Preliminary Preview for a Geographic and Monitoring Program Project: A Review of Point Source–Nonpoint Source Effluent Trading/Offset Systems in Watersheds

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Open-File Report 03-79

2003

U.S. Department of the Interior
U.S. Geological Survey

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ABSTRACT

Watershed-based trading and offset systems are being developed to improve policy-maker's and regulator's ability to assess nonpoint source impacts in watersheds and to evaluate the efficacy of using market-incentive programs for preserving environmental quality. An overview of the history of successful and failed trading programs throughout the United States suggests that certain political, economic, and scientific conditions within a temporal and spatial setting help meet water quality standards. The current lack of spontaneous trading among dischargers does not mean that a marketable permit trading system is an inherently inefficient regulatory approach. Rather, its infrequent use is the result of institutional and informational barriers. Improving and refining the earth science information and technologies may help determine whether trading is a suitable policy for improving water quality. However, it is debatable whether or not environmental information is the limiting factor. This paper reviews additional factors affecting the potential for instituting a trading policy.

The motivation for investigating and reviewing the history of offsets and trading was inspired by a project in the preliminary stages being developed by U.S. Geological Survey Western Geographic Science Center and the Environmental Protection Agency Region IX. An offset feasibility study will be an integrated, map-based approach that incorporates environmental, economic, and statistical information to investigate the potential for using offsets to meet mercury Total Maximum Daily Loads in the Sacramento River watershed. A regional water quality offset program is being studied that may help known point sources reduce mercury loading more cost effectively by the remediation of abandoned mines or other diffuse sources as opposed to more costly treatment at their own sites. An efficient offset program requires both a scientific basis and methods to translate that science into a regulatory decision framework.

NOTATION

ACSP: North Carolina Agricultural Cost Share Program

BMP: Best management practices

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

CWA: Clean Water Act

CZARA: Coastal Zone Act Reauthorization Amendments

EMC: Estimated Mean Concentrations

EPA: Environmental Protection Agency

ETP: Effluent Trading Program

MNA: Monitored Natural Attenuation

NC DEM: North Carolina Division of Environmental Management

NCPDI: National Coastal Pollutant Discharge Inventory

NPDES: National Pollutant Discharge Elimination System

NPS: Nonpoint source

NRI: National Resources Inventory

NSW: Nutrient-sensitive waters

POTW: Publicly owned treatment works (wastewater treatment facilities)

PS: Point sources

SRSCD: Sacramento Regional Sanitation County District

SRWTP: Sacramento Regional Wastewater Treatment Plant

TBEL: Technology-Based Effluent Limitations

TMDL: Total Maximum Daily Loads

TPA: Tar-Pamlico Association

WQBEL: Water Quality-Based Effluent Limit

REVIEW OF PROJECT DESCRIPTION

Over the past couple of centuries, mercury (Hg) from mining activities has been transported with sediments downstream (nonpoint contamination) into the Sacramento Estuary, where it is believed to have contributed to elevated concentrations in fish, resulting in consumption advisories. Most of the mercury lost to the environment in this area was from placer-gold mines, which used mercury to extract gold through hydraulic, drift, and dredging methods (Alpers and Hunerlach, 2000). Large quantities of placer gold originating from large gravel deposits within the Sierra Nevada gold belt provided the basis for large-scale mining in California in the mid 1800s until the 1890s (fig. 1).

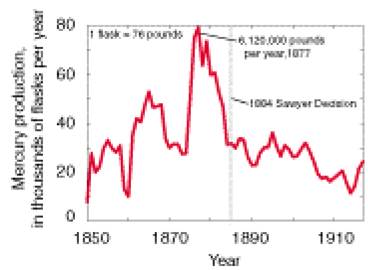

Figure 1. Mercury production from mines in the Coast Ranges of California, 1850-1917 (Bradley, 1918). (Provided by Alpers and Hunerlach, 2000).

Mercury is widely recognized as a serious environmental contaminant. Of particular environmental concern is the presence of methyl mercury (MeHg), an organometallic form of mercury that is a potent neurotoxin to humans through fish consumption. The Environmental Protection Agency (EPA) Region IX is developing total maximum daily loads (TMDL) for methyl mercury in various water bodies, among other criteria and standards for water quality, using EPA's new human health fish-tissue residue criterion.

The successful reduction of mercury loadings from nonpoint sources (NPS) will alleviate the need for stricter point source controls. Examples of point source (PS) controls are wastewater treatment plants, chloralkali plants, and industrial facilities. NPS controls are gold and mercury mines, erosion control activities, and mercury reduction programs, such as mercury recycling. PS reductions have already been made, and controlling additional PSs is difficult, expensive, and unlikely to significantly reduce mercury loading in the basin.

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Western Geographic Science Center, with support from EPA Region IX, will research the feasibility of using an alternative incentive-based policy (offset policy) to meet water quality standards. In an offset system, water quality can be improved when one party (PS) can maintain or increase its own loadings by reducing pollution from another location that may or may not have an owner (for example, abandoned mine). Thus, the discharger can accumulate pollution reduction credits that can be used to offset its own loadings. An integrative environmental, economic, and statistical map-based management approach has been proposed to investigate the potential for using offsets to meet mercury standards. This project is being supported by the USGS Geographic Analysis and Monitoring Program (GAM) in pursuit of its goal of developing "GIS-based decision support tools that integrate earth science information and economics in order to model complex human and natural systems to specific environmental or risk issues" (Acevedo and others, 2002).

The project will develop a highly focused, integrated study that incorporates various environmental elements to assess whether using offsets is technically (environmentally) and economically feasible as a management strategy for reaching water quality standards for mercury, using the Sacramento Basin (or subbasins) as a pilot case. This project provides an opportunity to ask an important question: can water quality be improved using a risk-based regional offset program? The hypothesis is that the nonpoint control option will turn out to be favorable and will reduce the need to pursue costly PS controls. A literature review will focus on this question and other principles of trading and offsets in making water quality policy decisions.

INTRODUCTION

During recent decades, considerable progress has been made in reducing PS pollution. However, the Nation's water quality has not improved proportionately with these PS reductions (Letson, 1992). Regulators have shifted their emphasis accordingly to NPS-related impairments, such as sedimentation, agriculturally driven nutrient enrichment, and toxic contamination of fish tissue and sediments (Letson and Crutchfield, 1993). NPS pollution, which is now the most common source of pollution, is transported by runoff from rainfall or snowmelt moving over and through the ground and deposited into sediment, soils, and various water bodies, endangering human health and the environment.

An NPS, technically and legally, is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act (CWA). According to the CWA, the term "point source" is defined as any "discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, or channel" (CWA §502(14); see also 33 U.S.C. §1362(7); 40 C.F.R. §122.2). Agricultural stormwater discharges and return flows from irrigated agriculture are not included in this definition.

Although diffuse runoff is generally treated as NPS pollution, runoff that enters and is discharged from conveyances such as those described above is treated as PS discharge and hence is subject to the permit requirements of the CWA (Hoag and Hughes-Popp, 1997). In contrast, NPSs are not subject to Federal permit requirements. The distinction between NPSs and diffuse PSs is sometimes unclear. Although NPS pollution is defined as being diffuse, knowing the general location of these NPSs, such as agricultural fields, urban development areas, mines, and land disposal sites, makes it possible to treat an NPS as a PS conceptually, thereby allowing remediation to take place at the site of contamination.

PS pollution has been controlled through the application of technology-based requirements administered by States using the National Pollutant Discharge Elimination System (NPDES) permit program. Almost 87 percent of the major municipalities and 93 percent of major industrial facilities were in compliance with NPDES permits by 1990 (EPA, 2002). Despite these accomplishments, water quality problems persist as a result of NPS pollution. The natural variability of NPS pollution, as well as political aspects and legal issues, has made identifying and locating sources problematical, thereby hindering the development of efficient and capable regulatory approaches. There has been a growing interest among private industries and regulatory agencies in using market-based incentives, particularly trading programs, for NPS mitigation to improve water quality in numerous watersheds and produce cost savings.

This report will explore the ability of trading/offset programs to resolve NPS problems in watersheds. It will explore the issues that constrain and support possible trading programs. It contains a literature review of these issues and examines associated concerns and questions. Empirical illustrations from both successful and failed incentive programs will help answer some of these questions. This information could be used to develop guidelines for future decisions about whether permit trading is an appropriate regulatory instrument.

LITERATURE REVIEW

The relevant literature for this project can be divided into four main categories:

- History of Trading and Offsets
- Significant Concepts and Issues: Scientific, Economic, and Legal Implications
- Empirical Evidence: Case Studies of Trading/Offset Programs in the United States
- Optimal Conditions for Water Quality Trading

We outline the state of research in each of the above categories and define the important research concepts from each of them. For this paper, we focus on those aspects of the literature that are most critical.

I. HISTORY OF TRADING AND OFFSETS

Environmental Trading

Trading/offset programs rely on financial incentives and decisionmaking flexibility to reduce control costs. A trading program allows dischargers to transfer discharge control responsibility in common units of exchange—a tradable commodity, such as units of air or water without violating the overall emission standard or limit. In theory, efficiency is achieved since the utility has the flexibility to either use the least cost abatement techniques or purchase additional permits if others can reduce emissions more cheaply (Stephenson and others, 1998). After meeting technology-based effluent limitations (TBEL) as part of the TMDL, PSs are allowed to gain credit for any further reductions (Wilson, 2001). Trading programs would allow the TMDL to be met at an overall lower cost. However, the success of a trading program depends on the type of contaminant, contaminant transport, ability to assume mixing, physical and chemical characteristics, and media. In addition, the potential for a cost-effective trading policy depends on whether or not the transaction costs of administering and monitoring the policy surpass the cost savings of implementing such a program (Ortolano, 1997). This literature review will expand on these environmental, economic, and legal concerns affecting trading policies.

Offsets and trading will be used interchangeably in this analysis, although they are not the same theoretically. The State Water Resources Control Board of California differentiates between each of them:

"Pollutant trading refers to an exchange of either permitted discharge levels or required abatement levels between two or more dischargers, either in a formal 'commodities' market or banking system, or a less structured exchange; offsets generally refer to unilateral abatement efforts by a discharger to remove a certain amount of pollutant discharge from existing sources to compensate for the discharger's own discharge." (Wilson, 2001)

Emissions trading programs (ETP) were first used to provide greater flexibility for emission sources to meet air quality standards. The first practical application of an ETP concerned the problem of sulfur dioxide emissions from coal-fired power plants. Sulfur dioxide emissions and the resulting acid rain have had negative impacts on vegetation throughout the Eastern United States and Canada. Established under the 1990 Clean Air Act, the Acid Rain Program is the most widely known and successful trading program. Although cost savings have been difficult to measure because of the proprietary nature of industrial pollution control-cost data, this program was expected to save more than $2 billion a year in compliance costs within the next decade compared with the cost of preexisting regulations (Jarvie and Soloman, 1998).

One of the potential problems with this program was its national structure. Sulfur dioxide is a regional pollutant, meaning that its effects may be felt hundreds of miles away from the source, but not thousands (Cramton, 2000). Therefore, reductions in one area may mean fewer reductions in others and cause “hot spots” (high concentration of pollution in a defined area). The alternative was to reduce trading flexibility by setting up regional caps that would prevent hot spots. This regional approach appears to have been effective, because no hot spots have been detected (Cramton, 2000). This is an example of how the types of contaminant and the media have a role in the development and success of a trading program.

Water Quality Trading

Since the early 1980s, the EPA has been planning new and innovative schemes to manage and reduce NPS pollution, including trading programs. The Water Quality Act of 1987 required States to assess NPS pollution and develop plans for managing it. In 1990, the Coastal Zone Act Reauthorization Amendments (CZARA), required coastal States to develop NPS programs that could include land use management and agricultural best management practices (BMP) that reduce loadings (16 U.S.C. §§ 1455 (d)(16), 1455b) (Ribaudo and others, 1999).

The EPA issued a broader Policy Statement on Effluent Trading in Watersheds (1996) and more recently a proposed water quality trading policy (2002) establishing a more clearly defined role for water regulation. The EPA supports and encourages water quality trading programs for many purposes: reducing the cost of compliance with water quality-based requirements, offsetting growth, achieving early reductions and progress toward water quality standards pending the development of such standards, and establishing economic incentives for voluntary reductions (EPA, 2002). Under EPA’s proposed policy, to create pollution credits to trade or offset, PSs must reduce pollution levels beyond the level of the most stringent technology requirements.

EPA’s proposed rules for the implementation of the (TMDL) program (1998) will have important implications for water quality trading. As the proposed rules explain, “the TMDL specifies the amount of a particular pollutant that may be present in a water body, allocates allowable pollutant loads among sources, and provides the basis for attaining or maintaining water quality standards” (EPA, 1998). TMDL implies that PS and NPS contributors must share the responsibility for meeting target levels. The question then becomes what is the best policy to meet these standards; for example, discharge standards, discharge fees, or tradable permits (Ortolano, 1997). Previous environmental regulatory policy focused on controlling the output of pollutants from each source separately without focusing on the final overall quality within the watershed or on different control costs (Boyd, 2000). Individual permits were issued without taking a holistic overview of a watershed. Currently, policymakers and regulators are focusing more on environmental and economic objectives while giving flexibility to dischargers to find ways to achieve public goals.

Although these rules will have significant implications for PSs, the impact on NPS pollution control will be most important. Since the focus has turned to NPS pollution, and ambient monitoring will find a large number of nonpoint polluted water bodies, “TMDL’s will change the politics, economics, and implementation of water quality regulation” (Boyd, 2000). Policymakers and regulators will need to become more flexible in allocating loads, as well as in devising methods to meet water quality standards as financial constraints limit opportunities for contaminant reduction.

Load allocations (the amount of total pollution allowed set by the States under a TMDL) for NPSs are not directly enforceable under the CWA but, according to the proposed rule (EPA, 1998) in 1998, are enforceable only by State laws and regulations. This proposed rule was promulgated in 2000 into law; however, Congress prohibited funding for the implementation (EPA, 2001). This law will be withdrawn in April 2003, but there will be a proposal for a similar rule (Matt Mitchell, oral commun., 2002). However, regulatory requirements still prevent the EPA from implementing any nonpoint regulations explicitly.

Watershed-based trading may provide a tool for sources to meet the stringent limits expected to result from TMDL development. These analyses supporting TMDL development estimate NPS and PS contributions to each watershed through data collection, expert judgment, and water quality modeling (Borsuk and others, 2002). After a TMDL identifies contributions from each source, the total amount of pollution that can be discharged to the water body is set, and allowable discharges are allocated to individual pollution sources. Figure 2 illustrates a simple schematic of the implications of PS and NPS contributions to water quality degradation and the impacts of trading/offsets.

Type of Source	NPS	PS
Status	Diffuse and large water contributor to water quality degradation	Easier to identify (end of pipe)
Solutions/Remedies	BMPs, source reduction, recycling	Technological/capital investments
Problems with remedies	Difficult to enforce and to clean-up/control	Costly
Trading/offsets	NPS Pollution is addressed	Reduction in costs

Figure 2. Impaired water quality.

Trading/offset systems are founded on the idea that it may be more economically efficient to have high-cost polluters pay low-cost polluters to reduce pollution further, providing more pollution reduction at a lower total cost. In other words, if it costs one entity much more than another entity to reduce the same amount of pollution, then these two entities can trade pollution credits. However, this approach has been limited because of the natural variability and uncertain monitoring of NPSs, as well as other issues, such as liability, lack of clear water quality standards, and lack of consistency in regulatory methods (Stephenson and others, 1998). The next sections will review some of these limitations.

II. SIGNIFICANT CONCEPTS AND ISSUES

Environmental Concerns: Natural Variability of Nonpoint Source Loads

The physical nature of NPS pollution has confounded attempts to regulate and control its occurrence (along with a lack of legal and/or regulatory authority). Problems include its sporadic and diffuse nature, a lack of monitoring capability, and the difficulty of assigning responsibility for the NPS pollution. It is generally not possible to observe or too expensive to identify the amount of discharge of any [individual] suspected polluter at all times or to infer NPS levels from observable ambient pollutant levels. Although predictive models exist, there are large areas of uncertainty about the fate and transport of target pollutants (Letson and others, 1993). With respect to water quality, emissions of several polluters contribute to the ambient levels, and only combined effects are observable (Sergerson, 1988). Therefore, it is difficult to monitor and regulate NPSs. In addition, NPSs have estimated loads that are neither completely known nor constant with the seasons (Jarvie and Soloman, 1998).

Efficient environmental policy for NPS pollution has been constrained as a result of the natural variability associated with weather conditions and episodic events, such as wind, rainfall, and temperature (Xepapadeas, 1992). Weather and climate strengthen the uncertainty of estimating the contaminant load and concentration. For instance, during a severe and prolonged storm, the erosion capacity increases, producing greater runoff and more contaminant discharge into the receiving waters. NPS loadings generally increase during rainy seasons and decrease during dry seasons. However, the effects of discharge on a water body depend not only on the total quantity of the effluent released but also on the assimilative capacity of the receiving water body (Stephenson and others, 1998).

Since rain also dilutes NPS runoff, the short-term effects of NPSs may be mitigated to some extent, thereby reducing the chance of violating the water quality standards, although there are other factors that determine the final outcome, such as slope, topography, hydrogeology, and so on (Jarvie and Soloman, 1998). Nonetheless, it is unclear that increased NPS loads caused by above-normal rainfall will significantly affect ambient water quality. These environmental processes are very site specific, thereby inhibiting efficient regulatory requirements (Stephenson and others, 1998).

Uncertainty Analysis

The physical realities of NPS pollution described above imply that there will be a range of possible loading or concentration levels associated with any given remediation practice or discharge level at any given time. Current monitoring technologies can't measure NPS emissions at a reasonable cost because they are diffuse (Ribaudo and others, 1999). However, through multiple sampling trials, one could estimate the range or probability of loading and concentration. The objective of a PS-NPS trading/offset policy would be to increase the probability that concentration levels of the targeted pollutant will fall below the water quality standard (Stephenson and others, 1998).

The risk of exceedance is the probability that the amount of targeted contaminant, say total mercury loading, discharged into the system will exceed the target (allowable) value set by the EPA or Regional Water Quality Control Board (Jack Schuenemeyer, written commun., 2000). That risk is a function of the uncertainty associated with the loading of mercury in any given time at the NPSs. Reducing the uncertainty of mercury loading at one or more of the NPSs can reduce this risk to the system. The following hypothetical situation illustrates the impact of uncertainty in controlling NPSs and how and why PSs make remediation decisions.

The goal of a PS is to comply with existing laws and regulations in a cost-effective manner. Suppose a PS is required to remediate Z volume of mercury and assume that the choices available to a PS at a certain time are to reduce total mercury loading at the point of discharge or to select an offset; that is, reduce pollution from one or more NPSs. The PS can choose among X number of NPSs. Each "what-if scenario" has an estimated mean and variance of mercury loading reduction and remediation cost. Note that the probability distributions can be estimated from data, expert judgments, or a probabilistic water quality model. Suppose a PS is required to remediate Z volume of mercury by cleaning up one or more of the X NPSs. To simplify matters, suppose there are three NPSs and a PS has to decide which one to offset. The following example provides data on three NPSs. An offset reduction requirement is estimated using the applicable regulatory standard. A percentage reduction is the percentage of contaminant the PS has to reduce. Consider the following specific example. The publicly owned treatment works (POTW) must offset 20 kg (or 20 percent of its total loading) of a contaminant to meet the requirement. Each NPS has a mean and a variance of how much contaminant can be reduced. The POTW has to decide which one to offset.

Offset Reduction Requirement = 20 kg (the amount of pollution that must be reduced)		
NPS #	**Mean (kg)**	**90% Confidence Interval (kg)**
1	22	(17-27)
2	18	(15-21)
3	25	(15-35)

Figure 3. Hypothetical example of remediation decisions.

In the proposed study, the data would come from existing field collection, water quality modeling, expert judgment, and historical discharge, or from new data collections. Although there is a reasonable chance that any of the NPSs could meet the PS's needs, other factors must be considered before a decision can be made. Suppose that the PS chose site 1 with the mean of 22 and a 90 percent confidence interval from 17 to 27. If we assume that these statistics are based on a representative sample (an average over all seasons and times), then one could estimate the probability distributions for the volume of mercury at NPS site 1. The reduction requirement is set at 20; thus, site 1 satisfies the cleanup requirement. At site 1, the sampling distribution of mean values is centered at 22, so undertaking this remediation project will meet and surpass the percentage reduction requirement. Although this example uses a normal distribution, other distributions could be tested. The risk, the probability of noncompliance, is the area to the left of 20 in figure 4 (indicated by a double-headed arrow). If this risk is perceived as too great, the PS might choose another site or invest resources in data collection.

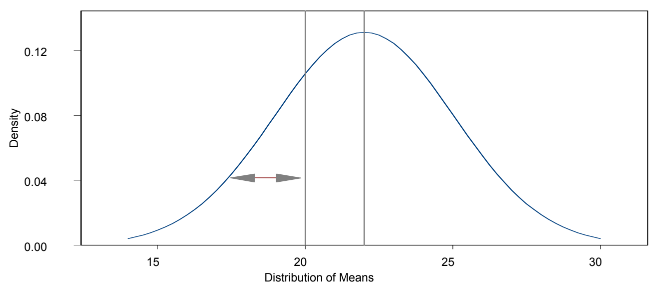

Figure 4. Total mercury loading distribution.

Remediation decisions made by PSs are quite complex. Uncertainties of remediation decisions include remediation costs at each site, the benefit to the PS if its cleanup/remediation exceeds the target value, whether there is a forward (banked) credit if a PS exceeds its reduction requirement, and potential penalties for noncompliance. Also, PSs will need to decide whether to collect more data or install new controls at their current facilities. The PS must account not only for the scientific uncertainties but also for legal and economic uncertainties.

Economic Considerations

It is often difficult to compute the economic and environmental damage caused by NPS pollution (Ribaudo and others, 1999). These damages may include fish kills, an increase in eutrophication, and a reduction in opportunities for recreational activities, depending on the designated beneficial use of the water body. Instead, dischargers can evaluate their policies on the basis of their ability to achieve specific environmental goals at the least cost, given the policy instruments available to a resource management agency, along with other political, legal, or information constraints that may exist. Such an outcome is referred to as "second best" (Lawrence Goulder, oral commun., 1999). "Second best" applies when, for one reason or another, regulators are unable to use the optimal regulatory instrument and so must do the best they can with restricted opportunities. Frequently, damages are not proportional to known discharges and exhibit nonlinear behavior; therefore, controlling discharges will most likely be a second-best strategy (Braden and others, 1989). The success of a trading system will depend on whether or not certain economic conditions are in place: differences in marginal abatement costs (the costs for each additional unit of contaminant reduction), the trading ratios (amount of NPS pollution reduced to receive a unit of PS pollution-reduction credit), transaction costs (the costs of negotiation and bargaining between sources), monitoring costs, and the number and size of participants.

The economic appeal of PS-NPS trading/offsets depends on the differences between unit/marginal costs of pollutant reduction for different PSs compared with such costs for NPSs. Although the volume of trades is important, efficiency will be greatest when the trading results in the marginal costs of abatement (that is, of avoiding a given amount of damage) being equal after transactions between the entities (Baumol and Oates, 1994). Differences in marginal costs arise when NPSs can implement cheaper methods to reduce loadings while PSs need to install more expensive technologies to achieve the same reduction in loadings. Equalization of marginal costs can come about with minimal trades if there is little deviation in marginal abatement costs at the initial allocation of permits.

NPS reduction is often cheaper on a per-unit basis (compared with PS control) because PSs often require expensive technological methods to control further discharge, but NPSs often rely on cheaper nonstructural BMPs to reduce pollutant loading. The development of BMPs is "based on the practical experience of land managers and improvements in the scientific and technical understanding of the relationship between land management practices and environmental impacts" (Boyd, 2000). Examples include installing riparian buffer strips, building adequate fencing to keep livestock from directly soiling surface water, and placing sheds over manure piles to minimize runoff (Boyd, 2000). However, BMPs sometimes never achieve what they are intended to do (Randall and Taylor, 2000). Because of the uncertainty of BMPs, regulators institute a trading ratio.

The natural variability of NPS pollution, the assimilative capacity of a water body, and the uncertain efficacy of BMP's and other strategies prompt regulators to establish a trading ratio. To obtain water quality goals, PSs generally must sponsor a larger reduction through the NPS because of the uncertainty of the volume of NPSs (Crutchfield and others, 1994). Trading ratios, most likely set by States, are used to overcome this uncertainty. These ratios define how many units (volume) of NPS pollutant reduction are equivalent to one unit of PS loading reduction. For instance, at a trade ratio of 2:1, point sources reducing 2 pounds of NPS nitrogen loadings would receive credit for 1 pound. This extra reduction represents a response to an attempt to compensate for the uncertainty about the relative effectiveness of PS and NPS controls (EPA, 1996). Although this helps ensure that expected water quality improvements actually occur, potential side effects may include increasing marginal costs of trades and decreasing trading potential (Hoag and Hughes-Popp, 1997).

Transaction costs are another important economic issue in assessing the usefulness of a PS-NPS trading scheme. Identifying potential trading partners, negotiating a trade, monitoring the water quality, and using government or private administration all contribute to transaction costs. The administration costs serve as an important determinant of trading potential: determining the type of pollutant to be traded; the structure of trading (through actual parties, watershed organization, EPA); the units of trade; directionality (must buyers always be downstream of source that reduces its pollutants?); size of trading area; trading ratio; monitoring requirements; enforcement costs; and verification of credits (EPA, 1996). Additionally, PSs and other stakeholders may have to incur lobbying costs to convince NPSs, which are not regulated currently, to create trading opportunities. The number and size of trading participants will also affect trading potential. For trading to be practical, a few PSs of significant size should exist. If there are too many participants, costs to locate available sources for trading, negotiation costs, and administration costs to run the program will all increase and reduce trading potential. Transaction costs will exceed the potential for control cost savings if a watershed contains numerous PSs requiring costly bargaining and negotiation time.

For PS-NPS trading to contribute to overall water quality improvement and increased cost savings, both types of sources must contribute significantly to total pollutant loadings (Ribaudo and others, 1999). For instance, if NPS contributions are relatively large in relation to PS contributions, then most likely PSs will not be able to afford the purchase of enough NPS permits to meet their required reductions and make any improvements in water quality. If NPSs contribute 99 percent of the loadings, implementing an incentive-based program may not help dischargers because requirements imposed on PSs will not be sufficient to meet water quality standards through offsets. There may be an improvement in water quality, but the focus of using an offset program is to help dischargers meet their regulatory requirements.

The logistics of a watershed network (for example, the number of each source contributing to the watershed, the contribution of each, the size of the trading area, enforcement and monitoring costs, differences in marginal costs) ultimately determine the potential of a PS-NPS trading/offset program as a suitable water quality policy. In addition to the environmental and economic uncertainties, legal and political motivations play a large role on deciding whether water quality trading is a feasible policy.

Legal Implications

Before any type of water quality incentive-based programs can be implemented, legal authority for these programs to supplement water quality regulation needs to be established. Legal issues that arise include antibacksliding rules from the Clean Water Act, the extent to which regulations authorize new or renewed permits, and potential liability postremediation (Wilson, 2001). Initially, provisions must be consistent with the CWA, including the following: requiring sources and activities to obtain a Federal permit before being allowed to participate in a trading program; developing baselines for trading derived from water quality standards; not accepting any use of pollutant reduction credits or allowances that would cause a localized impairment; requiring that NPDES permits describe how baselines and conditions or limits for trading will meet water quality standards, and so on (EPA, 2002). In addition, under section 402(b) of the CWA, all

NPDES permits issued by States require each PS to be subject to applicable TBELs as a floor, with the possibility of using offsets to make further progress toward water quality goals (Wilson, 2001).

An offset program must do more than substitute one contributing source for another because Federal law prohibits new discharges from contributing to violations of water quality standards. The antibacksliding rule draws on this distinction between new and existing sources by not allowing, unless certain exceptions are met, permits to be renewed or modified "to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit except in compliance with section 1313(d)(4) of this title" (CWA 33 U.S.C. ζ 1342 (o)). The application of antibacksliding rules could have significant consequences in terms of permissibility of offsets since, in theory, offsets provide dischargers with flexibility in lieu of the application of an otherwise stringent effluent limitation.

An essential legal implication of water quality trading is the potential for contingent liability suits. There is a potential for liability lawsuits when unilateral remediation action at a particular site is committed for an offset and contamination resurfaces in the future. Under the current CWA, a "Good Samaritan" that wants to clean up a site is not protected from liability if more discharges occur after the cleanup work is completed. These liabilities become an overwhelming disincentive to voluntary remedial activities for resolving the serious problems associated with abandoned and inactive mines. As a result, the potential legal costs, as well as further remediation costs, will prevent most remediation from taking place. If a "Good Samaritan" liability law were formulated to reduce potential contingent liabilities, dischargers might be more willing to risk adopting an "abandoned" offset site.

III. EMPIRICAL EVIDENCE: CASE STUDIES OF TRADING/OFFSET PROGRAMS IN THE UNITED STATES

A. Lake Dillon, Colorado

Dillon Reservoir, located 70 miles west of Denver, Colo., was the first PS-NPS trading program in the Nation and is still ongoing (Stephenson and others, 1998). Studies determined in the early 1980s that excessive phosphorous (P) discharge was accelerating algae growth, which was causing eutrophication[1] problems, particularly low dissolved oxygen levels in the reservoir (Stephenson and others, 1998). Estimations derived from

[1]Eutrophication occurs when organic matter increases in an aquatic environment or in the ecosystems of lakes, reservoirs, and streams and causes hypoxic, low dissolved oxygen levels; conditions when decaying organic matter on the bottom depletes oxygen and replenishment is blocked by stratification. The fluxes of organic matter to the bottom are fueled by nutrients carried by river flow or from upwelling that stimulates the growth of phytoplankton algae. (Source: http://www.nos.noaa.gov/pdflibrary/hypox_iafigs.pdf)

data collection and modeling indicate that about one-half of the anthropogenic P loads entering the reservoir were contributed by PSs, mainly from four POTWs, and half were from NPSs, primarily individual septic systems and urban runoff.

In 1984, using population projections, the State of Colorado estimated that the health of the lake would require a reduction in the quantity of P coming from the four major POTWs. Rather than having to upgrade their own facilities, the POTWs were offered the option of implementing controls for existing urban NPSs. Cost studies showed that POTWs could achieve the same overall reductions in P for half the cost if they concentrated on NPSs rather than solely on their own emissions (Jarvie and Soloman, 1998). The EPA approved a trade ratio of 2:1 so that there would be enough P reduction in the basin to allow for growth of the POTWs and new NPSs based on estimated population growth.

An example of how credits are created involved the community of Frisco. In 1985, the Frisco Sanitation District (a POTW) decided to address NPS storm-water runoff of P into the lake. The district built storm-water control structures to guide the surface runoff back underground. Approximately 50-70 percent of the P was removed as the water filtered through the pipes (Jarvie and Soloman, 1998). The number of credits gained from this project was set equal to the amount of P removed, determined by monitoring the flow and concentration of incoming and outgoing water. This is an example of a direct measurement of NPS effluent discharge. The Frisco District was offered P credits for its NPS reduction by the Colorado Water Control Commission. Frisco only needed a small portion of P allocated to it annually and donated its surplus credits to offset increased P discharge associated with the construction of a new town golf course (Jarvie and Soloman, 1998). The credits in this trade were not actually bought or sold, but the process worked to the benefit of both parties. In this instance, trading allowed further development while still improving lake quality.

The Dillon Reservoir example demonstrated that the direct measurement of NPS load is not impossible. Although NPS pollution is defined as being diffuse, knowing the relative location of these NPSs makes it possible to treat an NPS as a PS and measure it with more confidence. In addition, trading does not necessarily need a tangible cash transaction for cost savings to occur. As of November 1999, 2 trades have occurred and more than 10 NPS projects have generated credits that have been banked but not yet used or sold (Sohngen, 1998).

B. Tar-Pamlico River Basin, North Carolina

Excessive nutrient loading in the Tar-Pamlico Estuary in recent years has caused low dissolved oxygen levels, sporadic fish kills, and other water quality problems. Nitrogen (N) and P, the main culprits, came from agricultural NPSs (livestock and crop production) and wastewater treatment plants (Jarvie and Soloman, 1998). In 1989, as a result of severe eutrophication problems in the basin, the North Carolina Division of Environmental Management (DEM) Commission classified the basin as nutrient-sensitive waters (NSW). Under this classification, the DEM was required to implement a strategy to reduce PS and NPS loads of N and P. Cost studies showed that upgrading these POTWs to meet new discharge limits would cost the dischargers as much as $100 million (Jarvie and Soloman, 1998). Because of these large costs, 12 POTWs and 1 industrial firm voluntarily formed the Tar-Pamlico Association (TPA) to meet an overall nutrient cap. The association estimated that reducing one unit of NPS pollution would cost about 10 percent of the price of reducing one unit of PS pollution, or about $11 million (Jarvie and Soloman, 1998). The State of North Carolina and the TPA agreed to a plan for setting a basinwide reduction goal.

TPA members are jointly responsible for meeting the total nutrient loading allowance (cap). If the TPA exceeds this cap, it agrees to pay a $56/kg fee ("buying nutrient credits") for every excess kilogram (Hoag and Hughes-Popp, 1997). This fee accounts for a 3:1 trading ratio for cropland BMPs or a 2:1 ratio for confined animal operations and is based on average control costs and administrative fees. These funds go to a voluntary program called the North Carolina Agricultural Cost Share Program (ACSP), which provides technical assistance and pays farmers a percentage of the average cost to implement nutrient-reducing BMPs (Hoag and Hughes-Popp, 1997). Therefore, in this trading scheme, farms -the NPSs- are not direct participants in the "trading" of the credits. The ACSP, a representative entity of the farmers, acts as a mediator in this trading system. In addition, changes in nutrient discharge resulting from these BMPs are not measured directly. Credits for implementing these measures are given on the basis of average levels of pollution documented in prior research (Stephenson and others, 1998).

In the initial stages of the project, dischargers could trade reduction credits with other PSs or pay to implement BMPs at NPSs at a 3:1 ratio (Jarvie and Soloman, 1998). Annual reduction goals were met successfully and even exceeded in this first phase. It was estimated that the association avoided nearly 75-90 percent of the estimated cost of using standard industrial nutrient reduction technologies (Jarvie and Soloman, 1998). Through the application of various agricultural BMPs, the requirement for much more costly advanced wastewater treatment technologies was avoided. Moreover, in this case almost 80 percent of the nutrient pollution in the river was from NPSs sources (Jarvie and Soloman, 1998).

The TPA has not exceeded the maximum allowable nutrient loading yet, and therefore there has not been an actual PS-NPS trade. Most of the reductions were met through the initial cheap reduction opportunities from PS facilities and monetary contributions to a BMP fund. There is a growing sum of banked BMP credits. Additional program benefits include funding for additional collection of nutrient effluent data and the development of an estuarine model for the basin.

C. Clear Creek, Colorado

In the mid-1990s, the National Forum on Nonpoint Source Pollution began the Orphan Sites Feasibility Study to identify and display innovative, nonregulatory approaches to nonpoint pollution (U.S. Water News Online, 1998). An "orphan site" can be defined as a contaminated site that cannot be regulated under current laws, has no identifiable, responsible entity that can be located, and has no means to address the problem. The purpose of this study was to discover new approaches of market-based incentives to achieve water quality standards not otherwise attainable under existing regulatory programs. This offset program would allow any interested discharger to "adopt" and clean up an unregulated orphan source of pollution in exchange for discharge credits. The Clear Creek watershed, nearly 500 square miles in the Front Range west of Denver, Colo., served as the model watershed for this study (Holm, 2001). This area, containing more than 1,300 orphan mine sites, is contaminated by numerous heavy metals in the water caused by runoff and drainage (Environomics, 1999).

Although the previous two case studies were successful in implementing a trading/offset program, various barriers prevented this program from moving beyond its conceptual stages in this case. For instance, as a result of the "Good Samaritan" liability issue, dischargers weren't willing to risk adopting an orphan site because they could be held liable for further contamination (Carl Norbeck, written commun., 2001). Under the current Clean Water Act, a "Good Samaritan" that wants to clean up a site is not protected from liability if more discharges occur after the cleanup work is completed. Carl Norbeck, from the Colorado Water Quality Control Division, explained that dischargers were shielded from liability lawsuits by Federal and State agencies but not from citizen suits. In addition, he said that the amount of time spent by the Steering Committee was astronomical, with very little payoff. Other barriers included soliciting participants (unsuccessful development of a liability relief tool), evaluating the merits of the cleanup, evaluating the merits of the desired benefit, and spending far too much time to gain acceptability.

IV. DISCUSSION

These case studies highlight some of the challenges and benefits of trading programs. First, trading programs can be used to help nonattainment areas reach water quality standards more cost effectively. In some cases, the complete removal of a POTW would not have achieved as much water quality improvement, even if it were possible or practical. A program where PSs and NPSs cooperate with each other to reduce discharges for the least cost may save money, as well as meet water quality standards. These programs have the potential to limit top-down Government control and to encourage and institutionalize cooperation and discourse between interested parties (Woodward, 2002).

The cost-effectiveness of a trading program can be affected by additional transaction and program administration costs. In the Tar-Pamlico case, costs were greatly reduced by the formation of a PS association-trading group with another established entity, the ASCP, representing the farmers. Most of the transaction costs dissipated as the association became established. The only remaining transaction costs were to the firms for the effort and paperwork needed to buy the credits and to the farmer for implementing the BMPs (Stephenson and others, 1998). Since PSs pay for reductions elsewhere and farmers are paid for pollution prevention, transaction costs are reduced for the farmers and the association by making it easier for buyers and sellers to establish trades. These economic incentives will increase the likelihood of trading.

There are some attributes of these programs that limit cost-effectiveness. For instance, although the Tar-Pamlico program reduced transaction costs, the program was administered using average costs rather than marginal costs, thus eliminating some of the marginal benefits that could be achieved in a more efficient market. Also, both programs incorporated a fixed trading ratio. Although these ratios are used to reduce the monitoring and causal uncertainties associated with NPS loadings and provide a "margin of safety," the additional reduction of pollutants may outweigh the potential cost savings of meeting the established water quality standard.

Regulators use trading ratios to account for these uncertainties; however, in effect this produces greater costs in administering an offset policy. One solution would be to replace the fixed rate (ratio) with a variable rate based on random episodic events. For instance, a higher ratio could be used when there are higher probabilities that damage will occur, such as during high-precipitation seasons with more runoff. In addition, better monitoring technologies and information in the future could create less stringent trading ratios.

V. OPTIMAL CONDITIONS FOR WATER QUALITY TRADING

The previous section highlighted some of the specific conditions that would support and prevent implementation of a successful trading program. The following is a general description from the literature of recommendations for creating the best conditions to implement trading programs:

- *Responsibility*: The total amount of pollution discharge allowed, as well as the property rights and responsibility for all participants, needs to be defined clearly when the program is established.
- *Legal Authority*: Clear legal authority for trading must be established by the States and Federal Government through legislation, rulemaking, and incorporating provisions for trading through NPDES permits (EPA, 2002).
- *Delineated Watershed*: The geographic area, in which trades will take place, whether it is an entire watershed or small segments within a watershed, must be specified (Kerns and Stephenson, 1996). Provisions must be made to prevent potential "hot spots" or localized water quality problems.
- *Marginal Costs*: A necessary condition for any type of environmental trading program to work is that the marginal costs of abatement (the additional cost of eliminating discharge in controlling an additional unit of contaminant) must be different among a sufficient number of dischargers (Baumol and Oates, 1994). A trading program is only more cost-effective than the status quo policy if it can achieve the same environmental standard at a lower cost or a better standard at the same cost. Trading is effective under these terms because firms with high marginal costs of abatement can compensate those with lower costs.

- *Proper Regulation*: Mechanisms (monitoring, statistical models, and so on) are needed for determining compliance and ensuring enforcement. BMPs represent the analog to end-of-pipe controls on PSs (Boyd, 2000) and need to be monitored for effectiveness. The PSs need to be accountable for making the investment in NPS reduction.
- *PS and NPS Contribution*: Both PS and NPS loads must be significant and contribute a substantial share of the emissions/pollutants for trades to be cost-effective. If either PSs or NPSs contribute substantially more pollution relative to the other (for example, one source contributes more than 80 percent of the loading), a trading program may not be able to achieve water quality or cost-saving goals. A trading program, however, could still produce improvements in water quality even if short of meeting the standard; this isn't an aspect that should be overlooked. In addition, a trading program will not work if participant sources are too small or too few.
- *Transaction Costs:* Methods to reduce transaction costs must be identified and implemented. These costs include those of identifying potential trading partners, of negotiating a trade, and of having government and/or private administration (the costs of information collection, of time, and of communication). These costs could negate the potential cost savings from making trades between sources that have different marginal costs. One solution to reducing transaction costs is "piggybacking," or the act of PSs expanding NPS pollution control projects that are already being implemented. (EPA, 1996).
- *Information exchange*: Stakeholders need to share information about existing or planned projects with PSs that can then contribute additional funding to expand a project's scope. The costs to PSs that are associated with trade identification, evaluation, implementation, and monitoring are thereby reduced. A private or public information exchange system could help provide technical information to the trading participants to further reduce transaction costs.
- *Stakeholder involvement:* The general public needs to be involved in the decision process. If the public is included, its concerns can be considered and possibly incorporated into the trading program rather than being dealt with later through costly lawsuits. Public inclusion can provide understanding and confidence in the process that will make the issuing of regulatory permits easier and quicker by reducing time for planning and administration iterations. Public participation can in effect help a trading program become cost-effective.
- *Program Evaluations:* Environmental and economic effectiveness should be assessed periodically to ensure that localized violations of water quality do not occur.

CONCLUSION

This report reviews a general perspective on the suitability of a PS-NPS trading program. The objective was not to make a case that trading should be implemented but rather to review the conditions under which trading could be implemented. The current regulatory strategy is to focus on the ambient level of pollutants; however, the challenge is to infer how the actions of specific NPSs are affecting them. Alternatively, we can assess this uncertainty through statistical and economic means to provide appropriate regulatory approaches.

The lack of spontaneous trading among dischargers does not mean that a marketable permit trading system is an inherently inefficient regulatory approach; rather, its infrequent use is the result of institutional and informational barriers (Crutchfield and others, 1994). The idea and the institutional (administrative) and legal structures to support it are fundamentally quite new and untested. The outlook for a PS-NPS trading scheme is quite positive if these problems can be resolved. According to the literature reviewed, the potential for trading can be improved through technical advances, better monitoring, institutional upgrades, and better earth science information. Better defining the relationship between changes in land use and management practices and effluent discharges can reduce the uncertainty in measuring and monitoring NPS pollution. Ultimately, a compromise is needed between saving on costs and having an administratively simple, politically acceptable program. The literature review and issues discussed will be useful when evaluating the feasibility of offsets for meeting mercury TMDLs currently being developed by the USGS Western Geographic Science Center.

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