POLLUTANT TRADING FOR WATER QUALITY IMPROVEMENT

A POLICY EVALUATION

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FORWARD

This report presents the analysis and findings of a year-long investigation of point-nonpoint source (P-NPS) pollutant trading. The effort has been supported by funding from the Environmental Protection Agency, plus matching funds from state Clean Water Partnership projects. Its goal is to assess the suitability of P-NPS pollutant trading for Minnesota.

The author initiated the investigation in October 1993. Shortly thereafter, a steering committee was established to contribute to and guide the investigation. Water Quality Division members include: Wayne Anderson, Pat Corrigan, Dennis Devereaux, Russell Felt, John Hensel, Doug Hall, Jim Klang, Mary Knudsen, and Gary Rott. Other members include: Robert McCarron, Economist, Air Quality Division, MPCA; Rebecca Flood and Jack Frost, Metropolitan Council; Greg Larson, Minnesota Board of Water and Soil Resources; and Steve Taff, Dept. of Ag & Applied Economics, U of M

In a series of monthly meetings, the steering committee has been presented with various aspects of pollutant trading, and asked to respond with comments and criticisms. This report attempts to capture the results of this interactive process and of two case studies, and to present tentative conclusions regarding P-NPS trading policy for Minnesota.

The report is organized in four parts.

Chapter I presents an institutional analysis that deals with the underlying rationale for pollutant trading, and outlines the many variants of pollutant trading that appear to be feasible. These variants are evaluated with respect to three criteria: efficiency, effectiveness and equity. This section describes how pollutant trading could promote cost-effectiveness while helping to coordinate or integrate point and nonpoint source programs in the context of basin planning. Particular attention is paid to the analysis of incentives.

In Chapter II, the evaluation moves from the theoretical to the empirical plane. P-NPS trading is evaluated in the context of concrete water quality concerns and policies. In particular, phosphorus is selected as a pollutant to evaluate for potential benefits from P-NPS trading. Technical factors involved in P-NPS policy integration, as well as legal and economic factors, are explored. Relevant Minnesota statutes and rules are identified, as well as key policy considerations impinging on P-NPS trading. The cost of alternative point and nonpoint source phosphorus loading reduction technologies are estimated and compared, and the prospects for achieving economic gains from trading are assessed. Finally, a procedural guidance for P-NPS trading is presented.

In Chapter III, two case studies are presented in order to explore the feasibiliy of P-NPS trading in an empirical setting. The sites chosen are Rogers and Rochester, small and moderate sized communities, respectively, that have recently upgraded their wastewater treatment plants for phosphorus control. The case studies explore whether, and under which circumstances, P-NPS trading might have offered a cost saving without sacrificing water quality.

In Chapter IV, proposals for implementing pollutant trading are introduced. A proposal called the "Flexible Compliance Option" is presented as a short-term possibility. In addition, prerequisites for introducing more general pollutant trading schemes, including those based on basin management, are listed.

SUMMARY

P-NPS pollutant trading refers to the substitution of nonpoint source pollutant load reductions for point source load reduction requirements by a discharger permitted under the National Pollutant Discharge Elimination System (NPDES).

The investigation concludes that P-NPS pollutant trading could prove to be a very useful policy instrument for the Water Quality Division. If properly designed and implemented, it has the potential to promote efficiency, equity and effectiveness while integrating point- and nonpoint-source programs in the context of basin management. Introducing P-NPS trading does not appear to pose significant legal problems, although the relationship between P-NPS trading and National Pollutant Discharge Elimination System (NPDES) permit requirements needs to be carefully considered.

However, based on an evaluation of its potential use in managing phosphorus loadings, P-NPS trading appears likely to be feasible only in a limited set of circumstances. There are several reasons for this. First, the widespread assumption that additional pollutant reductions can be achieved at much less cost from nonpoint sources than through additional point source controls turns out not to be generally true. Over a wide range of circumstances, the opposite appears to hold true in Minnesota. That is, for moderate or large-sized municipal treatment systems where the initial concentration of total phosphorus in the waste influent is moderate to high, and the permitted effluent concentration level does not sink below 1 mg P/l, the cost of phosphorus removal tends to be low relative to nonpoint sources. Where one or more of these conditions does not hold, municipal treatment control costs may be higher than nonpoint source costs, and P-NPS trading may be advantageous. Moreover, phosphorus reduction costs are unique for each treatment plant, and may be sufficiently high to make P-NPS trading seem worthwhile even for plants which may appear on the surface to fit into a low-abatement-cost category.

On the nonpoint source side, the cost of phosphorus reduction often is higher than expected. On the surface, certain phosphorus-reducing best management practices (BMPs) appear to be very low cost or even *costless,* such as residue management and nutrient management, in that they involve farm management changes that have been demonstrated to result in increased net income. However, closer consideration reveals significant costs associated with these BMPs in the context of P-NPS trading. First, lack of adoption by landowners indicates some kind of resistance that has to be overcome. An educational program may be required, at a significant cost. In one Clean Water Partnership project in south-central Minnesota, the cost of running such a program per pound of expected phosphorus load reduction was in the neighborhood of \$12 to \$15 per pound. This alone is roughly double or triple the estimated unit cost of phosphorus removal to an effluent concentration of 1 mg P/l at the municipal wastewater treatment systems at Rogers and Rochester, for example, or at the Metro plant in the Twin Cities.

Add a $5-$10 per acre incentive payment, and the nonpoint source cost of phosphorus removal skyrockets to the range of $48 to $70 per pound. And this may not even cover all the costs that would be required under P-NPS trading, such as the cost of negotiating and enforcing contracts with dozens or hundreds of landowners.

There are other nonpoint source BMPs where such costs would be much reduced. In the case of feedlots, for example, large quantities of phosphorus loading reductions can be obtained at a few individual sites through manure containment structures, making general educational programs, and the enforcement of many individual contracts, unnecessary. Even here, however, the cost of nonpoint source phosphorus loading reductions are often on a par with point source reduction costs, rather than far below them. Exceptions include small municipalities, or larger facilities where influent concentrations of phosphorus are low -- in the range of 2-4 mg P/l, for example -- or where severe reductions below Minnesota's 1 mg P/l limit are required. In such cases, manure containment may offer considerable savings.

However, even where a clear cost advantage exists in favor of nonpoint source measures, it is not assured that P-NPS trading would be desirable. Besides efficiency, three additional criteria in particular come into play: equivalence, additionality, and accountability.

- *Equivalence* refers to the physical substitutability of point and nonpoint source loadings, a prerequisite for P-NPS trading that raises complex questions. There are often significant differences in the time and place of loadings from these two classes of pollution sources. Are nonpoint loads that enter the river after storms, typically at high flow, equivalent to point source loads that enter the river at a constant rate, year-long? What if a distance of 10 or 100 miles separates point and nonpoint source loadings? Can they still be treated as equivalent? In addition, there may be significant chemical differences between point and nonpoint source loadings. Point source loads typically are very high in biologically available phosphorus, whereas nonpoint source loadings tend to be very high in particulate phosphorus (except for feedlots). Or, it may be that a point source is faced with a BOD limit, against which it wishes to trade upstream nonpoint source loading reductions. Since BOD has a site-specific impact on water quality, how can equivalent upstream loading reductions be defined and quantified? These are the kinds of questions that arise under the equivalence criterion.

- *Additionality* requires that nonpoint source load reductions that are credited to a point source in a P-NPS trade would not have occurred otherwise, in the absence of P-NPS trading. The Division needs to develop a policy on additionality to provide guidance to potential parties to P-NPS trading. What exactly does additionality mean? Additional to nonpoint source measures that have already been applied? Additional to nonpoint source measures that are planned under current programs? Additional to nonpoint source measures that landowners should be applying, and units of government should be demanding, according to existing pollution control rules? Additional to what landowners are likely to do in their own economic self-interest, in the case of nutrient management, for example? Or additional to what the public should demand of landowners in the way of minimum land stewardship practices that are practical, affordable and effective? How the Division decides these questions will greatly influence which BMPs remain eligible for P-NPS trading, and therefore how much it is likely to cost to obtain nonpoint source reductions.

- *Accountability* refers to the need to ensure that a P-NPS trade satisfies the above criteria of equivalence and additionality, and that terms of the trade agreement are being lived up to. For example, have the nonpoint source BMPs specified in the trading agreement been implemented? Are they being maintained? Are they as effective as at first believed? A larger question of accountability is, will the application of these BMPs have a water quality impact that is comparable to the impact that would have resulted from equivalent point source loading reductions? The degree of monitoring of BMP implementation and maintenance, and of water quality trends, that is required under trading will depend on the degree of accountability desired. The answer to this question could greatly influence the cost and practicability of P-NPS trading.

In practice, P-NPS trading will involve a search for workable tradeoffs between point and nonpoint source load reductions that satisfy the criteria of efficiency, additionality, equivalence and accountability as well as a few others such as flexibility and perhaps public acceptance. This search may take a lot of time or a little time, depending on the quantity of loading reduction required, the possible alternative methods of reduction that are at hand, and the complexity of the issues involved.

There is a danger that the need to meet all of the above criteria, and to answer all the questions they raise, will present severe barriers to P-NPS trading. If this happens, the potential advantages of trading may never be realized. These advantages could be very significant -- for point sources facing high costs of additional pollutant reduction, for communities seeking a way to involve both point and nonpoint sources in meaningful pollutant reduction activities, and for the Water Quality Division, which requires new, flexible policy instruments in order to integrate point and nonpoint source programs to solve water quality problems in the context of basin management.

In order to reduce potential barriers to P-NPS trading, the Division may wish to offer point sources permit compliance alternatives that include two basic approaches to P-NPS trading. Under the first approach, the point source would be responsible for contracting with nonpoint sources for specific quantities of pollutant load reduction. This option would be likely to appeal to smaller point sources who could identify a few nonpoint sources for achieving its required reductions. A policy guidance would be provided to clarify all the requirements which the P-NPS trade would have to satisfy. Under the second approach, a point source interested in P-NPS trading would be given the opportunity to satisfy its load reduction requirement simply by paying into a fund dedicated to nonpoint source pollutant reductions. Payments would be based on the required volume of pollutant load reduction, and the anticipated cost of achieving equivalent, additional and enforceable load reductions from nonpoint sources. Several types of payment schemes could be devised, and integrated with permit enforcement. For example, the point source could be required to pay a surcharge on exceedences of the parameter in question, for discharges in excess of the limits prescribed in its NPDES permit, in a stipulation agreement or in a Memorandum of Understanding. The state then would be responsible for assuring that this payment was used to obtain equivalent, additional and enforceable pollutant reductions from nonpoint sources. The cost of undertaking this responsibility would be covered in the surcharge.

These topics are explored at length in the following evaluation of P-NPS trading, which includes two case studies. These case studies are a retrospective examination of two municipalities where phosphorus removal to an effluent concentration of 1 mg P/l was recently required, and where the necessary treatment plant modifications have already been made. In view of the nature of the water quality problem which prompted the limit on phosphorus, the cost of compliance with this limit through plant improvements, and the possibilities for nonpoint source reductions in the watershed in question, it is asked whether some form of P-NPS trading might have achieved equivalent water quality protection at less cost.

The limited number of potential sites for case studies in Minnesota resulted in a somewhat unusual use of this means of policy exploration. Since in both cases point source reductions were available at relatively low cost, it was necessary to investigate a number of what-if scenarios to investigate the conditions under which P-NPS might have paid off. It would have been better to describe an actual case where P-NPS trading would have clearly paid off, but the rather limited range of application of Minnesota's phosphorus control policy made it difficult to identify such a case.

If current discussions of the phosphorus policy relative to the problems in the Minnesota River lead to a broader application of the state's 1 mg P/l limit, there will be no shortage of municipalities where some form of P-NPS trading would offer considerable cost savings, provided that a user-friendly P-NPS trading option exists. In particular, smaller municipalities and point sources with relatively low initial concentrations of phosphorus in their wastewater are likely to encounter high costs of treatment. That, anyway, is what the following investigation strongly suggests. Easing the burden of compliance for such dischargers may turn out to be one of the main benefits of P-NPS trading, but this depends on the details of whatever trading policy the Division decides to develop. It is hoped that this report will be helpful in identifying the most important questions that such a policy raises, and in beginning to explore the range of possible answers and their consequences.

CHAPTER I: INSTITUTIONAL ANALYSIS

A. INTRODUCTION: POLLUTION, PROPERTY RIGHTS AND ECONOMIC INCENTIVES

Pollution has been described as a "tragedy of the commons" (Hardin, 1968). That is to say, resources such as lakes and rivers tend to become polluted through overuse as waste disposal media primarily because they are owned in common. Being common property, their use is not subject to the limits imposed by private property rights, which require those who wish to use the services provided by a resource to compensate its owner for this privilege. As a result, individual users have no economic incentive to adjust their use to the resource's carrying capacity.

Even if each user perceives that the aggregate result of resource use by many individuals will be to impair or destroy the quality of the resource, and hence its future value to them, it pays the individual to keep on using -- and perhaps abusing—the resource, as long as it keeps providing valuable services at zero cost. Until the early 19th century in Europe, the result was the "tragedy" of the grazing commons adjacent to villages being spoiled through overstocking. In modern America, the result has been water quality degradation through excessive waste discharges. Government action, such as restrictions on grazing or pollutant discharges, as the case may be, is required to protect public resources from such tragedies, and reconcile private use with public values. So goes the economic rationale for government restrictions on the use of public goods, such as water.

This diagnosis of the pollution problem points to a special class of solutions—those that assert public property rights over common property resources in a manner that generates user prices. These prices convert environmental externalities, or third-party effects, into a cost of doing business. The government can do this in two ways. Through an effluent tax or fee, it can demand direct compensation in return for uses which deplete or degrade the public resource, such as waste discharge. Or, the government can issue a limited quantity of pollutant discharge rights to those currently allowing waste to enter public waters. A price will attach to those rights if they are issued at a level that is less than current aggregate discharges, and if they are legally and inexpensively transferable among individual pollution sources. This price, like the effluent tax, will privatize the social cost of pollution by making waste disposal a costly activity.

Ideally, the effluent tax or the price of the right to discharge a unit of waste should equal the cost inflicted on the environment by an additional unit of waste discharge. Economic self interest then would ensure that pollution sources, responding to such a price, would reduce waste discharges to the socially optimal level—that is, to the point at which further reductions would cost more than the environmental benefit they would produce. In practice, however, this point is as difficult to determine as the cost of water quality degradation is to measure—which is to say, extremely difficult. Lacking reliable measures of environmental damages, pollutant loading fees and taxes tend to be determined by a mixture of technical, administrative, political, social and economic factors.

Whatever determines them, and whatever their magnitude, the general effect of such pollutant prices will be the same. As long as the cost of reducing a pollutant load is less than the cost of paying the tax or of purchasing the right to discharge it, pollution sources will have an incentive to reduce those loads. For low-cost-abatement sources, this incentive may persist through several phases of progressively more stringent pollution abatement. But as soon as the cost of additional pollutant abatement begins to exceed the unit tax price, the source will have an incentive to keep on polluting while paying the tax. For very high-cost-abatement sources, that may be forever. As a result, dischargers acting in their own interest will collectively arrive at the most efficient means of achieving a given water quality goal.

Beyond the achievement of such a result, however, a broadly applied pollutant tax or trading scheme would effect a fundamental change in pollution control policy. The invisible hand of the market would replace, at least in part, the heavy hand of regulation. Externally imposed commands would be replaced by internalized incentives. Detailed technical and legal requirements would give way to a range of choices, each with different economic consequences. As less-polluting goods became less costly to manufacture and cheaper to buy, pollution-reduction incentives could be expected to unleash a continuing stream of waste-reduction innovations. "Everyday acts of work and life (would) accumulate into a better world as a matter of course, not as a matter of conscious altruism" (Hawkin, 1993, p. xiv).

Our interest in evaluating incentive-based modes of pollution control, however, is not to reach utopia but rather to cope with emerging challenges. One of these challenges, limited federal and state budgets for water quality improvement, has an obvious relevance to mechanisms that promise greater efficiency. But the budget challenge is only one of many that are coming to the fore as water pollution control programs in Minnesota and across the United States are reaching a turning point. Municipal and industrial discharges from wastewater treatment plants have been significantly reduced by enforcement of secondary technological treatment standards. To accomplish this task over a period spanning two decades or more, state and federal agencies established elaborate systems for assessing pollution problems, requiring reductions in pollutant discharges through rigorous rule-making and permitting processes, assisting in the funding of required facilities, and monitoring performance to enforce compliance with the NPDES permit provisions for each point source. This phase of pollution control—the application of technology standards to all major point sources, one at a time—has largely been completed.

The next phase, still taking shape, will likely be characterized by a different set of challenges and a somewhat different mode of problem-solving. Early discussions indicate that future pollution control efforts will be water-quality driven and implemented in the context of comprehensive watershed programs. Effluent limits will often be determined for many sources at once, rather than one by one. Point and nonpoint pollution sources will be addressed simultaneously, rather than separately, as government resources are focussed on priority watersheds and basins.

Basin management is being introduced at the MPCA as a new context for setting priorities and designing comprehensive solutions on a watershed basis. Within this new context, ongoing activities such as assessment, planning, implementation and enforcement of both point and nonpoint water quality programs will need to be closely coordinated. This need for coordination, if successfully met, is likely to result in a synthesis of two approaches which so far have evolved separately for point and nonpoint source problems. The watershed management approach, which from the beginning has characterized nonpoint source pollution control programs, will be extended to incorporate point sources. Likewise, it is likely that some aspects of the NPDES permit program will be applied to nonpoint source problems, as indeed already is happening in the case of feedlots with more than 1,000 animal units.

The process of synthesizing, or coordinating, two previously separate approaches into a unified, comprehensive system for Basin Management will require the development of new coordinative tools. A system for allocating a pollutant loading within a watershed among point and nonpoint sources has yet to be developed. Monitoring programs will have to be modified, and modeling tools will have to be improved, to allow the more precise measurement of nonpoint source loadings, in terms that can be compared with point source measurements.

In addition to such technical tools, methods to facilitate coordinated planning and implementation of comprehensive, watershed wide programs will have to be developed. One of these methods, pollutant trading, is the subject of this report, which summarizes a year-long investigation of the topic funded by the U.S. Environmental Protection Agency (EPA). Whether, in what form, and to what extent pollutant trading could play a beneficial coordinative role in addressing the next generation of water quality problems is the main question at issue.

Pollutant trading is of interest, then, both as a mode of government intervention that can reduce water pollution with maximum efficiency, and as a coordinative mechanism for integrating point and nonpoint reduction efforts in a basin management context.

1. THE PROCESS OF POLLUTANT TRADING

In practice, the few water pollutant trading programs that have been tried in the United States have tended more toward administrative transfers of responsibility, and funding, than toward anything resembling a marketplace. However, no matter how closely an actual pollutant trading program approximates the economist's ideal market solution, its generic elements are much the same. The following steps are common to pollutant trading programs generally, although specific programs may differ considerably in the degree to which individual elements pertain to point or nonpoint sources:

Step 1: Define a trading area, usually a hydrologic unit such as a watershed or basin.

Step 2: Assess the receiving water body's problem, measure and allocate pollutant loadings from all sources.

Step 3: Define upper limits for all problem pollutants, and determine loading allocations to meet water quality improvement objectives.

Step 4: Allocate loading reduction requirements among sources -- both point and nonpoint.

Step 5: Allow each source a choice: either achieve the required loading reductions at the source, through investment in new or modified wastewater treatment facilities, or transfer the responsibility for reducing the loading to another source.

Steps 1-4 are fairly standard procedures required for a Total Maximum Daily Load (TMDL) determination -- or, more commonly, a yearly load allocation among sources. The new element is Step 5. It introduces choice and flexibility, through which the objectives defined in Steps 1-4 can be more readily and more efficiently achieved. In theory, sources for whom pollutant loading reductions are relatively costly will have an incentive to engage in pollutant trades with sources for whom such reductions can be achieved at lower cost.

2. POTENTIAL BENEFITS OF POLLUTANT TRADING

The potential benefits of pollutant trading can be summarized under three categories: efficiency, effectiveness and equity.

- Greater efficiency means that, under pollutant trading, either a given pollutant loading reduction can be achieved at lower aggregate cost or that a greater loading reduction can be achieved at the same cost as under status quo policies. If two or more sources contribute to a pollution problem in a watershed or basin, and significant differences in the cost of loading reduction exist between or among these sources, then potential efficiency gains from trading are present. In theory, if these estimated benefits are known to potential trading parties, and if they exceed the costs associated with completing a transaction, then trades can be predicted to occur, and the potential efficiency gains realized. The extent of the resultant efficiency gains depend on the degree of difference in abatement cost among sources in a watershed.

- Greater effectiveness means that a pollutant trading policy would achieve additional water quality improvement: lakes, rivers, streams and aquifers that would not be improved under current policies would be improved under pollutant trading. This will result if a pollutant trading succeeds in substantially reducing the cost of achieving water quality standards and, therefore, the willingness and ability of permittees to comply with them. "Need and reasonableness" are easier to demonstrate if compliance costs are relatively low and flexible than if they are high and rigid. Sources that may have balked at the high cost of complying with new standards or demands under current, "pre-trading" conditions may find compliance considerably less onerous under a more flexible system made possible by pollutant trading.

- Finally, greater equity means that pollutant trading would reduce the disparities among pollution sources arising from current policies. This includes disparities in regulatory burdens imposed, costs incurred, or benefits distributed among pollution sources. Even if load-reduction requirements are allocated fairly, wide differences among local sources in the cost of achieving these reductions might be perceived as placing an unfair burden on certain parties, and thus could serve as a remaining impediment to community-wide action. Pollutant trading goes to the source of this problem. By offering high-cost sources a means of reducing their cost of compliance, it helps to narrow cost discrepancies along with perceptions of unfairness.

  To restate this in the language of game theory, watershed management with pollutant trading may change the situation facing pollution sources in a community from a zero sum game to a positive sum game. In a zero sum game, gains and losses cancel each other, adding to zero. If one pollution source is forced to bear the cost of achieving a given load reduction, other sources in the watershed gain by facing a reduced burden. This characterizes the current regulatory mode, which sometimes pits point sources against one another and against nonpoint sources.

  But in the positive sum game represented by pollutant trading, it is no longer a question of one source or another being forced to make load reductions. All are compelled to make proportionate reductions -- a fundamental change in initial conditions. In addition, pollutant trading offers both high- and low-cost pollution sources a chance to improve on their initial condition—to gain through trading. No source is made worse off, and some are made better off. If these opportunities are well understood, then the resolution of equity issues by a pollutant trading program could be expected to lead to more effective implementation of water quality improvement projects.

B. POLICY DESIGN CONSIDERATIONS

Pollutant trading in the context of water quality improvement is a policy that is truly in its infancy. Although several water pollutant trading projects have been initiated, only one small bona-fide transaction between point and nonpoint sources has occurred so far—ll pounds of nonpoint source (stormwater) phosphorus loading reduction that was credited against the requirements of point sources in Colorado's Dillon Reservoir. Thus, in the evaluation of point-nonpoint pollutant trading, an examination of actual examples goes only so far. At most, one can learn which obstacles appear to have prevented trades from taking place (Apogee Research, 1992; U.S. General Accounting Office, 1992). But one searches in vain for sure guidelines to establishing an effective program. As for pollutant trading examples from air quality, they are mainly concerned with large point source examples, not point-nonpoint transactions. Limited trading experience has accumulated since the federal Clean Air Act was amended to allow trading of sulphur dioxide emission credits (Lannan and Serjak, 1994) Thus, it is premature to attempt to derive from air emissions trading examples general lessons of value in designing a trading program for water quality improvement.

This being the case, water pollutant trading cannot be treated as a definite, well understood policy that need only be examined in light of a state's or a region's or a watershed's particular circumstances in order to arrive at an adequate evaluation. Rather, pollutant trading must be treated as a policy requiring careful development and detailed delineation before an evaluation is possible. It turns out that a wide variety of pollutant trading programs are conceivable, depending on the prevailing legal-institutional environment, desired changes in general policy direction, and the nature of the pollutant in question.

Greater efficiency, effectiveness and equity are potential outcomes of a pollutant trading policy, as the previous discussion has shown. They are not guaranteed outcomes, however. The degree to which effectiveness, efficiency and equity are achieved in practice will depend on how the pollutant trading system is designed and developed.

1. COMPATIBILITY REQUIREMENTS

The necessity of integrating point and nonpoint source control programs imposes certain design constraints on point-nonpoint source (P-NPS) trading.

First, the pollutant traded must be compatible: either a unit of point pollutant must be equivalent to a unit of nonpoint pollutant from the start, or a means of establishing an equivalence must be found. Point source pollutants, which are readily measured and continuously discharged, must be compared to nonpoint source loadings, which are difficult to measure and impossible to predict, being largely rainfall activated. In river systems, this means comparing point source discharges which are most damaging at low flow, with nonpoint loadings which tend to occur at medium or high flow, when dilution reduces the harm incurred by the pollutants.

Second, the rules of trading must be compatible with the fundamental system for managing either system. In the case of point source programs, that is a rule-based system of commands and controls, combined with technical and financial assistance from the state and federal government. In the case of nonpoint source programs, it is mainly an incentive-based approach to watershed management, whereby local units of government and nonprofit organizations take part in improving local water quality problems, while state and federal agencies provide financial and technical assistance.

One of the challenges of establishing P-NPS trading, then, is to establish compatibility between two very different systems. This amounts to achieving at least a partial synthesis of two dissimilar systems: the one industrial, the other biological; the one managed by a few individuals, the other by thousands of individual land owners; the one amenable to direct command-and-control regulation, the other to flexible, incentive-based controls. Given these fundamental differences, it is not surprising that programs for each of these two types of activity have evolved separately over the years, each according to its own pattern.

To design a fully integrated point-nonpoint source management system goes far beyond the scope of this analysis. For present purposes, it is assumed that the point-nonpoint synthesis is dominated by either one or the other original systems. Accordingly, the variants of pollutant trading presented next are grouped into two main categories. *Type I trading* refers to a system in which the currently prevalent point source regulatory regime, the NPDES permit, is dominant; *Type II trading* refers to a synthesis in which the currently prevalent nonpoint source regime, watershed management, is dominant. The two systems do overlap—watershed management plays a part in Type I trading, just as the NPDES permit plays a role in Type II trading. But the NPDES permit is the starting point of Type I trading, just as a watershed approach is the take-off point for Type II trading.

2. A TAXONOMY OF POLLUTANT TRADING

The first design approach, designated "Type I Trading," is conceived as an additional option to be offered point sources under the current regulatory regime. It involves the transfer of pollutant loading reduction requirements from point to nonpoint sources within the context of the NPDES permit on a case by case basis, rather than in the context of a basin or watershed plan encompassing all sources.

Where a new permit limit has been imposed, or is about to be imposed, under what circumstances might a transfer of the associated loading reduction requirement be transferred to nonpoint sources? What kind of legal and institutional changes would need to be introduced to make such transfers not only possible, but likely to be undertaken by point sources which stand to realize substantial cost savings through this option? These are among the questions this investigation will try to answer.

Two main varieties of Type I trading are postulated. The first assumes the status quo, under which point sources are regulated much more strictly than are nonpoint sources. Under this regime, point sources have the option of contracting with nonpoint sources, while nonpoint sources remain largely free of regulatory requirements, except those which already have been imposed, such as for large feedlots. Accordingly, nonpoint sources wishing to assume the responsibility for a point source's pollutant loading requirement, have simply to contract with the point source to undertake the reduction under enforceable terms and conditions specified by the state and by the point source.

The second variant of Type I trading places a "stewardship" requirement of resource management on nonpoint sources. Nonpoint sources wishing to engage in trading by assuming the responsibility of a point source discharger would first be required to satisfy their stewardship requirement. Only reductions achieved beyond this minimum level would be eligible for transferring to a point source under this variant of Type I trading.

Depending on the variant of Type I trading selected, steps 1-5 above will apply with varying force to point and nonpoint sources. For example, Type I trading with no additional constraints on nonpoint sources would exempt nonpoint sources from all of the requirements listed. Type I trading with nonpoint source stewardship requirements, however, would substitute the stewardship requirements for nonpoint source loading reduction requirements.

Type II trading, is designed from the start to operate under a basin or watershed plan. It applies Steps 1-5 to point and nonpoint sources in a balanced fashion. From problem definition to load allocation to goal-setting, point and nonpoint sources are treated equally, with similar requirements and similar opportunities afforded to each. A Type II trading policy would begin in a voluntary, goal-setting framework, along the lines of a typical Clean Water Partnership project, with the crucial difference that both point and nonpoint sources would be included. Each source would be given a specific time period to achieve its required loading reduction. During this time, perhaps 10 years, it would have the option of either reducing its own loading requirement, or transferring this requirement to another source within the watershed. As in Type I trading, this transfer could be effected through a marketplace transaction, a bilateral contract, or an institutional arrangement such as contributing a surcharge to a fund to finance loading reductions within the watershed.

3. TRANSACTION MECHANISMS

P-NPS pollutant trading may be conducted by means of three alternative coordinative mechanisms: market transactions; a contractual transaction between two parties; or as an administered transfer of legal responsibility between or among sources.

MARKET TRANSACTIONS: The market transaction, though it is frequently considered the sine qua non of trading, is probably the form of coordination least likely to be successful in P-NPS water pollutant trading. The fundamental requirements for an open, efficient public market seem unlikely to be fulfilled by the conditions associated with water quality improvement activities. An efficient market requires a large number of buyers and sellers who meet frequently under conditions of freely available information as to prices, quantities and other attributes of a product or products that are well defined regarding both physical and legal characteristics, and for which a well defined set of trading rules has been established, including legal recourse in case one of these rules is abrogated in the course of an exchange.

None of the variants of water pollutant trading described above seems likely to meet any of these conditions, at least not on a regular basis. As we shall see, trading regions may be so small that only a handful of sources are included. If any of these sources is interested in pollutant trading, either as a buyer or provider of a loading reduction, it may be to fulfill a temporary need only, not a long-lasting requirement. Point sources, for example, may only be open to pollutant trading at permit renewal time, which occurs at five-year intervals. In addition, even within a fairly small trading region, it may be difficult to describe a standardized unit of pollutant which can be transferred between different sources. Each source's needs concerning risk management, timing, technical capabilities and a host of other site-specific factors may be so idiosyncratic as to defy standardization. Also, pollutant impacts can vary considerably by time and place. For example, BOD tends to diminish with distance traveled in a river and nutrient pollutants can change form with increased residence time.

CONTRACTUAL TRANSACTIONS: Bilateral contracts can be tailored to the individual needs of individual pollutant sources, and make far fewer demands for standardization than a market transaction does. Thus, where contracts can be written in a manner that meets state requirements for water quality goals, while also meeting the needs of the contracting parties, they would appear to offer the degree of flexibility required to coordinate point and nonpoint source exchanges. If properly designed, and adequately enforceable, such contracts can be self-enforcing:

"Contracts will be self-enforcing when it pays the parties to live up to them—that is, in terms of the costliness of measuring and enforcing agreements, the benefits of living up to contracts will exceed the costs." (North, p. 54) However, lack of information, poorly defined enforcement provisions, high perceived risk or other such factors may raise the cost of transacting a contract above its expected payoff, thereby preventing potentially beneficial trades from being completed. If a pollutant trading program is too complex, too poorly understood or too burdened with red tape, the chances of trades being conducted by contract are low, according to evidence from examples such as the Fox River, Wisconsin project (Apogee Research, 1992). Thus, an important consideration in designing a trading program is to keep transaction costs low. Suggestions on how this may be done are considered later.

Properly designed, a trading program that relies on contracting could achieve the same kinds of efficiencies that a market could be expected to produce, were it possible to design a market for water pollutant trading. Through free negotiations, contracting partners can arrive at mutually beneficial deals that can be expected to reduce the unit cost of reducing pollutant loadings by allocating a higher proportion of pollution abatement effort to lower cost sources than would otherwise occur. All the terms of trade, including prices, quantities, timing and enforcement, become items of negotiation between the trading parties. However, since contracts are most likely to involve only two parties at a time, it is not likely that contracts could exhaust the potential gains to trade as fully as a competitive public market could. Theoretically, therefore, bilateral contracting remains a second-best alternative to a competitive market.

ADMINISTRATIVE TRANSFERS: Just as contracts are an imperfect but practicable substitute for a public market, administrative transfers may be seen as a substitute for both contracts and markets. According to this mode of coordination among point and nonpoint sources, a government body—most likely a state agency with authority over water quality—would establish the price and perhaps other terms at which transfers of pollutant loading reduction responsibilities could take place among sources. Individual sources would choose the quantities of pollutant reduction responsibility that were transferred.

In practice, pollutant trading projects to date have been based on administrative transfers rather than markets or contracting. This may be because of high transaction costs associated with contracting, or perhaps results from state governments' desire for control over such projects. Whatever the reason, administered arrangements appear to be capable of achieving some of the purported advantages of true, marketplace transactions or bilateral contracting, while potentially reducing certain disadvantages such as the risk and cost of pollutant-trading transactions. If the cost of transacting contracts tends to exceed the potential gains, a program of administrative transfers is a workable, albeit a theoretically third-best, solution.

CHAPTER II: EMPIRICAL ASSESSMENT

The first chapter of this report has evaluated point-nonpoint source pollutant trading as a general policy. Chapter II examines pollutant trading options more specifically—for specific pollutants, in light of actual laws and rules, costs and benefits. We begin by focusing the discussion on one specific pollutant, phosphorus, in light of federal and state laws and rules and policy alternatives, as well as of cost comparisons for alternative point and nonpoint phosphorus loading reduction alternatives.

A. CHOICE OF POLLUTANT FOR TRADING

In principle, any pollutant could be traded between point and nonpoint sources. If point and nonpoint source loadings and impacts of that pollutant can be measured and compared within a well defined mixing zone, such as a lake, river segment or river basin, then trade-offs would seem to be possible.

In practice, however, problems of measurement within an acceptable trading area pose difficulties. How can a unit of loading 120 miles upstream be compared with a comparable discharge at the mouth of a river? Where should the impact of the loadings be measured? Which form of the pollutant should be measured? When and where? In the spring or summer, at low-flow, high-flow or somewhere in-between?

Such questions can be resolved with a greater or lesser degree of difficulty, depending on the pollutant in question. Phosphorus, nitrogen, ammonia, biochemical oxygen demand, total suspended solids, toxics—all these are capable of being traded, in principle, if only measurement and other technical questions can be resolved.

To complicate matters, quantitative questions must be approached differently for each pollutant. Take nutrients. Phosphorus and nitrogen have different transport routes and transport efficiencies from agricultural fields and feedlots. They differ in solubility, volatility and their role in water degradation processes. Or take organics. Biochemical oxygen demand and suspended solids are local measures of water quality subject to varying degrees of assimilation depending on the water's pH, temperature, flow rate, etc. Toxicity may be a matter of degree— that is, of concentration. However, for many toxics, assimilation into receiving water bodies is not recognized as an adequate solution. How is pollutant trading possible absent a mixing zone within which loadings from alternative sources can be compared? At most, pollutants without mixing zones might be "traded" under an umbrella policy covering adjacent or nearly adjacent sources, perhaps different parts of the same plant, or a pretreatment facility of a wastewater treatment plant.

The steering committee agreed to focus initially on phosphorus as a potentially tradeable pollutant, and on other pollutants after the initial investigation has been completed. There are several reasons why phosphorus was chosen as a starting point:

1) Trading may be hard to justify for pollutants with small or negligible mixing zones, as discussed above. The EPA has indicated that trading may be more appropriate for nutrients and organic pollutants than for toxics (Apogee Research, 1992).

2) Trading requires the comparison of pollutants over distance. How can a given end-of-pipe quantity at a specific location be traded against a multitude of nonpoint source reductions occurring over a broad area? Answer: Only if the pollutant is strongly conservative, i.e., not subject to significant change over distance. Phosphorus is such a pollutant. True, total phosphorus can change to varying degrees of solubility and biological availability over time and distance. But these changes merely ensure that, eventually, total phosphorus that enters a water system eventually will become available to feed algae, and thereby become a potential pollutant in those systems where algae growth contributes to water quality degradation.

3) Phosphorus has long been recognized as a lake pollutant that causes eutrophication. Recently, a study of the Minnesota River identified phosphorus as a serious contributor to river water quality, too. (Minnesota Pollution Control Agency, 1993) As in lakes, phosphorus causes rapid growth of algae. When high algae populations die and decompose, they deplete the supply of oxygen in the river to substandard levels, especially at low-flow. Thus, phosphorus is now recognized as an additional pollutant that needs to be controlled over a large portion of the state. Since it has not yet been controlled by secondary treatment, phosphorus is available to be traded: there is "something to trade."

4) There are known, effective, quantifiable measures for abatement of both point and nonpoint sources of phosphorus. Thus, in principle, it is not difficult to compare the cost of point and nonpoint phosphorus loading reduction methods. In practice, accurate estimates are hard to come by.

One potential difficulty in comparing the water quality effects of different sources of phosphorus discharges may occur in riverine systems. Nonpoint source loadings tend to occur at high and medium flow levels, at which time phosphorus tends to be diluted by the runoff which carries it to a surface water channel. Point source discharges, by contrast, tend to be continuous. They typically have their greatest impact during low-flow periods. Indeed, water quality impacts often are evaluated with respect to low-flow conditions. Thus, the direct impact of nonpoint sources may have little direct bearing on the water quality impact of point source discharges at low flow.

However, indirect impacts of nonpoint source phosphorus loadings may be quite significant. Since phosphorus is largely sediment-attached, much of it may settle out during medium flow, when the bulk of loadings may be occurring. Where the stream flow rate slows down, larger sediment particles will settle to the bottom or to the banks or in backwater ponds. That which settles to the bottom may contribute to internal loadings at lower flow periods. Evidence from the Minnesota River at low-flow periods suggests that such internal loading may be significant enough to maintain concentrations of soluble phosphorus at fairly constant levels. In addition, as the river rises, previously settled sediments are detached and moved further downstream. At slow moving stretches, they may again settle out. Most of the silt particles can be expected to settle out either before or in Lake Pepin, potentially contributing to internal loadings of soluble phosphorus at a time when the water body is becoming eutrophic (private communication, Erwin van Nieuwenhuyse, MPCA).

Data do not exist to establish a firm ratio of equivalence between point and nonpoint source loadings based on these considerations. However, it would appear that, in a riverine system which ends with a reservoir or lake, a great portion of the nonpoint source phosphorus loadings can be expected to become available for aquatic plant growth, and subsequently aggravate water quality problems.

In addition to point-nonpoint source trades of phosphorus loadings, there may be opportunities for defining tradeoffs between point source BOD concentrations and nonpoint source total phosphorus loadings upstream. Some evidence appears to suggest the possibility for such a trade-off in the lower Minnesota River Basin, according to a recent analysis (MRAP, Volume II, pp. 104-106; Van Nieuwenhuyse, 1995). There, it has been shown that upstream phosphorus loadings lead to growth of algae, indicated by high levels of chlorophyll. Algae growth and decay, in turn, lead to increased BOD concentrations at Jordan, Minnesota during 1979-1991.

It cannot be said without qualification that phosphorus will everywhere be suitable for pollutant trading, however. Considerations of time and space will place definite limits on the appropriateness of pollutant trading of phosphorus, on grounds of water quality protection. Two contrasting situations will illustrate this point.

At one extreme, take the example of a northern Minnesota lake that is extremely sensitive to phosphorus loadings. One such water body, Lake Bemidji, was recently protected from the threat of eutrophication by making substantial reductions in the phosphorus effluent from an upstream municipal wastewater treatment plant, in Bemidji. Effluent concentration was reduced to 0.4 mg/liter—below the usual phosphorus limit of 1 mg/liter. Nonpoint source reductions were achieved at the same time, by installing stormwater settlement basins and other measures. The latter were viewed as additional to, rather than as potential substitutes for, point source reductions, due to differences in the time dimension of point and nonpoint source loadings. Point source loadings are readily predictable on a daily, weekly and monthly basis, as are reductions in such loadings achieved by plant upgrades. Nonpoint source loadings of phosphorus, being rainfall activated, are inherently unpredictable, as are many of the BMPs recommended to reduce nonpoint source loadings. Water quality in the lake is determined by total phosphorus loadings from all sources. This total loading can most reliably be kept within limits established by water quality goals if point source reductions are maximized. To trade a sure reduction in point source loadings against uncertain reductions in nonpoint source loadings would increase the risk that water quality limits would be exceeded. The more sensitive a lake is to phosphorus-related eutrophication, the more risk would be involved in trading point source reductions against nonpoint reductions. For water bodies such as Lake Bemidji, where a relatively small increase in phosphorus loadings during the summer could trigger serious eutrophication, this risk may not be acceptable.

At the opposite extreme, take for example Lake Pepin, a natural reservoir-like shallow lake on the Mississippi River. The lake is subject to severe eutrophication during low-flow periods, especially in the summer during drought years such as 1988. Recent water quality monitoring has demonstrated that the lake acts as a sink for phosphorus. It accumulates phosphorus during normal times, at medium or high flow, and becomes a net exporter of phosphorus during low-flow, when bottom sediments release more phosphorus than the lake receives from upstream sources. Substantial sediment-attached nonpoint source loadings originate from the Minnesota River, which enters the Mississippi some 50 miles upstream in the Twin Cities. In addition, soluble phosphorus from major point sources becomes trapped in the lake through adsorption to sediments or by the feeding of algae which die and sink to the bottom.

Long-term reductions in both point and nonpoint sources will be necessary to reduce phosphorus loadings into Lake Pepin, effect a "flushing out" of phosphorus bound to accumulated sediments, and thereby restore the lake's water quality. During this long-term process, point and nonpoint sources can be treated with rough equivalence with respect to their impact on water quality. Thus, trading point source reduction requirements against nonpoint source reductions may be appropriate in the case of Lake Pepin, and in other such instances where long-term reductions in both point and nonpoint source loadings are required to achieve water quality goals.

B. MODELING AND MONITORING REQUIREMENTS

Where point-nonpoint source trading is appropriate, as in the case just cited, nonpoint reductions must be somehow verified to ensure accountability. Two possibilities exist: predicting the effect of nonpoint source BMPs on phosphorus loadings, and using this estimate to define a tradeable quantity of nonpoint source phosphorus loading reduction; or, monitoring the water-quality impact of BMPs adopted as part of a point-nonpoint trade, and using this estimate to define a tradeable quantity of phosphorus loading reduction. By a large majority, the steering committee favored the former estimate over the latter, which was judged to be inappropriate for anything but a long-term evaluation of the effectiveness of a trading policy.

The reasons for this judgment are straightforward. Predictive models are appropriate because the means (loading reductions) and the end (water quality improvement) would be expressed in compatible terms—as long-term trends expressed as expected annual average values. Loading reductions resulting from BMP application would be estimated ex ante using long-range probability models, and water quality changes would be measured ex post using long-range monitoring. Traded quantities of nonpoint source loading reductions would be estimated according to the former estimate, and a trading policy would be evaluated for long-term effectiveness based on the latter measurement. Predictive models such as AGNPS, GLEAMS and CREAMS have been used to predict the effect of BMP adoption on loadings of phosphorus—in addition to sediment and nitrogen—into adjacent water bodies. These models need to be improved, and adapted to smaller regions, before their estimates can be relied on to serve as accurate water quality project goals or benchmarks (National Research Council, pp. 119-224, 1993).

Besides predictive modeling of nonpoint source BMPs, compliance monitoring of the same BMPs would be necessary to ensure accountability in point-nonpoint source pollutant trading. To control the cost of monitoring, a certain percentage of farms could be selected for spot checks. The type of monitoring would depend on the type of BMP. For residue management, an on-site visit by a soil conservation technician after planting would be required to estimate the percentage of the ground surface covered by residue. For nutrient management, soil testing and recommendation documents, in addition to receipts for fertilizer purchases, may be required. For a drainage ditch buffer strip, a photograph including an identifiable landmark may suffice. Failure to demonstrate BMP compliance would result in a breach of contract, with penalties charged according to the terms of that contract. This could range from non-payment for the full amount of phosphorus abatement indicated in the contract, in cases where natural events hindered the landowner from achieving the full amount of abatement indicated in the contract, to penalties where landowners failed to make a good-faith effort to fulfill their agreements.

C. LEGAL ASSESSMENT: AUTHORITY AND ENFORCEMENT

Before a point-nonpoint source pollutant trading policy can be adopted for Minnesota, MPCA needs to ensure that an adequate legal foundation for such a policy exists, on both the federal and state level. In addition to the question of whether pollutant trading is permissible under current laws and rules, is the question as to what limits these laws and rules might impose on the design and implementation of a trading policy.

Federally, there is little explicit authority within the current Clean Water Act authorizing point-nonpoint source trading, although both Senate and House versions of the CWA reauthorization do include fairly explicit language on point-nonpoint trading. However, at this time, significant differences exist between the degree of attention afforded pollutant trading in House and Senate versions, making it very difficult to anticipate the provisions of a final bill—to say nothing about its eventual codification in EPA rules.

Under the current CWA, in Section 303(d), pollutant trading is discussed in the context of the TMDL. According to EPA's Guidance on TMDLs, the opportunity for point-nonpoint trading could arise as follows:

Step 1: State agency initiates TMDL process by estimating a water body's loading capacity (LC) for a relevant pollutant, and then allocates this quantity among three sources: point sources are assigned a waste load allocation (WLA); nonpoint sources are assigned a load allocation (LA); and a certain amount is designated as a margin of safety (MOS) to allow for uncertainties and variabilities in loadings.

Step 2: Implement loading reductions through appropriate point and nonpoint programs: the NPDES permit in the case of point sources, and whatever state or federal programs apply in the case of nonpoint sources. In Minnesota, except for feedlots with more than 1,000 animal units, nonpoint source programs are largely voluntary and educational.

Step 3: If, after a suitable lapse of time, these point and nonpoint programs do not succeed in achieving sufficient total load reductions, the state agency has the authority to reopen the NPDES permit, and impose a stricter limit on the pollutant parameter in question. At this point, the permittee may be given a choice to either achieve its additional load reduction through additional upgrades to its wastewater treatment facility, or by transferring its responsibility to achieve this load reduction to a nonpoint source, through a contractual or institutional arrangement approved by the state, and written into a revised permit (U.S. Environmental Protection Agency, 1991).

In Minnesota, a number of cases which approach or approximate P-NPS trading have come up in the past decade, none of them under the aegis of the TMDL process. Two cases have been handled as a memorandum or understanding attached to a NPDES permit renewal, and a policy guidance for trading has been developed relative to Outstanding Resource Value Waters (ORVWs). The Metropolitan Council together with the erstwhile Metropolitan Waste Control Commission (recently incorporated within the Met Council), requested and obtained "credit" in their renewed NPDES permits for the wastewater treatment plants at Blue Lake and Seneca (1987) and the Metro Plant (1993), for assurances that nonpoint abatement activities would be undertaken. In the first instance, these assurances were based on a planning goal to reduce BOD at the mouth of the Minnesota River by 40% through nonpoint and point load reductions upstream of Shakopee; in the second permit, the assurances were based on an agreement by the permittees to allocate $10 million toward a nonpoint source pollution abatement program in the seven-county metropolitan area. These are not instances of pollutant "trading", in that no specific quantity of point source abatement requirement was traded off against equivalent nonpoint source abatement commitments. But they are clearly cases in which trade-offs between nonpoint and point-source reductions were accounted for to settle permit issues/in conjunction with permit issuance, MOUs were established to deal with nonpoint issues.

In addition to these two cases, a guidance document outlining a variety of "prudent and feasible alternatives" for dischargers into an ORVW was written by MPCA for Castle Danger, a discharger in the Lake Superior Basin. Pollutant trading between point and nonpoint sources was one of seven alternatives listed for the discharger. The guidance acknowledged, however, that the P-NPS trading option had not been tested, and would require considerable documentation. As well, a number of cases where P-NPS trading might have been tried have come up for discussion in the past decade, the POTWs at Lyle and Elk River among them.

Several pollutant trading programs have been initiated in other states: the Tar-Pamlico Basin project in North Carolina; Dillon Reservoir, Cherry Creek Reservoir and Chatfield Basin in Colorado; and the Fox River in Wisconsin. These projects have been described in several reports (Apogee Research, 1992; U.S. General Accounting Office, 1992; and Zander, 1991). The only of these projects that emphasizes trading between urban point and agricultural nonpoint sources is the Tar-Pamlico project. Although no trades have yet taken place, the structure established to accommodate point-nonpoint transfers in this project is attractively simple, and several features have been incorporated into the "administered trading" model described in this report. A summary of these reports by the General Accounting Office is provided in the Appendix. The major lessons gleaned from them, as reported by Apogee Research (1992), can be summarized in the following list of prerequisites for a successful trading program:

PREREQUISITES FOR P-NPS TRADING

1) Water body must be identified as a watershed or river segment.
2) Point and nonpoint sources each must contribute a significant portion of the total pollutant load.
3) There must be a water quality goal for the water body that forces action.
4) There must be accurate and sufficient data with which to establish targets and measure reductions.
5) Point sources must meet the minimal technology-based standards of the Clean Water Act.
6) There must be significant load reductions for which the marginal cost of nonpoint source control is lower than for upgrading point source controls.
7) Point sources must be facing requirements to either upgrade facility treatment capabilities or trade for nonpoint reductions in order to meet water quality goals.
8) There must be an institutional structure to facilitate trading and monitor results.

Authority for all of the preceding examples of point-nonpoint source trading, or quasi-trading, has been granted by federal and state regulatory agencies; otherwise they would not have occurred. It is noteworthy that seldom is P-NPS trading applied strictly in the context of the only federal policy which explicitly allows P-NPS trading—i.e., a TMDL. Rather, authority often seems to have been based on the broad language of state and federal environment law and rules.

If the federal Clean Water Act is modified to address more explicitly the conditions under which pollutant trading could occur, as in at least two current CWA Reauthorization versions in the House and Senate, matching revisions would be required in Minn. Rules pt. 7050.0211 and Minn. Rules ch. 7065.

However, current state law appears to allow considerable scope for point-nonpoint trading. Type I trading could be undertaken under the authority cited in Minn. Stat. ch. 115, and in Minn. Rules ch. 7050. Since this type of trading, by definition, would have to be incorporated in a NPDES permit, the relevant state provisions refer to the state's prerogatives in the enforcement of federal standards, or state standards (as in the case of phosphorus) implemented through the federal permitting system.

Minn. Stat. § 115.03, subd. 1(e-5), reads:

"The agency is hereby given and charged with the following powers and duties: To adopt, issue, modify, deny, or revoke, enter into or enforce reasonable orders, permits, variances, standards, rules, schedules of compliance, and stipulation agreements, under such conditions as it may prescribe, in order to prevent, control or abate water pollution, or for the installation or operation of disposal systems or parts thereof, or for other equipment and facilities; (5) Establishing, and from time to time revising, standards of performance for new sources taking into consideration, among other things, classes, types, sizes and categories of sources, processes, pollution control technology, cost of achieving such effluent reduction, and any nonwater quality environmental impact and energy requirements."

Under Type I pollutant trading for the case of phosphorus, one of two legal situations might apply. In the first case, a water quality assessment might reveal that a point source discharging either directly or indirectly into a lake or reservoir was contributing a phosphorus loading that was quite likely to be having a negative effect on water quality. In such cases, the state is compelled to apply a phosphorus effluent standard of 1 mg/liter. As has been discussed, this standard could be relaxed in exchange for a commitment by the point source to achieve equivalent or more reductions in phosphorus loadings from other, nonpoint, sources.

In the case of riverine systems where phosphorus has been demonstrated to have a negative effect on water quality, the state phosphorus rule does not apply. However, the so-called "narrative standard" in Minn. Rules 7050 might be invoked to apply a phosphorus standard on a case by case basis, as specific water quality problems dictate. For that matter, the narrative standard could be invoked for any other pollution parameter that is not codified as an explicit state rule.

Minn. Rules, ch. 7050.021 - subp. 2, states the general or "narrative" standards for dischargers to Class 2C waters of the state as follows:

> "No sewage, industrial waste or other wastes shall be discharged from either point or nonpoint sources into any waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, visible oil film, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, aquatic habitat degradation, excessive growths of aquatic plants, or other offensive or harmful effects."

Similarly, in 7050.0220, under Section D, Minn. Rules state:

> "For all classes of fisheries and recreation waters, the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented from or hindered by the discharge of any sewage, industrial waste, or other waste into the river. No sewage, industrial waste, or other wastes from point or nonpoint sources shall be discharged into any of the waters of this category (2C) so as to cause any material change in any other substances or characteristics which may impair the quality of the waters of the state or the aquatic biota of any of the above listed classes or in any way render them unsuitable or objectionable for fishing, fish culture, or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs."

Minnesota laws and rules, then, appear to be sufficiently broad to allow Type I pollutant trading, with or without a state rule pertaining to the specific pollutant in question. In addition, the NPDES permitting process, with its requirement for public notice, offers interested citizens an opportunity to speak for or against innovative permitting alternatives such as point-nonpoint trading.

However, authority does not presently exist to introduce administered Type I trading, whereby fees would be charged on excess point source loadings and contributed to a local pollutant reduction fund. In order to allow fees to be collected for purposes other than administration, Minn. Stat. § 116.07, subd. 4d, would need to be modified.

Assuming the appropriate changes in the law were made, this would only set the stage for pollutant trading. In reality, a convincing case would have to be developed to justify each instance of pollutant trading. Where a thorough water quality assessment determines that a valid case exists for applying a 1 mg/liter limit on phosphorous concentration in wastewater effluent, according to state rules, the case for relaxing such a limit in exchange for nonpoint source reductions would need to demonstrate significant benefits from so doing. Some of these have already been discussed, under the potential benefits of trading in Chapter I.

C. POLLUTANT TRADING ENFORCEMENT: TWO APPROACHES

It is one thing to obtain authority to incorporate P-NPS pollutant trading into an NPDES permit; it is another matter to ensure its enforceability. The concensus of the steering committee is that P-NPS trading should be designed to be enforced by MPCA exclusively through the permit—any contract enforcement with a nonpoint source would be the responsibility of the permittee. Even if this is done, however, P-NPS trading poses knotty enforcement issues. That is, how can a fairly inflexible permit process, designed to regulate highly predictable and precisely measurable point-source discharges, accommodate the unpredictability and difficult measurement problems inherent in nonpoint source pollution?

Two broad approaches are possible to resolve this dilemma. Flexibility can be added "up front" by modifying the terms of the NPDES permit, or it can be added at the enforcement end.

The latter approach is easiest to describe. It would amount to changing the definition and measurement of compliance from a daily or weekly limit on effluent concentrations, to a yearly or multi-year average quantity of discharge adjusted for predicted nonpoint source load reductions. Enforcement would occur once, immediately following the period over which pollutant loads were averaged. Monthly or yearly variations that exceeded the permit standard thus would not trigger a permit violation. The permit enforcement provisions for spray irrigation used in Minnesota illustrate how this might be done.

Alternatively, to provide flexibility "up-front", the enforcement machinery inherent in the NPDES permit process would be held in abeyance for the parameter in question, phosphorus in our case. This would be accomplished by avoiding the rule-making process altogether, relying instead on a state phosphorus policy goal which could be interpreted for individual point source dischargers. The policy goal could be defined for a specific basin or watershed, and stated in flexible terms as a range or trend reduction over a specified period. Then, if the quantity of nonpoint source reductions contracted by a point source were not achieved in a given year, due to unforeseen circumstances, this would not trigger a permit violation.

This procedure, favored by the municipal and industrial section representatives on the steering committee, amounts to jettisoning the NPDES process for the parameter in question. It offers increased flexibility, and avoids the need to make rules in the case of partially regulated or unregulated parameters such as phosphorus, but at the cost of considerably reduced control over point source dischargers. This enforcement regime would lead to a limited form of Type II trading—limited in that it would be precipitated by the needs of a single point source permit renewal, and would not necessarily apply to all sources in a watershed.

Under Type II trading, the command-and-control framework of the NPDES permit would be replaced by the voluntary, cooperative framework of watershed management. On the point source side, this type of trading could be accomplished either through a relaxation of NPDES provisions, subject to anti-backsliding provisions in Minn. Rules 7050.0212, subp. 3 (a), or through a Memorandum of Understanding accompanying the permit. In either case, the narrative standard cited earlier would provide the basis for the transaction, since by definition Type II trading applies to cases where there is an insufficient basis for applying a 1 mg/liter phosphorus limit on a point source discharger.

The challenge under Type II trading would be to establish a legitimate case for point and nonpoint source load reductions within a watershed—a case which falls short of an enforceable legal requirement but goes beyond a mere suggestion that responsible sources undertake recommended strategies to reduce loadings. A watershed plan that asks for sacrifice, but cannot demand it, must be legitimate in the eyes of those who are asked to sacrifice: local government units, land owners, firms and citizens generally.

Is this possible? We do not know. Perhaps a sufficient degree of legitimacy can be achieved through a variety of measures of public involvement and support—the approval of point-nonpoint watershed plans, complete with allocation of loadings and load reduction requirements, by MPCA's Citizens Board; public hearings, focus groups, surveys. All of these measures could be used to demonstrate public support for a concerted, equitable approach to water quality improvement through a watershed plan.

But it is likely that such measures would often fall short. To supplement them perhaps a mixture of incentives and disincentives would have to be offered to encourage participation—state support for local water plan funding, for example, or imposition of fees and taxes on local units of government that refuse to assume responsibility for loading reductions under a watershed plan.

This is not the occasion to outline the details of such a plan, but only to note that some mixture of public involvement and support, together with incentives and disincentives to local governments or private landowners, would likely be required to achieve significant participation in a "voluntary" program. Even then, it may also be necessary for the state to commit itself to regulatory recourse under definite, well-defined circumstances, should voluntary measures fail.

D. COST COMPARISONS: POINT VS. NONPOINT SOURCE PHOSPHORUS LOAD REDUCTIONS

Pollutant trading opportunities arise where a significant difference exists in the cost of pollution abatement among sources within a watershed or basin. Thus, a critical component of this investigation is a comparison of phosphorus loading reduction costs for a range of point and nonpoint source measures.

Concerning cost comparisons between point and nonpoint source reduction measures, the first requirement is to define the unit being measured, and establish an equivalence between point and nonpoint sources. For our purposes, the unit being measured is total phosphorus pollutant loadings, rather than ambient phosphorus concentrations. Phosphorus loading measurements can be correlated to point and nonpoint management measures more easily, and with more confidence, than ambient concentrations could be correlated with source-reduction measures.

Why total phosphorus instead of ortho phosphorus or bio-available phosphorus? Again, the answer is practical: Phosphorus, being a conservative pollutant, eventually is converted to bio-available form if left in an aqueous environment for a sufficient period of time. In this form, it acts as a growth stimulant for certain types of algae in phosphorus-sensitive waters. Thus, control of total phosphorus loadings will be necessary to reduce phosphorus pollution in a fairly large watershed or basin, where the residence time of phosphorus loadings is sufficient to allow conversion into bio-available form.

For simplicity, it is assumed that a unit of nonpoint phosphorus loading is equivalent to a unit of point source loading, as might be the case for a non-sensitive lake within a large watershed where long-term loading requirements are needed. The same data can be used to evaluate other cases, however, including those requiring a margin of safety for nonpoint source loading reduction estimates.

One significant difference between point-source structures and nonpoint source management measures that complicates the measurement and comparison of abatement costs deserves mention. That is, rather than being a separate, observable activity, such as a wastewater treatment plant, nonpoint source measures often are an integral part of a production process. Nutrient management and residue management, for example, are integral components of crop production—the one concerning fertilization, the other tillage and planting. It is not possible to measure the cost of such measures in the same way one would measure the cost of wastewater treatment, or the cost of a structural nonpoint source pollution control measure, such as a sediment basin.

Far from being a costly activity, nonstructural BMPs such as residue and nutrient management have become integral to the trend of productivity improvement in agriculture. Properly used, they often increase net income. Approximately half of the cropland in the Midwest was reported to be under conservation tillage as of 1993, while variable-rate fertilizer application technology, which promises to institutionalize soil testing and optimum nutrient management, is being commercially introduced at a rapid pace.

In the case of BMPs that often increase the land user's net income, there may nevertheless be a cost associated with attempting to accelerate their adoption. Such costs, which will be borne by public or nonprofit agencies and organizations rather than land users, are likely to be very difficult to measure, especially if expressed as the unit cost of reducing phosphorus loadings. On top of uncertainties over the effectiveness of the management practices being promoted, are uncertainties about the effectiveness of alternative ways of promoting their use.

Despite these kinds of measurement difficulties, however, an attempt will be made to estimate both the effectiveness of nonpoint source BMPs in reducing phosphorus loadings, and their cost to the end user or to the organization that is promoting their adoption.

1. NONPOINT SOURCE LOAD REDUCTION MEASURES: EFFECTIVENESS AND COST

The cost and effectiveness of NPS phosphorus reduction measures varies from site to site, and from year to year. However, it is possible to generally assess the cost and effectiveness of alternative measures for broad regions of Minnesota. To the extent that the following measures produces water quality benefits in addition to phosphorus reduction, they could also be taken into account in a pollutant trading agreement or transaction.

a. Residue Management

Residue management affects total phosphorus loadings by reducing the loss of sediment from cropland into public waters. For every ton of soil prevented by residue management from entering the water, apporoximately one pound of total phosphorus is also prevented from polluting the water. (Donahue et al., 1971, p. 228; Ginting et al., 1994, p.78; Gupta et al., 1978; U.S. Department of Agriculture, 1993, chapter 4). Residue management will be the most effective in phosphorus reduction:

1) The steeper the slope of the field, and thus the higher the potential for sediment delivery to the nearest channel;

2) The higher the sediment delivery ratio—that is, the greater the proportion of dislodged sediment that reaches the nearest surface water channel. This depends on the proximity of the field to a water channel, and the ability of phosphorus-laden sediment to remain in suspension, which is a function of size and particle composition.

3) The quantity of sediment-bound phosphorus in the soil. Estimates range from a low of one-third pound of phosphorus per ton of sediment, to a mid-range of 1-2 pounds, to a high of 2.5-3.0 pounds per ton of sediment.

To estimate the cost of phosphorus loading reduction by using residue management, a number of assumptions are necessary. First, it is assumed that residue management will achieve a reduction in soil erosion of 3 tons per acre, on average. Each ton of soil is assumed to contain 1.2 lbs of total phosphorus, of which 1.0 lbs is sediment-attached. The sediment delivery ratio ranges between 0.1 and 1.0, the latter representing fields adjacent to surface water channels.

The residue management methods required to reduce soil erosion by 3 tons/a are assumed to have a neutral to positive effect on the farmer's net revenue, a realistic assumption for most of Minnesota if one excludes no-till and ridge-till from consideration in certain regions with tight, poorly drained soils. (Moncrief, private communication). To induce conventional-till farmers to try residue management, which may require a modest retooling of equipment, a payment of $10/a is made for three years. After this time, it is assumed that half of the farmers who have completed a three-year trial will permanently adopt residue management for the remainder of a 20-year career in farming. Thus, the annualized cost of this subsidy scheme is $6/a (8% interest rate, 20-year period, capitalization rate of .10)

Table 1: Cost-Effectiveness of Residue Management for TP Load Reductions

Erosion Reduction	Sediment Delivery Ratio	Sediment Load	Total Phosphorus Load	Annualized Cost/lb TP
3.0 t/a	0.1	0.3 t/a	0.3 lb/a	$20
	0.2	0.6 t/a	0.6 lb/a	$10
	0.5	1.5 t/a	1.5 lb/a	$4
	1.0	3.0 t/a	3.0 lb/a	$2

b. Nutrient Management

Nutrient management to reduce phosphorus loadings amounts to two basic approaches: Either change how much fertilizer is applied, or how it is applied. An effective recommendation that also is consistent with reduced tillage is to band phosphorus together with potassium and some nitrogen at planting, rather than surface-applying dry or liquid fertilizer and then working it into the ground with tillage.

Recently, the Natural Resources Conservation Service tested two approaches which combined banding and rate adjustment with two alternative tillage systems, one which left 15% of the surface covered with residue, and the second which left 30% of the surface covered with residue after planting (USDA, 1993). The results, from the Minnesota River Assessment Project, Level II Land Use Analysis, showed that a combination of phosphorus banding and rate reduction can significantly reduce phosphorus loadings. When 15% of the surface was covered with residue, banding of 70 lbs/a of phosphorus at planting contributed to a 41% reduction in phosphorus loadings. For every percent increase in banding within a watershed, loadings decreased by half a percent. When 30% of the surface was covered with residue, banding of a lesser quantity of phosphorus, 20 lbs/a, contributed to a 68% reduction in total phosphorus loadings. Again, for every percentage of increase in banding within the watershed, phosphorus loadings decreased by half of one percent.

Assuming that the quantities of phosphorus applied were sufficient to produce the target yield, the only costs that could be associated with the change to banding would be related to timeliness and modest equipment adjustments. By banding at planting time, corn planting inevitably is slowed down, owing to the time required to transport fertilizer to the field and fill the planter's fertilizer hoppers between rounds. While this cost can be avoided by shifting the banding operation to fall, fall banding requires accurate row delineation. The cost of a "strip till" toolbar capable of doing this is approximately $14,000 for a 12-row unit (Gergen, 1993). However, only part of this cost should be charged to nutrient management, as this implement is intended to substitute for a row-clearing attachment on the planter, which generally costs $200-$300 per row. Also, it is possible to attach row-cleaners to existing fertilizer toolbars to avoid the cost of a new implement. However, assuming a net cost of $10,000 for nutrient management purposes, the cost per acre for a 1,000-acre farm with a 50/50 corn/soybean rotation, would be $20/a. Amortized over 20 years, the annualized cost would be approximately $2/a.

Supposing $2/a is an approximate estimate of the cost of nutrient management, whether it is incurred as a timeliness cost or an equipment investment, how does this translate into a cost of phosphorus loading reduction? Before arriving at such an estimate, several assumptions must be made, i.e.: before nutrient management is introduced, average phosphorus loadings are estimated to be 0.5 lbs/a. Nutrient management, consisting of banding and optimum rates applied, reduces this loading by half, or .25 lbs/a. Thus, if it costs $2 to reduce loadings by .25 lbs, it will cost an estimated $8 to reduce phosphorus loadings by one pound.

c. Riparian Buffer Zones

The cost-effectiveness of riparian buffer zones is easy to estimate, in principle, but difficult to confirm in practice. In principle, a riparian buffer of an appropriate design width can trap a certain proportion of the sediment and sediment-bound phosphorus exported by runoff to the buffer. In practice, rainfall reaching the buffer can form channels that breach the vegetative strip. It is assumed, however, that such accidents can be largely prevented by design.

The cost of a buffer strip is simply the sum of money required by the land owner to give up certain rights to the use of riparian land, such as cultivation rights in the case of farmland. In addition, there may be an establishment cost, consisting of grass seeding and perhaps tree planting. In Minnesota, most riparian land in agricultural areas can be rented for $100 an acre or less. The cost of establishing a grass riparian buffer strip is estimated at approximately $50 an acre, with maintenance costs amounting to about $15 an acre annually. (Schultz et al., 1994). Thus, assuming a 20-year life for a newly established grass buffer, the annualized cost amounts to approximately $120/a.

The effectiveness of a riparian buffer in preventing phosphorus from entering the water will vary, according to the volume and velocity of the loadings that come from upland fields, and the width and vegetative cover of the buffer strip. As a conservative estimate, it is assumed that a buffer area 33 feet wide along a field drainage ditch or stream will prevent 50 percent of sediment-borne phosphorus from a 250-foot-wide adjacent portion of the field from entering the water channel. (Minnesota Pollution Control Agency, 1991a). In the case of a mile-long field ditch with such an adjacent loading area on either side, a two-sided buffer would occupy 8 acres of land, while protecting 60.6 acres of unprotected cropped land. The vegetative buffer zone will hold in place 95 percent of the sediment that otherwise would have been exported from this area. In addition, assuming a range of erosion rates, it is possible to estimate the total quantity of total phosphorus intercepted by the buffer from the upland, and the cost per pound of preventing phosphorus loadings. This information is summarized in the following table:

Table 2: Cost-Effectiveness of Vegetative Riparian Buffer Zones for TP Load Reduction

Sediment Delivery Tons/Acre	Phosphorus Delivery Pounds/Mile	Phosphorus Interception Lbs/Buffered Acre	Unit Cost of Phosphorus Interception at $120/a payment
5	343	23.7	5.06
4	274	18.9	6.35
3	206	14.2	8.45
2	76	9.5	12.63
1	69	4.8	25.00

d. Feedlot Containment

Manure containment is the first requirement for preventing pollution from livestock production systems, other than those based primarily on grazing. The following estimate of the cost of phosphorus pollution prevention is based on a facility of the following description:

500 Steers, 750 lbs each, on 5 acres of concrete
Annual rainfall: 30 inches
Feedlot runoff = 50% of rainfall, or 75 acre inches/yr
Phosphorus concentration of runoff is 85 mg/liter
Runoff enters surface water channel at edge of feedlot

This livestock facility generates an estimated total of 15,686 pounds of total phosphorus a year from manure, each steer generating .086 pounds daily and 31 pounds yearly (Minnesota Pollution Control Agency, 1991a) The annual predicted phosphorus loading, based on a formula by Young et al., (1982), is:

PHOS. LOADING = CONCENTRATION X VOLUME X CONVERSION FACTOR

1500 LBS/YEAR = 85 X 75 acre in. X .227

This loading can be prevented from entering surface water by containing it in a properly designed structure. The cost of such structures varies greatly with size and the nature of the lining of the pit. This cost estimate assumes a middle-grade containment structure with a 6-month storage capacity (Midwest Plan Service, 1985).

According to SCS estimates, this would cost approximately $37,500, or $3,700 on an annualized basis over a 20-year investment life.

The cost per pound of prevented phosphorus loading, then, is:

$3,700/1,500 = $2.50/lb

e. Created Wetland as Stream Treatment System

This type of nonpoint source BMP is unusual, in that it is used to "treat" a river. Part of the flow of the stream is diverted into a series of constructed wetlands, where it deposits significant loads of sediment and attached phosphorus before being returned to the stream in an improved state. Since not many such wetland treatment systems have been established, they still are considered somewhat experimental. However, based on a well-documented demonstration project, the Des Plaines River Wetlands Project in northwestern Illinois, it appears that constructed wetlands may be a fairly efficient means of sediment and phosphorus removal, which may also offer a range of additional benefits (U.S. Environmental Protection Agency, 1993). Since the Des Plaines River is described as a "good old muddy midwestern stream," its performance is thought to be applicable to similar streams in Minnesota (private communication, Joe Magner, MPCA, 1995).

Results of the Des Plaines River project to date allow phosphorus removal costs to be estimated, based on certain assumptions. The system consists of four wetlands on 450 acres of riparian land, through which about 15% of the variable stream flow is pumped and then allowed to return to the river through control structures followed by vegetated channels. In Minnesota, we assume that with proper site selection, gravity flow could eliminate the need for pumping. The cost of the system would consist of land acquisition costs and initial land-moving expenses. Its useful life is conservatively estimated to be 20 years (private communication, Joe Magner, 1995), with no dredging. Based on experience at the Des Plaines River project, the first wetland in the chain can be expected to last at least 5-10 years. After it became filled in, the second wetland would become the primary settling basin, and after a similar period would be filled to capacity, after which the third wetland would assume this function, etc. Obviously, upstream reductions in sedimentation resulting from increased implementation of upland and riparian BMPs would tend to extend the life of the system. Thus, if undertaken in conjunction with a total watershed management program, the useful life of a wetland treatment system could be extended considerably. For our purposes, a 20-year expected lifetime is assumed.

Land purchase of 450 acres in a floodplain in southern Minnesota is estimated to cost $340 to $567 per acre, which is the average payment made by the Minnesota Board of Water & Soil Resources for land without and with crop history, respectively, that is enrolled in the Reinvest in Minnesota program. Average wetland restoration costs are an additional $340 per acre under the RIM program (Wenzel and Behm, 1995). Assuming that wetland restoration expenses would be incurred on half of the 450 riparian acres used for a treatment system, and that upland grass establishment would cost $78 per acre on the remaining riparian land, the total purchase plus restoration cost for the 450 acre system would be $247,000 to $319,000. Using the rule-of-thumb figures of 8% interest rates and a 20-year project lifetime, this amounts to an annualized cost of $24,700 to $31,900, or an average value of $28,300.

The amount of total phosphorus expected to be removed are derived from the Des Plains River project report. Of the 5,000 tons of suspended sediment entering the wetland system, 90 percent or 4,000 tons is assumed to be removed from the stream (estimated sediment removal efficiency is 86-100% in summer, and 38-95% in winter). Each ton of removed sediment is assumed to contain 1 pound of attached phosphorus, in accordance with estimates used in Minnesota to credit sediment-reduction BMPs for phosphorus reduction (Klang, unpublished report, 1995). The wetland's phosphorus removal efficiency was estimated to be 65-80%. Thus, estimated phosphorus removal is 2,600 to 3,200 pounds.

The annualized cost of phosphorus removal, then, is $28,300 divided by the estimated phosphorus removal quantities. The resulting range is $8.84 to $10.88 per pound.

For purposes of phosphorus control, this is the relevant cost range to consider. However, this BMP is potentially productive of additional benefits, including turbidity reduction, provision of fish and wildlife habitat, and perhaps a smoothing of the peak-flow hydrograph. It is difficult to put a value on such additional benefits. Assuming that site selection and restoration design are adapted to produce the maximum range of benefits, up to half of the acquisition cost, or about $225 per acre, might be considered as reflecting environmental benefits additional to phosphorus reduction. From the standpoint of estimating true net social costs of phosphorus removal, a case could be made for deducting such an estimate of additional environmental benefits from the cost of establishing the wetland treatment system. This would reduce the total cost of the system by approximately $100,000, to an average of $183,000. The corresponding net social cost of phosphorus removal, on an annualized basis, would then be $5.74 - $7.04 per pound.

f. Alternative Measures of Cost:

The cost of phosphorus removal by nonpoint sources may depend as much on the program context as on the BMP selected. This is illustrated under the following five categories of cost:

Direct Cost:

Direct cost is defined here as the opportunity cost to private resource owners: How much would the land owner have to sacrifice in alternative uses of his wealth in order to implement a BMP? This is usually measured in dollars, and the amount is not reduced if subsidies cover part of the cost.

Examples: Direct cost of predicted total phosphorus reduction has been estimated for four types of BMPs:

Manure Containment:	$2.50/lb
Nutrient Management:	$8.00/lb
Residue Management:	$0.00/lb
Riparian Buffer:	$10.00/lb

As these were covered in detail earlier in this report, a brief summary will be provided here.

Incentive Subsidy Cost:

Incentive subsidy costs are defined as the incentive payment required to motivate the land-owner to install or adopt a BMP for a finite period of time.

Examples: Subsidies offered in Mountain Lake Clean Water Partnership project to farmers in order to adopt managerial BMPs:

Nutrient Management:	$48/lb
Residue Management:	$70/lb

Discussion: These estimates are based on per-acre incentives of $10 per acre for a variety of nutrient management and residue management measures, and predicted quantities of total phosphorus loading reduction. It is not known to what extent these incentives will succeed in stimulating trial or complete adoption of the BMP in question.

Transaction Cost:

This is defined as the cost, over and above economic cost and subsidies, required to conduct a transaction that culminates in the implementation of a BMP. Transaction costs include education, BMP planning and design, the negotiation and processing of contractual agreements, monitoring for compliance with the terms of the contract, etc.

Examples: In the following examples, transaction costs are estimated as the administrative costs of running cost-share program in the Mountain Lake Clean Water Partnership implementation plan.

Nutrient Management:	$15/lb (Mountain Lake CWP)
Erosion Control:	$12/lb (Mountain Lake CWP)

To the extent that transaction cost is a function of the number of transactions required to purchase a given quantity of phosphorus load reduction, it will be inversely correlated with the average quantity of phosphorus load reduction purchased per transaction. Thus, by using whole-farm planning techniques to estimate phosphorus load reduction potential from many nonpoint sources on a single farm, transaction costs may be significantly reduced. This will be particularly true for diversified crop and livestock farms requiring manure containment and management in addition to residue management, nutrient management and other BMPs. However, the advantages of increased per-farm load reductions must be weighed against another dimension of transaction costs -- the cost of monitoring compliance, or of enforcing the terms of a contract. Enforcement costs can be minimized by pre-selecting BMPs that are readily identifiable from a distance, such as manure containment structures, constructed wetlands, and riparian vegetative strips, and avoiding those that are management oriented, such as nutrient and residue management.

Targeting Effects:

This refers to the effect of BMP targeting on the cost of pollutant reduction. Generally speaking, the greater the degree of targeting, the more cost effective a BMP of a given type, size and scope will tend to be.

Examples: The feedlot example below is taken from the Jefferson-German Lake Complex Restoration Plan, a Clean Water Partnership project in south-central Minnesota. It involves three feedlots estimated to make large contributions of phosphorus loadings into surface water channels. The riparian buffer example is not project-related, but based on identifying sites where a given design of vegetative strip would be likely to result in a relatively high degree of pollutant reduction, such as highly erosive areas.

Manure Containment:	$1/lb
Riparian Vegetative Buffer:	$6/lb

BMP Trial Incentive Payments:

Incentive payments may be restricted to covering the costs of a trial, in the case of a BMP that is chiefly concerned with managerial change, such as crop residue management, manure management or nutrient management. If the trial subsequently leads to adoption across a whole farm, then the incentive payment that stimulated the trial can be credited with the pollutant reduction that the BMP is responsible for across the entire farm.

Example:

An incentive payment of $10 per acre is paid to a group of 36 demonstration farmers in a watershed each year of a three-year trial, on 40 acre fields, for a total payment per farmer of $400. Average total farm size is 800 acres. At the end of three years one half of farmers adopt residue management on the entire farm, reducing erosion by 2 tons per acre. This quantity of soil contains 2 lbs of total phosphorus. Of this quantity, 15% or .3 lbs is transported to a surface water channel.

For the average farm, the $1200 incentive payment ($400 for three years) to test residue management eventually will result in the following reductions in phosphorus runoff:

- 36 pounds from 40 acres times 36 demonstration farms for the three-year trial yields 1296 pounds saved in the watershed;

- 240 pounds from 800 acres times 18 adoption farms for the remaining 17 years yields 4320 pounds per year.

Cost-effectiveness can be measured in two ways:

- Short term: Cost per pound of TP reduction = $1,200/36 = $33.33/lb
- Long term: Cost per pound of TP reduction = $43,200/74,736 = $0 .57/lb

Thus, the cost-effectiveness of a demonstration project depends a great deal on assumptions regarding eventual adoption following the trial period.

2. MUNICIPAL POINT SOURCE COST OF PHOSPHORUS LOAD REDUCTION

A. POND SYSTEMS: SMALL TOWNS

There are three primary ways that small Minnesota municipalities use to meet a phosphorus effluent standard of 1 mg/liter. One solution has been to redirect wastewater discharge from entry into a lake or reservoir, into a river system where the state phosphorus standard does not apply. This solution will not be evaluated here.

A second solution has been to add alum to the secondary treatment cells of a pond before the pond water is discharged in the spring and fall. Generally, such additions of alum must be made three times in the spring and fall. Interestingly, since the discharge of ponds tends to coincide with high-flow periods of significant nonpoint source loadings, the high flow/low flow discrepancy common to point-nonpoint source loading comparisons may not apply in the case of pond systems.

A third system is to spray irrigate wastewater onto agricultural land after it has had a chance to settle and be acted upon biologically in holding ponds. Since spray irrigation was a grant-eligible practice in the 1980s, many such systems were installed during this period.

1. ALUM ADDITION

Alum treatment of wastewater ponds is estimated to reduce the concentration of phosphorus in effluent from approximately 3 mg/l to 1 mg/l. To achieve 2 mg/l of phosphorus reduction, it is necessary to add liquid (49%) alum at a rate of 38-50 gallons per acre-foot. The expense will therefore be proportionate to the size of the pond system.

Example: A town of 1,000 people, each of whom discharges 100 gallons a day of wastewater, will receive a total of 0.100 million gallons a day, which will require approximately 14 acres of ponds to treat.

The cost of alum treatment is approximately $1,000 per acre. Thus, to treat 4.7 acres will cost $4,700. At a maximum, this system will have to be discharged three times in the spring, and three times in the fall. The total annual cost of alum treatment, then, is $28,200.

In addition to the cost of alum, certain fixed costs must be incurred. Normally, a specially equipped pontoon boat and dock costing an estimated 26,960 dollars is used to apply the chemical. However, if several adjoining communities all were required to apply alum, this cost could be shared among several pond systems. In addition, applying alum requires labor. Supposing each application takes 8 hours, in a year 48 hours would be required. Assigning a cost of $15 per hour, $720 dollars a year should be allocated to alum application (See Table 3).

Table 3: Annual Cost of Phosphorus Removal From Stabilization Pond*

Variable Costs		
Alum	$28,200	
Labor	720	
Total Variable Costs		28,970
Fixed Costs		
Boat Ramp	2,800	
Tank	2,300	
Pump	1,600	
Piping/Values	4,560	
Boat	9,000	
Dock	4,500	
Total Fixed Costs	$26,960	
Annualized Fixed Cost		2,696
TOTAL ANNUAL COSTS		$31,616

*The fixed coats were taken from a stabilization pond system at Albertville, Minnesota; variable costs were based on an average of several pond systems in Minnesota.

How much phosphorus is removed by such treatments? As an estimate, suppose that the wastewater effluent from most pond systems in Minnesota has a phosphorus concentration of 3.0 mg/liter. For our town of 1,000, then, reducing the effluent to 1 mg/liter would entail the removal of 609 pounds of phosphorus a year. The unit cost of phosphorus removal by this method, then is:

$31,616/609 = $59.91/lb

Source: Personal Communication, Gene Erickson, Training Unit, Municipal Section, Water Quality Division, MPCA

2. SPRAY IRRIGATION

Where suitable land is available, spray irrigation may be used to remove phosphorus from the wastewater discharged from a municipal pond system. In agricultural regions, it is estimated that such systems cost $400-$600 per irrigated acre. (Personal communication, Tom Huffman, Hydro Engineering, Young America, Minn.).

To estimate the cost of a spray irrigation system for a specific town, therefore, requires determining the number of acres that would be required to be irrigated in order to treat the wastewater without endangering surface or ground water quality. As a rule, the capacity of the ground to absorb wastewater is a function of soil type and surface vegetation. The following table illustrates the range of estimates used by one Minnesota engineering firm.

Table 4: Water Absorption Capacity as Affected by Soil Type and Land Use

Soil Type	Land Use	Water Absorption Capacity
Heavy	cropped	4-6 inches per season
Heavy	grass	10-14 inches per season
Light	cropped	8-12 inches per season
Light	grass	20-24 inches per season

As an intermediate estimate, 12 inches was chosen as the water absorption capacity of the land receiving wastewater through a center pivot irrigation system. For a town of 1,000, generating wastewater volume of .126 million gallons a day or 46 million gallons a year, with an average phosphorus concentration of 3.2 mg/liter, the following quantity of phosphorus would be removed each year by a spray irrigation system:

.126 X 8.34 X 3.2 X 365 = 1,227 lbs/year

The cost of such a system can be estimated if we first calculate the irrigated acres required to treat the wastewater. This is estimated as:

Irrigated Acres = Acre Inches/Water Absorption Capacity

Acre Inches of Discharge = 46,000,000/27,225 gal = 1690 acre inches

Irrigated Acres = 1690/12 = 141

Thus, if each irrigated acre incurs a total cost of $500, the total cost for the town described here is:

$500 X 141 = $70,400

On an annualized basis, assuming an investment life of 20 years, this is approximately

$70,400/10 = $7,400

Thus, the annualized cost per pound of phosphorus loading reduction is

$7,400/1,227 = $6.03/lb

B. MECHANICAL SYSTEMS: FERRIC CHLORIDE ADDITION

One widely applicable means of removing phosphorus from wastewater is the addition of ferric chloride. Based on U.S. EPA's Innovative and Alternative Technology Assessment Manual (U.S. Environmental Protection Agency, 1980), the Municipal Section of the Water Quality Division of MPCA developed estimates of the total annual cost of ferric chloride addition for phosphorus removal. These estimates have been updated to 1994 dollars for a sample of the facilities listed in the original estimate, and expressed as annualized dollars per pound of phosphorus removed, in the following two tables.

Phosphorus removal costs are estimated for two influent phosphorus concentrations: 5 mg P/l in Table 4a, and 10 mg P/l in Table 4b. To estimate quantities of phosphorus removed, it was assumed that the mechanical treatment plants without any phosphorus treatment will remove the equivalent of 2 mg P/l from the wastewater (Jenkins and Hermanowicz, 1991). Thus, actual phosphorus removed through chemical treatment is measured as a reduction from 3 mg P/l to 1 mg P/l in the first table, and from 8 mg/P/l to 1 mg P/l in the second table.

Table 5a. Cost of Phosphorus Removal in Small to Mid-Sized Wastewater Treatment Plants by Ferric Chloride Treatment, With Typical TP Influent Concentration (5 mg P/l).

Facility	Permitted Design Flow (MGD)	Phosphorus Removed at 1 mg/l limit	Annualized Total Cost of Removal	Annualized Cost Per Pound Removed
Mankato	10.00	60,882	$638,000	$10.48
New Ulm	6.77	41,217	$445,000	$10.80
Red Wing	3.05	18,569	239,000	$12.87
Waseca	2.34	14,246	$194,000	$13.32
Elk River	1.04	6,332	$114,000	$18.00
Lake City	0.50	3,044	$80,000	$26.28
Vermillion	0.05	304	$46,000	$151.32

*Annualized cost based on 20 year life and 8% annual interest.
EUAC = (Total Capital Cost) (A/P, 8%, 20 yr.= 0.1019)

Table 5b. Estimated Cost of TP Removal in Small to Mid-sized Wastewater Treatment Plants by Ferric Chloride Treatment, Assuming High TP Influent Concentration (10 mg P/l)

Facility	Permitted Design Flow (MGD)	Phosphorus Removed at 1 mg P/l Limit	Annualized Total Cost of Removal	Annualized Cost Per Pound Removed
Mankato	10.00	213,087	$638,000	$2.99
New Ulm	6.77	144,260	$445,000	$3.08
Red Wing	3.05	64,992	$239,000	$3.68
Waseca	2.34	49,862	$194,000	$3.89
Elk River	1.04	22,161	$114,000	$5.14
Lake City	0.50	10,654	$ 80,000	$7.51
Vermillion	0.05	1,065	$ 46,000	$43.19

As can be seen, cost is inversely related to size of facility and the influent concentration of TP. This is illustrated in the Figure 1 below, which converts the tabular data to graphic treatment:

Figure 1: Cost of Phosphorus Removal as Affected by Flow Rate at Two Influent Concentrations

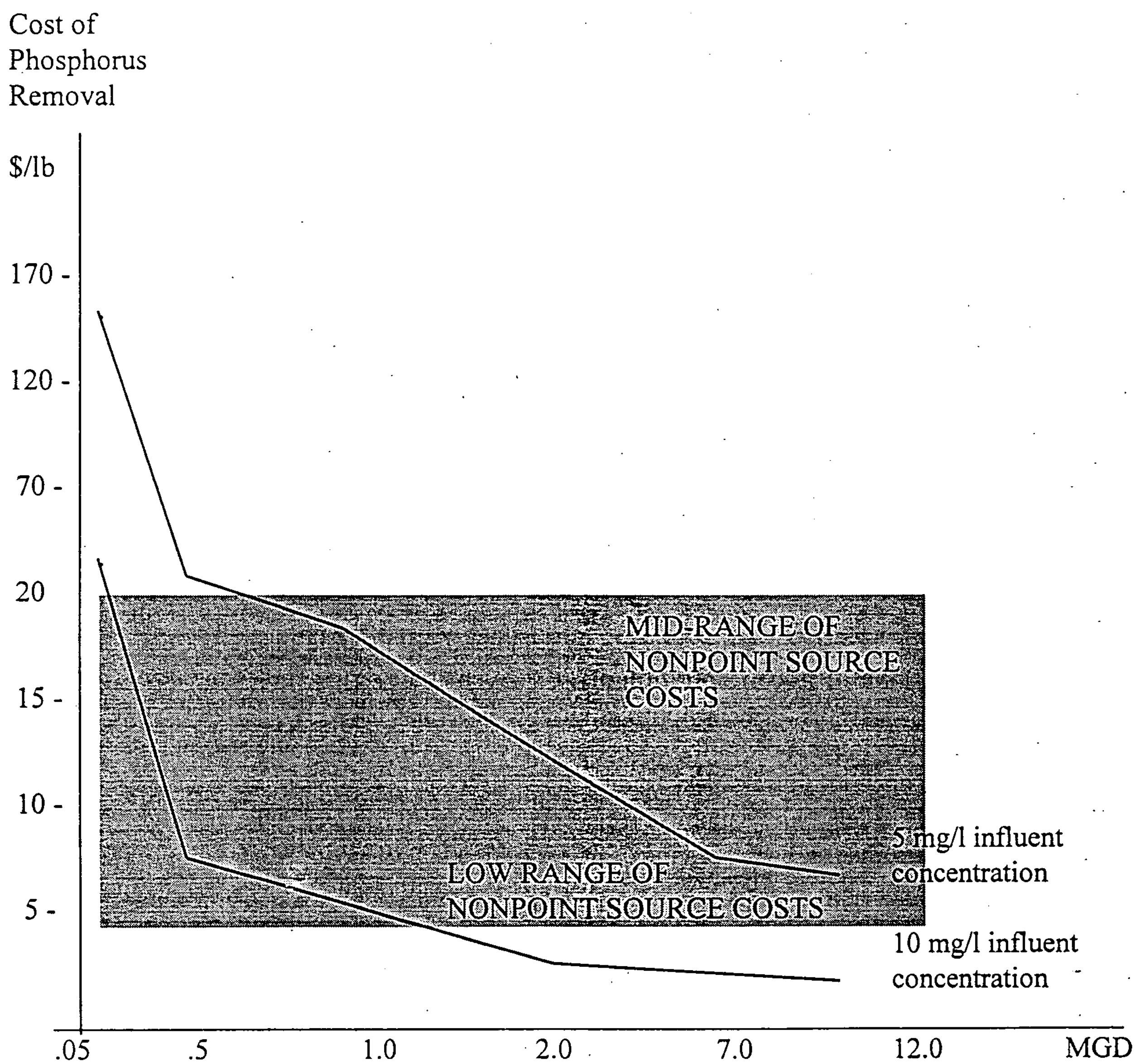

Figure 1 shows how the annualized cost of phosphorus removal decreases as the scale of the plant, as measured by the design flow, increases. Scale economies result in steeply declining costs up until about 2-3 MGD, after which the rate of decrease slows appreciably. The effect of initial phosphorus concentration in the wastewater influent is pronounced over the entire size range. A halving of influent TP concentration results in roughly a tripling of the unit cost of phosphorus removal, as shown by the distance between the upper and lower cost lines.

Superimposed on Figure 1 is a shaded area representing a range of annualized nonpoint source phosphorus load reduction costs. The lower range is limited by $5 per pound, which is the estimated cost of phosphorus removal by manure containment structures ($2.50) multiplied by a safety factor of 2. Transaction costs at the lower range are assumed to be low. The upper range represents nonpoint source direct costs in the middle range, of about $5 per pound, multiplied by a safety factor of two, plus a transaction cost of $10 per pound. In many agricultural regions of Minnesota, phosphorus reduction costs within this range should be attainable for at least some amount of phosphorus load reduction.

It is now possible to describe with some degree of specificity the circumstances under which P-NPS trading is likely to be clearly feasible, clearly infeasible or potentially feasible on economic grounds.

Clearly feasible: P-NPS trading appears to be clearly feasible for the very smallest scale of wastewater treatment plants that have a typical influent TP concentration of approximately 5 mg P/l. For plants with a flow of 0.5 MGD or less, the estimated annualized cost of TP removal is higher than the upper range of estimated nonpoint source costs.

Clearly infeasible: P-NPS trading appears to be clearly infeasible over most of the facility size range for plants with a fairly high influent TP concentration of 10 mg P/l. Any plant with a flow rate exceeding 1 MGD would have to go "outside the range" to find exceptionally economical opportunities for nonpoint source reductions. Only at the very smallest scale, approaching 0.05 MGD, does P-NPS trading appear to offer an economic advantage.

Potentially feasible: P-NPS trading appears to be potentially feasible for most treatment plants with a typical influent concentration of TP. Even at the larger end of the size spectrum, a plant could substitute nonpoint source reductions costing $5-$10 per pound (with the safety factor accounted for) realize considerable cost saving. However, for plants with a high influent TP concentration, P-NPS trading appears to be potentially feasible only for plants of 0.5 MGD or less flow capacity. Between 0.5 and 1.0 MGD, P-NPS trading would be likely to result in marginal cost savings, but not the extent of savings that could justify added fuss and bother. For P-NPS trading to work under such circumstances, point sources would have to be offered a "turn-key" system of trading: pay into a nonpoint source reduction fund, and let someone else take care of the details.

To summarize: the potential cost-savings of P-NPS trading are greatest for smaller sized treatment plants with typical influent phosphorus concentrations. Since required quantities of phosphorus reduction also are likely to be relatively small, transaction costs can be expected to be minimal for the smallest of plants in this category, since few transactions would be needed to secure the required quantity of pollutant reduction. At the other end of the spectrum, P-NPS trading appears to offer little or no cost saving to plants with relatively high influent TP concentrations, except those with a flow capacity of 1 MGD or less.

C. IMPACT OF INVESTMENT TIMING ON COST

The preceding cost estimates illustrate a trend of pronounced scale economies that generally holds true. An equally important consideration, however, may be the effect of investment timing, as well as site-specific characteristics, on the marginal cost of phosphorus control. This is illustrated in a recently completed planning study for wastewater treatment plants in the Twin Cities Metropolitan Area. The main thrust of the study was to compare the cost of alternative scenarios for continued consolidation of treatment plants in the metropolitan area, including expansion of some plants and the abandonment of others. For each such scenario in this "Centralization/Decentralization" study, the cost of plant expansions with and without the addition of phosphorus controls were compared, sufficient to reduce effluent concentration to 1 mg/liter. In all but one case—the Empire plant—biological phosphorus removal was the technology for which costs were estimated. In the case of Empire, ferric chloride treatment was assumed.

For all plants, the estimates showed drastically lower marginal costs of phosphorus control, compared to the costs that would have resulted if phosphorus controls were undertaken alone, instead of in the context of an hydraulic expansion. (The one exception is the Seneca plant, where no expansion is planned, but which is ideally suited for the addition of biological phosphorus control). For example, at the Metro plant, if a phosphorus limit of 1 mg/l had been imposed as part of the 1993 permit, the estimated cost of compliance would have been $28.9 million to $33 million on an annualized basis over a 20-year period. The reduction of phosphorus concentrations from 3 mg/l to 1 mg/l, would have resulted in the removal of 1.5 million pounds of total phosphorus a year from the waste stream, based on the plant's design flow of 251 million gallons a day. Assuming an annualized cost of $30 million, the unit cost of achieving this reduction would have been $19.63/lb. However, by timing the addition of phosphorus removal technology to coincide with a hydraulic expansion to 278.5 million gallons a day, the marginal cost of installing the same type of phosphorus-removal technology can be drastically reduced, to $5.75/lb, as shown in the table below. The reason: Most of the costs that would have been required for phosphorus equipment installation are incurred in the course of hydraulic expansion, leaving a much reduced marginal cost strictly associated with phosphorus removal. The effect is even more pronounced in several other plants, where the annualized cost of phosphorus removal is well below a dollar a pound.

Table 6: Estimated Annualized Cost of Phosphorus Removal in Twin Cities Metropolitan Area Wastewater Treatment Plants: Planning Projections to 2040

	Planned Design Flow (MGD)	Phos. in Effluent (mg/liter)	Annual Phos. Reduction at 1 mg/l limit	Marginal Annual. Cost Phos. Removal	Annual. Cost/lb of Phos. Removal
Blue Lake	55.3	3.0	336,677	$68,000	$0.20/lb
Empire	20.3	5.0	247,181	$195,000	$0.79/lb
Hastings	2.6	4.4	26,910	$16,000	$0.60/lb
Metro	278.5	2.3*	1,102,116	$6,333,000	$5.75/lb
Seneca	34.1	3.0	207,608	81,000	$0.39/lb

* This level assumes that the sidestream treatment currently being added for phosphorus removal will reduce the effluent concentration of phosphorus from the current level of approximately 2.9 mg/l to 2.3 mg/l, as estimated in the Memorandum of Understanding attached to the latest Metro permit.

This discussion illustrates the critical role of timing in the determination of costs. In general, the longer the time period allowed for adjustment to a new standard, the lower will be the marginal cost of meeting the standard. This consideration figured very importantly in the design of the P-NPS trading system developed for the Tar-Pamlico basin in North Carolina (personal communication, Malcolm Green, 1994). Instead of being confronted with an immediate need to comply with a standard for phosphorus and nitrogen, plants in the basin are confronted with a gradually declining upper limit on total nutrient discharges from plants within the basin. Thus, as certain plants expand, nitrogen and phosphorus discharges can be economically reduced over time.

To conclude this discussion of phosphorus reduction costs, it is evident that potential gains to P-NPS trading will exist under certain circumstances, but not in others. The potential gains will tend to be greatest where point sources abatement costs are high, and nonpoint source abatement costs are low. This will tend to occur where the potential for nonpoint source pollution is greatest, that is, where fields are steeply sloping and adjacent to surface water. This is illustrated in Figure 2 below:

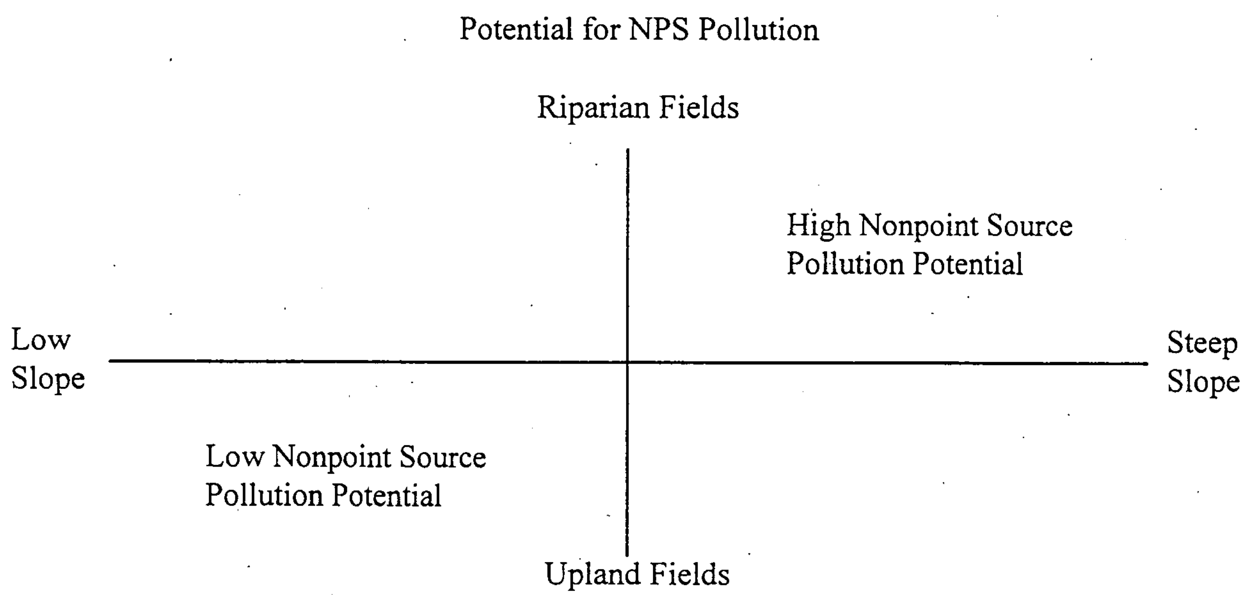

Figure 2

Point source abatement costs will tend to be highest for small municipalities, owing to scale economies in the reduction of phosphorus effluent. Generally speaking, then, Figure 3 illustrates where the highest potential gains to trading are likely to be found:

Potential Gains to P-NPS Trading

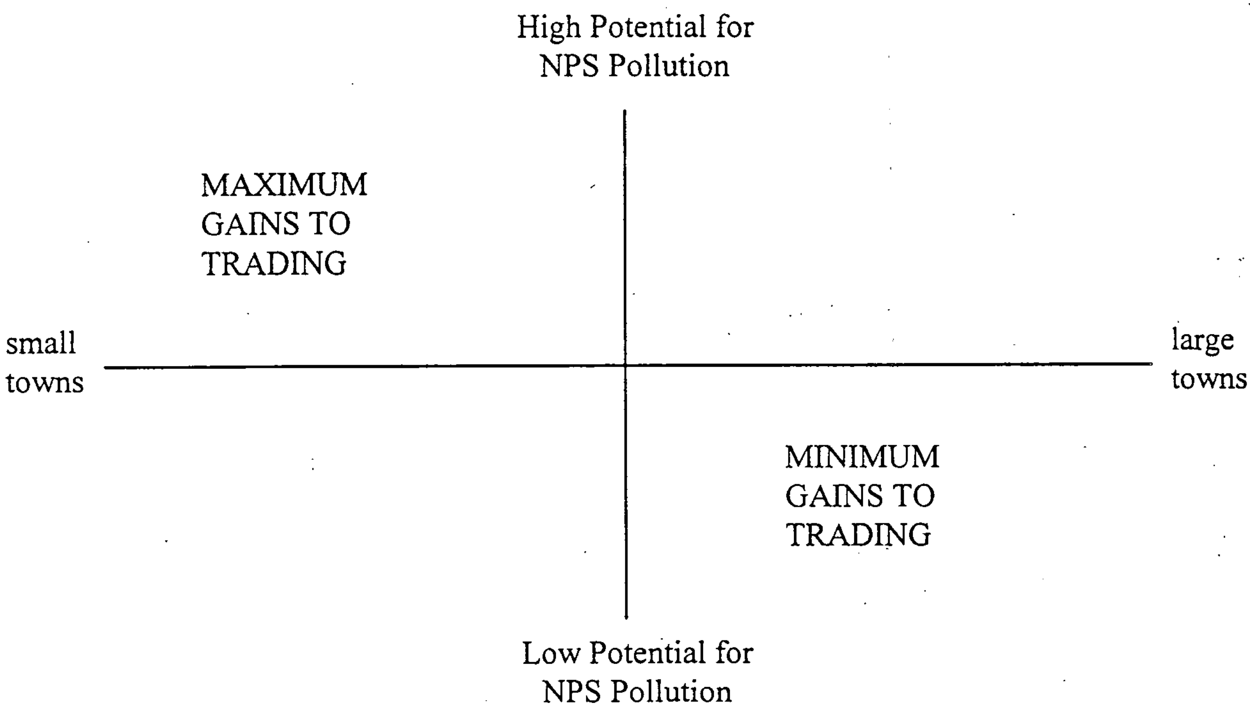

Figure 3

D. POLICY GUIDELINES FOR P-NPS POLLUTANT TRADING

For those treatment plants for which trading is feasible and potentially beneficial, the ability to realize the potential gains of trading will depend to a large extent on the type of P-NPS trading system available to them. If the point source is largely responsible for identifying potential nonpoint source reduction opportunities, negotiating contracts and enforcing compliance, its transaction costs are likely to be high if more than a few individual sources are involved (see Appendix C) On the other hand, if the state establishes a trading institution that assumes the burden of most of these tasks, P-NPS trading might be more attractive to plants for which it holds a potential cost saving. This, however, will depend on the structure of incentives and constraints that all parties to a potential trade are faced with (see Appendix B).

The following procedural guidance for P-NPS trading suggests organizational approaches that could streamline the trading process while assuring that trading results in a degree of water quality protection at least equivalent to that which would occur without trading.

Proposed Procedural Guidance for P-NPS Pollutant Trading

Definition: Point-nonpoint source (P-NPS) pollutant trading refers to the substitution of nonpoint source pollutant load reductions for point source pollutant load reduction requirements by a discharger permitted under the National Pollutant Discharge Elimination System (NPDES).

Procedure: The Water Quality Division of the MPCA has developed a procedure that defines the policy, legal and technical requirements of P-NPS trading, and a sequential implementation process which those parties wishing to engage in P-NPS trading should follow. For purposes of this guidance, it is assumed that a NPDES-permitted point source takes the initiative in pursuing P-NPS trading as an alternative form of compliance with new effluent limits.

A: Prerequisites for P-NPS Pollutant Trading

1. A point source discharge of a trade-eligible pollutant must be determined to have a significant negative impact on the water quality of a receiving water body or a downstream water body.

2. The affected water body must suffer from a chronic water quality problem to which the point source discharge, either individually or as part of a group of point source discharges, contributes significantly. An adequate diagnosis of the water quality problem must determine that it is chronic in nature, requiring years of significant load reductions to solve. P-NPS trading is not advisable for water quality problems that are acute in nature, e.g., highly sensitive to loading spikes.

3. Both point and nonpoint sources must contribute a significant proportion of the total pollutant loading.

4. The pollutant in question must be judged by the MPCA to be appropriate for P-NPS trading. To date, this requirement limits the potential for trading to total phosphorus. The conservative properties of this pollutant make it more suitable for tradeoffs over space and time than is the case with pollutants whose potency changes significantly over space and time. However, a point source may request a substitution of nonpoint source total phosphorus reductions for its BOD load reduction requirement if a quantitative equivalence between the two can be reliably established. Requests for P-NPS trading for other organic pollutants and for toxics will be evaluated on a case-by-case basis.

5. The point source must meet the technology-based discharge requirements of the Clean Water Act for the pollutant in question (antibacksliding).

6. The legal authority for P-NPS trading must be identified. Aspects of trading that lack legal support either must be modified, or the required rules must be developed.

   - Minn. Stat. 115.03, subd. 1(e-5) and the narrative standard described in Minn. Rules ch 7050.021, subp. 2, describe the legal authority for P-NPS trading in Minnesota. Specific P-NPS trades should conform to these citations.

   - If permit fees are dedicated to a P-NPS trading fund, as in the Flexible Compliance Option described below in B10, changes may be required in Minn. Stat. 116.07 subd. 4d to allow use of permit fees for purposes other than administrative expenses.

B: Implementation Process for P-NPS Pollutant Trading

1. The MPCA must define a ratio of equivalence between point sources and nonpoint sources that contribute pollutant loadings to the affected water body. This ratio should take into account all relevant factors, for example, differences in the time, place and chemical form of point and nonpoint source loadings. This task includes the delimitation of a geographic zone within which the ratio is intended to be used. More than one ratio may be used in a given watershed if required to establish equivalence. Ratios may be estimated for specific times of the year, if warranted, to account for differential stream flow, precipitation and runoff conditions, etc.

2. A safety factor should be applied to the ratio to compensate for uncertainties associated with nonpoint source management practices. The safety factor may differ by region or by the type of nonpoint source best management practice used to achieve load reductions. Where no reason exists to apply a safety factor, it should be designated as one (1) to indicate that the issue of uncertainty has been considered in establishing equivalence between point and nonpoint source pollutant loadings.

3. MPCA must establish pollutant load reduction targets and measure reductions based on adequate and sufficient data. Ideally, this should be done for both point and nonpoint sources within the watershed using accepted methods of waste load allocation. At a minimum, load reduction targets must be developed for point source dischargers.

4. MPCA must impose on the individual point source, on all point sources in the watershed collectively, or on all point and nonpoint sources in the watershed, a water quality goal that forces action. Under the current mode of regulation, water quality goals are used to develop individual NPDES permit limits beyond technology-based discharge requirements of the Clean Water Act. In the future, a basinwide approach to setting water quality goals and discharge limits for multiple sources may be developed. To set the stage for P-NPS pollutant trading, the water quality goal must be used to derive an annual loading reduction target for the point source. In some instances, it may be adequate simply to convert an effluent limit such as the 1 mg P/l limit that applies to phosphorus, into an annual loading equivalent.

5. In addition to specifying a load reduction requirement, MPCA must also determine a schedule for achieving it.

6. Confronted with this loading reduction requirement schedule, the point source needs to determine whether it would cost less to achieve these reductions through nonpoint source control measures than through upgrades of its treatment plant or pollution prevention measures.

7. To make this determination, the point source will require information about the cost and effectiveness of alternative nonpoint source BMPs. MPCA is developing a data base of such information, and is the process of refining procedures for on-site estimation of the effectiveness of alternative BMPs in reducing sediment and phosphorus loadings.

8. P-NPS pollutant trade agreements will be based on predicted quantities of pollutant reduction resulting from the installation of nonpoint source BMPs. MPCA in collaboration with the Natural Resources Conservation Service and other state agencies is developing a system of crediting BMPs for predicted sediment and phosphorus reduction. This crediting system must be used to determine quantities of predicted nonpoint source pollutant load reductions that are eligible for point-nonpoint source trading. Using this system, the point source or a designated agency will make in-field estimates of pollutant load reductions attributable to the installation of BMPs.

9. To be eligible for use in P-NPS trading, nonpoint source pollutant load reductions must satisfy each of the following three criteria:

   - *Equivalence*: This refers to the physical substitutability of point and nonpoint source pollutant loading reductions, as discussed in (B1) above. Equivalence in quantity and quality of the nonpoint source pollutant reduction achieved must be demonstrated by the point source.

   - *Additionality:* This is a requirement that nonpoint source load reductions that are credited to a point source in a P-NPS trade would not have occurred otherwise, in the absence of P-NPS trading. The Water Quality Division needs to determine guidelines on additionality for major types of BMPs that could be used in trading.

   - *Accountability/Verifiability*: There is a need to ensure that P-NPS trade satisfies the above criteria of equivalence and additionality, and that the terms of the trade agreement are being lived up to. This may require restricting P-NPS trading to BMPs that are inherently more verifiable than others. For example, only those BMPs that are visible from a distance, such as manure containment structures, riparian vegetative strips or constructed wetlands, might be allowed, unless less obversable BMPs can be verified by other means. An additional dimension of verifiability is the water quality impact of nonpoint source BMP installation. A long-term monitoring program to assist in this determination should be part of the P-NPS trading system.

10. An institutional structure must be established to facilitate trading and monitor results. The Flexible Compliance Option is proposed as the policy basis for such a structure. Point source dischargers would be offered three alternative means of meeting new loading reduction requirements that are additional to secondary treatment:

- *Option A*: Upgrade its wastewater treatment facility;

- *Option B*: Contract with nonpoint sources within a prescribed watershed or zone thereof to achieve equivalent load reductions at lower cost;

- *Option C*: For each pound by which the treatment plant's effluent exceeds its annual limit, pay a prescribed sum of money into a fund designated to achieving equivalent pollutant load reductions in the watershed. The point source may make this payment up front as a lump sum, based on anticipated exceedences, and subsequently adjusted based on effluent monitoring; or, it may follow a "pay as you go" schedule of payments, based on monthly monitoring results. The fee payment schedule selected for a particular case is a matter for negotiation between the point source and the MPCA.

11. The roles of the point source, the MPCA, local government and intermediaries in the Flexible Compliance Option need to be defined for each option:

- *Option A*: Roles remain the same as under current NPDES permit system.

- *Option B*: The MPCA is responsible for NPDES permit enforcement, including side-agreements with the permitee relative to nonpoint source load reductions. The permitee is responsible for enforcing any contracts with third-party agents to provide nonpoint source loading reductions. If the third-party agent is a county, then the county is responsible under its agreement with the point source for obtaining nonpoint source loading reductions on land within its jurisdiction, through agreements with landowners or other means.

- *Option C*: The MPCA is responsible for setting the unit exceedence fee at a level that will cover the cost of obtaining equivalent, additional and accountable nonpoint source loading reductions, including administrative and water quality monitoring costs. The MPCA is further responsible for carrying out contracts and agreements with counties or other third parties to secure equivalent, additional and accountable nonpoint source loading reductions. The point source is responsible for paying an exceedence fee whenever its effluent monitoring indicates that an exceedence has occurred.

12. A verification process is required to ensure that BMPs are applied and maintained as agreed, that they are as effective as supposed, and that anticipated pollutant load reductions are being

achieved. The need for verification must be balanced with the need to limit transaction costs. Which entity is responsible for verification depends on which of the above options is chosen. In addition, long-term monitoring to assess water quality changes should be implemented as practicable.

13. Because P-NPS trading is a new policy in Minnesota, pilot projects of limited scope which evaluate alternative approaches and BMPs may be advisable before undertaking major P-NPS pollutant trading projects. The above procedure is subject to modifications based on lessons learned in early projects, and on reasonable suggestions proposed by parties to a P-NPS trade.

Having now investigated the potential for pollutant trading in the specific context of Minnesota and federal law and policy, for phosphorus in water bodies with specific characteristics, and for a range of alternative point and nonpoint phosphorus abatement technologies, the paper now turns to examine pollutant trading in the context of specific case studies, in Chapter III.

CHAPTER III: P- NPS TRADING CASE STUDIES

A. INTRODUCTION

From the previous discussion of the relative cost of phosphorus load reductions from a variety of point and nonpoint sources, it is possible to identify conditions under which P-NPS trading can be expected to pay considerable dividends, that is, where point source costs exceed nonpoint source costs by a considerable margin.

To summarize for point sources, we have seen that the cost of phosphorus load reduction is likely to be relatively high in three situations:

- For a small town (population 1000) with a stabilization pond and an initial TP concentration of 3.2 mg P/l in its wastewater, treatment to a concentration of 1 mg P/l with chemical treatment can be expected to cost approximately $45 per pound of TP removed.
- For a small city with a mechanical treatment plant, daily flow of .5 MGD and initial concentration of 3.2 mg P/l in its wastewater, treatment to a limit of 1 mg P/l is estimated to cost $24 per pound of TP removed, on an annualized basis.
- For a small or large city that is required to reduce the TP concentration in its wastewater to less than 1 mg P/l , the cost per pound of TP removed can range from $36 for biological treatment in a large plant to as high as $824 to $7,861 for land treatment or reverse osmosis, respectively, as was estimated in the early 1980s for smaller treatment plants discharging into Colorado's Dillon Reservoir.

For nonpoint sources, the following low cost conditions were identified:

- On highly erodible land near surface water channels, BMPs such as conservation tillage, nutrient management and riparian vegetative strips can reduce phosphorus loadings by considerable quantities at a unit cost ranging from almost zero to $4 to $5 per pound, considerably below the point source costs identified above. However, if it is necessary to deal with large numbers of landowners to achieve the necessary reductions, transaction costs can increase total unit costs to as much as $20 per pound, removing much if not all of the cost advantage over point sources.
- Two nonpoint source BMPs that can greatly reduce transaction costs are manure containment structures for feedlots, and constructed wetlands that remove sediment and phosphorus directly from the stream. The cost of TP removal using these BMPs has been estimated at approximately $2.50 and $10 per pound, respectively.

To explore in more detail how potentially beneficial P-NPS source trades might work in practice, it would be useful to conduct case studies that illustrate combinations of high-cost point sources and low cost nonpoint sources such as those indicated above. However, it has been difficult to identify cases where high-cost point source reductions in phosphorus loadings have been made in Minnesota, and where additional conditions for P-NPS trading also exist. Therefore, in the following two case studies, the two relatively low-cost point sources are submitted to a number of "what if" scenarios in order to explore the conditions under which P-NPS trading might have provided a cost advantage. Mainly, this involves assuming lower than actual phosphorus concentrations in the wastestream.

The two case studies selected include the Town of Rogers, and the City of Rochester. These cases will be used to illustrate a unique set of conditions and possible P-NPS trades. They cover a wide range of wastewater treatment facility sizes, and watershed areas within which P-NPS trading conceivably could occur. For example, the Rogers case involves a small town discharging into a wetland within a minor watershed of approximately 9,000 acres in area. Rochester involves a much larger area—the Zumbro River watershed upstream from Lake Zumbro, which includes more than half a million acres.

In both of these cases, the municipality's wastewater treatment plant has been required to reduce effluent concentrations of total phosphorus to no greater than 1 mg/l as a monthly average. Their facilities have been upgraded to satisfy this requirement through chemical treatment. The cost of building and operating the chemical treatment systems is calculated on an annualized basis, and divided by the annual reduction in phosphorus loading to determine an average cost of phosphorus removal.

A key question being addressed in these case studies is whether phosphorus loading reductions might have been achieved more economically through nonpoint source phosphorus management measures. Only if this is true is point-nonpoint trading worth considering. Additional questions relate to the comparability of point and nonpoint source loadings: only if equivalence between them can be established in measurable form is point-nonpoint trading possible. Only after these two basic criteria are met do the "how-to" questions arise. These are reserved for the latter part of this chapter.

The average cost of point source phosphorus removal thus will be compared to estimates of the average cost of nonpoint source phosphorus loading reduction. These estimates are made for a series of Best Management Practices, ranging from manure containment and nutrient management to crop residue management and riparian vegetative buffer strips. Although cost estimates for BMPs within the two watersheds being examined in these case studies are not available, an attempt is made to use assumptions regarding BMP design and landscape features that are generally representative of conditions there.

Finally, these cost estimates will be used to evaluate the feasibility of P-NPS pollutant trading -- not with any kind of revision of past decisions in mind, but simply to explore this policy option in a concrete setting.

It will be seen that cost-estimation of nonpoint source BMP alternatives is not straightforward. Even where estimates of nonpoint source management practice costs are fairly reliable, uncertainty regarding long-term BMP use and effectiveness, program administration costs and the degree of equivalence between point and nonpoint source load reductions make cost comparisons difficult. To allow for these uncertainties, costs will be compared under a variety of operating assumptions regarding nonpoint source BMPs, phosphorus loadings and water quality relationships.

The cost of phosphorus loading reductions appears to vary as widely among nonpoint sources as among point sources. Physical factors such as location, topography and type of BMP can affect costs greatly, as can non-physical factors such as land prices and the cost of promoting, implementing and subsidizing BMPs.

C. CASE I: TOWN OF ROGERS WASTEWATER TREATMENT PLANT

Rogers is among many small towns undergoing rapid growth within the urban corridor between the Twin Cities and St. Cloud. This growth entails expansion of municipal wastewater treatment plants (WWTPs), which poses potential threats to receiving waters from increased phosphorus loadings. In the case of Rogers, the WWTP discharges its effluent into a ditch, which runs into a creek, which empties into Protected Wetland 27-292W before entering the Crow River. A 1 mg P/l effluent limit was placed on the Rogers WWTP in December 1991 to protect this wetland against excessive phosphorus loadings. The plant, which uses aeration ponds and an activated sludge process to treat the community's wastewater, was upgraded for chemical phosphorus reduction at the same time as it underwent a 10-fold expansion, from .15 to 1.5 mgd.

Land use in the 9,081-acre watershed draining into the wetland is changing from agricultural and small town (the population of Rogers was 684 in 1990) to suburban residential and commercial. Light industry is expanding next to the freeway that runs just to the north of Rogers, and is gradually encroaching on the creek that receives the treated wastewater effluent. Industry also has contributed to rather high influent concentrations of total phosphorus -- in 1994, the annual average was 8.8 mg P/l, with monthly averages ranging from 5.2 to 16.0 mg P/l.

1. Rogers WWTP Phosphorus Removal Technology, Costs and Loadings

Phosphorus removal is achieved by adding alum to the mixed liquor suspended solids between the aeration basin and the final clarifiers. The alum precipitates out the phosphorus in the final clarifiers. The treatment units specifically related to phosphorus removal are the alum building, the alum storage tank and feed system, and the alum instrumentation and control. The final clarifier is integral to the process; however, since the clarifier is required for the treatment in general, it is not included in estimating the cost of phosphorus removal.

To extend the applicability of the case studies over as wide a range as possible, alternative values for two cost-determining factors will be explored: the degree of treatment plant capacity utilization, and the concentration of phosphorus in the wastewater before chemical treatment. For Rogers, costs will be estimated for both the current (1994) capacity utilization of .285 MGD, and for full capacity utilization at 1.5 MGD. Similarly, costs will be estimated assuming the current (1994) concentration of phosphorus in the wastewater, 8.8 mg P/l, and a more typical value of 5.2 mg P/l. From these initial concentrations, 2 mg P/l will be subtracted to account for the quantity of phosphorus that typically is removed through wastewater treatment even without the addition of alum, ferric chloride or other chemical treatments (Jenkins and Hermanowicz, 1991). The quantity of phosphorus removed, which forms the denominator of the all-important dollars-per-pound ratio, thus is calculated by assuming that chemical treatment reduces this adjusted initial concentration to the effluent limit of 1 mg P/l, which is the concentration specified on the NPDES permit.

The resulting four cost estimates thus will reflect actual vs. potential conditions at the Rogers plant, as well as conditions found among similar treatment plants serving similar communities.

Cost of Phosphorus Removal

Table 3.1: Annualized Cost of Phosphorus Removal, Current Conditions

	Total	Annualized
Capital Costs		
Alum Building	$98,000	
Alum storage tank feed system & chemical piping	$13,000	
Instrumentation & control system	$5,000	
TOTAL	$116,000	$11,600
Operation & Maintenance Costs		
Phosphorus Removal Portion of Total ($53,700)	$13,200	$13,200
TOTAL ANNUALIZED COST		$24,800

Quantity of Phosphorus Removed, and Unit Cost of Removal

The total quantity of phosphorus removed, and the cost per unit removed, is estimated in five steps, as follows:

1: *The quantity of TP in the influent wastewater is estimated.*

Phosphorus Influent Loadings

Date	Daily Flow (GPD)	Total P (mg/l)	Annual Load (lb/year)
10-5 - 10-6-89	96,132	15.40	4,500
10-6 - 10-7-89	95,884	9.84	2,876
10-7 - 10-8-89	104,486	8.34	2,640
10-89 Average	98,834	11.19	3,339
1994 DMR Ave.	284,883	8.80	7,635

2: *From this influent quantity is deducted an amount corresponding to a normal reduction in the phosphorus concentration of wastewater by mechanical treatment. This reduction has been estimated as 2 mg/l, based on literature sources.* (Jenkins and Hermanowicz, 1991)

Adjustment for 2 mg/l mechanical removal

10-1989 Ave.	3,339 - 602 = 2,770
1994 DMR Ave.	7,635 - 1,734 = 5,900

Assumption: 2 mg/l is the limit of phosphate removal achievable by primary sedimentation and conventional biological secondary treatment processes.

3: *The amount of phosphorus remaining in the wastewater effluent after chemical treatment is estimated assuming compliance with the 1 mg/l limit.*

Post-Phosphorus-Treatment Loadings (at 1 mg/l)

	Annual Load (lb/year)
10-1989 Ave.	301
1994 DMR	868
2011 (at 1.5 MGD)	

4: *Total phosphorus loading reduction is estimated as the difference between (2) and (3)..*

Total Phosphorus Removed by Chemical Treatment:

	1989	1994
Annual TP influent loading:	3,339	7,635
Adjustment for average 2 mg/l TP reduction by plant (without chemical treatment)	2,770	5,900
Amount of TP in effluent at 1 mg/l	301	868
Total TP removed by treatment	2,469	5,032

Table 3.2: Phosphorus Removal Costs Under Current and Alternative Conditions

	Current Plant Utilization (.285 MGD)		Projected Plant Utilization (1.5 MGD)	
	8.8 mg/l Influent TP conc.	5.2 mg/l Influent TP conc.	8.8 mg/l Influent TP conc.	5.2 mg/l Influent TP conc.
a) Adjusted TP conc.	6.8 mg/l	3.2 mg/l	6.8 mg/l	3.2 mg/l
b) Annual TP removed at 1 mg/l	5,032 lbs.	1,909 lbs	26,484 lbs.	10,046 lbs.
c) Annual Capital cost of TP removal	$11,600	$11,600	$11,600	$11,600
d) Variable Annual Cost of TP removal*	$13,200	$13,200	$69,474	$69,474
e) Total Cost of TP removal	$24,800	$24,800	$81,074	$81,074
f) Ave. Cost of TP removal (e) / (b)	$4.93	$13.00	$3.06	$8.07

* Variable costs of phosphorus removal are assumed to increase in direct proportion to flow volume as capacity utilization increases.

Discussion: Determinants of TP Removal Cost:

The most important influence on phosphorus removal costs at the Rogers treatment plant turns out to be the concentration of phosphorus in the influent wastewater, not the degree of capacity utilization. If the influent TP concentration at Rogers were a "typical" 5.2 mg P/l instead of its actual average value of 8.8 mg P/l, at present capacity utilization the plant would be removing 3,123 pounds a year less phosphorus as a result of meeting its 1 mg P/l limit. That is a 62 percent reduction. The result of this reduction in estimated phosphorus removal is to increase the average annualized cost of phosphorus removal by 164 percent, from $4.93 to $13.00 per pound. The reason is straightforward: as the total annualized cost of $24,800 is divided by fewer pounds of phosphorus, the unit cost of phosphorus removal increases in direct proportion.

Unit costs are also sensitive to capacity utilization, but to a significantly lesser degree than to the initial phosphorus concentration. As capacity utilization increases from its current level of .285 MGD to full-capacity at 1.5 MGD, the total annualized cost of phosphorus removal increases a little more than three-fold, from $24,800 to $81,074, solely as a result of increases in variable costs. Meanwhile, the amount of phosphorus removed (assuming current influent concentrations) increases five-fold, from 5,032 to 26, 484 pounds a year. Since the rate of increase of phosphorus removal considerably exceeds the rate of cost increase, the denominator decreases faster than the numerator of the cost-per pound ratio, leading to a decline in the unit cost of phosphorus removal of about 38 percent. This rate of cost decline in response to capacity utilization increase may be artificially low at Rogers, because an existing pond was available for sludge storage. This eliminated the need to expand sludge storage facilities to handle the increased sludge volume that normally accompanies chemical phosphorus treatment, which can range from 60 to 70% (Water Environment Federation, 1992, page 1070). If such a pond did not exist, capital costs may have been considerably higher relative to variable costs, and total cost would have declined at a somewhat faster rate in response to increased capacity utilization. Thus, full-capacity costs at Rogers probably are lower than would exist at a comparable facility without its advantage in existing sludge storage facilities.

Evaluation of Point-Nonpoint Source Trading

At current influent concentrations of phosphorus, the relative cost of point vs. nonpoint source phosphorus load reduction would not favor P-NPS trading. Even if capacity utilization remained indefinitely at 1994 levels -- which is very unlikely -- the Rogers treatment plant would maintain a clear advantage over nonpoint source costs related to just about any BMP, especially after allowance is made for uncertainties and transaction costs associated with nonpoint source BMPs. A safety factor of 2 applied to the most economical nonpoint source BMP, manure containment facilities, would increase the cost per pound from a base value of $2.50 up to $5.00, which is nearly equivalent to the estimated point source control cost. Any extent of transaction cost, enforcement uncertainty, or doubts about the lifespan of the facility would tip the scales in favor of point source controls.

The conditions under which P-NPS trading might be advantageous are those under which point source control costs are the highest -- i.e., at a typical influent phosphorus concentration, under the present rate of capacity utilization. A plant facing a $13 per pound cost of phosphorus abatement might realize significant cost savings by engaging in P-NPS trading, provided that transaction costs can be held to low levels. Thus, several manure containment facilities might be constructed as an alternative to phosphorus treatment at the plant. At current flows and at 5.2 mg P/l influent concentration, a single feedlot with 500 animal units might even provide sufficient phosphorus reduction to compensate for point source controls.

Thus, it is possible to identify conditions under which P-NPS trading would be economically attractive for a wastewater treatment facility similar to the one at Rogers. But would nonpoint source reductions satisfy the three additional key criteria of equivalence, additionality and accountability? These questions can only be answered with reference to specific circumstances. Thus, the conditions surrounding the Rogers case will be used to evaluate these criteria.

First, could point and nonpoint source phosphorus loading reductions be treated as equivalent in the case of Rogers? There are technical reasons why substituting nonpoint for point source reductions may not be advisable. The discharge from the Rogers plant tends to dominate the wetland, both in terms of hydraulic flow volume and chemical loading. These loadings occur daily, and have a regular influence on the hydrology and the chemical loads of the wetland. To substitute reductions in regular loadings of P for reductions in highly irregular loadings from nonpoint sources may not maintain adequate water quality protection of the wetland.

Second, would nonpoint source loading reductions be truly additional? To begin with, the watershed that drains into the wetland in question is small, at about 9,000 acres, and may not afford an opportunity for agricultural nonpoint source phosphorus reductions. Supposing such opportunities did exist, they would need to be carefully reviewed to ensure that they satisfied the additionality criterion. The nonpoint source measures could not be required under the rules of a state or federal program, for example. This would exclude feedlot construction for new or expanding operations, or existing operations that had been cited for a violation of state water quality rules. However, funding of improvements for existing feedlots could satisfy the additionality criterion, provided that the increased funding were not somehow offset by reductions in funding of BMP cost-sharing in local, state or fereal programs. These kinds of concerns would need to be addressed to ensure that the additionally criterion is satisfied.

As for accountability, it may be presumed that if nonpoint source controls can be achieved at one or a few locations, the property owners who agree to construct the facilities can be held accountable for maintaining them. However, in case the property changes owners, provisions may have to be made for continuance of the P-NPS trade provisions, perhaps by specifying contract cessation procedures or attaching land-use provisions to the land title. For example, if trading funds were used to finance feedlot construction, and a year or two later the land parcel containing the feedlot were sold for urban use, the nonpoint source reduction credits lost in the process would have to be replaced. Provisions to ensure their replacement should be in the P-NPS trading agreement.

In summary, P-NPS trading does not appear to offer advantages in the case of the Rogers wastewater treatment plant. However, a similar facility operating at a low level of capacity and with a typical influent concentration of phosphorus might find trading to be an attractive cost-saving alternative. Even then, considerable care would need to be exercised in selecting nonpoint source BMPs that offer equivalent, additional and accountable phosphorus load reductions.

D. CASE II: LAKE ZUMBRO AND THE ROCHESTER WATER RECLAMATION PLANT

This case study examines, retrospectively, the potential for trades between point and nonpoint source phosphorus pollutant reduction requirements in the Lake Zumbro watershed in the 1980s. More specifically, it evaluates whether a relaxation of the NPDES phosphorus limit of 1 mg P/l for the Rochester Water Reclamation Plant (RWRP) could have been combined with nonpoint source phosphorus pollutant load reductions within the Lake Zumbro watershed in order to achieve water quality goals in Lake Zumbro at a lesser cost than was required for plant upgrades necessary to meet the 1 mg P/l limit.

The relationship between phosphorus discharges from the RWRP and Lake Zumbro water quality has been the subject of considerable monitoring and analysis over the past two decades. Much of it was a response to regulatory issues between the City of Rochester and the MPCA, concerning phosphorus limits on Rochester's NPDES permit. A brief summary of these studies and of the issues surrounding phosphorus limits is provided below, followed by an evaluation of P-NPS pollutant trading options.

1. Background

Concerns about the quality of water in Lake Zumbro beginning in the 1970s led to a series of studies by MPCA and independent consultants hired by the City of Rochester. The purpose of these studies was to ascertain the effect of discharges from the RWRP on Lake Zumbro water quality. MPCA studies in the late 1970s concluded that the RWRP contributed about 77 percent of the phosphorus income to the lake on a normalized basis, and the MPCA recommended phosphorus removal from plant effluent to an average level of 1 mg P/l . The City requested a variance from the phosphorus limit, citing its own studies and economic impacts. The issue was adjudicated at an administrative hearing in

1978. As a result of this and subsequent hearings before the MPCA's Citizens Board, the City was required to implement the 1 mg P/l effluent limitation.

In 1984, an upgrade of the wastewater treatment plant was completed, at a cost of $59 million. It included a biological phosphorus removal system called Pho Strip (cost: $655,190) to meet the 1 mg P/l effluent limit. For several months—from July 1984 to February 1985 -- the upgraded plant succeeded in meeting the phosphorus limit. However, during the subsequent three years the plant succeeded only once in meeting the monthly average phosphorus limit. Consequently, MPCA issued the City a notice of violation of its NPDES permit in January 1986.

In 1988, the City requested a review of its 1 mg P/l phosphorus effluent limit, based on the conclusions of the City's independent consultant. According to the consultant, phosphorus discharges from the RWRP had little, if any, effects on Lake Zumbro. It concluded further that additional treatment to remove phosphorus, especially below 2.5 mg P/l, was not needed. The City also requested consideration of seasonal phosphorus removal options as an alternative to the year-round 1 mg/l limit.

In the meantime, the City took steps to meet the final Environmental Protection Agency deadline for municipalities to meet their NPDES permit requirements, which was July 1, 1988. The City installed a temporary chemical feed system in the spring of that year, and subsequently installed a permanent chemical feed system for phosphorus removal. The plant was modified to allow chemical removal of phosphorus in primary clarifiers with additions of ferric chloride and polymer, and in final clarifiers with the addition of alum. Later, sludge storage and handling capacity was increased, in part to accommodate sludge generated by the chemical additions for phosphorus removal.

Since July 1988, the City has been in compliance with its NPDES phosphorus limit. Even so, the City persisted in its request that the 1 mg/l P limit be reviewed, and a seasonal P limit considered as an alternative.

The MPCA study begun in response to this request found that reductions in phosphorus discharges from the RWRP after the 1984 upgrade had resulted in a significant improvement in lake water quality, contrary to the City's assertion that its phosphorus discharges had no significant impact on lake water quality. Previous monitoring had shown total phosphorus concentrations in Lake Zumbro in the late 1970s to be very high, in the 300 to 900 microgram per liter range. These levels had declined to the 100 to 150 microgram per liter range by the late 1980s. Relative to other lakes in its ecoregion, Lake Zumbro TP concentrations had declined from very high to near normal levels.

The MPCA study also contradicted the City's contention that the 1 mg P/l phosphorus limit could be raised to 2.5 mg /l year-round without negatively affecting the water quality of Lake Zumbro. It determined that between 38 and 71 percent of the available phosphorus in Lake Zumbro originated from the RWRP, and that in-lake eutrophication responses will be most severe in low flow periods when the RWRP effluent dominates the lake.

In response to the City's request to consider seasonal limits as an alternative to the year-round limit of 1 mg P/l, the MPCA made the following recommendations:

- Oct. 1 - Mar. 31 — 2.5 mg P/l
- April 1 - May 30 — 1.0 mg P/l
- June 1 - Sept. 30 — 0.3-0.5 mg P/l

Intensive monitoring was recommended to evaluate the extent of internal P loading, with the understanding that the upper limits could be adjusted if warranted.

As for nonpoint sources, agricultural sedimentation and feedlots were listed as additional considerations for water quality management, but they were not evaluated as potential substitutes for point source reductions. On the contrary, trends to reduced sedimentation within the Zumbro River watershed were cited as a reason why further reductions in RWRP phosphorus limits may have to be considered in the future. The report cited research indicating that reductions in sediment and associated turbidity can cause increased algae production if light is the most limiting growth factor. Furthur decreases in RWRP phosphorus discharges could be required to compensate for such a development, according to MPCA's report.

2. RWRP Phosphorus Control Technologies, Loadings and Costs

Phosphorus Treatment Technology

The Rochester WRP has a rated design capacity of 19.1 mgd. The facility's current NPDES discharge permit requires that it provide advanced wastewater treatment to produce effluent that does not exceed 14 mg/l BOD5, 20 mg/l TSS, 1.6 mg/l NH3-N, and 1 mg/l P.

Raw wastewater is screened as it enters the plant, then is pumped from wet wells to grit basins and preaeration basins in series. Wastewater from the preaeration basins is combined in a splitter box that divides the flow to two primary clarifiers for removal of settleable solids. Ferric chloride feed facilities were installed for feeding the chemical to the splitter box. The ferric chloride addition supplements downstream phosphorus removal by precipitating a portion of the phosphorus in the primary clarifiers.

After clarification, primary effluent flows to the first stage aeration basins for carbonaceous BOD removal. The first and second stage covered aeration basins use pure oxygen for biological treatment. Oxygen is supplied by 2 ton/day cryogenic oxygen systems. Each train consists of three complete mix basins operating in series. Mixing energy oxygen is provided by mechanical mixers. Four intermediate circular clarifiers separate the solids (mixed liquor) from the liquid stream. The major portion of the intermediate return activated sludge (RAS) is recycled to first stage aeration directly and the rest of the RAS stream is routed through Phostrip stripper basins. Excess activated sludge (WAS) is pumped to the sludge holding basins for thickening before anaerobic digestion or land disposal.

Intermediate clarifier effluent and supernatant from the Phostrip process flow to the second stage aeration basins for nitrification and residual BOD removal. Following second stage aeration, solids are separated from the flow stream in the final clarifiers. RAS from the final clarifiers is recycled to the second stage aeration basins or is wasted to the sludge storage basins for processing. Alum and polymer are added to the final clarifier influent stream when needed to enhance capture of biological solids or to further reduce phosphorus levels. Final clarifier effluent is chlorinated and discharged to the Zumbro River.

The cost of phosphorus treatment includes chemical treatment at the primary and final clarifier influent streams, as well as the additional cost required to handle, store and dispose of additional sludge resulting from the addition of ferric chloride, polymer and alum. It is difficult to estimate exactly the proportion of total sludge handling and storage costs that are attrributable to addition of ferric chloride upstream of the primary clarifier. This is especially difficult in the case of the Rochester WRP, where significant expansion of sludge storage facilities were required for reasons having little to do with phosphorus management. In consultation with the RWRP supervisor, it was decided that 25 percent of the total costs of sludge storage should be attributable to phosphorus control (private communication, Lyle Zimmerman). While this may somewhat overstate the precise investment needs imposed by phosphorus control at the RWRP, for the purposes of this case study it reflects a conservative estimate of the sludge handling needs generally imposed by chemical phosphorus control on wastewater treatment plants. For example, in *Process Design Manual for Phosphorus Removal*, it is reported that chemical treatment increases the total sludge mass by 24%, (Black & Veatch Consulting, 1971, p. 4 - 15), while in *Volume 2, Design of Municipal Wastewater Treatment Plants*, a 60 to 70% increase is said to be typical (Water Environment Federation, 1992, page 1070).

Table 3.3 Phosphorus Removal Cost

Capital Costs:	TOTAL	ANNUALIZED
Chemical Pumps & Storage Tanks	$160,817	
Chemical Feed Structure	$940,750	
Engineering Fee	$144,000	
Polymer Storage (added in 1988)	$250,000	
Digesters and Sludge Storage*	$4,500,000	
Total Capital Cost	$5,995,567	$600,000

Operating & Maintenance Costs:

Alum	$137,000
Ferric Chloride	$167,000
Polymer	$ 76,000
Sludge Handling	$100,000
Additional Cost of Operating the Digester**	$37,500
Additional Cost of Operating Gravity Belts, Centrifuges, and Other Equipment***	$42,500
Total O & M Costs:	*$560,000*

Total Annualized Costs: **$1,160,000**

* 25% of a total investment of $18 million in digesters and sludge storage is allocated to additional sludge generated by chemical treatment for phosphorus control.

** 25% of a total expenditure of $150,000 for electrical power used to operate the digester is allocated to the cost of phosphorus control.

*** 25% of a total expenditure of $170,000 for operating gravity belts, centrifuges and other equipment related to sludge thickening and conveyance is allocated to the cost of phosphorus control.

Quantity of Phosphorus Removed and Unit Cost of Removal

The quantity of total phosphorus removed through chemical treatment, and its unit cost of removal from wastewater, is estimated in five steps as follows:

1: *The quantity of total phosphorus in the influent wastewater is estimated.*

Present (1987 average):

Plant Influent Loadings Per Year:

10.16 MGD * 8.34 * 9.5 mg/l * 365 = 294,000

Projected Plant Influent Loadings, 2010:	lbs/day	lbs/year
Peak Day	7,906	2,885,690
Peak Week	4,705	1,717,325
Peak Month	2,702	986,230
Average:Noncanning	1,270	463,550
Average: Canning	1,300	474,500

2: *From this influent quantity is deducted an amount corresponding to a normal reduction in the phosphorus concentration of wastewater by mechanical treatment. This reduction has been estimated as 2 mg/l, based on literature sources.*

10.16 MGD * 8.34 * 7.5 mg/l * 365 = 231,960 lbs TP/year

3: *The amount of phosphorus remaining in wastewater effluent after chemical treatment is estimated assuming compliance with the 1 mg/l limit.*

10.16MGD*8.34*1 mg/l * 365 = 30,557 lbs TP/year

(1994 Effluent Loading of TP: 82.21 lbs/day, 30,006 lbs/year)

4: *Total phosphorus loading reduction is estimated as the difference between (2) and (3).*

<u>Estimate: 1987 Conditions</u>

1987 Influent :	294,190 lbs TP/year
Adjustment for 2 mg/l incidental removal	231,960 lbs TP/year
1987 if at 1 mg/l TP effluent limit	30,557 lbs TP/year
TP REMOVAL ESTIMATE	201,403 lbs TP/year

Table 3.4: Phosphorus Removal Costs Under Current and Alternative Conditions

	Current Plant Utilization (10.16 MGD)		Projected Plant Utilization (13.25 MGD)	
	9.5 mg/l Influent TP conc.	5.2 mg/l Influent TP conc.	9.5 mg/l Influent TP conc.	5.2 mg/l Influent TP conc.
a) Adjusted TP conc.	7.5 mg/l	3.2 mg/l	7.5 mg/l	3.2 mg/l
b) Annual TP removed at 1 mg/l	201,403 lbs.	68,042 lbs	262,173 lbs.	88,736 lbs.
c) Annual Capital cost of TP removal	$600,000	$600,000	$600,000	$600,000
d) Variable Annual Cost of TP removal*	$560,000	$560,000	$730,315	$730,315

e) Total Cost of TP removal	$1,160,315	$1,160,315	$1,330,315	$1,330,315
f) Ave. Cost of TP removal (e) / (b)	$5.76	$17.05	$5.07	$14.99

*Variable costs of phosphorus removal are assumed to increase in direct proportion to flow volume as capacity utilization increases.

Discussion: Determinants of Phosphorus Removal Cost:

As in the case of Rogers, the most important influence on phosphorus removal cost at the RWRP is the initial concentration of phosphorus in the wastewater influent, not the degree of capacity utilization. If the influent TP concentration at Rochester were a "typical" 5.2 mg P/l instead of the current 9.5 mg P/l level, at present flows the plant would be removing 133, 361 pounds a year less phosphorus as a result of meeting its 1 mg P/l effluent limit. That is a 66 percent reduction. The result of this reduction in estimated phosphorus removal is to increase the average annualized cost of phosphorus removal by 296 percent, from $5.76 to $17.05 per pound. The reason is straightforward: as the total annualized cost of $1,160,315 is divided by fewer pounds of phosphorus removed, the unit cost of phosphorus removal increases proportionately.

Unit costs also are sensitive to the degree of capacity utilization, but to a much smaller extent than to the initial phosphorus concentration. As capacity utilization of the RWRP increases from its current level of 10.16 MGD to the annual average flow rate of 13.25 MGD, projected for 2010, the total annualized cost of phosphorus removal increases by $170,000 to $1,330,315, or by 15 percent, solely as a result of increased variable costs. At the same time, the quantity of phosphorus removed increases by 60,770 pounds, or 30 percent, assuming that influent concentrations remain unchanged at current levels. Since the rate of increase in phosphorus removal is twice the rate of increase in cost, average annualized costs of phosphorus removal decline moderately, from $5.76 to $5.07 per pound.

Evaluation of Point-Nonpoint Source Trading

At current influent concentrations of phosphorus, the relative cost of point vs. nonpoint source phosphorus load reduction would not favor P-NPS trading. A safety factor of 2 applied to the most economical nonpoint source BMP, manure containment facilities, would increase the cost per pound from a base value of $2.50 up to $5.00, which is nearly equivalent to the estimated point source control cost either at current or projected levels of capacity utilization. Any extent of transaction costs, enforcement uncertainty or doubts about the lifespan of the facility not captured in the safety factor would tip the scales in favor of point source controls.

However, P-NPS trading would appear to offer considerable cost-saving for a facility of about the same size and type as Rochester's, but with a more typical influent concentration. If P-NPS trading appears to be a break-even proposition, at best, when point source removal costs are \$5 - \$6 per pound, there would appear to be considerable potential for savings if point source removal costs were about three times this level, at \$15 to \$17 per pound. At a maximum, the point source could realize savings of about \$10 per pound of phosphorus removal. The extent of realized cost savings would depend on the ability first to find nonpoint source reduction opportunities that are cost-effective for land owners to implement, and secondly to minimize the transaction costs associated with implementing and monitoring the BMPs, and negotiating and enforcing the contracts required to secure the necessary quantity of nonpoint source load reductions.

Transaction costs could easily wipe out the potential gains to P-NPS trading, if they approach the levels estimated for a Clean Water Partnership project in the preceding chapter, of \$12-\$15 per pound. Deliberate efforts to minimize such costs would have to be part of a P-NPS trading scheme based on the point-source removal costs relevant to this case study. Two ways of doing so are to minimize the number of transactions required to achieve the total load reduction, and choosing BMPs whose installation, maintenance and effectiveness are easily monitored. Thus, BMPs such as manure containment structures and wetland systems for stream treatment would have much lower transaction costs than residue management and nutrient management.

As discussed in the Rogers case, the potential for P-NPS trading depends on more than the presence of potential cost reductions: The nonpoint source reductions specified in the trade also must satisfy the criteria of equivalence, additionality, and accountability. The latter two criteria apply in a similar fashion to both Rogers and Rochester. Since they have been dealt with in the Rogers case study, this discussion will not be repeated here.

However, the Rochester case study offers an excellent setting in which to explore interesting aspects of the equivalence criterion. This will be the emphasis of the following five scenarios. The first scenario summarizes elements of the preceding discussion of P-NPS trading under current conditions, to establish a "status quo" to which the other scenarios can be compared.

Phosphorus Loading Reduction Scenarios: Five Options

In order to identify and properly evaluate alternative solutions to Lake Zumbro's problems, a number of relevant technical issues must be addressed. These issues involve point and nonpoint source loadings of phosphorus, and how they contribute to various water quality problems under a variety of circumstances in Lake Zumbro.

Phosphorus loadings from the RWRP are primarily in a soluble form readily available to algae in Lake Zumbro. Monitoring indicates that these loadings have a particularly strong impact on Lake Zumbro chlorophyll levels during times of low flow. Since these times usually coincide with periods of low rainfall in the watershed, nonpoint loadings are likely to be low. Little potential for point-nonpoint tradeoffs in phosphorus loading reductions appear likely to exist at such times. However, the degree of internal loading at low-flow periods may be increased by phosphorus depositions from previous years. This includes nonpoint source particulate phosphorus depositions at average flow and high flow periods, accumulated over many years in the bed of the Lake Zumbro. These nonpoint source loadings, which enter the river system with rainfall and snowmelt, reappear as so-called internal loadings when conditions favor the release of sediment-attached phosphorus.

To the extent that internal loading of phosphorus at low flow times can be reduced over the long run by reducing depositions of particulate phosphorus, nonpoint source phosphorus loading reductions eventually may contribute to reduced phosphorus concentrations at low flow periods. The extent of this contribution is difficult to predict, however, making it difficult to quantify to what extent nonpoint source reductions might be exchanged for point source reductions. If P-NPS trading were initiated based on the above rationale, it would be prudent to monitor internal loading over time to determine whether the strategy of nonpoint source reductions were successful or not. A total annual mass balance estimate including all loading sources could form the basis for determining point-nonpoint source trade-offs.

In order to evaluate the feasibility and cost-effectiveness of point-nonpoint source trade-offs, all of these factors cannot be taken into account at the same time. Rather, in a series of five scenarios, these factors will be considered in the context of alternative phosphorus reduction strategies for Lake Zumbro and its watershed.

Several simplifying assumptions are used in this evaluation:

1. The quantity of annual total phosphorus loading reduction achieved by meeting an effluent limit of 1 mg P/l at the RWRP is used as a loading reduction goal for Lake Zumbro. This amounts to approximately 200,000 pounds a year.
2. Initially, in Scenario 2, annual point and nonpoint source phosphorus loading reductions are treated as equivalent. All combinations of point and nonpoint source loadings that add up to the loading reduction goal defined above are considered to be equivalently beneficial to Lake Zumbro's water quality.
3. In subsequent scenarios, allowance is made for differences in point and nonpoint source phosphorus loadings (solubility, predictability, and correlation with river flow stage -- high flow, average flow, and low flow). Two different assumptions will be made about the equivalence of point and nonpoint source reductions:
   - full equivalence
   - partial equivalence, such that two pounds of nonpoint source TP reduction are considered the same as one pound of point source TP reduction. This safety factor compensates for the uncertainty associated with nonpoint source loading reductions.

Scenario 1: All phosphorus removed from RWRP.

The costs and predicted results associated with this alternative are the best known of all, of course, because this is the approach that was taken. Actual cost and monitoring data indicate that the cost per pound of annual total phosphorus loading reduction was approximately \$5 - \$6 on an annualized basis, depending on whether one selects projected or current flow rates to measure phosphorus reduction. Extensive monitoring has demonstrated that, so far, the current approach of point source controls to an effluent limit of 1 mg P/l has had a dramatically positive impact on Lake Zumbro's water quality. Both of these statements have been elaborated on at length earlier in the report.

The phosphorus removal and cost data relevant to this scenario are as follows:

- Annual TP loading reduction requirement: 200,000 lbs
  (equivalent to a RWRP reduction to 1 mg/l)

- Cost of meeting requirement at RWRP:

Capital Cost:	$600,000
O&M Cost:	$560,000
Total Annual Cost:	$1,160,000

Annual Cost/lb of TP removal: $5-$6

As has been discussed already, P-NPS trading is very unlikely to provide a cost saving, and so is rejected as a viable policy option. In the scenarios outlined below, alternative ways of achieving a 200,000 lb/year loading reduction of total phosphorus will be evaluated with respect to cost , feasibility, and likely effect on water quality.

Scenario 2: P-NPS trading allowed to offset requirements of a 1 mg P/l effluent limit.

One alternative to Scenario 1 could have been to attempt no phosphorus loading reductions at the RWRP, but to attempt to achieve equivalent nonpoint source reductions in the watershed to achieve the same water quality result at lower cost. The cost and feasibility of pursuing such a policy with a range of nonpoint source BMPs is explored first, followed by a discussion of likely water quality impacts.

Residue Management

The watershed flowing into Lake Zumbro comprises some 500,000 acres of crop land, much of it on rolling terrain, planted to row crops, and subject to considerable erosion. On the glacial soils of this region, it is generally possible to reduce erosion and sedimentation through crop residue management without incurring yield losses or increasing costs. Often, reduced tillage reduces production costs while also reducing erosion and sedimentation by 40 to 60 percent, compared to clean till conditions.

Through conservation compliance, farmers have already been required to treat highly erodible fields with conservation measures that generally bring erosion rates down to T, the tolerable level of soil loss, which is generally 5 tons/acre under average conditions. Natural Resources Inventory data for 1992 indicate that approximately 10 percent of the row crop acreage was adequately protected, an achievable goal might be to quadruple this amount to 40 percent over a

5-10 year period. This would increase the land under conservation tillage (with at least 30 percent surface residue coverage) by 150,000 acres. If it is further assumed that the introduction of conservation tillage reduces erosion on this land by an average of 3 tons/a, that each ton contains 1 pound of total phosphorus, and that one-fifth of eroded soil and phosphorus are delivered to surface water channels in the watershed, then for each acre treated with conservation tillage, 0.75 pounds of TP would be prevented from washing into the water, on average. The 150,000 acres treated with conservation tillage then would provide 112,500 lbs of total phosphorus loading reduction -- somewhat less than half the total requirement.

Assuming residue management does not increase production costs or reduce yields, it could be considered a "costless" change. However, there is a cost involved in overcoming producers' resistance to change. This includes the payment required to induce producers to make the recommended change in farming practices, plus the expense of conducting an extensive campaign to induce those changes. Such factors were grouped under "transaction costs" in the section on BMP cost analysis earlier in this chapter. These were estimated to be $10 to $12 for each pound of phosphorus removed, based on the implementation plan for a southern Minnesota Clean Water Partnership project. Costs in this range would likely be required to achieve the degree of change in tillage required in Lake Zumbro, involving more than one fourth of the acreage in the watershed. Even then, there is little empirical evidence to suggest that a certain rate of adoption would result from the effort put forth. The degree of incentive payment required to stimulate change is not known; nor is the degree and type of education or technical assistance. Thus, even though the residue management BMP can be shown to be profitable (and therefore costless) in theory, the cost and effectiveness of a massive campaign to accelerate changes in tillage practices can't be well estimated, but very easily could be in the $10 to $12 per pound range.

If residue management were combined with phosphorus management practices such as reduced rates and, especially, subsurface banding or soil incorporation, considerably more phosphorus loading reductions could be achieved. However, it is difficult to arrive at good estimates without time-consuming field work, including computer modeling. Besides, the same difficulties in predicting the cost of inducing widespread change as were just discussed with reference to erosion control would apply to phosphorus management as well.

Manure Containment

With residue management on 150,000 acres accounting for 112,500 pounds of total phosphorus loading reduction, the remainder of the total loading reduction requirement is 87,500 pounds. Suppose that this total quantity were to be controlled by constructing manure containment structures of average cost and quality, and the contained manure was later spread on cropland in a manner that avoids surface runoff. To achieve the phosphorus load reduction goal, such structures would have to be built for an estimated 21,875 animal units at an estimated annual cost of $218,750, or $2.50 per pound of total phosphorus (estimates based on data in this report). If each feedlot contained 400 animal units, this would require the construction of 55 feedlot containment structures.

This analysis assumes a delivery ratio of unity: phosphorus leaving the edge of the feedlot is assumed to enter a surface water channel, before the containment structure is added. In reality, this will not always be true; therefore it is likely that manure runoff from additional feedlots would have to be contained to meet the phosphorus loading reduction requirement.

Summary & Cost Comparison:

To arrive at a total cost for NPS phosphorus loading reductions is not possible without more empirical knowledge of how farmers respond to varying degrees of incentive payments for residue management or nutrient management practices. It is possible, however, to specify maximum offers by the point source for NPS pollutant reduction credits. If point and nonpoint source reductions are treated as fully equivalent, the point source would only be willing to pay up to $5.76/lb for phosphorus control practices. In our residue management example, this would translate into a $4.32 per acre payment. If, on the other hand, a safety factor of 2 were applied to nonpoint source reductions, to account for the uncertainty associated with BMP adoption and effectiveness, then the point source's maximum bid price for nonpoint source reduction credits would be reduced by half, to $2.16 per acre. These rates are rather small compared to most agricultural BMP incentive programs, which often range from $5 to $15 per acre.

The cost of phosphorus abatement through manure containment, estimated to be $2.50 per pound on an annualized basis, appears to be more competitive from the point source's standpoint. What is more, manure containment structures may be treated as more predictable and dependable than managerial BMPs, and so may not require as high a safety factor, if any.

However, to promote the implementation of either or both of these BMPs would require substantial transaction costs -- for administration, travel, time spent planning and designing and dealing and discussing. Earlier, we have seen that these can amount to $12-$15 per acre. Once these costs are added to BMP incentive payments necessary to stimulate adoption, it seems unlikely that point-nonpoint source trading would be competitive, no matter which BMPs were implemented. However, due to higher transaction costs per pound of phosphorus reduction, residue and nutrient management would become uncompetitive before manure containment would cease to hold a cost advantage over point source reductions.

As indicated above, there are serious questions whether a total substitution of nonpoint source phosphorus loading reductions would have an equivalent impact on water quality in Lake Zumbro as total reliance on point source controls (Scenario 1).

Thus, on grounds of feasibility, cost and water quality effectiveness, Scenario 2 appears to be of doubtful value as a policy alternative to Scenario 1.

Scenario 3: Seasonal phosphorus limit on RWRP: Type I

If a complete trade-off seems infeasible, what about partial trade-offs? The City of Rochester has requested seasonally variable phosphorus limits as an alternative to a constant monthly average limit of 1 mg/l for effluent phosphorus concentrations. Suppose that the Rochester WRP was issued a 1 mg P/l effluent limit under certain flexible compliance conditions. For example, suppose that during certain times of the year, it were allowed to offset exceedences of this limit by ensuring that equivalent NPS load reductions were being undertaken. Such offsets would *not* be allowed at well-defined low-flow periods when point-source phosphorus has a strong and direct impact on Lake Zumbro water quality, and perhaps at other times as warranted to protect Lake Zumbro.

Such a flexible approach to compliance with a NPDES permit would present a different set of options to the point source, with potential savings in operating and maintenance costs during the "off-season" (during base and high flow). Suppose that, on average, the RWRP is required to satisfy the 1 mg P/l effluent limit during a three month period from June 15 to September 15, and for the rest of the year it purchases nonpoint source phosphorus reduction credits to meet its limit. Would trading be any more cost-effective under these circumstances? And would the water quality of Lake Zumbro be at least as well protected?

Seasonal phosphorus limit rationale

To answer the latter question first, here is a brief rationale for a seasonal phosphorus limit (This is put forward as a hypothetical possibility, purely for analytical purposes -- not as a seriously proposed policy alternative for Rochester.)

1. Point source phosphorus discharges, primarily of soluble P, have their greatest impact on Lake Zumbro during low flow periods (MPCA, 1988). At these times, point source phosphorus tends to dominate the lake. Owing to a longer residence time (35 to 74 days), higher water temperatures, and greater potential for internal loadings during summer season low flows, this is when the negative impact of point source discharges is the greatest.
2. At higher flows, residence times in Lake Zumbro drop to 5 - 15 days. Severe algae blooms are less likely, and point source phosphorus is more likely to pass through the lake without causing major nuisance problems than in a low-flow regime. Nonpoint source particulate phosphorus comprises a higher proportion of the total phosphorus loading at these times. Nonpoint source loadings at base flow, in particular, *may* have an equal or greater negative impact on water quality than point source phosphorus discharges at base flow, for several reasons:

    - Quantity of loadings is relatively high (Nutrient budgets for 1988 indicate that the South and Middle Fork of the Zumbro River contribute a total of 37 percent of the total phosphorus load into Lake Zumbro as a flow-weighted average. Since these loadings are mainly nonpoint source, it is possible that they comprise half or more of the total loading at base flow).

- Direct negative water quality impacts of nonpoint source loadings from agricultural fields and feedlots go beyond induced algae growth to include increased turbidity and reservoir bed sedimentation plus negative impacts from loadings of nitrates, bacteria and pesticides.

- Phosphorus-laden sediment depositions at base flow may be released later as internal loading during low-flow conditions, thereby making the reservoir more sensitive to bioavailable point source loadings at these times. It is possible that, over time, NPS reductions could reduce internal loadings and thereby the sensitivity of Lake Zumbro to point source loadings during low flow. As discharges increase with the expansion of the Rochester community, such a strategy could help to protect Lake Zumbro without making major improvements to the treatment plant -- such as an effluent limit of less than 1 mg P/l.

These arguments would have to be much better documented and developed before a seasonal phosphorus limit could be justified . They are introduced here simply to explore a possible application of point-nonpoint trading. Before undertaking any further analysis of point-nonpoint phosphorus loading interactions in Lake Zumbro, it would be interesting to see if a seasonal permit of the kind described would alter the economics of point-nonpoint source trading. Assuming water quality results would be equal or better, would a seasonal permit be more or less cost-effective than a constant annual effluent limit?

Cost Analysis

To answer these questions, the total phosphorus loading reduction target of 200,000 pounds per year will be allocated between the RWRP and agricultural nonpoint sources. The point source component is given by the proportion of the total volume that would be met by meeting the 1 mg P/l limit during the low-flow period June 15 - Sept. 15. This is estimated to be 50,000 pounds. The nonpoint source component is the remainder: 150,000 pounds.

Annual point source phosphorus removal costs will include the full amount of the fixed costs used in the above cost analysis, which is $600,000, plus 25 percent of the operating and maintenance costs to cover the three-month period of compliance with the 1 mg P/l limit. The latter is estimated to be $140,000. The total annualized cost of removing 50,000 pounds of phosphorus during this critical period is therefore the sum of these two cost components, or $740,000. This is $420,000 less than the total annualized cost of meeting the 1 mg P/l limit year-'round.

The question is, could the total phosphorus loading reduction goal be met more economically by obtaining 150,000 pounds of nonpoint source phosphorus load reduction? The answer is, not likely. We know with near certainty that $420,000 could be used to obtain point source reductions of 150,000 pounds, for an incremental cost of $2.80/lb. Transaction costs are near zero. At best, Rochester could come out about even by purchasing loading reductions from feedlots. But as soon as administrative costs are taken into account, the balance shifts back in favor of point source reductions.

The conclusion is inescapable. In order for a seasonal permit of the type described above to be more cost-effective than an annual permit, substantial fixed cost reductions in point source phosphorus removal technologies would be necessary. This could be realized in decreased sludge storage requirements, or in reduced chemical feed housing costs, or perhaps in a non-chemical technology (biological treatment).

Trading off point source Operating & Maintenance costs for nine months of the year against equivalent quantities of nonpoint source phosphorus reductions appears to be a losing proposition in dollars and cents terms. Only if there were clear, major water quality benefits associated with a point-nonpoint source coordinated phosphorus reduction effort should trading be attempted with a seasonal permit.

In general, NPS phosphorus reductions would have to be available for about $1-2 a pound before P-NPS trading would be attractive to a city such as Rochester -- regardless of whether the phosphorus permit is seasonal or annual.

Scenario 4: Seasonal phosphorus permit: Type II.

If the above type of seasonal permit failed to make point-nonpoint trading an attractive policy alternative, would a slightly different type do so? To find out, the following variant on the Scenario 3 permit is evaluated: the 1 mg P/l limit must be met at the plant during low flow periods, say, June 15 - Sept. 15; at all other times, the RWRP can either meet a 2.5 mg P/l effluent limit, or offset this requirement with equivalent reductions of NPS phosphorus loading reductions.

This alternative, like the one above, is not proposed as a serious policy option for Rochester to consider. Rather, it is a means of analyzing intermediate stages between a complete dependence on point source reductions, and a complete substitution of nonpoint for point source load reductions.

The total required phosphorus loading reduction is somewhat reduced from 200,000 pounds a year in this scenario. From Sept. 16 to June 14, RWRP would be required to reduce phosphorus loadings by 116,000 pounds instead of 150,000 pounds, as in Scenario 3. During the period June 15 - Sept. 15, the loading reduction requirement would remain unchanged at 50,000 pounds. The total annual loading reduction requirement thus would be 166,000 pounds instead of 200,000 pounds.

Table 3.5: Point Source Costs of Phosphorus Removal:

	TP Reduction	Capital Cost	O&M	Total Cost	Cost/lb
9/16 - 6/14	116,000	$600K	$323K	$923K	$7.96
6/15 - 9/15	50,000	$600K	$140K	$740K	$14.80
Annual Total	166,000	$600K	$463K	$1,063	$6.40

The choice is between two ways of meeting the need to reduce 116,000 pounds of phosphorus loading, in addition to the 50,000 pounds removed during the June 15 - September 15 period. Reductions could be made through the RWRP by meeting the 1 mg P/l limit during the rest of the year, at an incremental cost of $323,000, or $2.78/lb. Only if nonpoint source reductions of this magnitude could be achieved at a lower cost would point-nonpoint tradeoffs be worth considering. As we have seen, it is unlikely that this could be achieved. Thus, Scenario 4 also must be judged to be an unsatisfactorv solution relative to Scenario 1, the status quo.

Scenario 5: Need to Reduce Phosphorus Effluent Concentration to Less Than 1 mg/l.

The evaluation of the preceding four scenarios indicates that, in the case of Rochester, point-nonpoint trading cannot compete economically or environmentally with the status quo solution described in Scenario 1. However, in exploring these alternatives some potential interdependence between point and nonpoint source loadings has been noted. In short, reductions in nonpoint source loadings over time could gradually reduce internal loadings of phosphorus at low flow periods, thereby reducing the sensitivity of Lake Zumbro to point source loadings at critical times. This suggests a potential substitution of nonpoint source loading reductions for eventual point source reductions below the present 1 mg/l effluent limit.

If phosphorus loadings from the RWRP increase by 75 percent over current levels by 2010, according to the projections used in designing the plant, while the sensitivity of Lake Zumbro to bioavailable phosphorus loadings at low flow periods remains unchanged, the need to impose lower effluent limits on the RWRP would be likely to increase, all else equal. The possible need for RWRP phosphorus effluent limits of less than the current level for such reasons has been seriously discussed: "...future growth of the plant may require successively lower nutrient limitations or incorporation of other ways to reduce nutrient supplies to the lake" (MPCA, 1988, p. 78). The potential for point-nonpoint source trading is evaluated here as an "other way." As in the previous scenarios, the critical issues concern relative costs of point vs. nonpoint control measures, and the technical and social feasibility of substituting nonpoint source reductions for an incremental degree of point source control.

The cost of phosphorus loading reductions below the 1 mg/l level at the RWRP are likely to be quite high, compared to current costs of treatment. It is likely that effluent filters would have to be added to reduce small particulate phosphorus loadings, at a considerable cost (Lyle Zimmerman, personal communication). The alternative of biological phosphorus removal is often expensive, too. Neither of these alternatives have been evaluated for the RWRP, because the City of Rochester has not been required to meet a limit below its present 1 mg P/l. However, some indication of the cost increase may be gained from examining the recent evaluation of biological removal of phosphorus at the Metropolitan Council's Metro plant, to bring effluent concentrations from approximately 3 mg/l to .4 mg/l. An estimated annualized cost of $71 million would have had to be spent to remove approximately 2 million pounds of phosphorus loading annually, for a unit cost of $36/lb.(MPCA, 1993---"Findings of Fact....) The incremental cost of reducing effluent concentrations from 1 mg/l to .4 mg/l at the RWRC could be considerably greater, because the incremental quantity removed would be small relative to the cost. At average annual flows projected for 2010, or 13.25 mgd, an estimated 24,200 pounds of additional phosphorus would be removed from the waste stream over the course of a year.

At phosphorus load removal costs of $36 and more, point-nonpoint source trading begins to look very attractive. At an estimated $2.50/lb, phosphorus removal through manure containment structures would be very economical. If residue management can succeed in reducing phosphorus loadings from cropland by an average of .75 lbs/acre, $10/acre incentive payments would translate to a $13.33/lb cost of phosphorus removal -- a third of the cost of point source removal. Even after administrative costs were taken into account, there could be a considerable cost advantage on the side of nonpoint source reductions. In addition, the task of obtaining nonpoint source reductions equivalent to 24,200 pounds of point source phosphorus reductions would be much more feasible than the task evaluated earlier of substituting for 200,000 pounds point source phosphorus load reductions.

However, if a point-nonpoint trading policy is initiated only after the need for it is identified, it may be too late to be effective in the case of Lake Zumbro. The intertemporal nature of the substitution is crucial: nonpoint source loading reductions of particulate phosphorus would need to occur over several years, perhaps over many years, before internal loadings in Lake Zumbro could begin to substantially and reliably decrease. The impact of nonpoint source reductions on internal phosphorus loadings would have to be monitored, along with potential additional impacts on algae growth caused by increased light penetration if sediment reductions result in increased light penetration during low flow periods -- a possibility raised in MPCA's Limnological Review of Lake Zumbro.

Ideally, it would seem that a program of nonpoint source reductions should be initiated well before the need for it becomes urgent. If projected increased loadings from the Rochester WRP indicate a strong likelihood that Lake Zumbro will be adversely affected at current effluent concentration standards, and if it is thought that nonpoint source reductions over a period of years could reduce the sensitivity of Lake Zumbro to increased point source loadings, then it would seem to be prudent to start a program of nonpoint source reductions soon. This suggests a preventive variety of point-nonpoint source trading -- or, in the absence of trading, a coordinated watershed strategy whereby current nonpoint source phosphorus reductions are treated as a potential means of reducing the need for future point source reductions.

Prerequisites to the development of such a strategy include the following measures:

1. Step one: Assess the probability of a future need to reduce point source TP mass loadings by reducing the permitted level of phosphorus discharge to less than 1 mg/l concentration;
2. Step two: Assess the likelihood that, over time, nonpoint source phosphorus load reductions could appreciably reduce the need for tighter point source phosphorus effluent limits.
3. Step three: Estimate the cost of achieving point source reductions to a concentration of less than 1 mg/l, such as 0.4 mg/l.
4. Step four: Estimate the scope and kind of reductions in nonpoint source phosphorus required to reduce or present the need for more stringent point source controls in the future. Should particulate P, bioavailable P or Total P be considered the relevant form in which to measure nonpoint source loading reductions? What kind of a safety factor should be applied?
5. Step five: Develop a strategy for achieving these nonpoint source reductions according to the required timetable, and at the lowest possible cost.

Supposing that the successful completion of steps one through four prepare the way to implement Step 5, how might a nonpoint source reduction strategy be designed? Could point-nonpoint source trading be designed as a preventive policy? More specifically, how could the "strong likelihood" of more stringent point source phosphorus emission concentration limits in the future be converted into an urgent present need to undertake preventive action through nonpoint source loading reductions? What kinds of incentives and constraints could be brought to bear on the City of Rochester on the one side, and the many institutions and individuals with responsibility for nonpoint source reductions on the other side, to implement a nonpoint source reduction strategy years before the need for it becomes clearly apparent?

Following are a few ways in which the Flexible Compliance Policy outlined in an earlier chapter of this report might be modified to meet the particular requirements of the case in question:

- An effluent limit of 0.4 mg/l could be introduced as a target to be achieved within a defined time period, such as a decade, with gradual reductions over the intervening years. The RWRP would be given a choice: Either meet these gradually reduced limits through plant upgrades, or by purchasing comparable quantities of verifiable nonpoint source reductions.

    1. To facilitate such a policy, RWRP could be allowed to "bank" nonpoint source credits in advance, and then use them to compensate for exceedences in months when effluent concentrations exceed the target. The quantity withdrawn from the bank account would need to be equivalent to the quantity of the exceedence, taking into account such factors as the form and timing of the phosphorus loading reductions, and the degree of uncertainty attached to the adoption and efficacy of the BMPs used to obtain nonpoint source loadings.

- Alternatively, the City of Rochester could form a joint powers agreement with Olmsted County and Dodge County, where the majority of the Lake Zumbro watershed is located, and this legal entity could be held responsible for meeting the effluent limit described above. This entity could then determine a politically acceptable, lowest-cost solution.

    1. This strategy may open up more flexible funding alternatives. For example, instead of requiring the RWRP (and thereby the City of Rochester) to bear the entire financial burden for achieving the phosphorus loading reductions required to protect Lake Zumbro, county residents could share the cost as well. For example, a sales tax or property tax surcharge could be levied to finance the most cost-effective mix of phosphorus reduction measures, including the implementation of nonpoint source BMPs and improvements to the RWRP.
    2. Alternatively, such a surcharge could be converted into an incentive for nonpoint source loading reductions For example, per-acre or per-animal-unit surcharges could be levied on farmers. The surcharge could be rebated to those farmers whose practices meet minimum water quality protection standards. The unrefunded revenues from the surcharge could be used to finance nonpoint source phosphorus loading reduction BMPs. A similar rebatable surcharge could be implemented for non-farmers.

- As a third basic policy alternative, local governmental units could simply make more intensive use of existing nonpoint source pollution reduction programs to attempt to accelerate the adoption of BMPs sufficiently to meet the phosphorus loading reduction targets required to protect Lake Zumbro. Existing funding sources could be focused on the Lake Zumbro watershed to the extent needed to achieve the goals laid out in a watershed or basin plan.

Which of the above alternatives would be likely to be the most successful? It is impossible to say, because there is little or no empirical evidence regarding the effectiveness of any one of them. It can be said, however, that the third alternative would require the least change in institutions, and would probably engender the least political resistance. Thus, it might be prudent to begin with this voluntary approach based on a focusing of current resources and programs on the problems in the Lake Zumbro watershed. If after a prescribed period of, say, 3 to 5 years, intensive application of voluntary programs is shown to be inadequate, then one of the other two alternatives could be tried. To prepare for such a need, further studies and pilot projects could be undertaken while the voluntary plan is underway, to test and refine whichever of the other two approaches is deemed most suitable for use in case purely voluntary methods prove inadequate. Even if these methods are not applied in the form outlined above, their continued study and testing might uncover ways of providing improved measurement, accountability and incentives for nonpoint source phosphorus loading reductions. The development of these qualities for nonpoint source programs are important prerequisites for the management of point and nonpoint source phosphorus loading reductions in an integrated fashion, according to a single basin plan.

Summary:

A number of factors combine to make point-nonpoint source phosphorus reduction trading an unlikely solution to Lake Zumbro's water quality problems, based on current conditions.

- Lake Zumbro is dominated by the RWRP, especially at low flow periods;
- Initial influent concentrations of P in wastewater stream are high, at approximately 9.5 mg P/l, reflecting several large industrial contributors. This means that, for a given investment in phosphorus treatment, a large quantity of TP is removed.
- Rochester is an expanding City. Thus, influent loads are likely to increase further, making point source reductions from the existing plant investment that much more economical.
- Cost advantage to nonpoint source reductions are not large: they virtually disappear if a safety factor of 2 is applied to nonpoint source control measures.
- Even if it were justified, very many acres and feedlots would have to be treated to come up with an equivalent quantity of NPS reductions. A large program with high transaction costs would be needed. Even so, there is no guarantee that an adequate number of acres or feedlots could be treated economically.
- Partial trade-offs are possible, and perhaps technically justifiable, but tend not to offer a cost advantage of point source controls. Such options as low-flow restrictions on the point source, accompanied by year-round nonpoint source controls, should only be pursued on technical grounds. No cost advantage is apparent.

P-NPS trading would present potential net benefits under two conditions.

First, if influent phosphorus concentrations at the RWRP were near the typical range of 5.2 mg P/l, rather than at its current high level of 9.5 mg P/l, the unit cost of point source phosphorus removal would triple to the range of $15-$17 per pound. However, the need to achieve large total phosphorus reductions could impose high transaction costs on nonpoint sources, by requiring the involvement of a large number of nonpoint sources in a trade. Thus, the potential benefits of trading are likely to be retained only if ways are found to reduce the number of individual sources included in the trade, and the time required to verify the installation, maintenance and effectiveness of the BMPs. Therein lies the challenge of making P-NPS trading work on a large scale.

Secondly, P-NPS trading could become viable if industrial and residential expansion in Rochester results in significantly higher loadings of phosphorus. If increased phosphorus loadings from the RWRP were sufficient to trigger more frequent algal blooms in Lake Zumbro, effluent limits below 1 mg P/l may be justified. To meet such limits, it is likely that RWRP would have to add effluent filters to remove phosphorus that is attached to very small suspended particles. This would be very costly on a per-unit of phosphorus removal basis.

If such a circumstance is in prospect, or at all likely in the coming decade or two, then the technical feasibility of substituting nonpoint source loading reductions for more stringent point source controls should be evaluated soon. Is it possible that, if nonpoint source loading reductions during base flow and high flow were sufficient, that internal loadings of phosphorus in Lake Zumbro at low flow periods over time would be reduced, making the lake less sensitive to point source loadings at low flow periods? If so, it might be prudent to begin a program of nonpoint source controls now, before a sense of urgency over Lake Zumbro's state of water quality develops. Given the long lead time necessary to implement a massive nonpoint source control program, and the additional time required for the effects of such a program to take hold in Lake Zumbro, point-nonpoint trading in the case of Lake Zumbro is perhaps best viewed as a preventive program. Nonpoint source measures may need to be launched before the symptoms pointing to their justification are allowed to fully manifest themselves. For by then it may be too late.

Although the two just-cited conditions under which P-NPS trading might seem exceptional or unlikely with reference to the two cases studied, they may not be unusual for point source dischargers as a whole. These case studies suggest that, for small and large municipal systems alike, the cost of meeting a 1 mg P/l effluent limit can be relatively high if influent phosphorus concentrations are typical, around 5.2 mg P/l. This will be true of treatment systems serving communities with largely domestic wastewater, where commercial and industrial discharges do not have a high phosphorus content, or where high-phosphorus industrial sources pre-treat their waste for phosphorus before sending it through the municipal system. Treatment costs will be still higher for treatment plants currently operating with very low phosphorus emissions, that are required to meet an effluent limit of less than 1 mg P/l. The Rochester case study shows that P-NPS trading should be undertaken well before the need to impose such limits becomes urgent. Most nonpoint source BMPs require time to implement on a large scale, and nonpoint source load reductions can require considerable time to exert a restorative influence on a receiving body's water quality, especially if the loading is in the form of particulate phosphorus entering a large river system.

CHAPTER IV: P-NPS TRADING CONCLUSIONS AND RECOMMENDATIONS

A. POTENTIAL BENEFITS

This investigation suggests that P-NPS pollutant trading could benefit Minnesota in several ways:

1. **Efficiency**: By minimizing the total cost required to achieve water quality goals. The potential for P-NPS trading to lead to more cost-effective pollutant-reduction solutions lies in those watersheds with the greatest discrepancy between the marginal cost of point and nonpoint source pollutant load reductions. As a general rule, these opportunities are most likely to arise in watersheds with the following combination: small towns with high phosphorus abatement costs, coupled with highly erodible farmland adjacent to a close network of surface water drainage channels. In such a situation, the spread between point and nonpoint source abatement costs is likely to be very high.

2. **Equity**: By providing a mechanism through which the cost of compliance with water quality mandates can be narrowed among sources in a watershed. By allowing point and nonpoint sources to transfer the responsibility for loading reductions through trades, P-NPS trading reduces the cost of compliance for all sources. For high-abatement-cost sources, P-NPS trading can make compliance with stricter limits economically achievable, while for low-abatement-cost sources it provides an incentive to reduce loadings beyond mandated levels.

3. **Effectiveness**: By making it more attractive for all pollutant sourcesto participate in comprehensive water quality enhancement programs, pollutant trading increases the likelihood that remaining water quality problems can be improved. The "finger-pointing stage" so common to watershed projects could be shortened or even eliminated if pollutant trading in the context of a watershed management policy resulted in a program that was perceived as fair, equitable and capable of achieving significant water quality improvement.

B. POTENTIAL BARRIERS

However, pollutant trading is largely an untried concept, and there is no assurance that a given trading program could achieve the full potential of these advantages. In fact, there are rather formidable obstacles to the attainment of these objectives, such as:

1. **Measurement Accuracy**: How can point and nonpoint source pollutants be compared in equivalent terms? Differences in pollutant potency, time of discharge, and predictability of discharge may be crucial for some water bodies, but not to others. Determining comparability of point and nonpoint discharges with regard to time and space dimensions is a crucial aspect of P-NPS trading.

2. **Transaction Costs**: The time and expense required to learn about the potential benefits of pollutant trading, locate potential partners, determine a suitable price and drawing up a defensible contract with adequate provisions for monitoring and enforcement all contribute to transaction costs. If these costs exceed the expected gains of pollutant trading, they eliminate both private and social benefits of trading.

3. **Legal-Institutional Requirements**: Assuming that federal and state laws are modified to explicitly sanction pollutant trading, the need for institutional innovation could be significant as the scope for pollutant trading expands. Local government organizations may have to play a major role, and accept certain responsibilities for nonpoint source pollution. A nonpoint source fund may have to be established, and administered to ensure efficient use of point source contributions. The writing and enforcement of NPDES permits will have to be adjusted, in ways difficult to predict from the outset.

4. **Political Barriers**: Lastly, assuming that the foregoing concerns areadequately addressed, there remains the question of public acceptance of pollutant trading. Efforts will have to be made to explain the potential benefits as well as the several prerequisites for pollutant trading to sometimes skeptical legislators, environmental activists, and members of the general public.

C. RECOMMENDATION: A TWO-TRACK APPROACH

These barriers are not insurmountable. But it will take time to remove them—through improvement of models, introduction of legislative and rule changes, development of new institutional roles, and education. However, to delay the introduction of trading until all of these concerns have been dealt with satisfactorily would risk indefinite delay.

That is neither desirable nor necessary. It is possible to introduce a limited pollutant trading system designed to work within the current basic framework of rules, institutions and technical capabilities. If the state wishes to take immediate advantage of the benefits of pollutant trading, the proposed "Flexible Compliance Option" described in C(1) below provides a means of doing so that would require minimal changes in present laws, rules, etc.

At the same time, if the state decides that a more comprehensive pollutant trading policy should be introduced on a broader scale, this would require considerably more preparation. The main prerequisites for introducing comprehensive pollutant trading, as an integral component of basin management, are outlined in C (2).

These two approaches could be pursued in sequence or simultaneously. It all depends on the urgency which the state attaches to the introduction of pollutant trading.

TRACK I: THE FLEXIBLE COMPLIANCE OPTION

PROPOSAL: Offer a flexible compliance option for point-source dischargers in the Minnesota River Basin. This option would apply only to loading reduction requirements additional to secondary treatment. It would present point source dischargers with three alternative means of meeting such requirements:

Option 1: On-site modifications to a WWTP
Option 2: Contract with other point or nonpoint sources within a prescribed watershed to achieve equivalent load reductions at less cost.
Option 3: For each pound by which a plant's effluent exceeds its annual limit, pay a prescribed sum into a fund designated to achieving equivalent pollutant reductions in the watershed.

Initially, the flexible compliance option would be offered only to point sources regulated under the National Pollutant Discharge Elimination System. However, as nonpoint sources are brought under more stringent systems of accountability, they too could be eligible for the flexible compliance option. For example, under Basin Planning, both point and nonpoint sources may be required to reduce their share of pollutant loadings. Flexible compliance could be available to either type of source to meet these requirements.

PILOT PROJECT: To test this proposal, develop a flexible compliance program for phosphorus in the Minnesota River Basin. This program would apply to any point source for which a 1 mg/liter phosphorus effluent limit is being contemplated by MPCA, or to instances where nonpoint source phosphorus loading reductions are deemed an adequate substitute for on-site pollutant reduction measures. The program would include a set of guidelines for point-nonpoint source (P-NPS) phosphorus trading (Option 2), as well as establishment of a fund called the Minnesota River Bank (Option 3).

The guidelines for P-NPS pollutant trading would be designed to reduce trading costs while maintaining accountability for achieving water quality goals. Rules would limit trading to easily observable and readily measurable BMPs that are beyond the scope of major nonpoint source programs, e.g., manure containment structures, riparian corridors seeded to permanent vegetation or created wetlands for stream treatment. MPCA would prepare worksheets to allow estimates of phosphorus loading reductions resulting from their installation of approved BMPs. P-NPS trades would be documented in MOUs between point sources and the MPCA, and transacted through contracts between point and nonpoint source parties to a trade.

The Minnesota River Bank fund would be dedicated to achieving required levels of phosphorus load reductions through the establishment of BMPs. In order to allow point source fees to be used for purposes other than administration, changes would need to be made in Minn. Stat. 116.07, subd. 4d. These changes would include establishment of a fund, and rules governing its use.

The payment rate would be established by the MPCA at a level that ensures the achievement of equivalent phosphorus loading reductions, and which covers acquisition and administrative costs of the program.

TRACK II: ESTABLISH PREREQUISITES FOR COMPREHENSIVE POLLUTANT TRADING

The kinds of changes needed to prepare for more comprehensive P-NPS trading in the long run are likely to be necessary anyway to build a watershed management framework. They are the kinds of policies needed to ensure greater accountability in nonpoint source pollution control, and to facilitate more effective integration of point source and nonpoint source programs in basin-wide and watershed projects. These recommended changes are presented under three categories: 1) those that would enhance the prospects for success of any kind of P-NPS pollutant trading system; 2) those required before Type I-Institutional trading could be introduced into NPDES permits; and 3) those required to pave the way for Type II trading in the context of a basin plan. The recommendations apply most particularly to water quality problems caused by excessive phosphorus loadings, where current rules do not compel reductions, but are relevant to unmet water quality problems in general.

1. General Pollutant Trading Prerequisites

   a. Develop guidelines for determining the degree of equivalence between point and nonpoint sources of pollutants including phosphorus, nitrogen, CBOD, TSS and other parameters. These guidelines should take into account differences in time and place of discharge, chemical form (e.g., solubility) and the sensitivity of the receiving water body to increased loadings. Also, the risks and uncertainties associated with nonpoint source loading reductions should be weighed against the multitude of pollutants that are usually curtailed after the application of a nonpoint source BMP.

   b. Refine the accuracy of computer models used to predict nonpoint source loadings, such as AGNPS, GLEAMS and CREAMS, working in cooperation with the Natural Resources Conservation Service, which shares this objective. Field-monitoring of primary BMPs should be conducted in distinct regions of Minnesota, and the results used to improve parameter estimates for specific regions, soil types, and management practices. Improved accuracy will increase the confidence with which point-nonpoint trade-offs can be undertaken. The quantities of pollutant loading reductions specified in a trading program should be based on the best predictions available, and on methodologies approved by the state.

   c. The monitoring results obtained in (b) should also be used to develop worksheets that local resource managers can use to predict the loading reductions expected to result from the application of specific BMPs under specific conditions. Local resource managers should be given a choice to use either a manual worksheet or a computer program to estimate nonpoint source pollutant loadings. These estimation procedures should be integrated into a system for total farm resource planning.

d. The need for water quality monitoring for pollutant trading needs to be explored, and watershed monitoring systems based on these needs developed. The purpose of such monitoring would be to assess the long-term results of a trading program, not to measure the year-to-year impacts of pollutant reductions for enforcement or verification purposes.

e. To prepare for administered trading, an attempt should be made to determine appropriate fees or charges to levy against excess pollutant loadings, and to develop a system for administering the fund created by contributions of such fees. Minn. Stat. § 116.07, subd. 4(d) should be revised to allow the collection of fees on the basis of environmental damages, rather than only to cover administrative costs. Plus, it should be changed to create a special fund for the expenditure of such contributions, if a decision is made to prepare for administered pollutant trading.

f. Pollutant trading, if conducted so as to ensure maximum accountability by nonpoint sources, would introduce a major change into the financing of nonpoint source reductions. Instead of being paid to install specific practices, nonpoint sources would be paid to achieve a definite quantity of pollutant loading reduction. Most likely, payments would be for a predicted quantity, estimated by a computer model. As indicated in Chapter I, such a policy shift can be expected to strengthen the incentives of land users to reduce nonpoint source loadings, compared to incentives provided by cost-share subsidies. This is a hypothesis requiring empirical testing, however. Before pollutant trading is introduced, a number of "Payment for Pounds" trials should be undertaken in individual counties or watersheds, in order to gauge the acceptance and effectiveness of market-like transactions for nonpoint source pollution abatement.

g. An important key to reducing transaction costs of P-NPS trading is to designate local units of government as representatives of all nonpoint sources in a watershed or county, to avoid having to deal with scores, hundreds or thousands of nonpoint sources one at a time. To prepare for P-NPS trading, therefore, it will be necessary to clarify and, perhaps, to codify the role of local units of government relative to nonpoint source pollution in state law. Since counties have primary authority over land use, this may simply require a clarification that this authority extends over land uses that impact water quality.

h. If, as suggested in (g), local units of government assume a critical role in P-NPS trading, then the state may need to consider whether certain types of policies or assistance could help local government to better perform such a role. A related consideration may be whether certain types of state assistance should be offered conditionally, depending on the local government unit's readiness to undertake new responsibilities over nonpoint source pollution, including but not necessarily limited to P-NPS trading.

i. If the federal Clean Water Act is modified to include more specific provisions regarding pollutant trading, matching revisions will be required in Minn. Rules pt. 7050.0211 and chapter 7065.

2. Prerequisites Specific to Type I (NPDES permit-based) Trading

   a. P-NPS trading has significant implications for the drafting and, especially, enforcement of NPDES permits. It is recommended that a task force examine these implications and advise the Division how pollutant trading rules or procedures should be developed to accommodate and, if possible, harmonize with permit writing and enforcement requirements.

   b. According to one variant of Type I trading, both point and nonpoint sources would be faced with a load-reduction requirement. Defining such a requirement for nonpoint sources, and codifying it in state laws and rules, would likely be a formidable undertaking. Both political and technical challenges would be substantial. But the lack of such a requirement, or performance standard, for nonpoint sources is likely to limit the scope for point-nonpoint coordination policies required for effective basin and watershed planning, including but not limited to P-NPS Trading. Thus, it is recommended that the Division's Watershed Assistance Section investigate the question of nonpoint source requirements, standards or guidelines, suggest how they might be determined and applied, and specifically how they might be used in integrated watershed management involving point and nonpoint source reduction measures.

3. Prerequisites Specific to Type II (basin plan-based) Trading

   a. The main prerequisite for Type II pollutant trading is to develop a basin management system which allows scope for P-NPS trading as a means of point-nonpoint source coordination. Such a system should be developed as a case study of a well documented basin.

   b. Type II trading would be designed to operate outside of the context of an NPDES permit, although it would involve point sources which are regulated by such a permit for matters not related to the pollutant trade in question. To maintain the flexibility of conducting P-NPS trading "off-permit" without sacrificing too much of the enforcement authority conferred on MPCA by an NPDES permit is a balancing act that may be hard to achieve, but may be necessary to make Type II trading work. One solution, indicated earlier, may be for the MPCA to bind itself to a permit review related to the traded parameter, if by a specified time pollutant loading reduction milestones specified in the Basin Plan are not being achieved. This possibility, and perhaps others, should be evaluated by the Point Source Compliance Section.

c. Likewise, MPCA needs to develop a plan for ensuring compliance with load reduction goals and milestones by nonpoint sources, in case voluntary measures fail. These might include incentives and disincentives of various types, presented either directly to landowners or to those local government units responsible for nonpoint source reductions. Such a plan would be a major policy change, and should be coordinated with the state's response to any similar requirements arising from changes in the Clean Water Act or the 1995 Farm Bill.

d. A point-nonpoint source load allocation process needs to be developed that produces reliable estimates for use in a basin plan. Along with this, a process for deciding which sources should be required to reduce pollutant loadings by how much also is needed.

As stated earlier, it is likely that many of these recommendations will have to be considered or acted upon in the near future for reasons other than pollutant trading, some are under way already. Whether to develop the state's emerging basin management apparatus, or to satisfy state or federal demands for greater accountability in nonpoint source pollution control, a good many of the measures required to further evaluate or to introduce pollutant trading will have to be undertaken anyhow. In fact, the recommendations should be considered in light of the agency's broad water quality programming concerns, not simply the special needs of pollutant trading.

As the agency answers the questions and concerns listed above, the time may come to "test the waters," so to speak, and to give pollutant trading a try. It is recommended that this be done carefully, gradually, and in the following order:

First test "Payment for Pounds" in a number of locales, until the "transaction" approach to nonpoint source reduction financing is developed into a workable system.

Next, after the necessary prerequisites have been met, introduce Type I Trading with the following options: the point source may satisfy its loading reduction requirement either by making at-plant reductions, paying a fee on excess loadings, or contracting with nonpoint sources. Nonpoint source stewardship requirements should be introduced from the start, if a suitable method can be devised.

Third, introduce Type II Trading in the context of a basin plan. This form of trading is likely to require the most preparation, depending as it does on a reliable method of point-nonpoint source load allocation, and on the development of a delicate balance of flexibility and accountability.

Thus, it is not necessary to make a once-and-for-all decision for or against pollutant trading. As the prerequisites listed above are progressively satisfied, a judgment can be made whether or not pollutant trading could help to advance water quality objectives as they exist at that time.

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POINT-NONPOINT SOURCE COORDINATION

Not only may pollutant trading programs differ with respect to tradeoffs between regulation vs. voluntary programs, or the symmetry of regulations and incentives facing point and nonpoint sources. They also will differ according to the degree of point-nonpoint source program coordination desired, and the type of instrument chosen for transactions.

a. Program Coordination Alternatives

Three degrees of program coordination can be distinguished:

1) Parallel Programs: Point and nonpoint programs remain separately designed and administered, but are focussed on the same water body or watershed. This minimal degree of coordination could be effected within priority waters identified under basin planning, for example. The type of pollutant trading consistent with parallel programs would be the simplest form of Type I trading, with no additional constraints on nonpoint sources.
2) Correlated Programs: Point and nonpoint programs stay separate, but loading allocations and loading reduction requirements are jointly determined. Either Type I trading with nonpoint source stewardship requirements, or one of the Type II trading variants would be consistent with correlated programs.
3) Integrated Programs: Point and nonpoint programs are united under a single management and administration. For example, a municipality with responsibility for both stormwater pollution and a wastewater treatment plant could be assigned an aggregate load reduction target to be met by reductions from either or both of these sources. Or, a county and municipality which establish a joint powers board for purposes of pollution control also could be assigned an aggregate load reduction target to be met by any combination of point and nonpoint source reductions within its jurisdiction. Under such circumstances, pollutant trading is internalized, much as interfirm transactions are internalized after two firms become vertically integrated as a single management unit.

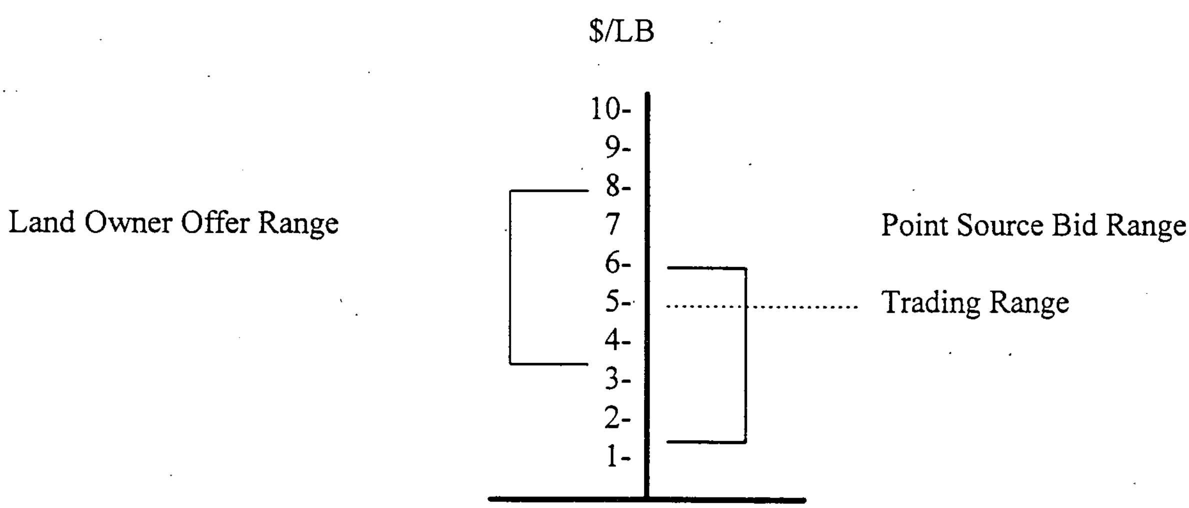
INCENTIVES TO TRADE

The success of a pollutant trading system depends on its ability to maintain and perhaps even to accentuate incentives to trade that are inherent in the cost differences among pollution sources within a trading region. If economic incentives to trade are absent, trading obviously makes no sense, and other means of point-nonpoint coordination must be employed. If incentives are present, but weak or uncertain, policy measures might be used to strengthen the incentives, perhaps by making transactions easier or less costly to undertake. Finally, if economic incentives to trade are inherently strong, good policy measures can help to ensure that they are not dissipated in complex policies and rules, or go unnoticed by potential trading partners for lack of information.

1. Unit of Analysis: The Two-party Transaction

The incentives inherent in a potential trade are best illustrated by a two-party transaction between pollutant sources whose cost of loading reduction differs. Such a case, involving a landowner and a wastewater treatment facility, is illustrated in Figure I below. The vertical scale measures the cost per pound of pollutant loading reduction, up to $10/lb. The landowner, who is a potential supplier of pollutant-reduction services, is shown on the left side of the scale. The treatment plant, a potential purchaser of these services, is shown on the right-hand side.

A Point-Nonpoint Trading Transaction



(Figure 1)

In this example, it is assumed that each party to the transaction has determined two reference numbers as a guide to negotiations with the other party. On the supply side, the landowner has determined that the minimum price which would convince him to undertake tradeable pollutant loading reductions is $4/lb. The maximum price, which the landowner hopes the wastewater treatment plant will be willing to pay, is $8/lb. Thus, the landowner's offer price range is from $4 to $8. On the demand side of the transaction, the wastewater treatment plant has a somewhat different range of prices in mind. These are determined by its estimates of loading reduction costs at its plant, and expectations about the other party's cost and likely response. At a maximum, the plant would be willing to pay the landowner $6/lb to undertake loading reductions on its behalf. This approximates the plant's own cost of pollutant loading reduction, with due allowance for the uncertainty and inconvenience of trading vs. achieving reductions at the plant. The plant would never pay more than this amount. At the lower end of the scale, $2/lb represents the "bottom dollar" at which the plant representatives believe the landowner may be willing to offer pollutant loading reduction services. Thus, the plant's bid range is $2 to $6. Where the bid and offer price ranges overlap, from $4 to $6, is the trading range of relevance to the transaction. If a price is established within this zone, both parties stand to gain economically from a transaction.

In a bilateral transaction, the actual outcome which determines the distribution of the gains from trade cannot be predicted, depending as it does on the relative negotiation skills of the two parties. However, the example can be extended to show how policy constraints could affect the scope of the trading range, and tilt the trade toward the advantage of one party or the other (Fig. 2a, b).

Pollutant Trading
Under Supply Constraint

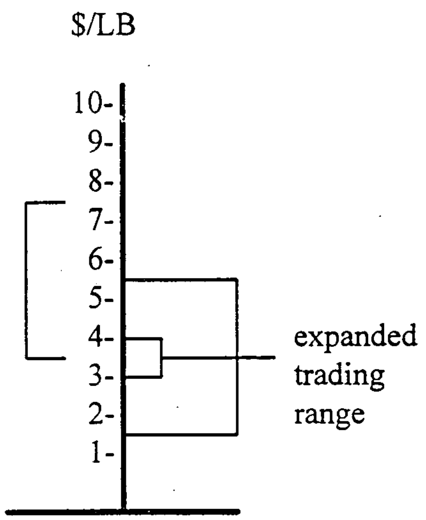


Figure 2a

Pollutant Trading
Under Demand Constraint

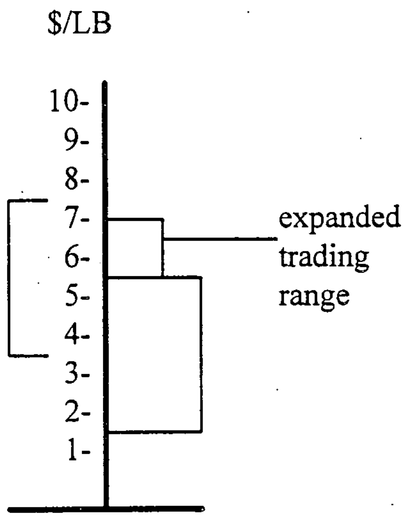


Figure 2b

Suppose, first, that a supply constraint were placed on the landowner, such as a surcharge of $1/lb for pollutant loadings predicted to result from his current land use practices. The effect of this policy would be to reduce the landowner's reservation price by this full amount, to $3/lb, as shown in the diagram. This works to the potential advantage of the plant—if its negotiators are successful in holding out for the best deal available from the landowner, they will be able to purchase the services they need at a price of $3 instead of $4. Similarly, suppose that a demand constraint were placed upon the plant, for example, an effluent tax of $1/lb. As a result, the total expected benefit to the plant of avoiding the need to undertake its own loading reductions would be $7 rather than $6. The plant's trading range would move up by this amount, increasing the potential gains from trade available to successful negotiation by the landowner.

The imposition of such constraints may accomplish more than widening the trading range. It may have the effect of driving one or the other of the parties to the bargaining table, so to speak. This is especially pertinent in the case of nonpoint sources, who seldom are compelled to achieve loading reductions. Without a surcharge on expected loadings, as in this example, the landowner who is not regulated faces an opportunity cost only—the foregone benefit of providing a service at a price greater than its cost. However, if a surcharge on loadings is imposed, the landowner suddenly is confronted with the prospect of an out-of-pocket expense. This expense may seem more real than a lost opportunity to earn money by offering a service -- an unusual kind of service at that—though both are equally real as economic costs. To most people, the prospect of writing out a check to pay a fee—of actually paying money—is more real than the notion of losing money by not taking advantage of an opportunity. Hence, if a policy goal is to encourage trading, imposing or increasing noncompliance costs is one possible way of drumming up business.

2. Strength of Incentives

It is difficult to apply an objective measure to incentives, as the strength of incentives, conceived as their degree of influence on behavior, consists of both objective and subjective elements. Consider the incentives of the landowner in our example. At a maximum, if no additional constraints are placed on the landowner, his maximum expectation of gain from a transaction is $4/lb. The landowner's incentive to engage in pollutant trading might be measured by this expectation of maximum gain. Or, if the landowner in question is unskilled in negotiations, and realizes it, his expectation of gain might be in the range of $1-$2/lb. Similarly, the plant representatives' incentive might be measured at the maximum possible gain to trading of $4/lb, or some lesser amount. Thus it is that expectations of gain, shot through with subjective elements, determine the strength of incentives.

Subjective expectation of gain is not the end of the story, however. The landowner's incentive, though it be only $1/lb., may act more strongly as a motivating factor than would a $3/lb incentive for the plant, because the landowner's income is directly affected by the outcome of the transaction, while the income of the plant representatives probably is not. Their incentives are likely to act more indirectly. For example, a plant manager may perceive that his job performance rating, hence future salary and job security, depends on his ability to minimize the rates charged to users of the plant's services, while meeting state water quality standards. In the terminology of institutional economics, the landowner, as residual claimant to income generated by assets he owns, is subject to high-powered incentives. The plant manager, as an employee rather than an owner, is subject to low-powered incentives such as bonuses, raises, etc. (Williamson, 1985, chapter 6).

Suppose, for sake of illustration, that the landowner and plant representatives agree on an exchange price of $5/lb. What are the gains to trade for each trading partner? The landowner experiences a gain of $1/lb over the minimum price at which he would have been willing to supply pollutant loading reduction services. Likewise, the plant representatives gain by having to pay $1/lb less than they would have otherwise had to pay to reduce loadings at the plant. Society gains by $2/lb, the full extent of the trading range, which measures the cost difference between loading reductions by the two sources.

As this example illustrates, pollutant trading can generate incentives that motivate economic actors' behavior in socially desirable directions: that is, toward the efficient and equitable achievement of public water quality goals. The willingness of parties to trade, the trading range and distribution of gains to trade can be influenced— though not determined—by public policies such as surcharges on expected runoff or effluent. Through the introduction of pollutant trading as part of a mixed voluntary/regulatory policy, the state can utilize high-powered types of incentives to increase the performance of its water quality improvement efforts. This is illustrated in Figure 3.

The Incentive Structure of Pollutant Trading

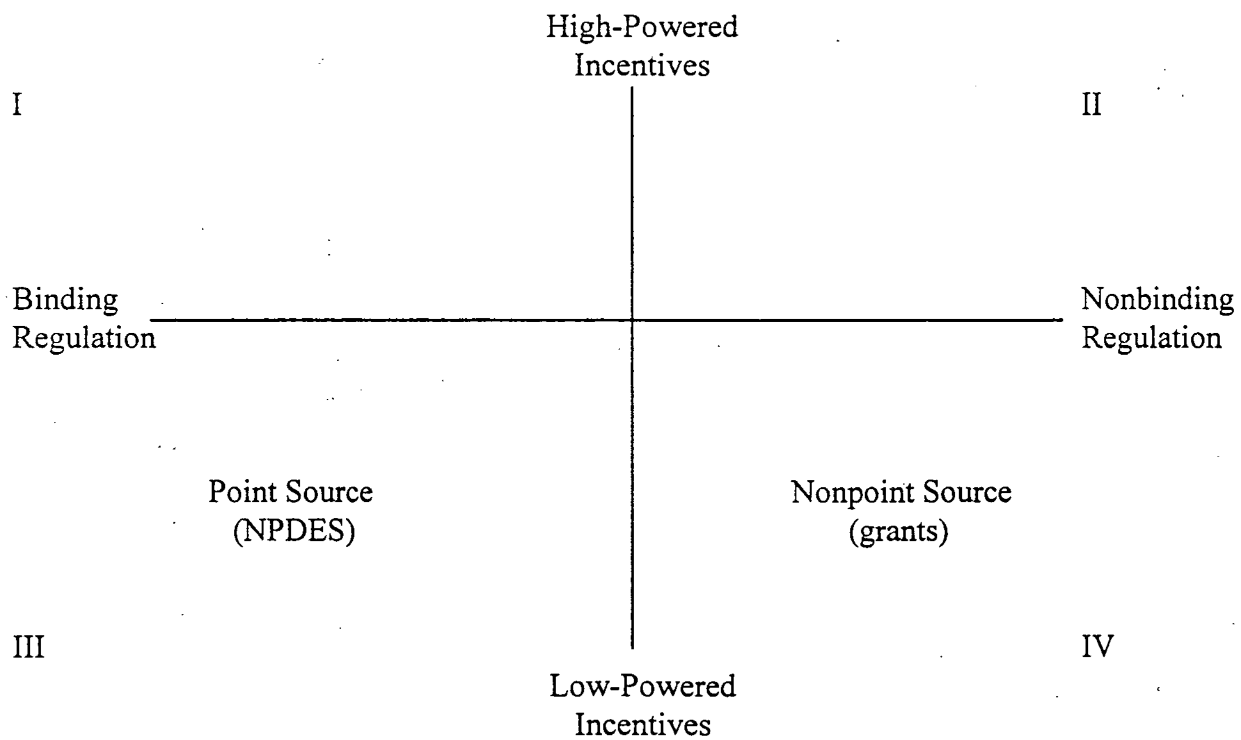


Figure 3

The quadrant is formed by two axes. The vertical axis measures the strength of incentives, which range from low-powered to high-powered; and the horizontal axis measures the degree of regulation, which varies from binding to nonbinding. The status quo situates point sources in quadrant IV, with the NPDES permit system based on binding regulation and low-powered "bureaucratic" incentives, while nonpoint sources are situated in Quadrant III, with BMPs being preferred in a voluntary setting with assistance from low-powered incentives such as grants and subsidies.

How would pollutant trading influence the structure of incentives? Suppose Type I trading were introduced with no further accountability demands on nonpoint sources. The outcome is captured in Figure 4(a), where the point source has moved from the northwest corner of Quadrant IV to the middle of Quadrant I, while the nonpoint source has moved vertically from the southeast corner of Quadrant III to the northeast portion of Quadrant II.

Incentive Structure With and Without
Nonpoint Source Stewardship Requirements

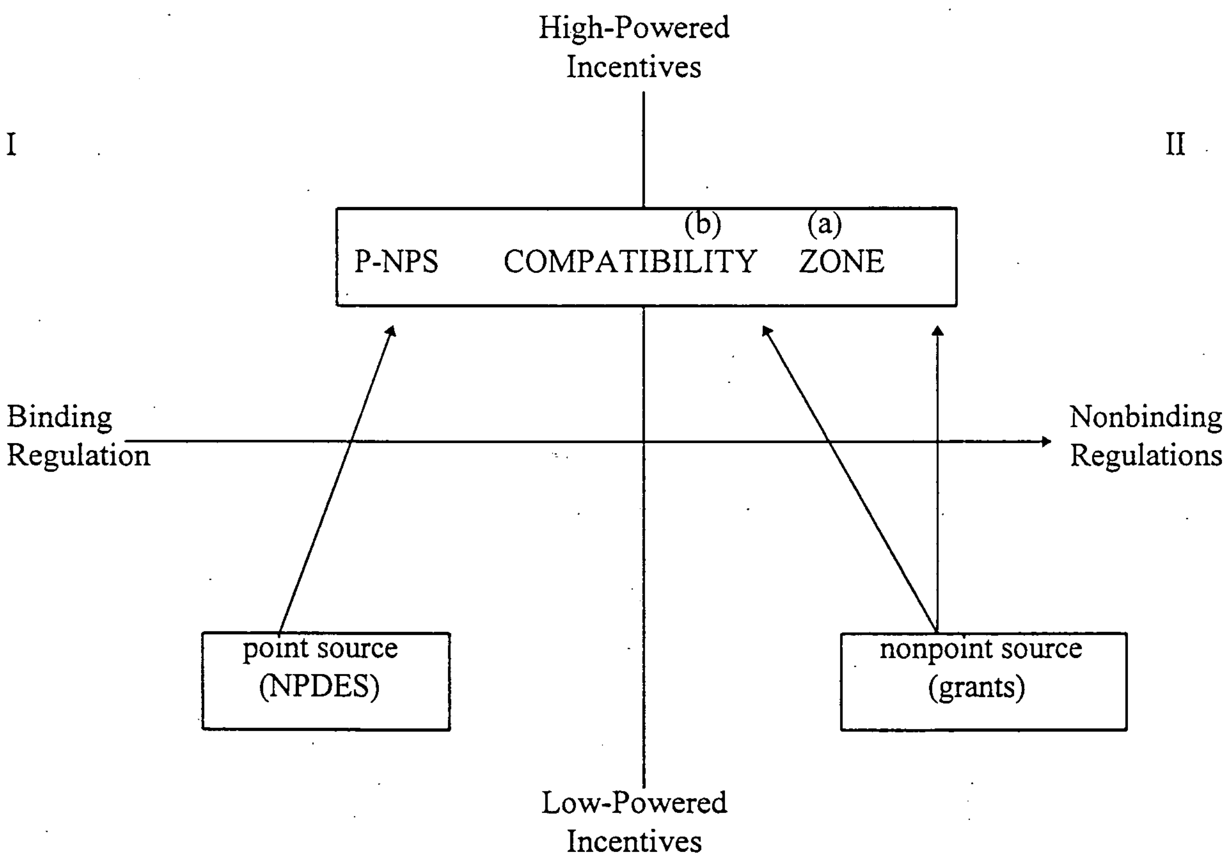


Figure 4

What do these movements signify? Pollutant trading has somewhat relaxed the regulations binding the point source, offering it a choice of alternative means of achieving a loading reduction. But, being under an NPDES permit, the point source stays on the "binding" side of the regulation spectrum. The point source moves further along the incentives spectrum, crossing the threshold from low-powered to high-powered incentives. Prior to trading, strong incentives may have acted on point source managers to choose low-cost solutions to state and federal mandates, and perhaps to resist the imposition of costly mandates by political or legal means. The introduction of a pollutant trading option would further strengthen incentives both by expanding the range of choice, and allowing the point source to capture the gains of trading.

For the nonpoint source, a pollutant trading option would effect a still more dramatic transformation in incentives, but, by assumption, none in the degree of regulation. Initially, in Quadrant II, nonpoint sources are motivated by grants, subsidies, technical and educational services, which are offered in exchange for, or in hope of, the landowner's adoption of best management practices. The introduction of pollutant trading replaces this "grants economy", to use Galbraith's term, (Boulding, 1973) with an exchange relation. The prospect of appropriating the potential gains of trade produces high-powered incentives which can be expected to strongly motivate economic behavior. Whereas under the grants economy the landowner at best might adopt a given practice in exchange for a payment, under trading the landowner is placed under continuing motivation to discover low-cost means of achieving further loading reductions.

Suppose that a "stronger" form of Type I Trading is introduced, under which the nonpoint source is made subject to a resource stewardship requirement. As explained above, this loading reduction requirement would have to be satisfied before the nonpoint source could offer to undertake loading reductions in exchange for payment as part of a pollutant trade. The effect of such a policy can be illustrated in two ways. In the context of the quadrant analysis, it would entail a parallel movement from left to right in Quadrant II, as shown in Figure 4(b). In the context of the trading range analysis, it would probably entail an increase in the minimum price at which the source would be willing to provide additional loading reduction services. This assumes a rising supply price for loading reduction services, owing to decreasing marginal returns as quantity supplied increases.

The preceding discussion of incentives has been limited to Type I trading only. The structure of incentives which would result from Type II trading is more ambiguous. Recall that in Type II trading a voluntary approach to watershed management is the starting point. A loading allocation would result in the assignment of voluntary load reduction goals to each major source. However, the state would make it clear from the outset that, if voluntary methods fail, mandatory provisions are likely to be imposed. If these threats are credible, then sources may act as if they were under a legally enforceable requirement to achieve load reductions. For example, in a basin agreement with all sources the state could bind itself to take specific regulatory steps if voluntary measures did not meet load reduction targets by a certain date. This kind of credible commitment could serve as a substitute for regulation, offering a window of opportunity during which a flexible, non-regulatory approach to watershed management could be attempted. There is considerable support within the steering committee for such an approach to point-nonpoint coordination in a watershed setting. The question for this investigation is, could point-nonpoint pollutant trading function as a coordinative mechanism if none of the sources were directly compelled to satisfy their loading reduction requirements? Could the prospect of eventual regulatory measures be made sufficiently credible to motivate sources to undertake costly measures?

Limited experience suggests that point sources, which have operated for years under a fairly rigid regulatory system, may take the prospect of eventual regulation, together with their public responsibility to control recognized pollution problems, with sufficient seriousness to motivate costly actions to reduce loadings. A recent Minnesota case in point is the Metropolitan Council, which agreed in a 1993 Memorandum of Understanding to spend approximately $25 million to reduce phosphorus emissions from its Metro plant, in addition to funding projects to reduce nonpoint loadings of phosphorus. Even though its NPDES permit did not specify a phosphorus limit, MPCA and others expressed strong concern about the impact of Metro-generated phosphorus on a downstream lake, and the prospect of eventual phosphorus limits on the plant were discussed as not unlikely.

No experience is available to suggest how nonpoint sources might respond to the prospect of eventual regulation. It is safe to assume that most farm and agricultural organizations would express strong opposition.

Transaction Costs

The time, risk and expense of conducting a transaction can act as serious impediments to trade, in particular where these transaction costs, as they are collectively designated, equal or exceed potential gains of trading. Transaction costs may be pervasive with respect to pollutant trading (Stavins, 1993); but several types of transaction costs appear to be amenable to change through public policy. By designing a governance structure for pollutant trading that minimizes transaction costs, the potential benefits of pollutant trading can be more fully realized than if nothing is done about these impediments to trading.

Generally speaking, transaction costs can be described as "the cost of running the economic system" (Arrow, 1969, p. 48), or as "the economic equivalent of friction" (Williamson, 1985, p. 19). More specifically, transaction costs have been described as "the costs of drafting, negotiating and safeguarding an agreement, (Williamson, 1985, p. 20), or still more specifically as being composed of several components: search and information costs, bargaining and decision costs, and monitoring and enforcement costs (Stavins, 1993). They do not include production costs, the traditional subject of microeconomics, or environmental externalities, the subject of welfare economics.

The pervasiveness of transaction costs in pollutant trading, and how these costs might vary among sources, can be illustrated by a couple of hypothetical examples. Take the manager-operator of a relatively small wastewater treatment plant for a community of, say, 2,500 population. Managing the plant amounts to a part-time job, to be accomplished along with exercising responsibility for street repair, snow-plowing, city park maintenance, maybe even law enforcement. Suppose the state imposes a new standard on the town's wastewater treatment plant, but presents the manager with a couple of options for meeting it: either upgrade the plant, or contract with another lower-cost source to achieve an equivalent reduction in pollutant loadings. What are the relevant transaction costs facing such a municipality, and such a manager?

To begin with, the entire process of learning about "pollutant trading" may be very time-consuming, and therefore costly. The idea may seem foreign, contrary to the way the manager has been used to thinking about wastewater treatment responsibilities. Once the general rationale of the policy is understood, its detailed rules and provisions have to be digested before a rational decision can be made to trade, or not to trade. These provisions may be quite complex, particularly if the state and federal authorities who developed the policy take pains to ensure as precise an equivalence between point and nonpoint source loading reductions as is technically possible to determine, for example; or if monitoring and enforcement provisions multiply tasks and paperwork for the municipality. Even after all such provisions are understood, and the cost of complying with them duly assessed, the manager may still harbor uncertainties about how a pollutant trading arrangement might shake out. Might not the government change the rules of the game after the city signs a contract with another source to reduce loadings? Might not additional requirements be imposed on the city? And how does one write an iron-clad contract that is enforceable, in case something prevents the other source from reducing its loadings according to the schedule in the contract? What if contract abrogation results in the imposition of a penalty on the city for violating its NPDES permit?

With his mind reeling with such questions, the manager may never get to the point of wondering which other sources might be suitable to contract with for loading reductions. If he does, the manager will have another set of vexing questions to answer—another field of detailed knowledge to conquer: 'What are the boundaries of the watershed within which trading is allowed? Which farmers should I approach first? What do you suppose their reaction will be? How much of a pollutant loading reduction could farmers achieve? What are their costs of reducing the loadings of the pollutant in question? How do you figure all this out? Who can help me?'

Even if the manager manages to get satisfactory answers to all these questions, he still has to figure out how to verify compliance with the contract terms. Has the landowner installed the promised BMPs? Are they as effective as they are supposed to be? Are they permanent changes, or could they be reversed on a moment's notice? What happens if the farm is sold?

It is easy to imagine that the "cost" represented by all these questions, in addition to the sheer detail work involved in negotiating, monitoring and enforcing a contract, could far exceed the gains of pollutant trading which the town might face, in the plant manager's mind. Such transaction costs thus are likely to act as a serious barrier to a pollutant trading policy, preventing transactions that, in theory, could be mutually beneficial to the sources, as well as to society as a whole, from ever taking place.

It is not likely that the small plant manager can find answers to these vexing questions, and to others that are bound to arise, by pressing the HELP button on his personal computer—as desirable as that would be. However, there are other ways in which a trading policy might be designed to minimize these kinds of transaction costs, as will be explored shortly.

The manager of a larger facility may not be as overwhelmed by such questions as the small-facility manager portrayed here. She and the municipal staff may be familiar with the idea of pollutant trading and used to writing and enforcing contracts. Some of them may be fairly knowledgeable about nonpoint source pollution, and with a little training able to predict and monitor the effect of alternative BMPs on pollutant loadings. But even such a facility will face certain transaction costs.

Following are several institutional innovations that could help to reduce the kinds of transaction costs described above:

1) BROKERAGE SERVICE: The government could either encourage private brokers to help match up potential buyers and sellers, or provide such a service itself. Brokerage services could include counseling on the advisability of pollutant trading, fielding technical questions on costs, prices, rules and regulations, methods of compliance

monitoring, etc. In the start-up phase of pollutant trading, especially, government provision of such a service would likely be necessary. Even after trading became successfully introduced, the government may need to continue providing such services, given the probable low frequency of trading, and consequent low volume of revenue available to private brokerages.

2) INFORMATION AND EDUCATION: Whether the government or a private firm were to undertake the brokerage function, transaction costs could be reduced through the public provision of information about trading policy in general, the details of recent transactions (costs, prices and quantities) as well as training and education on measuring and monitoring loading reductions, writing contracts, etc.

3) GROUPING OF NONPOINT SOURCES: The large number of nonpoint sources imposes a potentially very high transaction cost on those wishing to engage in point-nonpoint pollutant trading. One way of reducing this cost considerably would be to assign the responsibility for nonpoint source pollution to local government agencies, such as a county or watershed district. Then, municipal and industrial point sources wishing to enter into nonpoint trades would have one or at most several sources with whom to deal. Counties, for example, could be encouraged or required to assume responsibility for land-use activities that affect water quality. The counties which entered into pollutant trading contracts would then determine how the required loading reductions would be achieved. Soil and Water Conservation Districts, the local SCS field office, or a private consultant could be asked to provide technical services. The county could enact land-use ordinances to help achieve the required loading reduction, or it might draw on state-funded programs to provide incentives to private landowners to reduce loadings. In the end, the county may need to contract with private landowners to provide the required loading reductions.

4) ADMINISTERED TRADING SYSTEM: In lieu of the above measures, which are based on contractual trading, an administered pollutant trading policy might be introduced. According to such a system, sources wishing to exercise the option of pollutant trading could do so simply by contributing to a fund, according to a certain schedule of required payments. For example, suppose a source were required to meet a certain loading reduction over a period of years. It could either make loading reductions on site, or contribute to a fund for each unit by which it exceeded its loading limit for a certain year. This fund would be used to finance loading reduction efforts in the local watershed, presumably where additional funding would have the greatest impact on loadings. Thus, through a fairly simple administrative procedure, the responsibility for pollutant loading reductions could be transferred from high- to low-cost sources, and most of the transaction costs associated with contractual trading could be avoided.

5) FLEXIBLE TRADING SYSTEM: Instead of allowing either contractual or administrative pollutant trading, offer both. Set up an administrative system for those whose contractual costs are likely to be high, but allow those for whom such costs are relatively low to conduct pollutant trades by contract.

6) REDUCE MEASUREMENT COSTS: Regardless whether contractual, administrative or flexible trading is chosen, a remaining significant cost is likely to be measurement and monitoring of nonpoint source pollution. Several possibilities exist:

   a) Allow trades on the basis of predicted nonpoint source pollution loading reductions. The art and science of nonpoint source loading prediction is far from perfect. But it has advanced considerably in recent years, and for short-term purposes is far more feasible than water quality monitoring to measure the impact of BMPs on water quality. However, predictive models need to be improved to refine the measurement of specific pollutants in specific regions.

   b) Develop rules of thumb, and trading guidelines for specific BMPs. For example, in the measurement of loadings of sediment, and sediment-attached pollutants such as phosphorus, it is important to know the specific field's sediment delivery ratio to the edge of the field, and into the nearest water channel. By restricting trading to sediment-reduction BMPs installed on fields adjacent to surface water channels, the need to estimate this parameter could be eliminated, and the cost of measurement made much easier.

7) DEVELOP SPECIFIC TRADING RULES: At present, sources may perceive the risk of entering into a pollutant trading agreement as being increased by the lack of specific federal and state policies on the subject. Federally, the rules associated with TMDLs provide the only explicit reference to pollutant trading. Early versions of the Clean Water Act reauthorization from the Senate and House—as well as the Clinton Administration's earlier proposals—include much more explicit reference to pollutant trading. After federal policy is made more explicit, state policy can be modified accordingly, providing much firmer guidance to sources as to what is allowed under pollutant trading, how it relates the permitting process, etc.

APPENDIX D

Political Barriers to Pollutant Trading

In addition to legal, economic and technical factors, psychological and ethical considerations can act as barriers to the acceptance of pollutant trading as a legitimate solution to water pollution problems. To many—perhaps most—who are professionally engaged in water quality protection, any reduction in pollutant loading is welcomed as an absolute good, regardless of whether the receiving water body in question can be objectively described as polluted, or in danger of becoming so. Additional reductions in loadings below the threshold of pollution can always be welcomed as a buffer against potential water quality degradation under exceptional or unforeseeable situations, such as extended low flow conditions in a river, or sudden flashes of nonpoint source loadings.

Economists, by contrast, tend to take a relativist approach, demanding to know what, if any, water quality benefits may reasonably be expected to result from further reductions in pollutant loadings. Lurking behind such questioning is the suspicion that such benefits may be nonexistent or negligible in some circumstances, and the conviction that costs should not be incurred where corresponding benefits at least as great in absolute value cannot be expected with a reasonable degree of certainty. Tradeoffs between gains and losses are the economist's stock-in-trade, and where ideological presumptions appear to foreclose the possibility of trade-offs the economist tends to suspect that zealotry, rather than rational thought, is serving as the basis for decisions, and that society's resources are being wasted as a result.

Public opinion, to the extent that it becomes aroused over specific water quality issues, will tend to side with the fundamentalist-environmentalist position, except where the cost of additional pollution reduction is believed to fall on a community's economy heavily enough to threaten its well-being or survival. Such cases aside, however, the slogan "Polluter Pays" seems more likely to command public sympathy than a declaration to "Let Polluters Trade." Cost-effectiveness is a feeble rallying cry in the public square, easily drowned out by allegations of injustice inflicted by polluters on Earth and its inhabitants. Trading is inevitably associated with commercial interests and the spirit of compromise, whereas the idea of banning—as expressed in the National Pollutant Discharge Elimination System—may call forth heroic images of crusading against Earth's infidels: the unsewered, unrepentant and ecologically unsaved.

If the idea of pollutant trading is suspect in the minds of some, the more specific notion of point-nonpoint source pollutant trading also has its skeptics -- namely, some point sources. Their concern is not simply that pollutant trading is ethically questionable, but that in fairness nonpoint sources should be required to undertake mandatory pollutant loading reductions at their own expense, just as the nation's point sources have. Once a level playing field has been established between point and nonpoint sources in the regulatory sphere, say the skeptics, then let the trading begin. But, they emphatically assert, in the meantime do not ask point sources to underwrite the obligation of nonpoint sources to clean up their act. Point sources are apt to make such objections when discussing point-nonpoint source trading in the abstract.

When it comes to specific government demands to undertake high-cost point source loading reductions, however, point sources thereby affected have demonstrated strong support for the idea of point-nonpoint pollutant trading. Indeed, in North Carolina's Tar-Pamlico Basin project, point source dischargers not only took the initiative in developing a P-NPS trading system, but vigorously defended it against environmentalist critics who feared the state government was letting point sources "off the hook." Thus, whether point sources oppose or welcome P-NPS trading appears to vary according to their circumstances. As long as additional demands for point source load reductions appear as a distant or indefinite prospect, point sources may abjure P-NPS trading while demanding nonpoint source reductions as a substitute for further demands on point sources. But in the course of a NPDES permit review, confronted with immediate demands for costly load reductions, point sources are likely to welcome P-NPS trading if it offers the permittee potential relief from those requirements.

Nonpoint source representatives, for their part, are likely to welcome additional funding that P-NPS trading may make available for nonpoint source load reductions, while opposing efforts to make such reductions mandatory. It can be—and has been—argued that nonpoint source pollutant reduction efforts benefit the public far more than the landowners who undertake them, and so should be underwritten with public subsidies comparable in generosity to the grants which in recent years supported the construction of municipal sewage treatment plants. Furthermore, since the primary nonpoint source, farming, is the economy's most competitive sector, it is usually impossible to pass along added production costs in the form of higher prices. For these and other reasons, it has been very difficult to impose costly changes on farmers.

Strictly from the standpoint of economic efficiency, the above arguments are of little if any relevance. The introduction of a P-NPS trading system will help to allocate loading reduction effort to those dischargers for whom the cost of making reductions is the least, thereby minimizing the social cost of achieving a given pollutant load reduction goal. This result depends only on economically rational behavior on the part of pollutant sources—that is, cost-minimization by high-cost point sources and profit-maximization by lower cost nonpoint sources. Efficiency does not depend on which types of sources are legally required to reduce loadings. If the trading process is initiated by imposing reductions on point sources only, the full extent of potential efficiency gains from P-NPS trading can be achieved. If loading reductions are required of all sources, point and nonpoint, P-NPS trading can be expected to produce no more efficient outcome than in the former instance. However, the distribution of the gains of pollutant trading would be radically altered in favor of point sources. Whether the result of this distributional change is socially beneficial or not is a political— not an economic—judgment.

If P-NPS trading is judged to be economically beneficial, at least potentially, the remaining questions are political, involving fairness and equity. If, further, the primary political questions turn out to be the objections raised by point sources against the lack of symmetrical controls on nonpoint sources, a way around this dilemma might be to deal with efficiency and equity issues separately, on two parallel tracks, as follows:

TRACK ONE: Initiate P-NPS trading in the current regulatory environment, providing it as an option to point sources in the process of NPDES permit renewal where appropriate, i.e., accounting for antibacksliding and nondegradation criteria in state and federal law.

TRACK TWO: At the same time, begin working toward a long-range goal of greater symmetry between point and nonpoint source regulation, defining and aiming for a coordinated point-nonpoint policy that balances fairness and equity with efficiency.

According to the taxonomy introduced earlier, Type I Trading would be launched as soon as possible, as an adjunct to the NPDES permit, on Track One, while at the same time steps would be taken to introduce Type II Trading in the context of a broader basin management policy, on Track Two. Certain prerequisites, common to both types of trading, would need to be taken before either option could become effective. These are listed on pages 83-85.