding for nonpoint source management. For example, in the Tar-Pamlico, the program regulators required advanced payment to start up a trading program and then used that money for nonpoint source pollution treatment funding and other purposes related to water quality improvement.

Offset is an alternative for point sources to expand new or existing business facilities to meet the regulatory requirement. Without trading, the point sources would have to pay more to meet the regulatory requirements or they would not be allowed to expand. The Rahr Malting Co. is a good example of how trading helps the company to save a lot of money. Moreover, Rahr Malting Co. exceeded its goal of offsetting 150 lbs of CBOD per day and BMP implementation was ahead of schedule.

(4) Promoting or increasing efficiency of water pollution management

Trading, in general, can increase efficiency of pollution control and resource usages, as shown in the Grassland Area Farmers and in the Tar-Pamlico Program, where the pollution level is steadily decreasing while the amount of discharges increase in these programs. Because polluters focus more on pollution control planning with greater flexibility for trading, they can also implement a long-term plan that best suits them economically while still keeping the pollution under the limit.

Trading allows flexibility in business planning to buy or sell credits instead of upgrading facilities when they are not ready or cost-effective to do so. For example, in the Tar-Pamlico, trading creates a flexible system for meeting limits with least-cost incurred according to each individual's plan with penalty-reserve system being implemented among members of the Association. In the Grassland Area Farmer, the farmers decide how they will control selenium to meet the limit.

In the Long Island Sound Program, point sources can buy and sell credits via a clearinghouse which guarantees they will cost-effectively achieve the requirements.

Moreover, regulators should allow trading as an alternate mechanism to manage pollution reduction in the area where assimilative capacity of the watershed is limited but economic growth is necessary. All of the offset-type trading programs are good examples of this role for trading. The Lake Dillon program is a good example where trading helped the firm to meet the need of business expansion cost-effectively. The firm generated offset credits by connecting the homeowner's private septic system (major nonpoint sources) to the treatment system. This also reduced the nonpoint source pollution in the area by increasing the efficiency of the household treatment.

In the future, trading can be the mechanism for collaborating and negotiating the responsibility of pollution control at the local level (negotiation process: case-by-case e.g. offset, credit trading) and multi-state level (co-operation between states or districts) for a statewide trading policy. Instead of having more regulators with slightly different set-ups, it may be more efficient and cost-effective to use a single regulator/agency to manage the pollution market to achieve the same water quality goal throughout multiple states. In addition, expansion of the market size could also lead to more profits from trading.

(5) Distribute equity on pollution abatement between diverse groups of polluters

Currently point sources and nonpoint sources face different level of regulatory requirements to control water pollution. Nonpoint sources in many regions significantly contribute to the water quality problem however the regulatory control is less stringent or sometimes only on a voluntary basis. Part of the reasons for an inability to effectively control NPSs is because of the difficulty in identifying the NPS sources and obtaining information about their operation and treatment.

Trading programs can slowly increase fairness of pollution control responsibility among point sources and nonpoint sources. Trading may help distribute equity among sources which means sources that can reduce pollution with less expensive cost should reduce more pollution; i.e. NPSs can generate reduction credits at lower cost than PSs. NPSs are encouraged to generate more reduction and sell reduction credit to PSs. Trading between point sources and nonpoint sources can provide significant benefits to all of them. The Tar-Pamlico Trading Program is a good example of a trading program that increases the reduction requirements from nonpoint sources. In this program, trading gradually created an equitable distribution of pollution abatement between point sources and nonpoint sources. In Phase III of the Tar-Pamlico program, the regulators increased the reduction goal from nonpoint sources by 30%.

Chapter 5
CONCLUSION

Introduction

This chapter explains a general conclusion drawn from experience gained as a result of researching trading programs in the US; and provides an overview of the current conditions of the trading programs (based on information from the databases and literature reviews). Factors affecting the WQT program's success and principles for designing WQT programs and suggested approaches for developing a trading program framework for WQT program implementation are described as well.

Water pollution control is complicated due to the nature of water pollution and its inability to address water quality in many dimensions. There are two major mechanisms in place to control water pollution: (1) command-and-control and (2) market-based mechanism. Traditionally, a command-and-control approach sets technology-based and uniform-performance-based standards for regulating identifiable sources of water pollution. The command-and-control effluent standards have been largely ineffective for achieving additional pollution control (particularly controlling NPS pollution). A market-based approach, however, when appropriately applied, can be more cost-effective than a command-and-control approach and can also guarantee environmental improvements.

Water pollution trading policy aims to tighten the gap of the abatement costs between point sources and nonpoint sources. Water pollution trading is expected to generate cost-effectiveness in controlling pollution from point sources and nonpoint sources as compared to the command-and-control regulation. The tradable permit system is required for decentralized water quality management. In this permit system, the regulator establishes a cap on total releases from a defined set of sources, while still allowing for flexibility to meet the cap by means of trading permits within a market. The desire for trading arises from significant differences in pollution control costs across various sources of water pollution.

Even though the command-and-control system was the easiest and least expensive approach to achieve point source reductions, the costs of water pollution control significantly increased when water quality standards were strengthened.

Moreover, nonpoint source pollution, which is becoming a significant water pollution source, is hardly controlled by traditional regulation. Trading, on the other hand, creates opportunities for those with more expensive control (i.e. point sources) to pay those with inexpensive controls (i.e. nonpoint sources) in order to reduce overall pollution. Whereas, the command-and-control technology-based standards do not accommodate potential cost savings that result from differences in incremental costs for operating controls of one source *versus* another, or even within the same plant. The tradable permit system can also generate a strong incentive to innovate, as better pollution control translates into salable credits. In the command-and-control approach there is a lack of flexibility and incentive for discovering and implementing superior water pollution control strategies.

5.1 What Distinguishes the Success of One WQT Program versus Another?

Indications of success for any pollution trading market are signified by both environmental quality improvement and economic achievement. Success in water quality trading programs could be determined as a result of either an improvement in water quality at lower cost, or as an increase in regulatory compliance flexibility in pollution control to achieve environmental goals faster than the traditional command-and-control approach.

WQT programs in the US are predominantly lacking in active trades or have a limited number of transactions. Therefore, the WQT programs with active trading activities may be considered successful for having implemented a trading policy. However, not all activities with money transactions are an indication of a successful trading program. Any economic and environmental improvement from the traditional command-and-control approach could be considered an accomplishment of the trading policy.

For example, as compared to command-and-control approach, water pollution trading provides flexibility of compliance in order to meet regulatory standards. Such as to shift its discharge obligations to another party or to have ability to determine how to limit its own discharge (Stephenson et al. 1999). The common use of trading is to offset pollution; particularly in a watershed area where there is limited assimilative capacity. Point sources allow buying a way out of tighter pollution reduction requirements by purchasing lower cost credits from other point sources and/or nonpoint sources. Another example is where the regulators allow a group of polluters to internally manage the group members in order to work out the best pollution control strategies to meet pollution reduction requirements with a minimum level of involvement from the regulatory agency. The internal agreement may not involve an actual money transaction but would instead allow the group to achieve a pollution reduction goal at a relatively lower cost.

5.2 How Well Do the WQT Programs within the US Perform?

There are approximately 47 effluent trading programs in operation and in developmental stages within the United States today (Morgan and Wolverton 2005). A large number of water quality trading programs implemented within the US can be divided into nineteen ongoing trading programs, eight offset agreements, and twenty various proposals and small projects in development stages under feasibility studies (more detailed information is found in Chapter 3). The majority of water quality trading programs currently implemented within the US are not typical forms of trading where buyers and sellers independently and directly negotiate their transactions without a third party becoming involved, i.e. regulator-approval trades. A water quality trading market is a combination between a regulatory-directed pollution control decision and the flexibility of shifting its discharge reduction obligations to another party.

Among all of the WQT programs, nutrients (phosphorus in particular) are the most commonly traded pollutants, followed by nitrogen (Morgan and Wolverton 2005). On a regular basis, only the same type of pollutant is allowed to be traded within a single program. Rarely, is there cross-trading between different pollutants. The most common type of trading occurs between point sources and nonpoint sources (Morgan and Wolverton 2005). The offset agreement undertaken by point sources to reduce nonpoint source pollution is the most common form in the WQT programs and only occurs when the need for business expansion exists in a watershed with limited assimilative capacity to defer plant upgrade.

The most predominant structure of trading is a credit trading program. However, a few water quality trading programs within the U.S are implemented as a cap-and-trade program; for example the Long Island Sound Program and the Grassland Area Farmers Trading Program. There are 6 states and regions that are developing a statewide trading policy but trades will only be allowed within the same watershed (Morgan and Wolverton 2005).

There are several reasons why the credit trading program is the predominant choice for implementation. First, development of a cap-and-trade system requires an estimation of the total amount of pollution; i.e. mainly a TMDL or a similar technical assessment. This is costly and it takes a great amount of time to set up a TMDL. Second, regulators have a chance to approve the trading in a formal review process to ensure water quality improvement. Third, it is easier for the regulators to set up and/or transform from the traditional system to the credit trading system (as compared to a cap-and-trade system), because less information is needed at the initial development stage of the program. The grandfathering method is predominantly used to allocate permits to polluters in the WQT program. Legal liability and penalties are determined under the NPDES permits. Point sources are mainly held responsible for obtaining and verifying nonpoint source credits unless otherwise specified in an individual contract.

Market structure, size of watershed, and number and characteristics of participants in the programs all combined together affect trading activity. However, the relationship of the success of each factor is random and unclear. Two types of market structures used in WQT are bilateral negotiation and clearinghouse. Bilateral negotiation is the most common structure of a WQT market. This mechanism generally involves high transaction costs. Clearinghouse structure provides certainty for generating a uniformed good at a fixed price for buyers, and also reduces transaction costs. A few WQT programs have clearinghouse markets; for example, the Tar-Pamlico Trading Program and the Long Island Sound Trading Program. A number of WTQ programs are implementing more than one market structure. Market structures may evolve over time and are not necessarily mutually exclusive (Woodward and Kaiser 2002).

The size of a watershed covered by each trading program varies significantly. It is unclear whether or not the size of a trading program is the most significant factor effecting active trading since there are many trading programs covering large watershed areas (>1,000,000 acres) that do not have any, or minimal, active trades. In some smaller watershed areas, active trading did occur. The size of the watershed combined with other factors may sometimes become more significant in precluding trading activities.

The numbers of active trades in each program are not highly correlated with the number of participants in WQT programs and the diversity of the sources (PS and NPS). However, having a limited number of point sources and nonpoint sources in the program could have a negative effect on the success of the programs.

Large numbers of nonpoint sources with diverse characteristics in the watershed are major obstacles for effective management.

Trading ratio in WQT programs is applied to manage uncertainties associated with the effectiveness of nonpoint sources control, to ensure water quality improvement, to prevent hot spots, and to ensure the equivalency of the potential environmental impact of different locations. A wide variety of calculations are used to evaluate trading ratios; for example, defining trading ratios in ranges, setting different ratios for attainment and nonattainment areas, and multiplying a number of precalculation ratios to account for different characteristics of the source location. Additionally, one approach to deal with uncertainty of effectiveness of BMPs is to make trading retroactive for NPS. Moreover, in regards to temporal issues, a few water quality trading programs allow banking. Borrowing water quality credit, however, is not allowed in any trading programs.

The majority of active trading programs (12 out of 19 programs) had trading which occurred only once (Morgan and Wolverton 2005). The market structure of these programs is a one-time offset. Only four programs had more than ten trades within its program. Numbers of trading alone, however, does not necessarily mean the program is successful. The Tar-Pamlico Trading Program meets the collective nutrient limits without trading. With an internal trading agreement among members of the association, nutrient loading is significantly reduced despite a steady increase in flow. Moreover, with trading implementation, it cost less than it would have if uniformed technology-based standards had been applied.

There is no set standard price for credits of the same pollutant across different programs. In addition, the amount of pollutant trades varies widely. Market structures affect the prices of credits. Clearinghouse structure normally sets up a standard price/credit with lower transaction costs as compared to bilateral negotiation. Cost-savings in trading programs vary significantly. It is difficult to compare the amount of cost-saving between different programs due to the variation of information from sources and estimation methods. Transaction costs and administrative costs vary significantly across programs. Several mechanisms used in trading programs to reduce these costs included transaction cost paid by States, setting up a clearinghouse for credits, using the existing federal monitoring system, and lowering levels of oversight for NPS sources implementation.

5.3 Why Did WQT Programs Fail to Have Active Trading?

A significant number of obstacles inhibiting the participation of water pollution trading are identified from current WQT programs within the US. Several barriers in water trading programs can be largely divided into three categories: regulatory-related barriers, economic-related barriers and technical- and environmental-related barriers. The following sections describe each category in more detail.

5.3.1 Regulatory Related Barriers

A critical element for generating incentives for trading is an enforceable framework to reduce pollution. Regulators are responsible to set an optimal (financially achievable) level of reduction to stimulate trading activity. In the Clean Water Act, the regulation for nonpoint sources is not as effective as in controlling water pollution from point sources. Point sources and nonpoint sources have inadequate levels of reduction requirements, and unequal standards for achieving water quality goals. Nonpoint sources are not required to have pollution permits to control their pollution. To achieve water quality goals via trading, it is difficult to establish trading programs and promote trading activity further than point sources, especially where nonpoint sources largely contribute to water pollution problems.

Many trading programs operate without having a TMDL already set up for the watershed. The credit trading programs, without having set up a total mass cap for pollutants under a TMDL, are facing a thin market due to the absence of a realistic and enforceable framework. In addition, without the TMDL, there is no mandatory requirement for nonpoint sources reduction. Even though nonpoint sources are not subject to a mandatory requirement, they can be sources of reduction credits. Therefore, a baseline still needs to be established. It is not always clear what that baseline should be; however, it is often taken to be business-as-usual or at a level of discharge without regulation. The participation of these sources in trading is voluntary, as is in any trading, even within a cap-and-trade program since any source can adjust discharges to the level of allowances. A motivation factor for the NPS to trade is from the resulting payment received from the regulated point sources. If point sources did not face a mandate to make an additional expensive reduction, there would be no demand for trading.

Regulators set up strict trading rules for WQT programs. For example, trading rules sometimes restrict the opportunity to trade; e.g. point/point sources trading is not allowed in the Lake Dillon Trading Program. Regulatory provisions inhibit incentives to trade; for example, trades cannot be used to comply with technology-based standards. In credit trading, sources must over-comply to have credits to sell but in doing so two regulatory risks come into focus. Boyd et al. (2003) pointed out that the CWA provisions undermine the incentive to over-comply. Over-complying sources that return to more normal levels of compliance at a later date may run afoul of the anti-backsliding provision. Over-compliance signals to the regulator that greater levels of control can be attained cost-effectively. This can then lead to future ratcheting down of the standards (Boyd et al. 2003). Thereby, these provisions can discourage the trades.

Technology-based standards implemented on point sources create a hardship for point sources to concurrently and independently decide whether or not to meet reduction requirements via trading. Particularly, anti-backsliding and anti-degradation provisions indirectly discourage trading due to uncertainty of trading approval and possible additional requirements in the future. Although strict trading rules are set to protect water quality, it can also at times prevent trading by increasing overhead costs. Additionally, the controversy regarding potential change in standards and trading liability leads to limited participation in trading.

Credit trading still very much depends on regulatory judgment. Credit denomination in a credit trading system is sometimes not set as a mass-unit of pollutants and therefore it becomes more difficult to trade credit directly as in a cap-and-trade system. A cumbersome and costly process from the government agency to adjust the permit limit makes trading less-attractive for participation.

There is a lack of communication/coordination and perception among the parties involved in trading. There is a difference of opinion between the states and EPA over what may or may not be legally allowed. There are multiple parties responsible for implementing various actions, and thus coordination is made difficult. Central facilitation from the government to support trading or educating participants is inadequately provided.

5.3.2 Economic Related Barriers

High transaction costs and administrative costs are major trading barriers within most of the trading programs. Many programs are delayed due to insufficient funding and lack of staffing to run the programs. Project development has been expensive and resource-intensive. There has not been a sufficient need to develop guidance for trading.

Transaction cost is high mainly due to the process of searching, negotiating and executing trades. In addition, gathering data relevant to trading is difficult because information is either not available or very costly to attain. Processes related to government administration and approvals make the cost of trading higher. High administrative costs are due to significant needs for monitoring and enforcement of nonpoint sources, extensive review of application for trading, and oversight and inspection for nonpoint sources BMPs.

Demand for and supply of credits trading is restricted by the government agency (King and Kuch 2003). King and Kuch argued that water management initiative programs and subsidies for NPS reduction by local government or states could possibly make trading unnecessary. These programs affect the viability of credit trading by raising the baseline for scoring nonpoint source credits. Moreover, the major sources of nutrient impairment (i.e. nonpoint sources) frequently receive significant government subsidies to manage their nutrients. It has been proven to be unfair to create demand for credit trading by further reducing point source dischargers, as nonpoint source dischargers face less restriction and have subsidy available.

Having a thin market is a major problem in WQT programs. There are not many point sources interested in trading due to the competition amongst firms (e.g., Fox River Program), or due to the lack of diversity and the smaller numbers of firms and industries located in the watershed. The insignificant difference of abatement costs between trading and not trading is also a problem. The marginal cost of water treatment after the plant is upgraded is very small. Moreover, due to political uncertainty and unreliable trading systems, the firms may be better off controlling pollution by upgrading their present system instead of buying credits.

5.3.3 Environmental Related Barriers

Water pollution problems are confined to a watershed. The size and complex nature of a watershed makes program development difficult. The effect of effluents on ambient water quality is a function of location and geography, timing of discharge, location of other polluters, and stochastic elements due to weather and other factors. The size and configuration of effluent permits regions affect the number and size of potential market participants and the achievement of market equilibrium. Many programs face a limited number of potential traders and little diversity of activity among pollution sources in the watershed.

Water pollutant characteristics which are nonuniformly mixed, and potential damages accumulated from up-stream to down-stream, make trading complicated for establishing an equivalent trading ratio and for monitoring the trades. Water pollution impacts can be highly variable depending upon the point of discharge. Trading could lead to localized pollution problems or “hot spots”. Unlike many air pollutants, water pollution would not be suitable to treat as uniformly dispersed over a wide area. Water pollution trading, therefore, is most appropriate for pollutants such as nutrients that are biologically degradable and assimilable within the ecosystem.

Instead of considering the water quality of adjacent areas from the buyers, most trading programs allow only upstream trading where sellers are located upstream from the buyers. As a result, this could eliminate any chance for potential trading. A few trading programs allow multimedia trading and cross-parameter trading because there are very complicated issues involved with scoring pollution reduction and establishing an equivalency ratio.

When a significant number of polluters operate different activities, it is difficult to set up a system to generate and estimate uniformed credits. Mainly because there is a lack of a reliable measuring system for water pollution to accurately keep track of their discharge. Moreover, the impact of pollutants depends on the forms and types of pollutants, and the time and location of discharge.

Monitoring nonpoint sources pollution is a major problem for achieving potential cost-savings. It is difficult to accurately quantify and monitor nonpoint sources credit to keep it at a low cost. Predictions of loads are likely to either be expensive or imprecise. Therefore, it is difficult to target best management practices (BMPs) to the extent envisioned in the trading. Moreover, nonpoint sources are concerned that their participation in generating credits by reducing loads may result in being subjected to regulations requiring load reductions.

5.4 What Should the Roles of Trading Be in Water Quality Management?

In conclusion, based on observations of current water quality trading programs within the US, water quality trading is likely a regulatory devolution. Water quality trading is a market-trading-like system but it is not a pure market form. To date, the credit trading and offset agreement predominate the program's structure (Morgan and Wolverton 2005). Most participants in WQT programs use trading as a temporary alternative for expansion of their business under a more restricted regulation. A typical water quality trading market is credit trading towards a one-time offset. One-time offset, even though providing flexibility in meeting water quality, fails to stimulate an incentive to further reduce pollution in the long-term as compared to a cap-and-trade system.

The actual active role of trading is to sharpen the water quality goal by shifting the responsibility for meeting the pollution reduction goal to the polluters. The polluters, then, based on the information gathered on which methodology would be most suitable for each operating situation, would decide with flexibility on how to cost-effectively meet the water quality requirements. The role of the regulators in trading is to emphasize improving effectiveness in monitoring water quality and trading compliance.

The generic roles of trading in water quality management can be elaborated on specifically as an approach to:

1. Shift the focus of pollution control toward the overall water quality (total amount of pollution) rather than controlling specific technology choices

The key to achieving water quality improvement is to focus on reducing the total amount of pollution without being restricted to any technology, as long as the polluters surrender pollution with their permits and independently decide on how to meet the pollution reduction without any regulatory requirement on which technology is to be used. Polluters who achieve pollution reduction with the least amount of cost involved should do more. These polluters have incentives to do so because they could make a profit from selling their permits to other polluters who face higher costs in reducing their pollution. Costs and benefits drive polluters to decide whether or not to buy credits or install more advanced technology which would then give them the most cost-effective approach for their business. Ideally in the future, polluters should be able to install any treatment technologies best suited to the firm's conditions. Trading rules will allow the traders to use the most cost-effective technology without facing additional rules (e.g. valid credit should be from an additional reduction using minimal technological requirements).

2. Establish a system to facilitate an independent pollution control decision

The governmental agency decentralizes pollution control decisions to the polluters by allowing the trading of pollution permits or allowances. Trading allows regulators to focus on evaluating the regulated performance and water quality, instead of adjusting the use of more advanced technology requirements from the polluters, to further improve water quality. Without a tradable permit system, polluters have limited options to meet the regulatory requirement. Instead of enforcing technology requirements, the roles of the regulators will be to oversee the trading transaction, monitor and enforce the trading rules, and update the environmental goals and trading requirements. The government agency can then promote the use of trading by being an intermediary for facilitating trading and reducing costs associated with trading at the initial start of a program.

3. Reduce overall costs of water quality control to achieve more cost-savings to the polluters under increasing regulatory constraints and economic growth

Current command-and-control approach is not cost-effective. Most frequent use of trading is to provide an escape for firms having a need for expansion of their business; however, they are under regulatory constraints in a limited capacity area. Additionally, trading regulators can effectively spend more money for monitoring and enforcing the trading rules to meet water quality goals instead of revising inefficient technology-based standards.

4. Promote effectiveness and efficiency of water pollution management particularly with nonpoint sources pollution

Trading allows collaborating and negotiating the responsibility of pollution control in all levels, including the local level to a state or a multi-state level, to achieve a greater scale of reduction and cost-savings. Trading, when appropriately implemented, can provide polluters with greater flexibility for planning their pollution control to best suit their financial situations. Water quality trading can be a way to encourage nonpermitted nonpoint sources to generate least-cost reductions than the permitted point sources could achieve, and a means to recruit nonpoint source to take responsibility in a nonthreatening manner.

5. Distribute equity on pollution abatement between diverse groups of polluters

An urgent concern regarding the current water pollution control is that it does not put mandatory control on nonpoint sources. Except in a watershed where there is a TMDL established, point sources and nonpoint sources do not face the same stringency and responsibility for cleaning up their discharges. The reasons have been well known regarding the difficulty in managing pollution from these sources. It is quite unfair to put more pressure on point sources by making them indirectly share responsibility for the water quality problem when nonpoint sources are the ones largely responsible for the problems. With a TMDL and trading policy, trading can provide options for sources to find the most cost effective solution for their pollution problems. If possible, an adequate number of point sources and nonpoint sources in the trading program can provide financial benefits to meet regulatory requirements.

5.5 What Is the Suggested Guidance for Designing WQT Programs?

5.5.1 Relevant Issues

The necessary elements and considerations required for structuring and evaluating WQT trading programs were previously explained in Chapter 2. These trade variables include pollution selection, load calculation, potential trading partners, credit denomination and allocation, market structure, size of trading area, approval mechanism, certification and trading tracking system, center for attaining trading information, period of valid credit use, trading ratios, banking, directionality of the trade (upstream only or allowing downstream), cross pollutant trading, state-wide and inter-state trading, assurance of credits and liability, monitoring report requirements, penalty and responsibility, and educational programs and public participation.

Observations of trading programs revealed that water pollution problems are highly-localized problems. Therefore, each area needs specific drivers for trading and slightly different structures for program implementation. However, key issues involved for all programs to meet requirements might be grouped into 3 categories: legal, economic, and technical issues, which are explained as follows:

Legal issues: A legal authority needs to establish an enforceable framework for trading that is consistent with the requirements in the CWA and other federal laws to meet water pollution reduction goals. The regulatory agency has to initiate legal rights and allocate responsibility to all parties. The trading rules must establish a process by which permits can be issued and can be transferred. There must be an authorized agency to administer, oversee, and enforce the trading. The agency needs to establish a mechanism to encourage and facilitate the use of trading to increase public participation.

Economic issues: A trading program and market structure has to make the trading process as simple as possible to minimize transaction costs and as an attractive option to take full advantage of flexibility and potential benefits of capturing all point sources and nonpoint sources located in the watershed to maximize the size of the market. If possible, the program structure has to be designed to promote competition and prevent market powers and hot spot problems.

Environmental issues: It is critical to establish baseline loads for all pollution sources. Coverage of the trading area should be within a watershed boundary or segment. Pollutants allowed to be traded should be in the classes of pollutants that are biologically degradable and assimilable including nutrient, and organic carbon, so that they have biological capacities for treatment within a water body.

5.5.2 Principles

Based on lessons learned from the literature reviews and the current water quality trading programs (more details were discussed in Chapters 3 and 4), the following sections suggest the principles and guidance necessary for program designers to take into consideration to improve the current implementation and future design of a trading program. Three principles recommended are: (1) simplicity, (2) reliability and (3) minimum costs.

5.5.2.1 *Principle 1: Simplicity*

The trading system design (structures and rules) should be as straightforward, administratively simple, and flexible as possible, and the framework must be enforceable. The system should allow a broad set of compliance options to attract traders. Processes which make trading transactions too complicated should be avoided as they will discourage participation. The governmental agency has to maximize decentralization of a pollution control decision for the trading participants while minimizing regulator's roles involved in trading programs; e.g. trade approval process. The simple and standard trading framework with appropriate levels of policy safeguards for protecting water quality will take a minimum amount of time and financial investment from the regulators and the regulated to switch from the current command-and-control system to a market-based approach. There are several lessons learned from the successful WQT trading programs that should be introduced and applied to other programs to make a trading program simpler and more attractive to the trading participants, including:

- *Trading drivers*: It is important that all impaired waters eventually have TMDLs in-place. TMDLs lay out an enforceable framework for trading especially for nonpoint sources control to estimate pollution cap for total pollution and for allocating the pollution reduction to responsible parties (both PS and NPS). Without the TMDLs, it is difficult to achieve pollution reduction goals as there is only vague guidance. Several elements within a trading program; i.e. credit denomination and allocation, trading conditions, monitoring and enforcement of the trading program, can be achieved with TMDL structure.

- *Credit denomination*: The pollution cap and/or baseline for pollution are best to be established in terms of the mass of pollutants. Each credit allows the point source to discharge a unit of pollutant/ time (e.g. pounds of P/day). The unit should be the same as the unit of measure used in the Waste Load Allocation. Forms and impacts of pollutants, time and quantity of generating and using credits, are necessary to take into consideration when defining the term-of-use of the credits. There should be an expiration period for unused credit to prevent locally-increased pollution loads for the long term. The cap may have to be tightened over a certain period of time (after program initiation) in order to stimulate market demand for and supply of pollution reduction credits.

- *Assigning NPS the right to trade*: It is essential to create an enforceable permit for nonpoint sources to allocate the legal responsibility for NPS pollution. Permit language may need to re-define nonpoint sources as a large collection of small, independent and controllable sources based on their units of operation, capacity of operations, type of firms and activity, and area of farm coverage; rather than define them as diffused, uncontrollable, and unmonitored sources (Young and Karkoski 2000). If there are many nonpoint sources in a watershed with a variety of operations, it might work better if permits are allocated to a group of polluters to share a single group permit or a group cap, instead of issuing permits to individual nonpoint sources.

- *Water quality standards should be used instead of technology-based standards* (Stephenson 1999). Regulators may have to shift their focus from technology choices towards the formulation of physical constraints, such as ambient water quality standards that are more in line with environmental objectives and offer greater flexibility in the choice of means to achieve compliance.

- *Defining upfront the trading requirements and eligible conditions for credits.* Cleary defined rules in trading guidance and regulations, as well as in the permit itself, help polluters to make their management plan with necessary information and eliminate unnecessary administrative approval process when the program is implemented. For example, the regulator can establish a list of acceptable best management practices associated with potential reduction credits generated. The lists of acceptable practices enable the sources to screen the qualifying trades themselves. Setting up trading requirements and conditions upfront at the initial start of a program that participants must follow, will help minimize administrative review process and transaction costs. Qualified trades that meet these requirements should be able to automatically adjust the permit limit without a formal review process (Schary and Fisher-Vanden 2004).

- *Establish an information center or market center*: A clearinghouse will help create a standard commodity and central facility for providing necessary information for buyers and sellers who are looking for an opportunity for current and future transactions; i.e., to buy credit or to report demand for credit (Woodward and Kaiser 2002). An internet-based central database may be a good approach for developing a communication channel among participants and with the regulators (Faeth 2000); e.g., a trading forum to obtain information related to trading process, regular update or news from trading programs regarding trading rules and acceptable requirements for BMPs.

- *There should be a trading cycle for performing a trade* (Schary and Fisher-Vanden 2004); e.g., monthly or every two months to report available credits and post credit demand on a regular basis. The agency can then help identify potential buyers to potential sellers. The reduction credit can only be valid within a trading cycle. The permit holder may require submitting a trading report (credit certification, total allowance) and a monitoring report to the regulatory agency after transactions take place during each trading cycle.

5.5.2.2 Principle 2: Reliability

An accurate and reliable monitoring system is the key for a successful trading program. Discharge estimation, as a currency for trading, has to be correctly measured. Usually, the polluters are liable for the credits they generate; however, requirements for the credits to be reviewed and approved before they could be traded shifts liability to the regulatory agency. The review process ensures that water quality will not deteriorate as a result of a trading transaction; however it can slow down the trading process and significantly increase trading costs. Thus, instead of establishing trading rules and safeguards that are too restrictive, there are a number of mechanisms to ensure that trading will improve water quality.

- *Fully closed allowance trading programs are encouraged* because they give regulators greater assurance that total discharge will not exceed the wasteload cap. From before trading to after trading, net pollutants from all participants should not change.

- *Establish a certification and trading report system* to verify transactions between buyers and sellers (Schary and Fisher-Vanden 2004). The regulatory agency can set up the trading report system where both buyers and sellers will have to sign a credit certification when they perform a transaction, and will have to report to the agency on a regular interval. This certification should include information about buyers and sellers, their treatment technology, and amount of credits before and after it is transferred. A trading report should also include the monitoring of water conditions. The agency can then check the validation of the trades after the transactions. If discharge levels exceed permits limits, the polluters will face penalties. With credit certification, the regulator should allow buyers and sellers to arrange their trades outside the permit process. Trading with qualified trades can automatically adjust the permit limit without a formal review process, which would then help in reducing administrative costs and transaction costs and ensure that environmental goals are being met (Schary and Fisher-Vanden 2004).

- *Monitoring both direct and indirect methods* should be encouraged if possible. The discharges should be measured in the same way across all dischargers. By direct monitoring and measuring of the real discharges, collection and measurement methods and equipment use, should be as uniform as possible. For indirect monitoring, usually based on an estimation using equations or modeling with some real data, the regulators have to provide the standard information of the credit calculations for point sources and nonpoint sources; for example, types acceptable BMPs associated with number of potentially generated credits.

- *Establishment of an independent administrative authority* can ensure compliance with regulation and develop fair trading activity and transactions for the long term.

- *Generation and use of credit must occur in the same period.* Credit after generated should be used concurrently within the same cycle of buying and selling trade (Schary and Fisher-Vanden 2004). Banking may not be allowed in order to prevent an impact of pollution within a small area.

- *Make trading approval from NPS retroactive* (Young and Karkoski 2000). Credits from nonpoint sources should be established after the reduction has taken place. Nonpoint sources reductions are only considered valid if they are proven to be surplus or additional to the reductions specified by the nonpoint sources load allocation.

- *Point sources should be liable for the validity of any credits purchased from nonpoint sources*. Before trading, the point sources have to check on whether or not the credits are valid. In a credit trading system, permit holders assume all liability for the validity of credits used to adjust their permit limit and therefore are subject to any enforcement action if a credit is proven to be invalid. Nonpoint sources that create an invalid credit are subject to the penalties or action agreed upon in private contracts with point sources.

- *Private contracts should be used to manage the uncertainty between nonpoint sources and point sources* (Schary and Fisher-Vanden 2004). Since the traders know more about their operating conditions, regulators should encourage trading parties to negotiate the terms to manage the trading risks in private contracts.

- *Stiff penalties* should be set to provide incentives for high degrees of compliance.

- *Prevent localized impacts by setting up protective limits, trading ratios, and trading zones* (Tietenberg 1995).

  - *Protective limits*: establishing an upper discharge limit in the permit that cannot be exceeded no matter how many credits the point sources holds to offset its discharge.
  - *Trading zones*: upstream trading only allowed within the zones. Inter-zone trading will apply the trading ratio for the zones that are not adjacent to each other. The trading ratio is a product of the ratio from all relevant zones.
  - *Trading ratios*: set a location-based ratio and set a common reference point to limit the direction for allowing trades only within a small zone, not for the whole watershed because the whole watershed at large may gain more benefits from down stream trading between different zones (Hung and Shaw 2005). There is no reason to prohibit a trading direction along the river. Only the direction of trade that would increase loads to the problem zone should be restricted.

5.5.2.3 *Principle 3: Minimal Costs*

Costs involving trade have to be minimal in order to attract trading participants. Costs related to trading processes are probably the most significant barriers inhibiting the success of WQT trading. Some suggestions to reduce these costs are explained as follows:

- *Frequency of monitoring schedules and in-stream monitoring should be adjusted according to the polluter's monitoring report*. Transaction costs due to credit verification can be reduced by requiring point sources to have the burden of certifying the credits they bought and by subjecting them to legal penalties if the credits are falsely reported.

- *Funding*: the regulator may set up an initial requirement for potential participants of a WQT program to get start-up funding by asking for an advanced payment from the majority of polluters located within the watershed; e.g. industrial sectors or POTWs.

- *Spread the costs across all parties involved in trading and trading processes* or require the primary beneficiary to cover a substantial portion of the administrative costs. For example, an innovative approach adopted in the Tar-Pamlico Trading Program, was that a substantial amount of costs (in terms of time and money) were borne by the association of point source dischargers (Green 1997).

- *Permit distribution*: In a credit trading – which is the predominant form of water quality trading – the rights for discharge are granted free to permit holders as they are under conventional regulation.

- *Maximize the number of participants and numbers of trading*: anyone should be able to buy or sell reduction credits regardless of their purpose of credit uses. Regulators should encourage brokers, speculators, environmentalists and other citizens to purchase the credits to either resell them or retire them (Fossett et al. 1999).

- *Minimize the government's role by creating a quasi-governmental entity/a third party to launch and administer all aspects of the trade*; including identifying and facilitating potential trades, and quantifying the number of credits generated by a particular practice (Fossett, Kaiser et al. 1999). The regulatory agency should establish an information center to provide relevant information of the trades; e.g. trading rules, demands for, and future available credits to help traders save money on searching for information they need to acquire to complete their trades.

5.6 How to Promote a WQT Implementation?

There are several strategies suggested to introduce a WQT program to improve effectiveness of existing policies, or to design a new framework separate from the existing control system. Five potential approaches are recommended for a program designer to introduce and implement the water pollution trading programs into a particular watershed. These approaches are not comprehensive nor are they mutually exclusive. Specific strategies may be required to be developed for a particular watershed situation:

- Approach 1: Develop a real cap-and-trade program for WQT;
- Approach 2: Encourage a general permit or a multi-party permit;
- Approach 3: Promote a statewide trading policy;
- Approach 4: Set up a hybrid trading system; and
- Approach 5: Support pilot programs/simulations.

5.6.1 Approach 1: Develop a Real Cap-and-Trade Program for WQT

To set up a real cap-and-trade program for water pollution, the TMDLs must be in-place for the watershed to establish an enforceable framework and to estimate the total mass of pollution cap which can then be allocated to all responsible parties contributing to the pollution in the watershed. The trading programs can then be developed and implemented based on the TMDLs requirements. A significant requirement for a cap-and-trade program is to set up a reliable monitoring system. Standard measuring methods and lists of allowable devices and acceptable BMPs have to be clearly defined to ensure that credits generated are uniformed and accurately measured and therefore tradable.

It is important that the regulator define pollution permits in terms of the mass of allowable pollutants; so that permits can be tradable and transferred. All types of trading structure (PS/PS, PS/NPS, or NPS/NPS) should be allowed since market scale is for the entire watershed. The brokerage market structure should be encouraged if there is a need for larger trades. However, relatively small trades from many sources may not create enough financial profits due to brokerage fees. The regulatory agency may assist and promote the trade by setting up a central facility providing information about trades; e.g. future demands and supply, and prices of the credits.

Certainty for achieving and maintaining the pollution reduction goals and the financial benefits to the polluters will be high if the real cap-and-trade program is implemented. The government role involved in the trading process is minimal. However, a real cap-and-trade program requires a significant amount of time and money at the initial start of the program; i.e., establishing a TMDL for a watershed, distributing allowances to all sources, and setting up standard equipment for monitoring.

5.6.2 Approach 2: Encourage a General Permit or a Multi-Party Permit

Multi-party watershed permits for both point sources and nonpoint sources is another potential challenge, particularly in addressing nonpoint sources pollution problems. A group permit allows a group of polluters to become a bubble where they can set internal rules and agreements among its group members to meet a group reduction requirement. In this case, the regulators only focus on final water quality, not individual discharge.

There may be more than one group permit in the same watershed. Each group is potentially subjected to synchronization of permit issuance across a watershed of multiple parties, which allows coordinated monitoring, assessment and characterization, prioritization, planning, and implementation. This type of permit will lower transaction costs and integrate larger numbers of sources with different marginal control costs to create potential cost-saving situations within a watershed.

Two approaches that the regulators may use to decentralize pollution control decisions are (1) development of a general permit and (2) allowing the establishment of an association. For a general permit approach, the main idea is that pollution sources will share a portion of a total number of permits which also correlate to the pollution cap of a watershed. The general permit system can be set up based upon the NPDES system which is already well established and implemented in the US. This approach is easier to set up and to adjust for a reduction goal over time because each pollution source owns a share of the permit. The general permit approach is successfully implemented in the Long Island Sounds. The approach includes all point sources under a single permit. Each WWTP owns a share of the permit proportionate to the historical record of their discharge compared to the total allowable discharge. This approach provides an advantage for separating complex permit processes for each WWTP.

The second option is to allow a group of polluters to form an association, which may consist of polluters from similar industries or businesses discharging the same pollutants into the same water body. The association can implement any internal agreement or trading strategy among its members to meet a pollution cap allocated to them as a group. The government agency only oversees and monitors pollution reduction at the level of the association as a whole.

A successful example of a group approach is the Tar-Pamlico program. A group cap agreement is made between the NC state and group of WWTPs. The advantage of having a trading association is to have a flexible compliance with the regulation and minimum requirements from the government to reduce costs for the agency to oversee the program. The members of an association can share information and thus internally manage their pollution to meet a group cap more cost-effectively. Another example of a group approach is the Grassland Area Farmer Trading Program where the mass-based cap of selenium loads is allocated to the irrigation districts as a group of large collectors. Each district applies local management strategies among farmers within their districts. Trading is only allowed between districts. It has been proven that districts can efficiently manage their pollution with fairly low administrative and transaction costs.

5.6.3 Approach 3: Promote a Statewide Trading Policy

A statewide trading policy regulated through administrative rules provides a general and uniformed trading framework that could be implemented across an entire state. Statewide trading policies have several advantages including: (1) expanding market coverage to increase the number of trading participants and potential benefits gained from trading, (2) coordinating water pollution management for a region, and (3) increasing overall efficiency of pollution management on a larger scale.

The difficulties of this approach are in (1) not being able to create an accurate oversight mechanism to prevent conflict among different agencies, (2) having a high probability of no water quality improvement, (3) not being able to establish sufficient protection for preventing local adverse impact, (4) reaching consensus for several different parties in order to get a program started, and (5) having significant amounts of administrative and transaction costs for overseeing, monitoring and enforcing the rules for an entire state.

There are a number of states developing a statewide trading policy; for example, Colorado Pollutant Trading Policy, Idaho Pollutant Trading Guidance, and Maryland Nutrient Trading Policy. The success of this type of policy is still unclear as many programs have only just started and thus it may take a number of years before an evaluation can be conducted.

5.6.4 Approach 4: Set Up a Hybrid Trading System

A hybrid trading system which is a combination of two different market-based approaches (quantity-based and price-based) may be appropriate in situations where there is uncertainty about cost and damage functions. The combination between tradable permit and tax, or between tradable permit and fee-and-rebate, can provide certainty for improving environmental performance (by setting a pollution cap), while the regulatory agency would avoid excessive costs when only a tradable permit is implemented. A tax exceedence and a fee should not be confused with a penalty for sources that exceed permit limit. A penalty is usually set at a very high price to prevent any intentions of noncompliance with permit requirements. Whereas, the level of a tax or fee would be set to represent the estimated maximum unit cost which would be reasonable in order to obtain pollution reduction. There are a few WQT programs implementing a combination of a credit trading with a tax exceedence or a credit trading with a fee-rebate.

An example of the tax-exceedence and a credit trading system is the Tar-Pamlico Trading Program. With tax exceedence, the government agency generates revenues from the polluters who exceed their permit allowances. The regulators can then use this payment to fund NPS pollution reduction. This situation often happens in credit trading where nonpermitted nonpoint sources only voluntarily participate in the trading program. The polluters may choose to pay a tax exceedence when there are no credits available, or when searching and buying credits from other parties become difficult and more expensive for them than having to pay a tax.

Another example is the Grassland Area Farmers Program. This program implements a cap-and-trade with a fee-and-rebate system. A group of farmers in each district must pay a fee for any discharges above the regional cap. The groups who maintain the cap below their allocation will receive a rebate. The fee-and-rebate system ensures that the distribution of pollution abatement will be fair for all districts. The fee will increase over time as the cap is reduced during the lifespan of the program. This system generates incentives for the districts to reduce pollution below their allocation.

The hybrid system may require significant amounts of resources (time, funding, and staffs) to establish clear program rules that ensure environmental protection, create a well-functioning market, and establish an appropriate tax rate to stimulate incentives for reducing pollution. In addition to developing a tradable permit system, additional information is also needed in order to set up a tax system and a fee-and-rebate system.

5.6.5 Approach 5: Support a Pilot Program/Simulation

A pilot project or simulation should be undertaken for testing the program's principles and trading rules on a smaller scale to obtain data and experiences before it actually gets implemented on a larger scale. Program designers encourage performing trading simulations before developing a pilot program in order to predict the trading results with different scenarios; e.g. different pollutants, different trading zones, different trading ratios, and different types of structure (PS/PS, PS/NPS, NPS/NPS).

After the pilot program is successfully implemented, the regulatory agency can then adjust the total cap and extend the coverage area on a larger scale. If the program fails to meet any objectives, the regulatory agency can then decide whether or not to discontinue the program or to find other solutions. The pilot program provides an opportunity to readjust certain factors the program administrator may not have taken into consideration, and/or the opportunity to make an adjustment if something just does not quite turn out as expected or predicted.

It is critical to choose a section of a watershed with an appropriate size that represents the rest of the watershed well. A pilot program has to include enough participants with a diverse group of polluters in order to evaluate the relation to the imparted waters and pollution trading initiatives. Based on the limited area and unique characteristics covered by the pilot program, there is a challenge for choosing good representatives of point sources and nonpoint sources, and scale and scope of the system. Therefore, with precaution, the program designers in a pilot program should fine-tune conditions to become the actual size program of a program.

Appendix
SUMMARY DETAILS OF WATER QUALITY TRADING PROGRAMS

A.1 Part I Regarding Activity, Type of Participants, Pollutants and Market Structure

	Name of program	State	Activity	Type of participants	Pollutants	Market structure
1	Grassland Area Farmers Tradable Loads Program	CA	Watershed TP	NPS/NPS	Selenium	Bilateral
2	San Francisco Bay Mercury Offset Program	CA	Regional offset program	PS/NPS	Mercury	N/A
3	Bear Creek Trading Program	CO	Watershed TP	PS/NPS	P	Bilateral
4	Boulder Creek Trading Program	CO	Watershed TP	PS/NPS	Ammonia, Temp., pH	Sole source offset
5	Chatfield Reservoir Trading Program	CO	Watershed TP	PS/NPS	P	Clearinghouse; bilateral; third party
6	Cherry Creek Trading Program	CO	Watershed TP	PS/PS, PS/NPS	P	Clearinghouse
7	Clear Creek Trading Program	CO	Watershed TP	Mine clean up (PS/NPS)	Multiple heavy metals	Third party brokers
8	Lake Dillon Trading Program	CO	Watershed TP	PS/NPS, NPS/NPS	P	Bilateral
9	Lower Colorado River Selenium and Aquatic Habitat Offset Program	CO	Conceptual stages	PS/PS, PS/NPS, NPS/NPS	Selenium, possibly habitat	N/A

	Name of program	State	Activity	Type of participants	Pollutants	Market structure
10	Long Island Sound Trading Program	CT	Watershed TP	PS/PS, PS/NPS	N	Clearinghouse
11	Blue Plains WWTP Credit Creation	DC, VA	Single trade, offset for 1 discharger	PS/PS	N	N/A
12	Tampa Bay Co-operative Nitrogen Management	FL	Regional cooperation	N/A	N	N/A
13	Cargill and Ajinomoto Plants Permit Flexibility	IA	NPDES permit flexibility	PS/PS	Ammonia, BOD/DO	N/A
14	Lower Boise River Effluent Trading Demonstration Project	ID	Watershed TP	PS/PS, PS/NPS	P	Bilateral; third party
15	Illinois Pretreatment Trading Program	IL	Pretreatment program	Pretreatment trade (PS/PS)	Multiple	N/A
16	Piasa Creek Watershed Project	IL	Watershed project	PS/NPS	Sediment	Third party brokers
17	Specialty Minerals, Inc. in Town of Adams	MA	Offset for 1 discharger	PS/NPS	Temp.	Bilateral; clearinghouse; third party
18	Town of Acton POTW	MA	Offset for 1 discharger	PS/NPS	P	N/A, possibly third party facilitation
19	Wayland Business Center Treatment Plant Permit	MA	Offset for 1 discharger	PS/NPS	P	Third party facilitation
20	Charles River	MA	Watershed project	PS/NPS	Water flow	Clearinghouse; third party
21	Edgartown WWTP	MA	Offset	PS/NPS	N	No official offset or trade
22	Falmouth WWTP	MA	Offset	PS/NPS	N	Sole source offset
23	Massachusetts Estuaries Project	MA	Watershed project	PS/NPS	N	N/A
24	Maryland Nutrient Trading Policy	MD	State-wide TP	PS/PS, PS/NPS	N, P	Banking and clearinghouse concepts

	Name of program	State	Activity	Type of participants	Pollutants	Market structure
25	Kalamazoo River Water Quality Trading Demonstration	MI	Watershed TP	PS/NPS	P	Clearinghouse; third party
26	Michigan Water Quality Trading Rules	MI	State-wide TP	PS/PS, PS/NPS	N, P	Bilateral
27	Minnesota River Nutrient Trading Study	MN	Watershed TP	PS/PS, PS/NPS	P	N/A
28	Rahr Malting Permit	MN	Offset for 1 discharger	PS/NPS	P, BOD/DO	Sole-source offset
29	Southern Minnesota Beet Sugar Cooperative Plant Permit	MN	Offset for 1 discharger	PS/NPS	P	Sole-source offset with bilateral negotiation
30	Chesapeake Bay Nutrient Trading Program	Multi-states	Watershed TP (Regional VA, WV, MD, PA, DE, NY, DC)	PS/PS, PS/NPS, NPS/NPS	N, P	TBD
31	Neuse River Nutrient Sensitive Water Management Strategy	NC	Watershed TP	PS/PS, PS/NPS	N	Clearinghouse
32	Tar-Pamlico Nutrient Reduction Trading Program	NC	Watershed TP	PS/PS, PS/NPS	N, P	Clearinghouse
33	Passaic Valley Sewerage Commission Effluent Trading Program	NJ	Pretreatment program	PS/PS	Multiple metals	Bilateral; third party
34	Truckee River Water Rights and Offset Program	NV	Offset for 1 discharger	PS/NPS	Flow, N, P, TSS/TDS, Temp, BOD/DO	Bilateral
35	New York City Watershed Phosphorus Offset Pilot Programs	NY	Regional TP	PS/NPS	P	Bilateral
36	Clermont County Project	OH	Watershed TP	PS/NPS	P	N/A

	Name of program	State	Activity	Type of participants	Pollutants	Market structure
37	Great Miami River Watershed Water Quality Trading Pilot Program	OH	Watershed project	PS/NPS	N, P	Third party
38	Pennsylvania Water-Based Trading Simulations	PA	Watershed TP	PS/PS, PS/NPS	N, P, TSS/TDS, NH_3	N/A
39	Conestoga River Nutrient Pilot	PA	Watershed TP	PS/NPS	N, P	Clearinghouse (trading registry and credit bank)
40	Pennsylvania Multimedia Trading Registry	PA	Simulation State-Wide project	PS/PS, PS/NPS, NPS/NPS	CBOD, P, N, SS, NH_3, acid, metals	Bilateral (likely)
41	Henry County Public Service Authority and City of Martinsville Agreement	VA	Offset for 1 discharger	PS/PS	TSS, TDS	N/A
42	Virginia Water Quality Improvement Act and Tributary Strategy	VA	State-wide TP	PS/PS, PS/NPS	N, P	N/A
43	West Virginia Trading Framework	WV	State-wide TP	PS/PS, PS/NPS	N, P	N/A
44	Wisconsin Effluent Trading Rule Development	WI	State-wide TP	PS/PS, PS/NPS	P	N/A
45	Fox-Wolf Basin Watershed Pilot Trading Program	WI	Watershed TP	PS/PS, PS/NPS	P	Clearinghouse; third party
46	Red Cedar River Pilot Trading Program	WI	Watershed TP	PS/NPS	P	Bilateral
47	Rock River Basin Pilot Trading Program	WI	Watershed TP	PS/PS, PS/NPS	P	Bilateral; third party

A.2 Part II Regarding Size of Watershed, Number of PS, Trading Ratio, Number of Trade, and Characteristics of Participants

	Name of program	Size of watershed	Number of PS	Trading ratio	Number of trade	Characteristics of participants
1	Grassland Area Farmers Tradable Loads Program	97,000 acres	7	1:1, retroactive	39	7 Irrigation and Agricultural Drainage Districts
2	San Francisco Bay Mercury Offset Program	N/A	33	3:1	0	20 POTWs and 13 industrial dischargers
3	Bear Creek Trading Program	83,700 acres	17	1:1	1	6 POTWs and 7 industrial dischargers
4	Boulder Creek Trading Program	286,642 acres	1	N/A	One-time offset agreement	The City of Boulder and nonpoint sources
5	Chatfield Reservoir Trading Program	1.92 million acres	7	2:1 or less	1	6 POTWs and 1 industrial discharger and nonpoint sources
6	Cherry Creek Trading Program	243,000 acres	6	1.3:1 to 3:1	3	6 WWTPs and non-point sources
7	Clear Creek Trading Program	N/A	N/A	N/A	1	N/A
8	Lake Dillon Trading Program	3,200 acres	4	2:1 (PS:NPS), 1:1 (NPS:NPS)	3	4 POTWs, several miner WWTP, and nonpoint sources
9	Lower Colorado River Selenium and Aquatic Habitat Offset Program	N/A	N/A	N/A	0	N/A
10	Long Island Sound Trading Program	~3.5 million acres	79	N/A	63	79 PS (mostly POTWs) and non-point sources
11	Blue Plains WWTP Credit Creation	N/A	>2	1:1	0	Several POTWs, the Blue Plain WWTPs

	Name of program	Size of watershed	Number of PS	Trading ratio	Number of trade	Characteristics of participants
12	Tampa Bay Cooperative Nitrogen Management	1.4 million acres	N/A	N/A	0	24 consortium members (9 private sectors, 3 counties, 3 cities, 3 regulatory agencies)
13	Cargill and Ajinomoto Plants Permit Flexibility	N/A	2	1:1	0	2 industrial plants
14	Lower Boise River Effluent Trading Demonstration Project	41,000 acres	18	3 ratios: river location, drainage delivery, site location	0	7 POTWs, 3 industrial dischargers, 8 irrigation districts
15	Illinois Pretreatment Trading Program	N/A	>100 PS	N/A	0	45 POTWs and hundreds of significant industrial users
16	Piasa Creek Watershed Project	78,000 acres	1	1.5:1	One-time offset agreement	Landowners, City of Alton, IEPA
17	Specialty Minerals, Inc. in Town of Adams	2.2 miles of channels	1	2:1	One-time offset agreement	Specialty Mineral, the Town of Adams, envi groups, the Army Crop of Engineers, USEPA, MEPA
18	Town of Acton POTW	241,280 acres	1	3:1	0	The Town of Acton, USEPA, MEPA, nonpoint sources
19	Wayland Business Center Treatment Plant Permit	28.8 mile long river	N/A	3:1	One-time offset agreement	The Wayland Business Center, 25 property owners, the town of Wayland
20	Charles River	197,000 acres	N/A	2:1–2.5:1	0	WWTPs, stormwater systems, residential and industrial developments, water supplies, municipalities
21	Edgartown WWTP	5,150 acres	N/A	N/A	One-time offset agreement	N/A

	Name of program	Size of watershed	Number of PS	Trading ratio	Number of trade	Characteristics of participants
22	Falmouth WWTP	N/A	N/A	1:1	One-time offset agreement	Sewering 400 properties west of Route 28, installing on-site denitrification systems east of Route 28
23	Massachusetts Estuaries Project	N/A	N/A	N/A	0	N/A
24	Maryland Nutrient Trading Policy	N/A	N/A	2:1	0	N/A
25	Kalamazoo River Water Quality Trading Demonstration	1.28 million acres	50	2:1–4:1 PS:NPS, 1:1 PS:PS	0	50 PSs(POTW, paper companies) and many NPS
26	Michigan Water Quality Trading Rules	N/A	N/A	N/A	0	N/A
27	Minnesota River Nutrient Trading Study	10.9 million acres	212	3:1	0	212 point sources and a number of nonpoint sources
28	Rahr Malting Permit	10.7 million acres	1	2:1 (8 CBOD:1P cross parameter ratio)	One-time offset agreement	Rahr Malting plant and 3 nonpoint sources
29	Southern Minnesota Beet Sugar Cooperative Plant Permit	10.7 million acres	1	2.6:1	One-time offset agreement	Southern Minnesota Beet Sugar Cooperative and multiple farmers
30	Chesapeake Bay Nutrient Trading Program	N/A	N/A	N/A	0	40 members of negotiation team
31	Neuse River Nutrient Sensitive Water Management Strategy	3.96 million acres	22	2:1	0	22 PSs and many NPSs
32	Tar-Pamlico Nutrient Reduction Trading Program	2.88 million acres	16	2:1	0	16 members of the Tar-Pamlico Association and NPSs

	Name of program	Size of watershed	Number of PS	Trading ratio	Number of trade	Characteristics of participants
33	Passaic Valley Sewerage Commission Effluent Trading Program	534,000 acres	260	5:4	2	260 PSs (Industrial users and POTW)
34	Truckee River Water Rights and Offset Program	~1.4 million acres	N/A	1:1	33	The city, 3 PSs, many NPSs
35	New York City Watershed Phosphorus Offset Pilot Programs	1.26 million acres	>100	3:1	1	>100 WWTPs, many NPSs
36	Clermont County Project	320,000 acres	4	N/A	0	4 major point sources
37	Great Miami River Watershed Water Quality Trading Pilot Program	2.56 million acres	314	1:1–2:1	0	314 PSs with NPDES permits and upstream agricultural producers
38	Pennsylvania Water-Based Trading Simulations	N/A	N/A	1.1:1	0	POTWs, landowners
39	Conestoga River Nutrient Pilot	N/A	N/A	N/A	0	Many parties, PSs and NPSs, ~1,250 small farms
40	Pennsylvania Multimedia Trading Registry	N/A	N/A	N/A	0	N/A
41	Henry County Public Service Authority and City of Martinsville Agreement	N/A	N/A	1:1	0	Two POTWs from neighboring municipal jurisdiction
42	Virginia Water Quality Improvement Act and Tributary Strategy	N/A	N/A	N/A	0	N/A
43	West Virginia Trading Framework	N/A	N/A	N/A	0	N/A
44	Wisconsin Effluent Trading Rule Development	N/A	N/A	2:1	0	N/A

	Name of program	Size of watershed	Number of PS	Trading ratio	Number of trade	Characteristics of participants
45	Fox-Wolf Basin Watershed Pilot Trading Program	4.1 million acres	100	2:1–10:1	0	~100 PSs, many NPSs
46	Red Cedar River Pilot Trading Program	1.92 million acres	18	2:1	22 each year	18 PSs, many NPSs
47	Rock River Basin Pilot Trading Program	1.15 million acres	24	1.1–1.5:1 PS-PS; 1.75:1–3.6:1 PS-NPS	0	~60 participants, 24 are POTWs

A.3 Part III Regarding TMDL in the Program, Cost-Saving and References

	Name of Program	TMDL	Cost-saving	Ref.*
1	Grassland Area Farmers Tradable Loads Program	no relation	Many trades exchanged in-kind of service. Cost saving is difficult to be estimated, ~$14,320 changed hand during the first five years	(1), (2), (3), (4), (5)
2	San Francisco Bay Mercury Offset Program	coordination	N/A	(2), (3)
3	Bear Creek Trading Program	control regulation	Forest Hills saved the cost of system replacement over $1.2 million, instead it has to pay ~$5,000 per year for offsetting discharges	(2), (3)
4	Boulder Creek Trading Program	control regulation	The City saved $3–7 million by deferring full nitrification modification, although it needed to upgrade its WWTP	(2), (3)
5	Chatfield Reservoir Trading Program	control regulation	N/A	(2), (3)
6	Cherry Creek Trading Program	control regulation	NPS projects (pond retrofit) can generate credits worth $456,000, with the cost of the project $400,000	(2), (3)
7	Clear Creek Trading Program	N/A	The ASARCO agreed to pay a clean up cost of ~$50,000	(2), (3)
8	Lake Dillon Trading Program	N/A	Trading could reduce an estimate cost of maintaining WQ of over $1.5 million annually by about a half	(2), (3), (6), (7), (8), (9)
9	Lower Colorado River Selenium and Aquatic Habitat Offset Program	no relation	N/A	(2)
10	Long Island Sound Trading Program	control regulation	Nearly 200$ million over 15 years	(2), (3), (10), (16), (17)
11	Blue Plains WWTP Credit Creation	no relation	With the same money to reduce 1 million lb of N in 2 years, result of trading can reduce 6 million lb in 2 years	(2), (3)

	Name of Program	TMDL	Cost-saving	Ref.*
12	Tampa Bay Cooperative Nitrogen Management	not required	The consortium's action may help avoid TMLD costs and legal and administrative costs	(2), (3)
13	Cargill and Ajinomoto Plants Permit Flexibility	no relation	N/A, Offset trading between two neighboring industrial plants meets effluent limits jointly	(3)
14	Lower Boise River Effluent Trading Demonstration Project	coordination	Expected cost-savings are \$10–158/lb of P reduced	(2), (3)
15	Illinois Pretreatment Trading Program	coordination	~6.9 million if able to trade federal categorical pretreatment limits	(2), (3)
16	Piasa Creek Watershed Project	no relation, related to NPDES	~3.25 million, Illinois American Water Company avoided capital, operation and maintenance costs associated with lagoon and landfill system	(2)
17	Specialty Minerals, Inc. in Town of Adams	control regulation	Avoid estimated capital cost of \$300,000 and reduced amount of money that company has to pay to the Town	(2), (3)
18	Town of Acton POTW	control regulation	Acton residents save ~\$2.25 million annually	(2), (3)
19	Wayland Business Center Treatment Plant Permit	no relation	~\$937,000	(2), (3)
20	Charles River	under development	N/A	(2)
21	Edgartown WWTP	no relation	N/A	(2)
22	Falmouth WWTP	no relation	N/A	(2)
23	Massachusetts Estuaries Projects	no relation	Provide roadmap for trading and watershed-wide permitting	(2)
24	Maryland Nutrient Trading Policy	under development	N/A	(2), (3)
25	Kalamazoo River Water Quality Trading Demonstration	under development	N/A	(2), (3)
26	Michigan Water Quality Trading Rules	coordination	saving \$10–20/lb of P reduced	(2), (3)

	Name of Program	TMDL	Cost-saving	Ref.*
27	Minnesota River Nutrient Trading Study	control regulation	Saving $18/lb for PS alone, to $4–5/lb for the combination of subsidies for NPS BMP	(2), (3)
28	Rahr Malting Permit	control regulation	Savings in WWT costs and avoid uncertainty regarding industrial user fees to POTW	(2), (3), (11)
29	Southern Minnesota Beet Sugar Cooperative Plant Permit	control regulation	N/A	(2), (3), (11)
30	Chesapeake Bay Nutrient Trading Program	under development	Depending on each state's trading rules	(2), (3)
31	Neuse River Nutrient Sensitive Water Management Strategy	control regulation	Estimated cost of control $25–30/lb but the offset rate is $11/lb	(2), (3), (13)
32	Tar-Pamlico Nutrient Reduction Trading Program	control regulation	The offset rate is at $29/lb while cost for at-the-plant control were estimated to be $55–65/lb	(2), (3), (12)
33	Passaic Valley Sewerage Commission Effluent Trading Program	no relation	N/A, Buyers are able to avoid non-compliance fines, whereas sellers generate revenues from sale of excess reductions	(2), (3), (18)
34	Truckee River Water Rights and Offset Program	control regulation	N/A	(2), (3), (15)
35	New York City Watershed Phosphorus Offset Pilot Programs	under development	N/A, A pilot program to allow new or expanding WWTP to obtain offsets	(2), (3)
36	Clermont County Project	no relation	N/A	(2), (3)
37	Great Miami River Watershed Water Quality Trading Pilot Program	control regulation	$314–384 millions over 20 years period	(2)
38	Pennsylvania Water-Based Trading Simulations	no relation	These water meet all applicable standards and no TMDL is planned	(2), (3)
39	Conestoga River Nutrient Pilot	control regulation	N/A	(2)

	Name of Program	TMDL	Cost-saving	Ref.*
40	Pennsylvania Multi-media Trading Registry	under development	N/A	(2)
41	Henry County Public Service Authority and City of Martinsville Agreement	no relation	N/A, The trade can be seen as facilitating economic growth in the area	(2), (3)
42	Virginia Water Quality Improvement Act and Tributary Strategy	under development	N/A	(2), (3)
43	West Virginia Trading Framework	control regulation	N/A	(2)
44	Wisconsin Effluent Trading Rule Development	control regulation	N/A	(2), (3)
45	Fox-Wolf Basin Watershed Pilot Trading Program	under development	Expected cost-savings are $47/lb of P reduced	(2), (3)
46	Red Cedar River Pilot Trading Program	under development	The trading saved Cumberland approximately $15,000 in 1998	(2), (3)
47	Rock River Basin Pilot Trading Program	under development	N/A	(2), (3)

A.4 Summary of Analysis Results from Appendices A-1, A-2, A-3

Table A4.1 **Type of trading *versus* number of programs.**

Type of trade	Number of programs
PS/PS only	5
PS/NPS only	22
NPS/NPS	1
PS/PS and PS/NPS	14
PS/NPS and NPS/NPS	1
All possibility	3
N/A	1

Table A4.2 **Program structure *versus* number of programs.**

Program structure	Number of programs
Watershed TP	19
Offset for 1 discharger/projects	11
State-wide TP	6
Pretreatment	2
NPDES flexible permit	1
Regulatory offset/Watershed project/ Conceptual stage	8

Table A4.3 **Pollutants *versus* number of programs.**

Pollutant	Number of programs
Nutrient (both N and P)	11
N only	7
P only	16
TSS/TDS	3
NH_3	4
Temp.	3
pH	1
BOD/DO	3
Multiple metals	3
Flows	2
Mercury	1
Selenium	2

Table A4.4 **Market structure *versus* number of programs.**

Market structure	Number of programs
Bilateral	7
Clearinghouse	6
Third party broker	3
Sole source offset	4
More than 1 structure	8
N/A	19

Table A4.5 **Area of watershed *versus* number of programs.**

Size of watershed (acres)	Number of programs	Number of programs with active trades
<100,000	6	2
100,000 < Size < 1,000,000	7	5
>1,000,000	15	7
N/A	19	N/A

Table A4.6 **Number of point sources *versus* number of programs.**

Number of PS	Number of programs	Number of programs with active trades
<10	13	9
10 < PS < 50	7	2
>50	8	3
N/A	19	N/A

Table A4.7 **Number of trade occurred in the program *versus* number of programs.**

Number of trade	Number of programs
1	12
$1 < N < 10$	3
>10	4
No trade	28

Note: Data in the following tables correspond to figures in Chapter 3, i.e. data from Table A4.1 is presented in Figure 3.2, Table A4.2 is presented in Figure 3.3, Table A4.3 is presented in Figure 3.4, Table A4.4 is presented in Figure 3.5, Table A4.5 is presented in Figure 3.6, Table A4.6 is presented in Figure 3.7, and Table A4.7 is presented in Figure 3.8.

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