APPENDIX A

JASON WHITEHEAD M.S. THESIS

ASSESSING THE POTENTIAL FOR WATER QUALITY TRADING IN THE BEAR RIVER WATERSHED

by

Jason R. Whitehead

A thesis submitted in partial fulfillment
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ABSTRACT

Assessing the Potential for Water Quality Trading
In the Bear River Watershed

by

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The purpose of this thesis is to assess the potential for water quality trading in the Bear River Watershed by following the U.S. Environmental Protection Agency's water quality trading guidelines (2004). Chapter I of this thesis introduces general issues pertinent to water quality. The chapter summarizes regulatory approaches taken by the United States to address water quality concerns; specifically the United States Clean Water Act and the total maximum daily load management planning process are discussed. The chapter also describes common water quality concerns in the United States, i.e., nutrient pollution from non-point sources that create the need to examine whether economic incentives, i.e., a water quality trading program, can be used to lower pollutant loadings in water bodies and remain financially feasible. Chapter II discusses the economic theory related to water quality trading and explains the U.S. Environmental Protection Agency's water quality trading guidelines (2004). Chapter III attempts to apply the U.S. Environmental Protection Agency's guidelines (2004) to the Cub River

Watershed. To highlight the feasibility of trading, Chapter IV presents potential trading scenarios. It is concluded in Chapter V that water quality trading for total phosphorus is financially feasible in the Bear River Watershed based on the given assumptions used in the analysis. Chapter V summarizes the results and discusses future research the author considers necessary.

(117 pages)

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Jason R. Whitehead

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CHAPTER I

INTRODUCTION

This thesis provides a preliminary assessment of the potential for trading of total phosphorus loading credits between point sources and non-point sources and among non-point sources themselves. The assessment follows the U.S. Environmental Protection Agency's water quality trading guidelines (2004). The trading focus area includes the main stem of the Bear River from the Oneida Narrows Dam in Idaho downstream to the Cutler Reservoir in Utah, including the Cub River Drainage, as well as the Little Bear River and Spring Creek Drainages as depicted in figure 1.

Within the focus area, water bodies have been designated for agricultural use, recreational contact, and cold-water fish habitat. Many of the water bodies have failed to meet their designated uses under the United States Clean Water Act. Table 1 on page 3 lists the water bodies located within the focus area that have failed to meet their designated uses (303(d) listing), and the associated pollutant/stressor causing the impairment. Total phosphorus is the most common pollutant/stressor for these impaired water bodies.

The remainder of this chapter discusses the regulatory structure governing water quality in the United States, the total maximum daily load management planning process, the phosphorus cycle, and eutrophication.

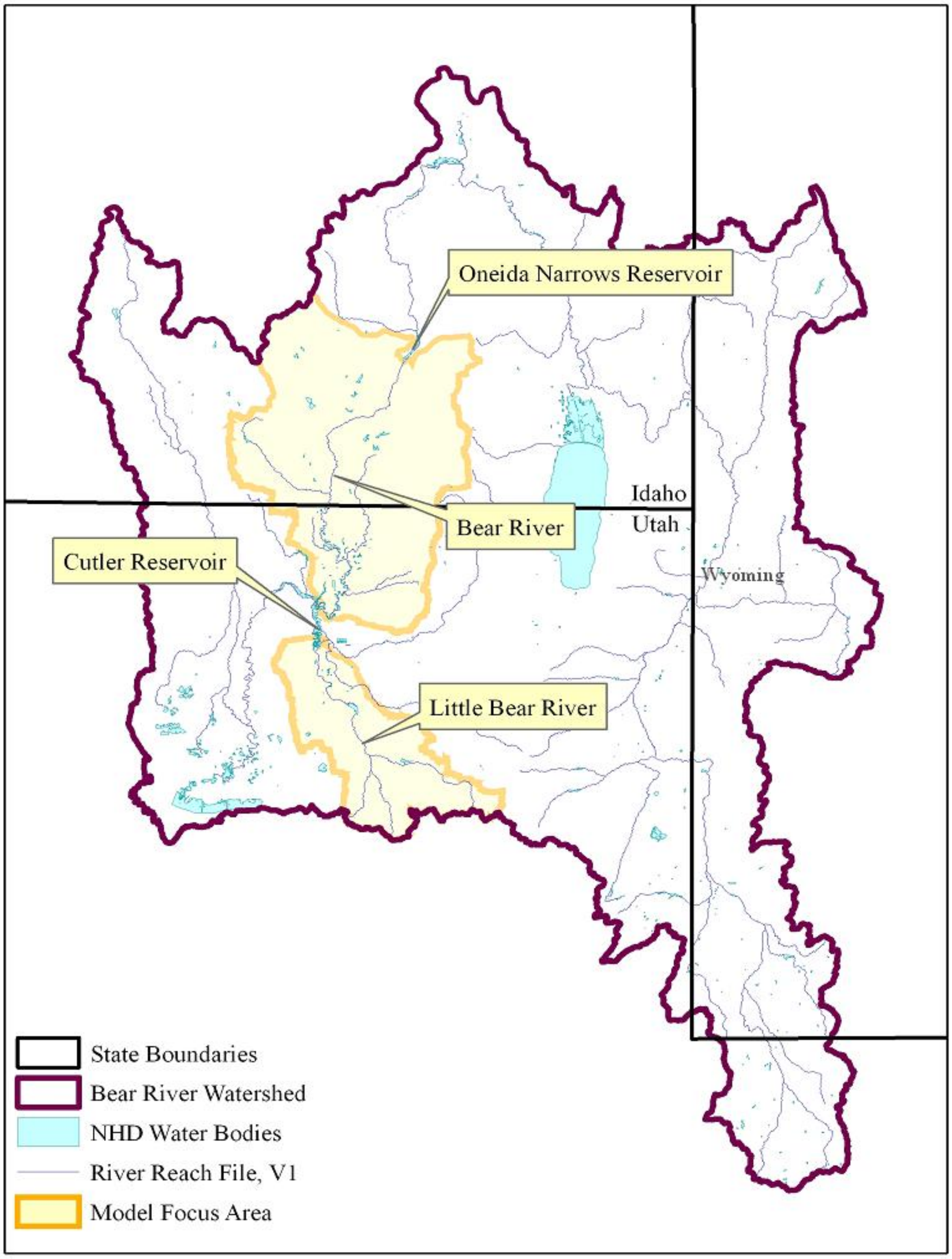

Figure 1. Water quality trading focus area (Horsburgh et al. 2005).

Table 1. Water Bodies Within or Bordering the Focus Area with 303(D) Listings

Water body	Pollutants/Stressors
Weston Creek	Total phosphorus, sediment
Newton Reservoir	Total phosphorus, dissolved oxygen, temperature
Clarkston Creek	Total phosphorus
Cub River	Total phosphorus, sediment
Porcupine Reservoir	Temperature
Hyrum Reservoir	Total phosphorus, dissolved oxygen
Spring Creek	Total phosphorus, dissolved oxygen, ammonia, temperature, coli form
Little Bear River	Total phosphorus

According to Copeland (1999), the Clean Water Act is the primary law governing the pollution of surface waters in the United States. The act's objective is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. To accomplish this objective, the Clean Water Act calls for states to establish water quality standards for their respective waterbodies. Water quality standards define the maximum amount of a pollutant that can enter a waterway without impairing the integrity of the aquatic ecosystem. Water quality standards consist of designated uses for each waterbody, such as agricultural use, cold-water fish habitat, or recreational contact. In addition, water quality standards include the permissible concentration of various pollutants for each water body, and a narrative statement listing factors which protect against degradation. Water bodies failing to meet the quality standards of their designated uses are listed as impaired for the particular pollutant causing the impairment, according to section 303(d) of the Clean Water Act.

Copeland (1999) continues, stating that the Clean Water Act makes use of the U.S. Environmental Protection Agency's technology-based effluent limitations for industrial and municipal dischargers, such as waste water treatment plants. These dischargers, also called point sources, release effluents from identifiable, discrete points, such as pipe outlets. Technology-based effluent limits are explicit numerical restrictions for certain pollutants and are specified for individual point sources through the National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires that point sources obtain permits from the U.S. Environmental Protection Agency or from a qualified state regulatory agency for their effluent discharges. A NPDES permit specifies numerical effluent limits for point sources, applicable control technologies to be used in controlling different pollutants, and deadlines for compliance.

In spite of the Clean Water Act's strict regulatory guidelines for discharges from major point sources since its enactment in 1972, approximately 40% of rivers, 45% of streams, and 50% of lakes assessed in the United States have failed to meet their designated uses as of 2003, including several located in the Bear River Watershed (U.S. Environmental Protection Agency 2003b). How could this be?

The answer is that agricultural non-point sources, such as cropping and feedlot operations, and urban non-point sources, such as storm water runoff from parking lots, have been "loading" through natural runoff and leaching processes. These non-point sources have been loading a growing amount of pollutants since the Clean Water Act's enactment (Freeman 2002). Concomitantly, regulation of non-point sources has been stymied by the very nature of the loadings themselves; they are diffuse, which effectively prevents the ability to monitor and thereby distinguish which loadings belong to which non-point sources within a given watershed. Also, non-point source loadings are often transported through a combination of surface and subsurface flows and consequently may exhibit delays. Unlike point sources, which are regulated through the NPDES permit system, non-point sources are not required to obtain permits, and thus are not liable for their discharges. In the past, non-point sources have been managed using voluntary, incentive based approaches. It should be noted that the Clean Water Act allows for both point and non-point sources to be managed by individual states.

Many incentives for non-point source pollution control come through “cost-share” programs from agencies such as the National Resource Conservation Service (NRCS). The 2002 Farm Bill authorizes the NRCS to provide substantial incentive payments through programs such as the Environmental Quality Incentives Program to agents that voluntarily undertake either “structural” or “cultural” best management practices on eligible land (Utah National Resource Conservation Service 2006). Structural best management practices involve implementing physical structures, such as vegetative buffer zones and graded construction sites. Cultural best management practices are practices used in the production of plants, such as sod-based rotation and conservation tillage.

To resolve non-compliance with section 303(d) of the Clean Water Act, the U.S. Environmental Protection Agency has initiated the Total Maximum Daily Load (TMDL) management planning process. U.S. Environmental Protection Agency (1999) states that TMDL management plans are written with the intent of ensuring that waterbodies meet their designated uses. TMDL management plans accommodate reasonably foreseeable increases in pollutant loads due to economic growth. They account for point source loads individually and non-point source loads indirectly in the aggregate. In a TMDL management plan, current pollutant loadings are quantified, with the goal of establishing links between sources, pollutants, and associated impacts on water quality. A TMDL management plan identifies an allowable pollutant load, which is the amount of a pollutant that may be contributed to a water body and still allow that water body to attain and maintain its designated uses. An allowable pollutant load is equivalent to the sum of “waste load allocations” for point sources, “load allocations” for non-point sources, a margin of safety sufficient to account for uncertainty and lack of knowledge, and allowances for future growth. A TMDL may be expressed as an allowable pollutant load for an entire watershed, for different reaches within a watershed, or for a receiving waterbody, such as a reservoir (Ecosystems Research Institute 1995).

Environmental Literacy Council (2005) implies that phosphorus is required by plants and animals in order to sustain life. The phosphorus cycle begins when weathering rocks introduce phosphorus into soils. Rain, overland runoff, and groundwater fluxes transport the phosphorus via drainage networks to receiving streams. Once the phosphorus reaches a water body, it is taken up by macrophytes and micro-organisms. After phosphorus has been incorporated into plant tissue it moves through the food web primarily as organic phosphorus. Organic phosphorus may subsequently be broken down to phosphate in urine or other waste and reabsorbed by plants or algae to start another nutrient cycle. Total phosphorus is the total concentration of phosphorus found in water.

Minerals containing phosphorus are naturally in short supply. Therefore, phosphorus is often the limiting nutrient to plant growth (Goldman and Horne 1983). To compensate for the limited natural supply of phosphorus, farmers apply fertilizers containing phosphates to their cropland, either in synthetic form or as manure. Carpenter et al. (1998) estimates that six million metric tons of phosphorus fertilizer was applied to croplands in the United States between 1950 and 1995. Satiation typically occurs before the crops use all the available phosphorus. Carpenter et al. (1998) estimate that between 1950 and 1995, 250 million metric tons of phosphorus was removed from croplands nationwide in the form of produce, leaving 350 million metric tons remaining in the soil, potentially available for transport to the nation's waterbodies. Phosphorus is highly reactive and binds well to soil. However, Carpenter et al. (1998) estimates that 3% to 20% of the available phosphorus on croplands is estimated to be exported to surface waters through erosion and leaching.

Livestock farming also contributes to phosphorus loadings in waterways. Animal feeding operations raise animals in confined spaces to intensively produce animal products. An animal feeding operation is defined by the Utah AFO/CAFO Committee (2001) as a facility where:

> animals have been, are or will be stabled or confined and fed or maintained for a total 45 days or more in any twelve-month period and crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

The costs of properly disposing of manure created by these operations can be high and, until recently, regulation of manure effluent has been lax, resulting in untreated effluent draining into waterways. To combat this problem, animal feeding operations meeting certain criteria are defined as "confined" animal feeding operations.[1] Confined animal

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[1] Confined animal feeding operations are defined by the Utah AFO/CAFO Committee (2001) as:

feeding operations are considered point sources as defined by the Clean Water Act and thus are regulated using NPDES permits (Utah AFO/CAFO Committee 2001).

Sedimentation, mainly from farming activities, has been described as the greatest pollutant in the United States (Haslam 1990). The problem has been aggravated by the clearing of forest and brush from the banks of millions of miles of stream channels. In addition to facilitating increased sedimentation, forest and brush clearing allows more sunlight to penetrate into streams, raising water temperatures and increasing algal growth (Hynes 1967).

Waste water treatment plants are another significant source of phosphorus. Detergents containing phosphates are a significant source of phosphorus in residential sewage. Industrial companies, such as food-processing firms, require extensive washing procedures and are also likely to release effluents having high phosphorus concentrations into waterways. Other industrial sources export phosphorus for other reasons, i.e., rendering plants, fertilizer plants, etc.

Excess phosphorus concentration in a water body can lead to eutrophication, a process whereby water bodies receive excess nutrients that stimulate excessive plant growth (U.S. Geological Survey 2005). Eutrophication is the most common surface water impairment in the United States and accounts for about half of the impaired lake area and 60% of impaired river reaches in the United States (Carpenter et al. 1998). Artificial or cultural eutrophication occurs when a water body experiences an increase in

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animal feeding operations where more than 1,000 animal units are confined at the facility, or more than 300 animal units are confined at the facility and either one of the following conditions are met: pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar man-made device; or pollutants are discharged directly into waters of the United States which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with animals confined in the operation.

nutrients, such as phosphorus, due to human activities or natural nutrient sources such as leaf fall or decomposition of a dead animal near a waterway (Mason 2002; Haslam 1990). Ultimately, eutrophication affects aquatic ecosystems, resulting in the loss of sensitive species and an increase in the abundance of tolerant species, effectively altering the aquatic ecosystem. Eutrophication also results in increased aquatic plant biomass leading to increases in turbidity and degradation of water quality. Excess microscopic algae or blooms can then cause fish kills, foul odors, and poor water taste. Blooms of cyanobacteria (blue-green algae) can also be toxic. As cyanobacteria die, compounds toxic to the nervous system and liver are released, causing a potential threat to livestock and humans (Carpenter et al. 1998). In addition, bacterial decomposition of plant matter consumes dissolved oxygen, lowering the dissolved oxygen levels below the critical threshold for other species.

Water quality problems such as eutrophication have been identified throughout the Bear River Watershed since, at least, the early 1970s. As a result, the Idaho, Wyoming, and Utah Departments of Environment Quality and the U.S. Environmental Protection Agency have acknowledged the need for cost-effective water quality solutions. One possible solution is a water quality trading program. Water quality trading is a market-based approach, which theoretically can be used to meet TMDL standards in a least-cost manner, however, whether water quality trading is a lower cost approach when compared to other methods is an empirical question, not a forgone fact. Trading is feasible when different sources of a pollutant in a watershed face differing control costs. Sources facing relatively high control costs have an incentive to purchase environmentally equivalent pollutant reductions from other sources facing relatively low control costs. This assumes that high control-cost sources are high value producers because low value producers with high control costs may not be able to purchase discharge quotas.

Chapter II discusses water quality trading methodology, the basic theory behind water quality trading, and the U.S. Environmental Protection Agency’s water quality trading guidelines (2004). In Chapter III, the water quality trading guidelines are applied to the Cub River Sub-Watershed, which is located in the Bear River Watershed. Chapter IV presents empirical results showing the potential for point source to non-point source and non-point source to non-point source trading. Chapter V includes a summary and discussion of the inherent limitations of water quality trading and suggests directions for future research.

CHAPTER II

METHODOLOGY

Markandya et al. (2002) state that a negative externality arises when the actions of an agent negatively affect the welfare of others and the agent responsible does not take account of the effect that it has on the others. A common negative externality is pollution. For example, suppose upstream farmers apply fertilizer to their crops and in the process inadvertently load phosphorus into a nearby river. The river flows into a reservoir resulting in excess plant and algae growth in the reservoir. The reservoir is mainly used to supply water to a nearby city and citizens begin notice the taste and smell of their tap water has recently degraded.   The inadvertently loaded phosphorus has diminished the welfare of society. However, the farmers do not take account of their effect on society because the river and the reservoir are public goods by nature. In other words it is impossible to exclude anybodies use of the river (non-excludable) and one persons use of the river does not diminish others ability to use the river (non-rival).

Historically, pollution externalities have been dealt with using various methods, among which are command and control policies and economic incentives. Command and control policies involve the government imposing emissions standards upon firms and/or forcing them to use certain abatement technologies, commonly referred to as “mandated abatement technologies” (Markandya et al. 2002). The major advantage of command and control policies is that they are flexible for regulating complex environmental processes. Thus, the outcome of these policies is more assured and the monitoring of compliance is simplified (Kolstad 2000). The major disadvantages of command and control regulatory systems are that they have high information costs and the polluter has the incentive to distort the information provided to the regulator. Also, it is nearly impossible for command and control regulation to ensure that the marginal costs of pollution control are equalized among the different polluters. In other words, it is almost impossible to ensure that the equi-marginal principle holds (Kolstad 2000). In addition, in command and control policies, the polluter pays only for the pollution abatement and not for the residual damage from the pollution that is still emitted even after controls are in place (Kolstad 2000).

There are various kinds of economic incentives that have been used in the past to deal with pollution externalities. One type of economic incentive is a Pigouvian tax. A Pigouvian tax or fee is a charge per unit of pollution set equal to the marginal damage of pollution, theoretically resulting in the efficient level of pollution generation. This effectively informs the polluter as to the full social costs of its operation and fairly compensates the victims (Kolstad 2000; Markandya et al. 2002). However, problems arise with taxes and fees when markets are not competitive. When a firm has monopoly power, a Pigouvian fee can actually make matters worse resulting in a sub-optimal outcome (Kolstad 2000).

Another type of economic incentive is marketable emissions permits. Marketable permits involve the creation of a market in which firms can buy and sell the right to emit certain quantities of pollution. The responsible authority sets the environmental standard and identifies the total pollution emissions compatible with the achievement of this standard (Markandya et al. 2002). Permits that allow firms, in aggregate, to emit this level of pollution are then distributed, either by means of an auction, or by grandfathering. Grandfathering refers to a permit allocation that is in proportion to the firms' emissions at an agreed prior date (Markandya et al. 2002). Permit trading induces firms to place a value on their permits causing them to see polluting as an expense activity (Kolstad 2000).

Kolstad (2002) discusses the advantages and disadvantages of economic incentives. One advantage of economic incentives when compared to command and control policies is that informational requirements are significantly less. Economic incentives also provide the polluter with the motivation to be innovative in seeking less expensive ways of controlling pollution. Also, economic incentives result in the equi-marginal principle being held under most circumstances. A disadvantage of economic incentives is in forging a set of incentives that can accommodate the complexities of environmental transformation without being excessively complex and impractical. Another disadvantage is that if there is a great deal of uncertainty associated with the environmental problem being controlled, it may be necessary to adjust the level of the incentive over time, as information becomes available. This may be difficult in practice. Finally, another disadvantage with economic incentives is that many incentives involve massive wealth transfers from firms to the government.

As mentioned in Chapter I, water quality trading is a mechanism that can induce economic agents to voluntarily minimize the alternative cost of abatement. The argument in favor of water quality trading as a least-cost mechanism is depicted in figure 2. The figure shows the marginal abatement costs for two sources (1 and 2). The vertical axis is a dollar measure of abatement cost and the horizontal axis measures the level of

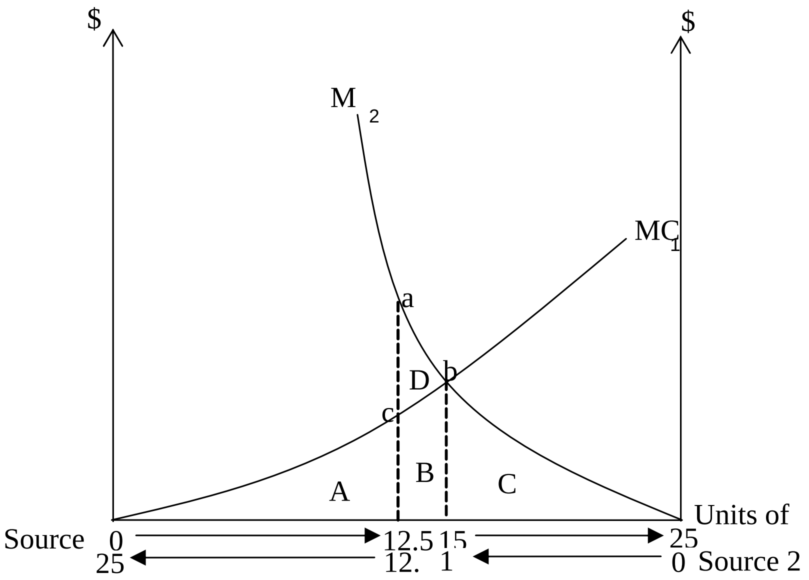

Figure 2. Two-source example of water quality trading.

abatement. The level of abatement increases from 0 to 25 units going left to right for Source 1 and right to left for Source 2. In this example, a total of 25 units of abatement across both sources are required by the regulatory authority, and any point on the horizontal axis represents an allocation between Source 1 and 2 that sums to 25 units of abatement. As depicted in the figure, Source 2 faces relatively higher abatement costs than Source 1 per unit reduction due to its steeper marginal cost curve. Source 2 has incentive to purchase abatement units from Source 1 whenever a quota established by the regulatory authority allocates anything greater than 10 units of abatement to Source 2 and 15 units to Source 1.

To see why a trade between Sources 1 and 2 will be mutually beneficial, assume the regulatory agency determines that the two sources must clean up 12.5 units each, i.e., each source's initial allocation, or quota, is 12.5 units. At this allocation, total variable cost of control for Source 1 equals area A, while for Source 2 it equals area B + C + D. Therefore, the total variable cost across both sources equals A + B + C + D.

An incentive to trade exists for the two sources at this allocation because the marginal cost for Source 2 (point ‘a’) is substantially higher than for Source 1 (point ‘c’). Source 2 could therefore lower its control costs by paying Source 1 something less than ‘a’ but greater than ‘c’ to incrementally increase its abatement to more than 12.5 units so that Source 2 can incrementally reduce its abatement to less than 12.5 units. In other words, point ‘a’ represents Source 2’s maximum willingness to pay for the first unit of reduction obtained from Source 1, and point ‘c’ represents Source 1’s minimum willingness to accept payment from Source 2 for that unit of reduction.

Continuing in this manner, until all gains from trade are exhausted, the least-cost solution is obtained where the marginal abatement costs for each source are equal. In figure 2, this occurs at point ‘b’, where Source 1 cleans up 15 units and Source 2, ten units, leading to (minimized) total control costs of area A + B + C. In other words, unrestricted pollution trading naturally leads to the least-cost allocation of abatement across the two sources.

With this basic theory in mind, the U.S. Environmental Protection Agency has recently published guidelines for implementing water quality trading at the watershed level (U.S. Environmental Protection Agency 2004). According to U.S. Environmental Protection Agency (2004), the following four actions are necessary to determine whether water quality trading is a viable option for meeting a watershed’s total maximum daily load. First, a determination needs to be made of pollutants that are suitable for trading. Second, the financial attractiveness of trading within the watershed needs to be assessed.

That is, it must be determined whether abatement cost differences, such as those depicted in figure 2, are widespread enough across both non-point sources and point sources to induce trading. Third, an evaluation of the market infrastructure is necessary; a market having rules, procedures, and norms is more likely to succeed. Fourth is a determination of stakeholder readiness. Water quality trading requires the combined effort of all watershed stakeholders, including effluent dischargers, local businesses, and any special interest groups with particular interests in the watershed.

The main objective of this research project is to determine whether the second condition is met for total phosphorus in the Bear River Watershed; in particular whether trading is financially feasible in the Cub River Sub-Watershed. In other words, the main objective is to determine whether abatement cost differences primarily between point sources and non-point sources are substantial enough to overcome the transaction costs incurred through trading in the sub-watershed. The remainder of this report is confined to the first two conditions of the U.S. Environmental Protection Agency's water quality trading guidelines (2004).[2]

As mentioned above, the first step in assessing the potential for water quality trading is to review the watershed's pollutant characteristics to determine if the pollutants are suitable for a water quality trading system. For trading to occur, it is necessary for dischargers to develop a common understanding of the pollutant commodity to be traded. This requires the pollutant commodity to be both measurable and controllable. Along

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[2] We focus on the Cub River sub-watershed for two reasons. First, two TMDL management plans have been completed for this area (an updated TMDL management plan for the Utah portion of the watershed has yet to be completed). Second, this sub-watershed, which contains both point sources and non-point sources, provides ample opportunity for us to demonstrate how U.S. Environmental Protection Agency (2004) might be applied throughout the entire watershed.

these lines, U.S. Environmental Protection Agency (2004) identifies four "suitability factors" that need to be assessed: type/form, impact, timing, and quantity.

The first suitability factor, type/form, requires the identification of a single pollutant with a common type or form. For example, phosphorus can be present in soluble or non-soluble forms. To simplify trading in the Bear River Watershed, total phosphorus has been chosen as the common pollutant.

The second suitability factor, impact, requires that any trade between up and downstream sources must result in equivalent or better water quality at a given receptor point than would have occurred without the trade. Therefore, the "environmental equivalence" between the locations where the reduction is made and where it is purchased needs to be predictable and pre-determined. This issue will be discussed at length below.[3]

The third suitability factor, timing, requires that the purchase of excess reductions (or credits) by one source from another needs to be made during the current permit compliance reporting period. In turn, this implies that the schedule for achieving pollutant reduction targets must align among trading partners.[4]

Quantity is the fourth and final suitability factor. This factor simply requires that, in equilibrium, the quantity of excess pollutant reductions available should align with the

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[3] Until the fate and transport of total phosphorus in the Bear River Watershed has been modeled, we are constrained to assume an environmental equivalence ratio of one-to-one between any two up and downstream sources in our empirical analysis in Chapter III and IV. Part of the Bear River Water Initiative grant is to develop a full-scale dynamic water quality model that will calculate environmental equivalence of pollutants in the Bear River Watershed. For more information on this component of the project, see Horsburgh, et al. (2005).

[4] We assume in our empirical analyses in Chapter III and IV that the permit compliance reporting period is the same for sources located in the sub-watershed.

needs of the purchasers of those credits. In other words, there must be enough supply and demand to result in a point such as ‘b’ in figure 2.

From here, U.S. Environmental Protection Agency (2004) proposes a six-step pollutant suitability analysis to further analyze the pollutant’s trading suitability. The first step is to create a watershed loading profile, as depicted in table 2. Current load is the quantity of total phosphorus discharged by the source at the present time and is specified in the TMDL management plan. Target load is also specified in a TMDL management plan. This is the pre-trade allocation (or quota) specified by the regulatory authority (such as 12.5 units for Source 1 and 12.5 units for Source 2). The total reduction needed is the difference between the current and target loads.

The second step is to identify the type/form of the pollutant discharged by sources. Normally, the type/form of pollutant discharge per source is also included in the watershed loading profile (table 2) to determine whether sources are discharging equivalent forms of the pollutant.

The third step is to assess water quality equivalence of pollutant reductions at different discharge points. For trading to be viable, the establishment of a common

Table 2. Example Watershed Loading Profile

Name of Discharge Source	Discharge Location (River Mile)	Form of Pollutant	Discharge (seasonal, cyclical, etc.)	Control Obligation (regulatory)	Current Load	Target Load	Total Reduction Needed
Source 1							
Source 2							
Source 3							
Source 4							
Source 5							

currency is needed so that market participants can evaluate potential trades, and regulators can evaluate relative water quality impacts of trades at pre-determined receptor points. Ratios that account for differences in type or form must therefore be estimated in order to ensure equivalent trades. Figure 3 provides a simple example of this concept.

In figure 3, the river is flowing from the down from the top of the figure. The main receptor point used for determining environmental equivalence between sources is at the point where the river converges with Leaky Reservoir. Point sources include WWTP #1, Stinky's Cheese Factory, WWTP #2, and Smelly's Cheese Factory. Bob's Farm is the only non-point source. The U.S. Environmental Protection Agency's water quality trading guidelines (2004) presume that non-point source loadings can be estimated and monitored similarly to point source loadings. As mentioned in Chapter I, non-point load estimation and monitoring is generally considered to be more complex than this.

In figure 3, we assume that phosphorus discharges from Bob's Farm are 70% soluble and that discharges from WWTP #2 are 90% soluble. Therefore, for WWTP #2 to purchase phosphorus credits from Bob's Farm, the solubility ratio is 9/7 to reflect the fact that WWTP #2's total phosphorus loadings are more "potent" at the main receptor point than are loadings from Bob's Farm. In other words, WWTP #2 must purchase 1.29 reduction credits from Bob's Farm for each additional unit of total phosphorus above its target load that it does not abate in order for the trade between the two sources to equilibrate at the main receptor point in terms of equivalent solubility and therefore not

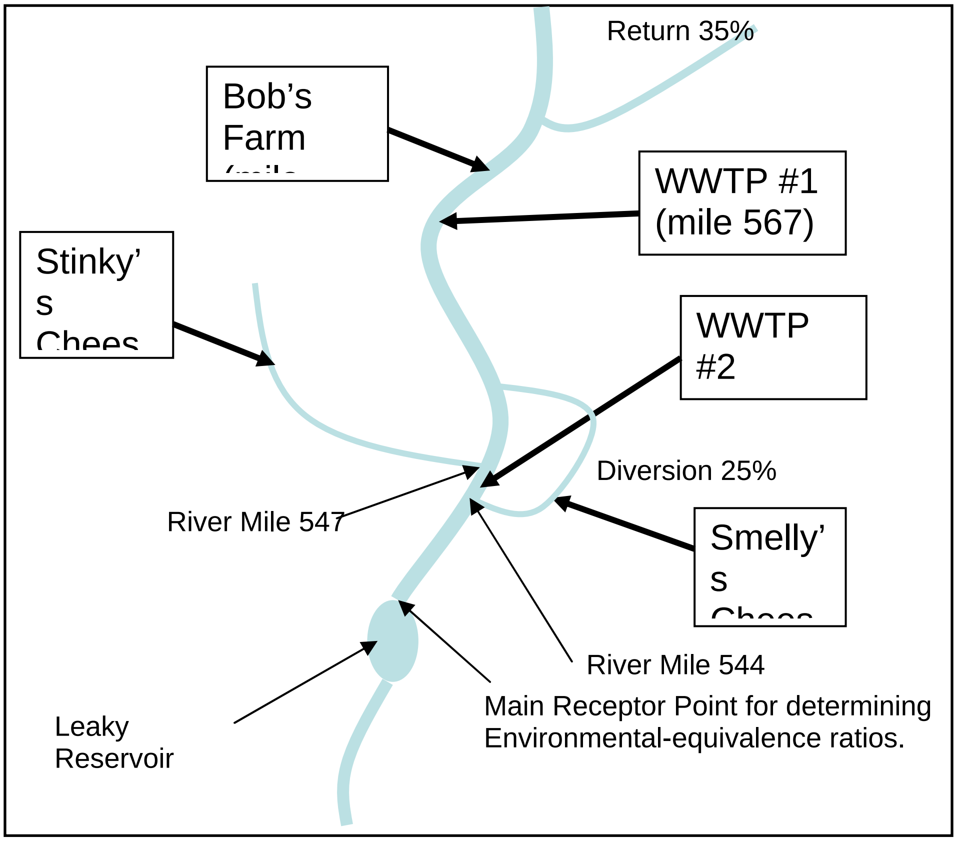

Figure 3. The role of environmental equivalence in the watershed loading profile.

violate the total maximum daily load, ceteris paribus.[5]

The solubility ratio of 1.29 is then adjusted in order to account for spatial differences between the two sources. This is necessary because as phosphorus moves down a river, soluble phosphorus is taken up by plants, non-soluble phosphorus settles to the river floor, and both types of phosphorus are diverted when water is used for

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[5] It is interesting to note that the many TMDL management plans provides total phosphorus allocations but do not account for differences in the form of phosphorus, based on the assumption that over the mid-to-long term both forms of phosphorus play an equivalent role in nuisance algal growth. This simplifies the identification of potential phosphorus trades in the Bear River Watershed by effectively pre-determining a one-to-one solubility ratio throughout the Bear River Watershed.

irrigation purposes. Fortunately, the fate and transport of phosphorus is well understood, and a dynamic flow model is being created to determine spatial equivalence ratios for the Bear River Watershed. As previously noted this dynamic model is a work in process and is unavailable for use at this time.

To clarify the concept of spatial equivalence, refer again to figure 3. Since WWTP #2 is located downstream from Bob's Farm, and thus closer to the receptor point, its loadings are again more potent at the reservoir than Bob's loadings are. Suppose that WWTP #2's spatial equivalence ratio (or transfer coefficient) is 0.9 and Bob's Farm's is 0.3. In the spatial dimension, WWTP #2's discharge is therefore three times as potent as Bob's Farm's.

Accounting for both solubility and spatial equivalence, if WWTP #2 purchases credits from Bob's Farm it will have to purchase 3.87 credits for each unit of discharge above its target load that it does not control as shown in equation 1:

$$\text{Solubility Ratio} \times \text{Spatial Ratio} = 1.29 \times 3 = 3.87 \tag{1}$$

Aligning the timing of point source waste load allocations and non-point source load allocations is the fourth step in the six-step pollutant suitability analysis. Over time, a discharger's load may vary. Large variations in the timing of loadings may be problematic. Seasonality of discharges, TMDL management plans, and compliance deadlines must be accounted for. Trades must be consistent with the time periods used to determine permit compliance limitations in order to be viable. For example, a permit requiring quarterly compliance limitations can only trade with a discharger that can demonstrate quarterly reductions. Compliance deadlines similarly need to be aligned.

The fifth step is to align the demand and supply of total phosphorus credits. It is necessary for the supply of credits due to over-control relative to target loads (e.g., from Bob's Farm in the example above) to meet or exceed the demand for credits due to a given source's under-control relative to its target loads (e.g., from WWTP #2 in the example above).[6]

The sixth and final step is to compile the data, as hypothetically demonstrated in table 3. As mentioned previously, all four of the pollutant suitability factors–form, impact, timing, and quantity–must align for trading to be viable. Sources that are geographically close but differ widely with respect to control costs (as depicted in figure 3) are the most likely candidates for trading.

Notice that table 3 does not include any cost information. However, based solely on the four suitability factors discussed above, there appears to be scope for possible trading. This is primarily because the solubility, timing, and spatiality of total

Table 3. Hypothetically Completed Watershed Loading Profile

Name of Discharge Source	River Mile	Form of Pollutant	Discharge (e.g. seasonal, cyclical, etc.)	Control Obligation (regulatory)	Current Load	Target Load	Total Red. Needed
Bob's Farm	570	TP 70/30	Seasonal	June-Sept.	873	527	346
WWTP #1	567	TP 90/10	Yearly	June-Sept.	917	633	284
Stinky's	547	TP 100/0	Yearly	June-Sept.	689	410	288
WWTP #2	546	TP 90/10	Yearly	June-Sept.	72	50	22
Smelly's	541	TP 100/0	Yearly	June-Sept.	195	274	108

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[6] Note that with only point sources being regulated (due to, say, political expediency), the maximum amount of credits demanded will simply equal the point source's total reductions needed. If non-point sources are also regulated (in order to reach full compliance with the TMDL management plan), the quantity of credits will need to be estimated by combining aggregate non-point source discharge data from the TMDL management plan with arbitrarily determined non-point source-specific load allocations. This scenario is explored at length in Chapter III.

phosphorus discharges across the sources align relatively closely, and the relatively low reductions needed (relative to current loads) indicate the possible supply of credits.

Given the hypothetical form-of-pollutant information listed in table 3 (i.e., the soluble/insoluble percentages), a solubility ratio matrix that lists the ratio for each possible trade in the watershed is derived in table 4. Purchasers are represented by the columns and sellers by rows. For example, if WWTP #2 purchases credits from Bob's Farm, then the trade's solubility ratio is 1.29. Similarly, if Stinky's Cheese purchases credits from WWTP #1, then that trade's solubility ratio is 1.11, etc.

Given the hypothetical transfer coefficients listed in table 5, a transfer-coefficient matrix that lists the ratio for each possible trade in the watershed is derived in table 6. For example, if WWTP #2 purchases credits from Bob's Farm, then the trade's transfer coefficient is 3. Similarly, if Stinky's Cheese purchases credits from WWTP #1, then that trade's transfer coefficient is 1, etc.

Table 4. Hypothetical Solubility Ratio Matrix

		Purchaser				
		Bob's	WWTP #1	Stinky's	WWTP #2	Smelly's
Seller	Bob's	---	1.29	1.43	1.29	1.43
	WWTP #1	0.78	---	1.11	1.00	1.11
	Stinky's	0.70	0.90	---	0.90	1.00
	WWTP #2	0.78	1.00	1.11	---	1.11
	Smelly's	0.70	0.90	1.00	0.90	---

Table 5. Hypothetical Transfer Coefficients

Name of Discharge Source	Transfer Coefficient
Bob’s Farm	0.3
WWTP #1	0.6
Stinky’s Cheese	0.6
WWTP #2	0.9
Smelly’s Cheese	0.8

Table 6. Hypothetical Transfer Coefficient Matrix

		Purchaser				
		Bob’s	WWTP #1	Stinky’s	WWTP #2	Smelly’s
Seller	Bob’s	---	2.00	2.00	3.00	2.67
	WWTP #1	0.50	---	1.00	1.50	1.33
	Stinky’s	0.50	1.00	---	1.50	1.33
	WWTP #2	0.30	0.67	0.67	---	0.89
	Smelly’s	0.38	0.75	0.75	1.13	---

To determine a matrix of final trading ratios, we multiply the solubility ratios and corresponding transfer coefficients, as was previously done for WWTP #2’s purchase of credits from Bob’s Farm in which the final trading ratio is 3.87. Final trading ratios for each possible trade are presented in table 7.

Of course, to ultimately determine the financial feasibility of trading, cost data, along with estimates of the effectiveness of control technologies, must be included in the

Table 7. Hypothetical Final Trading Ratio Matrix

		Purchaser				
		Bob’s	WWTP #1	Stinky’s	WWTP #2	Smelly’s
Seller	Bob’s	---	2.58	2.86	3.87	3.82
	WWTP #1	0.39	---	1.11	1.50	1.48
	Stinky’s	0.35	0.90	---	1.35	1.33
	WWTP #2	0.23	0.67	0.74	---	0.99
	Smelly’s	0.26	0.68	0.75	1.01	---

analysis. According to U.S. Environmental Protection Agency (2004) incremental cost of control should be estimated in order to determine financial attractiveness. Incremental cost of control is defined as the average cost of control of the incremental reduction required for an individual source to achieve its target load. According to the U.S. Environmental Protection Agency, incremental cost of control is an approximation of a potential buyer's willingness to pay for credits. To see how incremental cost of control is calculated, we present the hypothetical cost of control and control effectiveness data in table 8.

To begin, note that the current loads, target loads, and total reductions needed for each source align with those presented in table 3. Next, note that consecutive technology

Table 8. Hypothetical Control Effectiveness and Cost of Control Data

Source	Current Load	Target Load	Reduction Needed	Reduction Achieved	Cumulative Reduction Achieved	Incremental Reduction for Compliance	Incremental Annual Control Cost	Incremental Control Cost	Average Control Cost	Potential Surplus Reduction	Weighted Average Control Cost
Bob's	873	527	346								
Step 1				91	91	255	$49,823	N/A	$1.50	0	N/A
Step 2				623	714	N/A	$464,444	$4.99	$2.04	368	$1.97
WWTP1	917	633	284								
Step 1				662	662	N/A	$2,074,237	$20.01	$8.58	378	N/A
Step 2				107	769	N/A	$5,222,364	N/A	$133.72	485	$26.00
Stinky's	698	410	288	506	506	N/A	$6,308,251	$60.01	$34.16	218	$34.16
WWTP2	72	50	22								
Step 1				16	16	6	$56,032	N/A	$9.59	0	N/A
Step 2				24	40	N/A	$219,022	$100.01	$25.00	18	N/A
Step 3				55	95	N/A	$339,450	N/A	$16.91	73	$17.72
Smelly's	274	166	108	163	163	N/A	$590,906	$14.99	$9.93	55	$9.93

"steps" are assumed to exist for each source (Stinky's and Smelly's Cheese each have a single technology step). For point sources such as WWTP #1 and WWTP #2 and the two cheese factories, these steps are typically referred to as "tiers" (U.S. Environmental Protection Agency 2003a). For non-point sources, such as Bob's Farm, these steps represent various best management practices, e.g., conservation tillage, grass buffer strips, etc. Each step is associated with an "incremental reduction achieved" and an "incremental annualized control cost," (henceforth denoted as TC_j, j = 1… *m* different possible technology steps). For example, technology step 1 for Bob's Farm results in a reduction of 91 kilograms of total phosphorus per day at a TC_1 of $49,823, leaving 255 kilograms still needing to be reduced.[7] Adding Step 2 technology at a TC_2 of $464,444 results in an additional reduction of 623 kilograms. This results in a potential surplus reduction (i.e., credits) of 368 kilograms.

With respect to point sources, NPDES permits usually provide a 3-to-5-year window within which to come into compliance with new permit requirements, giving point sources some time to weigh the options of abating themselves or purchasing credits from other sources. Point sources should therefore be concerned with the implications of their own abatement options over a long horizon to ensure that a control technology can maintain compliance during its useful life. As depicted in table 8, more control generally means an increase in TC_j.

As suggested earlier, to calculate the incremental cost of control the incremental reductions needed for compliance must first be determined. Incremental cost of control is

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[7] TC_j equals the sum of (1) fixed cost of installing technology step j/useful life of technology step j, (2) annual operating and maintenance costs of technology step j, and (3) opportunity cost (which equals the sum of (1) and (2) times the market interest rate).

then TC_{j*} (where j* represents the technology step at which the source comes into compliance with its TMDL allocation) divided by the incremental reductions needed for compliance, divided again by 365 (to normalize to a daily basis). For example, Bob's Farm's incremental cost of control in table 5 is:

$$(\$464{,}444 \div 255) \div 365 = \$4.99 \tag{2}$$

The cost, therefore, represents the cost per unit reduction that Bob's Farm must incur to ultimately (or incrementally) bring itself into compliance (without the counterfactual possibility of participating in a water quality trading market, perhaps even as a seller of credits).

As shown in Caplan (2006), incremental cost of control is unlikely to be a good estimate of a potential purchasing source's willingness to pay. This is because a forward-looking source will always base its willingness to pay on marginal control costs, as depicted in figure 2.[8] As Caplan (2006) shows, given the discrete, lump-sum nature of abatement, marginal control costs are themselves discretely constant (i.e., step-like) over successive technology steps (e.g., think of there being successive levels of marginal control costs (MC_j) defined over corresponding ranges of abatement). Further, each MC_j effectively coincides with its corresponding average control cost (AC_j). Finally, Caplan (2006) shows that incremental cost of control generally exceeds AC_j, thus it exceeds the purchasing source's willingness to pay.

AC_j equals TC_j divided by technology step *j*'s corresponding reduction achieved (normalized by 365 days per year). For example, the AC_1 per unit reduced associated with Bob's Farm's Step 1 technology equals:

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[8] By forward-looking we mean that the potential purchasing source understands that if it instead chooses to abate more than its TMDL abatement allocation it will have credits to sell.

(3) $$(\$49{,}823 \div 91) \div 365 = \$1.50$$

Similarly, the AC_2 associated with Bob's Step 2 technology is equal to:

(4) $$(\$464{,}444 \div 623) \div 365 = \$2.04$$

Weighted average control cost is a single measure of average control costs, measured simply as the sum of the AC_js (i.e., $\Sigma_j AC_j$) divided by the total amount of reductions achieved. Continuing with Bob's Farm, its weighted average cost of control equals:

(5) $$[(91 \div (91 + 623)) \times \$1.50 + (623 \div (91 + 623)) \times \$2.04] = \$1.97$$

The final stage in assessing the financial attractiveness of a trade is to analyze the results. Theoretically, sources with higher control costs will be willing to trade with sources having lower control costs. As complicating factors, such as transaction costs, uncertainty of environmental equivalence, etc., are included in the analysis, the financial attractiveness of a trade may decline.

Referring to table 8 above, weighted average control costs are \$1.97 for Bob's Farm, \$26.00 for WWTP #1, \$34.16 for Stinky's Cheese, \$17.72 for WWTP #2, and \$9.93 for Smelly's Cheese. Sources facing a higher average control cost have an incentive to consider buying credits from sources facing lower average control costs. Assuming one-to-one final trading ratios, Bob's Farm and Smelly's Cheese are likely sellers, while Stinky's Cheese, WWTP #1, and WWTP #2 are likely buyers.

It should not be forgotten that additional complicating factors need to be assessed. Average control costs will likely need to be discounted for uncertainty and overall environmental equivalence. According to Jarvie and Solomon (1998) some control technologies result in water quality improvements that are measurable, while other control technologies require excessive time or costs to measure improvement. For instance, when a point source applies a new control technology, the results can be seen quickly. However, results from a non-point source that is applying a best management practice may be less certain because of the amount of time it takes for runoff to occur and the fact that runoff itself is highly variable.

Large watersheds are more likely to require the establishment of overall environmental equivalence, which will require that average control costs be adjusted. Overall environmental equivalence is necessary to ensure that trades result in equivalent or better water quality conditions. It could be that the environmental equivalence may erase cost advantages of trading (Jarvie and Solomon 1998). For example, if a downstream source considers purchasing credits from an upstream source and its final trading ratio is large due to its proximity to the receptor point, the trade is less likely to occur, all else equal.

Significantly large transaction costs can also occur while negotiating a trade. Transaction costs include the cost of bargaining and initiating a trade, the cost of collecting data to accurately predict trading results, the cost of monitoring to ensure trade conditions are met, and the cost of implementing best management practices to reduce non-point source pollution. Successful trades will occur if the total costs of all activities surrounding the trade are less than the difference between what a credit-purchasing source would incur by purchasing its own control technology and purchasing credits from another source (Jarvie and Solomon 1998).

A local permitting agency must approve trades between point sources and non-point sources because the non-point sources are essentially unregulated. Potential traders must be able to prove that the new control technologies (i.e., best management practices for non-point sources) will indeed work. Point sources must meet their NPDES permit requirements and will be accountable if their non-point source trading partner fails to produce the required credits. TMDL management plans must be obeyed and even if a non-point source is implementing its best management practice properly, a dry or wet season may affect local conditions enough that the TMDL is not met. A margin of safety is therefore typically incorporated into non-point source and point source trades because of the variability of non-point source effluent (Jarvie and Solomon 1998).

CHAPTER III

APPLICATION

The Cub River Sub-Watershed, henceforth the Watershed, is located in southeastern Idaho and northeastern Utah. The headwaters of its main river, the Cub River, are located in the mountains of Idaho and eventually converge with the Bear River in Utah. As the Cub River moves toward the Bear River it flows in close proximity to crop land, pasture land, animal feeding operations, and residential areas. Several tributaries, including Worm Creek, Maple Creek, Spring Creek, High Creek, Cherry Creek, and City Creek, merge with the Cub River as it flows towards the Bear River. Preston and Franklin (Idaho) and Richmond, Utah, are the main cities in the Watershed, each having a waste water treatment plant. A map of the Watershed is provided in figure 4. The confluence of the Cub River and the Bear River is marked with a blue star, and is the receptor point for determining environmental equivalence of effluents discharged into the Watershed.[9]

The Cub River has received a 303(d) listing by Utah and Idaho because of excessive total phosphorus loadings (see table 1), culminating in two TMDL management plans. The first plan, the *Lower Bear River Water Quality Management Plan* (Ecosystems Research Institute 1995), henceforth, the Utah plan, was written for the Utah portion of the Watershed. The second plan, the *Bear River/Malad Sub basin Assessment and Total Maximum Daily Load Plan* (Ecosystems Research Institute 2005), henceforth, the Idaho plan, was written for the Idaho portion of the Watershed.

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[9] For now, the final trading ratio used for calculating environmental equivalence is assumed to equal 1. As mentioned in Chapter II, a dynamic flow model is currently being developed for the Watershed, which will calculate final trading ratios for potential trades.

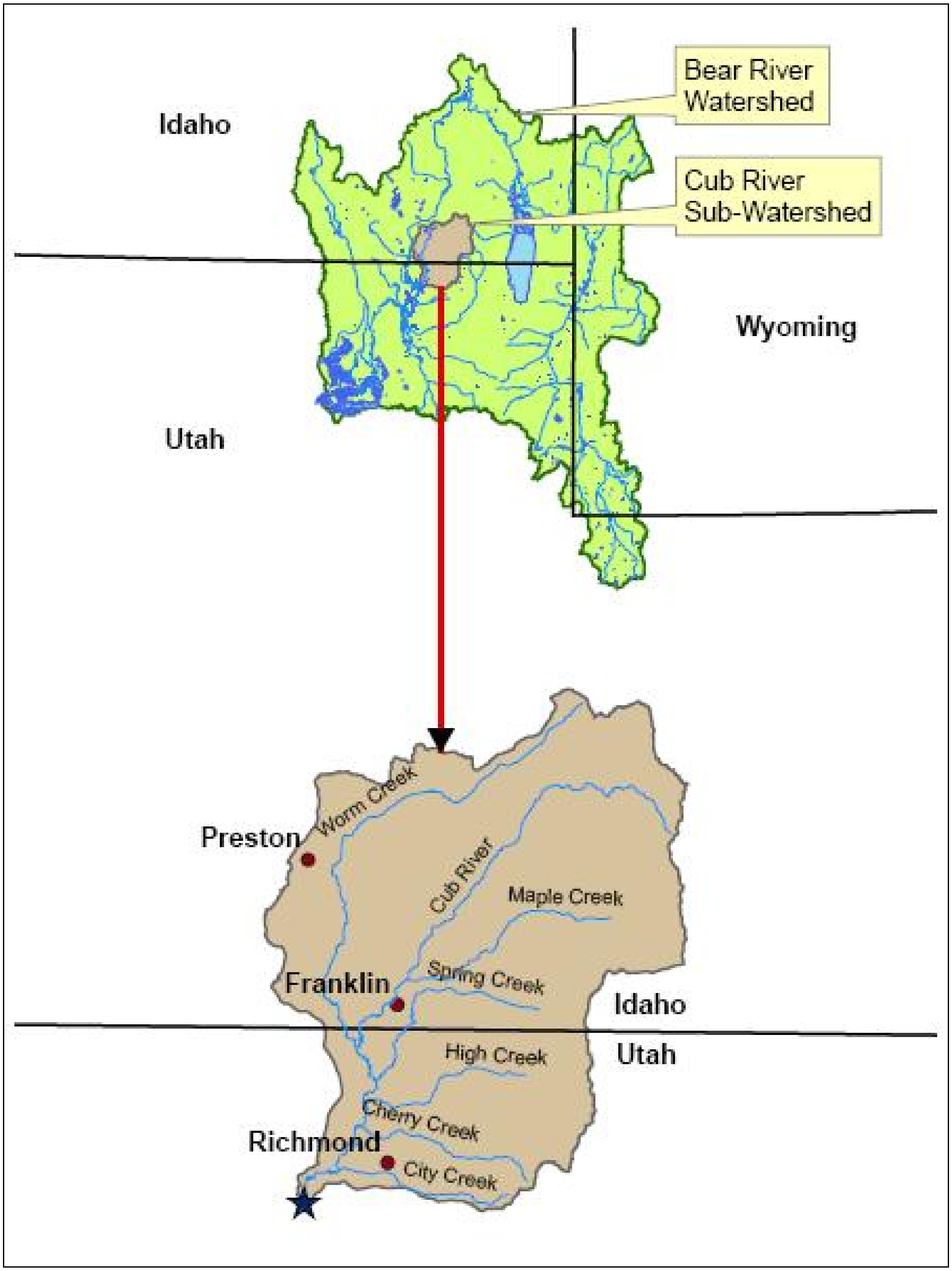

Figure 4. The Cub River sub-watershed.

The Utah plan prescribes a daily target load for total phosphorus in the Watershed by multiplying the state of Utah's specific concentration for total phosphorus in riverine systems of 0.05 milligrams per liter by the Utah Division of Water Quality historic median flow rate for the Watershed of 72 cubic feet per second and then multiplying the result by a conversion factor of 2.45.[10] This equals 8.808 kilograms per day (3,215 kilograms per year) and is the daily total phosphorus target load specified for the Utah portion of the Watershed (Ecosystems Research Institute 1995).[11] Table 9 shows the calculation of the Watershed's target load and the calculation of mean, minimum, and maximum target loads based on the Utah Division of Water Quality historical record, as well as a mean target load based on 1993 water quality data.

Table 9. Total Phosphorus Target Loads from the Utah Plan

	Utah Division of Water Quality Historical Record				1993 Study
	Mean	Median	Min	Max	Mean
Flow (cfs)[a]	100.000	72.000	10.000	331.000	191.000
TP criteria (mg/L)[b]	0.050	0.050	0.050	0.050	0.050
Conversion factor	2.447	2.447	2.447	2.447	2.447
Target load (kg/day)[c]	12.233	8.808	1.223	40.491	23.365

a. Utah Plan, Table 4-6, p. 72.

b. Utah's specified total phosphorus criterion for stream reaches.

c. Utah Plan, Table 4-7, p. 74.

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[10] The Clean Water Act requires states to identify its waterbodies' beneficial uses and to specify pollutant concentration limits, the exceedence of which impairs beneficial uses (Ecosystems Research Institute 1995).

[11] Multiplying a pollutant concentration (mg/L) by a rate of flow (cubic feet per second) and converting to common units gives an estimated load (kilograms per day). For example,

$$\left[\left(\frac{72\,ft^3}{second}\right)\times\left(\frac{0.05mg}{Liter}\right)\times\left(\frac{1Liter}{0.035\,ft^3}\right)\times\left(\frac{1kg}{1{,}000{,}000mg}\right)\times\left(\frac{86{,}400\,seconds}{day}\right)=\frac{8.808kg}{day}\right]$$

The Idaho plan prescribes an annual target load for total phosphorus in the Watershed by multiplying the specific total phosphorus concentration of 0.05 mg/L by U.S. Geological Survey monthly median flow rates and multiplying the result by a conversion factor of 2.45 times the number of days in the month.[12] Monthly target loads are added together to determine an annual target load of 5,114 kilograms. Table 10 visually displays this procedure.

The following analysis will use the annual total phosphorus target load of 5,114 kilograms, as determined in the Idaho plan (see table 10) because it is based on water quality data obtained more recently than the water quality data used in the Utah plan.

Table 10. Total Phosphorus Target Loads from the Idaho Plan

Month	Mean Monthly Flow (cfs)	Average concentration (mg/L)	Conversion Factor	Days in Month	Target load (kg)
Jan.	42.8	0.05	2.447	31	162
Feb.	84.1	0.05	2.447	28.25	291
Mar.	115.0	0.05	2.447	31	436
Apr.	200.0	0.05	2.447	30	734
May	421.0	0.05	2.447	31	1,597
June	278.0	0.05	2.447	30	1,020
July	32.4	0.05	2.447	31	123
Aug.	28.0	0.05	2.447	31	106
Sept.	40.7	0.05	2.447	30	149
Oct.	54.0	0.05	2.447	31	205
Nov.	38.3	0.05	2.447	30	141
Dec.	39.6	0.05	2.447	31	150
Total					5,114

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[12] The rate of flow used in the Idaho plan to calculate loading information in the Watershed is based on mean monthly flow data obtained from U.S. Geological Survey gaging station 10102200 near Richmond, UT, because this is the only U.S. Geological Survey gaging station along the Cub River that gathered water quality data after 1990. Results from a paired t-test show that flows at the U.S. Geological Survey gage near Richmond are not significantly different from flows from other gaging stations along the Cub River near Preston, at a 95% confidence level. The period of record used for calculating the mean monthly flows is from 1962-1963 and 1998-2000 (Ecosystems Research Institute 2005).

Theoretically, if the Watershed is able to lower its current load to the target load, water quality conditions will improve.

The Utah plan provides median, minimum, and maximum historic average daily load estimates for the Watershed of 40, 14, and 199 kilograms per day, respectively, based on information collected by the Utah Division of Water Quality. A 1993 daily loading estimate of 136 kilograms per day is also provided in the Utah plan. This estimate is based on a more comprehensive data set that uses time-weighted values to account for the fact that the majority of samples were taken during good weather when river flow was relatively low and total phosphorus load estimates were easy to obtain, and not during stormy conditions when river flow was high and total phosphorus loads were difficult to obtain. Based on 1998 data, a total phosphorus load of 63 kilograms per day has also been estimated for the Watershed; however, the data set was of poor quality.

The Idaho plan uses 32 samples, taken from October 1998 to August 2001 at a United States Geological Survey water quality gage near Richmond, Utah, to calculate an average total phosphorus concentration of 0.20 mg/L. Multiplying this average concentration level by the U.S. Geological Survey monthly median rates of flow (obtained at the Richmond gage), and then multiplying the result by a conversion factor of 2.4 times the number of days in the month, gives an estimated monthly current load. Addition of the monthly estimates provides an annual total phosphorus load estimate of 20,057 kilograms (54.95 kilograms per day) for the Cub River. Subtracting the target load from the current load gives a necessary load reduction of 14,943 kilograms per year (40.94 kilograms per day). Table 11 provides a visual display of this process.

Table 11. Current Total Phosphorus Load Information from the Idaho Plan

Month	Flow (cfs)	Average concentration (mg/L)	Conversion Factor	Days in Month	TP Load Estimates (kgs)	Needed Reduction (kgs)
Jan.	42.8	0.2	2.4	31	637	474
Feb.	84.1	0.2	2.4	28.25	1,140	849
Mar.	115.0	0.2	2.4	31	1,710	1,274
Apr.	200.0	0.2	2.4	30	2,879	2,145
May	421.0	0.2	2.4	31	6,262	4,665
June	278.0	0.2	2.4	30	4,001	2,981
July	32.4	0.2	2.4	31	482	359
Aug.	28.0	0.2	2.4	31	416	310
Sept.	40.7	0.2	2.4	30	586	436
Oct.	54.0	0.2	2.4	31	803	598
Nov.	38.3	0.2	2.4	30	551	411
Dec.	39.6	0.2	2.4	31	589	439
Total					20,056	14,943

To ensure that the following analysis is consistent with both the Utah and Idaho plans, the given point source wasteloads plus estimated non-point source loads used to analyze potential trades will fall within the range of estimated current loads in the Utah and Idaho plans as previously discussed.

The next section includes a calculation of point source loading information and the associated cost of control information. Subsequently, non-point source loading information and the associated cost of control information is calculated. Potential trades will be analyzed in Chapter IV.

Three point sources emit total phosphorus in the Watershed; each point source is a waste water treatment plant servicing the Watershed’s main cities of Richmond, Preston, and Franklin. The Utah plan lists a daily wasteload estimate of 2.3 kilograms for the Richmond waste water treatment plant. The daily wasteload is converted to an annual wasteload of 840 kilograms per year because this analysis is based on an annual target load. This 1993 wasteload estimate is calculated by multiplying 1993 flow measurements by 1993 total phosphorus concentration measurements at water quality station 490372 near the Richmond waste water treatment plant and multiplying that result by a conversion factor of 2.44 (Ecosystems Research Institute 1995).

Table 12 shows the calculation of this estimated wasteload as shown in the Utah Plan. Richmond's target load is calculated by multiplying the plants design flow of 0.43 million gallons per day by the specific total phosphorus concentration of 0.05 milligrams per liter and multiplying the result by a conversion factor of 3.785 multiplied by 365.[13] This results in a target load of 30 kilograms per year implying a necessary reduction of 810 kilograms per year.

The Idaho plan lists annual wasteload estimates for the Preston and Franklin waste water treatment plants of 1,617 and 43 kilograms per year, respectively. The

Table 12. Richmond Water Treatment Plant's 1993 Total Phosphorus Load Calculation

Date	Flow (cfs)	TP (mg/L)	Conversion Factor	TP Load (kg/day)
92-12-08	0.10	3.008	2.44	0.73
93-03-23	0.50	3.526	2.44	4.30
93-03-23	0.50	3.526	2.44	4.30
93-05-05	0.50	2.472	2.44	3.02
93-06-02	0.10	3.349	2.44	0.82
93-06-15	0.30	3.155	2.44	2.31
93-07-20	0.20	1.799	2.44	0.88
Average	0.31	2.980	2.44	2.30

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[13] The Utah plan does not provide a target load for the Richmond waste water treatment plant. Therefore, it follows similar logic to that used in the Idaho plan's calculation of the Preston and Franklin Waste Water Treatment Plant's target loads.

load's are calculated by multiplying mean monthly average flows of 1.17 and 0.024 cubic feet per second (see tables 13 and 14) by average total phosphorus concentration levels of 1.545 (see table 15) and 2 milligrams per liter and multiplying the result by a conversion factor of 2.45 times 365.[14] Target loads are calculated by multiplying the specific total phosphorus concentration of 0.05 milligrams per liter by the Preston and Franklin waste water treatment plants' mean average monthly flow estimates, resulting in target loads of 52 and 1 kilograms per year, respectively. Thus, Preston and Franklin waste water treatment plants' necessary reductions are equal to 1,564 and 42 kilograms per year, respectively.

Table 13. Preston Water Treatment Plant's Mean Monthly Average Flow Calculation

Month	2000 Flow (cfs)	2001 Flow (cfs)	2002 Flow (cfs)	2003 Flow (cfs)	Monthly Totals
Jan.	1.24	0.99	0.97	0.96	4.16
Feb.	1.38	1.02	1.01	1.02	4.43
Mar.	1.64	1.19	1.30	0.94	5.07
Apr.	1.45	1.39	1.24		4.08
May	1.41	1.28	1.19		3.88
June	1.45	1.33	1.18		3.96
July	1.49	1.27	1.13		3.89
Aug.	1.42	1.14	1.07		3.63
Sept.	1.16	1.05	1.24		3.45
Oct.	1.19	0.97	1.04		3.20
Nov.	1.07	0.96	0.99		3.02
Dec.	1.01	1.02	0.93		2.96
Totals	15.91	13.61	13.29	2.92	45.73
Average flow = 45.73 cfs / 39 samples = 1.17 cfs.					

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[14] There were not total phosphorus concentration data for Franklin Waste Water Treatment Plant in the Idaho plan. It appears they assumed a current concentration of 2 milligrams per liter.

Table 14. Franklin Water Treatment Plant’s Mean Monthly Average Flow Calculation

Month	2000 Flow (cfs)	2001 Flow (cfs)	2002 Flow (cfs)	2003 Flow (cfs)	Monthly Totals
Jan.	0.06	0.05	0.06	0.04	0.21
Feb.	0.07	0.06	0.00	0.05	0.18
Mar.	0.07	0.06	0.07	0.05	0.25
Apr.	0.06	0.06	0.06		0.18
May	0.00	0.00	0.00		0.00
June	0.00	0.00	0.00		0.00
July	0.00	0.00	0.00		0.00
Aug.	0.00	0.00	0.00		0.00
Sept.	0.00	0.00	0.00		0.00
Oct.	0.00	0.00	0.00		0.00
Nov.	0.03	0.00	0.00		0.03
Dec.	0.05	0.00	0.04		0.09
Totals	0.34	0.23	0.23	0.14	0.94

Average flow = 0.94 cfs / 39 samples = 0.024 cfs.

Table 15. Preston Water Treatment Plant’s Average Total Phosphorus Concentration

Month	2000 Total Phosphorus Concentration (mg/L)
January	2.03
February	1.83
March	
April	2.48
May	2.17
June	2.41
July	2.44
August	0.8
September	0.8
October	0.74
November	0.42
December	0.86
Totals	16.98

Average total phosphorus concentration =16.98 mg/L / 11 samples = 1.54 mg/L

With respect to annualized control cost estimates for these three point sources we follow Lee and Jones (1998), Keplinger et al. (2004), and U.S. Environmental Protection Agency (2003a) in assuming that each waste water treatment plant has a basic tier 1 control technology in place for general nutrient control. Tier 2 technologies reduce total phosphorus outflow concentrations to 1 milligram per liter, while tier 3 technologies reduce outflow concentrations to 0.5 milligrams per liter.[15]

Lee and Jones (1998) estimate the annualized control cost of a tier 2 technology. The cost is calculated by multiplying city population by an inflation-adjusted cost per person per day estimate and multiplying the result by 365 days. Waste water treatment plants with an average discharge of more than 1 million gallons per day have an estimated 2004 inflation-adjusted cost per person per day of $0.01159. Waste water treatment plants with a discharge of less than 1 million gallons per day have an estimated 2004 inflation-adjusted cost per person per day of $0.1159. Richmond, Preston, and Franklin have 2004 U.S. Census Bureau population estimates of 1,971, 4,962, and 673, respectively. Each respective waste water treatment plant has a current discharge of less than 1 million gallons per day and thus an inflation-adjusted estimated cost per person per day of $0.1159. Using the Lee and Jones (1998) approach, the Richmond, Preston, and Franklin waste water treatment plants are therefore estimated to have inflation-adjusted annualized control costs of $83,380, $209,910, and $28,470, respectively.[16]

Keplinger et al. (2004) estimate annualized control cost for tier 2 technology, using alum addition as the primary supplemental removal mechanism. The cost estimates are for rural Texas waste water treatment plants, and can be extrapolated to the Richmond, Preston, and Franklin waste water treatment plants using two approaches

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[15] The Idaho and Utah plans were written using Utah's specific in-stream total phosphorus concentration of 0.05 milligrams per liter. In the literature it is assumed that tier 3 technologies reduce total phosphorus outflow concentrations from their current level to 0.50 milligrams per liter. For the present analysis it is assumed that tier 3 technologies reduce waste water treatment plant loads to a level that allows them to just satisfy their regulatory requirements.

[16] The inflation-adjustment factor of 1.159 is obtained from NASA's website, www1.jsc.nasa.gov/bu2/inflateCPI.html

similar to Lee and Jones (1998). One approach matches the Richmond, Preston, and Franklin populations with those of corresponding Texas cities. Using this approach the Richmond, Preston, and Franklin waste water treatment plants have inflation adjusted estimated annualized costs of $197,374, $86,021, and $64,531, respectively.

A second estimation method based on Keplinger et al. (2004) matches waste water treatment plants from the Watershed to those in the study based on pounds of total phosphorus needing to be removed to bring the waste water treatment plants to a concentration level of 1 milligram per liter. Using this approach, the Richmond, Preston, and Franklin plants have estimated annual control costs equal to $94,683, $119,482, and $35,547, respectively.

Similar to Keplinger et al. (2004), U.S. Environmental Protection Agency (2003a) provides two methods for estimating annualized control costs. The first method utilizes a cost formula to estimate control costs for tiers 2 and 3 technologies. Using this formula (U.S. Environmental Protection Agency 2003a, 8), Richmond, Preston, and Franklin have inflation-adjusted estimated tier 2 control costs of $186,503, $270,787, and $146,276, respectively, and estimated tier 3 costs of $249,958, $334,243, and $209,731, respectively.

The second U.S. Environmental Protection Agency (2003a) method lists various waste water treatment plant design flows and their associated annual tiers 2 and 3 control costs. Waste water treatment plants having similar design flows as the Richmond, Preston, and Franklin plants are grouped together. The median values of the comparable cities' estimated annual control costs are then assigned to the Richmond, Preston, and Franklin plants. The Richmond, Preston, and Franklin plants have tier 2 inflation-adjusted control costs of $248,674, $280,284, and $244,002, respectively, and tier 3 costs of $333,243, $404,349, and $303,657, respectively.

Table 16 summarizes the annualized control cost estimates. For the following analysis, the medians of the estimates for each waste water treatment plant are used as the tier 2 & 3 annualized control cost. Preston, Franklin, and Richmond waste water treatment plants tier 2 annualized costs are $209,909, $64,531, and $186,503, respectively. Their tier 3 annualized control costs are $369,296, $256,694, and $291,600, respectively.[17]

Application of a tier 2 control technology by the Richmond waste water treatment plant would be expected to yield a 66% reduction from the Utah plans average total phosphorus concentration of 2.98 milligrams per liter to 1.0 milligram per liter, which results in a reduction of 554.4 kilograms per year at an annual cost of $186,503. The Richmond waste water treatment plant therefore needs a reduction of 255.6 kilograms per year in order to meet its target load. Application of a tier 3 control technology is assumed to result in the needed reduction at an annual cost of $105,088. Table 17 summarizes this information.

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[17] We assume that tier 3 technology enables each waste water treatment plant to attain its respective needed reduction. This assumption precludes the waste water treatment plants from ever having pollution credits to sell, either to other point sources or to non-point sources, and thus restricts our subsequent analysis in Chapter IV to assessing the potential for point source to non-point source trading.

Table 16. Summary of Control Cost Estimates

Waste Water Treatment Plant	Tier 2 Estimates ($)	Tier 3 Estimates ($)
Richmond WWTP		
Lee & Jones (1998)	83,380	--
Keplinger et al. (2004) Method 1	197,374	--
Keplinger et al. (2004) Method 2	94,683	--
U.S. Environmental Protection Agency (2003a) Method 1	**186,503**	249,958
U.S. Environmental Protection Agency (2003a) Method 2	248,674	333,243
Preston WWTP		
Lee & Jones (1998)	**209,910**	--
Keplinger et al. (2004) Method 1	86,021	--
Keplinger et al. (2004) Method 2	119,482	--
U.S. Environmental Protection Agency (2003a) Method 1	270,787	334,243
U.S. Environmental Protection Agency (2003a) Method 2	280,284	404,349
Franklin WWTP		
Lee & Jones (1998)	28,470	--
Keplinger et al. (2004) Method 1	**64,531**	--
Keplinger et al. (2004) Method 2	35,547	--
U.S. Environmental Protection Agency (2003a) Method 1	146,276	209,731
U.S. Environmental Protection Agency (2003a) Method 2	244,002	303,657

Table 17. Control Costs and Total Phosphorus Reductions for the Point Sources

WWTPs	Current Load	Target Load	Necessary Reduction	Control Tech.	Potential Reduction	Total Cost ($)	Average Cost ($)
Richmond	840	30	810	Tier 2	554.40	186,503	336
				Tier 3	255.60	105,098	411
Preston	1,617	51	1,566	Tier 2	565.95	209,910	371
				Tier 3	1,000.05	159,386	159
Franklin	43	1	42	Tier 2	21.50	64,531	3,048
				Tier 3	20.50	192,163	9,374

Similarly, application of a tier 2 control technology by the Preston waste water treatment plant yields a 35% reduction from the Idaho plan's total phosphorus concentration of 1.54 milligrams per liter to 1.0 milligram per liter, which results in a reduction of 565.95 kilograms per year at a total annualized cost of $209,910. The Preston waste water treatment plant therefore needs a reduction of 1,000.05 kilograms per year in order to meet its target load. Application of a tier 3 control technology is assumed to result in the needed reduction at an annual cost of $159,386.

Finally, application of a tier 2 control technologies by the Franklin waste water treatment plant yields a 50% reduction from the current concentration of 2.0 milligrams per liter to 1.0 milligram per liter, which results in a reduction of 21.5 kilograms per year at an annual cost of $64,530. According to its target load in table 17, Franklin still needs a reduction of 20.5 kilograms per year in order to meet its target load. Application of a tier 3 control technology is assumed to result in the needed reduction at an annual cost of $192,163.

Turning now to non-point sources, PLOAD version 3, an ArcView Geographical Information System tool, is used to calculate total phosphorus loads from farm fields. The loads are calculated by multiplying total phosphorus loading rates, i.e., export coefficients, for various land cover types, i.e., cropping systems such as row crops, pasture/hay, etc., by the area of each land cover type within a specified boundary. PLOAD can therefore be used to estimate both total stream-reach and individual farm loads.

The location and size of land cover type is determined using the Geographical Information System compatible National Land Cover Dataset. The National Land Cover

Dataset is based on a 21-class land cover categorization system with a spatial resolution of 30 meters.[18] Figure 5 presents a breakdown of the various land cover types within the Watershed based on the National Land Cover Dataset.[19] The eastern portion of the Watershed is mainly forest, shrub, and grass land. The headwaters of the Cub River and its associated creeks are located in this area, which are responsible for a small portion of the Watershed's total phosphorus load. In contrast, the western portion of the Watershed is mainly agricultural land with some residential and industrial areas. The Watershed's creeks join the Cub River in this area, which is responsible for the bulk of the Watershed's total phosphorus load.

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[18] The National Land Cover Dataset for the Bear River Basin is available online at www.bearriverinfo.org as a raster in ESRI GRID format.

[19] At a scale of 1:2500 the 30 meter spatial resolution is apparent. GIS data used in PLOAD must be ArcView shapefiles or Arc/Info coverages. Accordingly, the National Land Cover Dataset raster has been converted to a polygon shapefile.

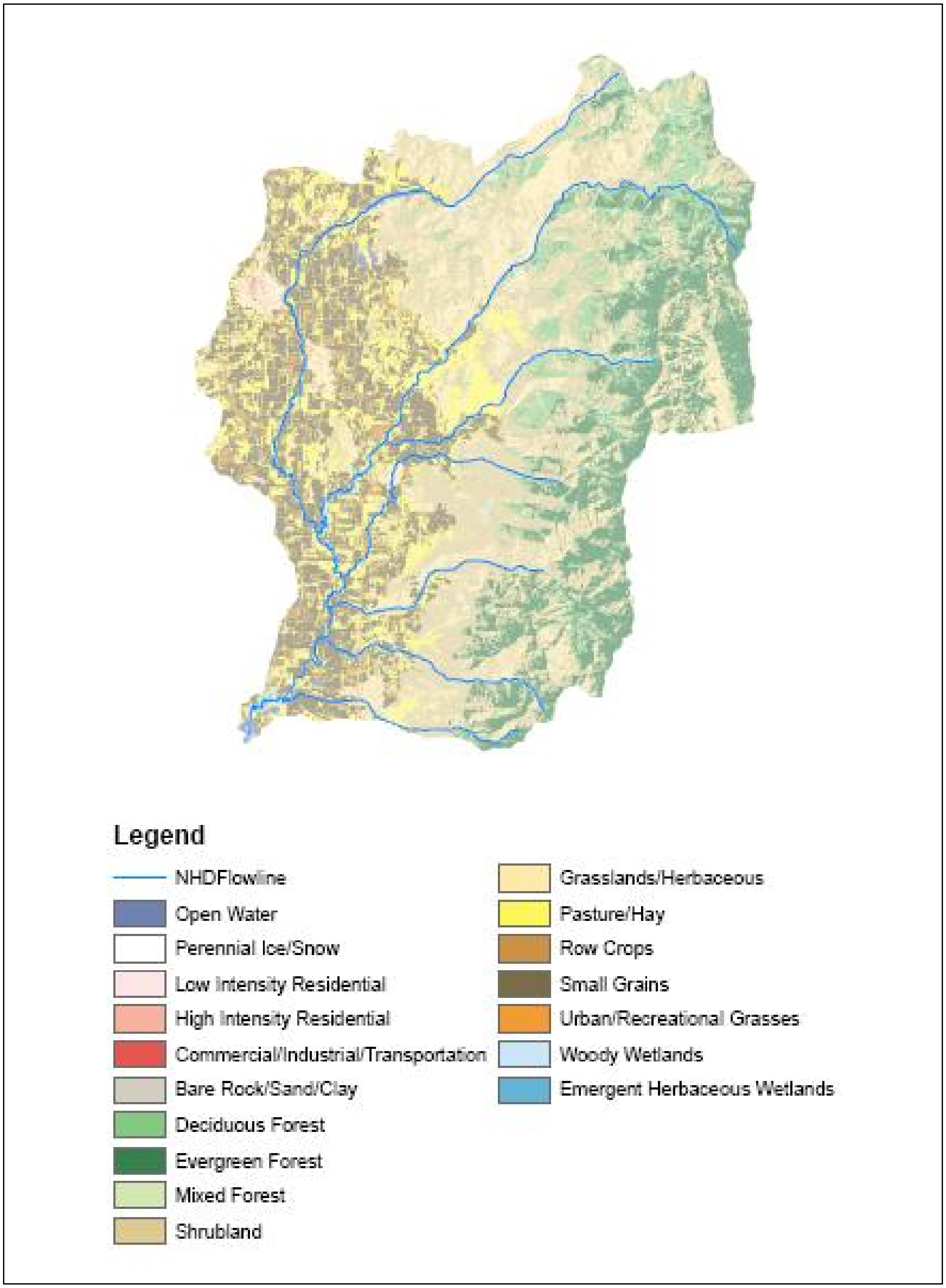

Figure 5. The National Land Cover Dataset’s land cover types within the Watershed.

Table 18 lists the export coefficients by land type used in this study. These were obtained from the Utah plan and through an exhaustive review of the academic literature (Reckhow, Beaulac, and Simpson 1980; McFarland and Hauck 2001; Winter and Duthie 2000; Endreny and Wood 2003; Johnes 1996; Hanrahan et al. 2001; McElroy et al. 1976).

Table 18. Export Coefficients Based On Land Use Type

Land-Use Type	Export Coefficient (kg/ac/yr)
Open Water	0.324
Perennial Ice/Snow	0.324
Low Intensity Residential	0.445
High Intensity Residential	0.445
Commercial/Industrial/Transportation	0.445
Bare Rock/Sand/Clay	0.324
Quarries/Strip Mines/Gravel Pits	0.324
Transitional	0.324
Deciduous Forest	0.080
Evergreen Forest	0.080
Mixed Forest	0.080
Shrubland	0.324
Orchards/Vineyards/Other	0.324
Grasslands/Herbaceous	0.324
Pasture/Hay	1.053
Row Crops	3.212
Small Grains	1.878
Fallow	0.371
Urban/Recreational Grasses	0.445
Woody Wetlands	0.324
Emergent Herbaceous Wetlands	0.324

PLOAD fails to account for the fate and transport of total phosphorus as it moves from land to water. As a result, the program will calculate equal loading estimates for two farmers having identical land coverage and acreage, but different locations within the Watershed. It is unlikely that a farmer located relatively far from a waterway will have the same loading as a farmer with identical land cover and acreage located relatively close to a waterway. Therefore, for our analysis only farm fields having a portion of a field within 10 meters of designated flow lines are included as non-point sources in the Watershed.[20] Flow lines are comparable to rivers or creeks and are identified as areas with high flow accumulation.

Flow lines are created in ArcGIS 9 using a digital elevation dataset and its hydrology toolset. Digital terrain data are made available by the U.S. Geological Survey in Digital Elevation Model format. Environmental Management Research Group (2005) provides a web link to a 30-meter National Elevation Dataset Digital Elevation Model for the Bear River Watershed. The ArcGIS 9 hydrology toolset is discussed below.

To create a flow line it is necessary to "fill" any sinks in the elevation model using the sink and fill commands on the ArcGIS hydrology toolset. Sinks can be thought of as areas that do not drain to anywhere in specific. Sinks are filled in order to determine the flow path of every cell. The top left image in figure 6 shows the Digital Elevation Model with filled sinks.

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[20] Our attention is confined to land located within 10 meters of a flow line because the author feels that this land has a higher probability of contributing a pollutant load than land located further away from a flow line, especially during a high flow or runoff period.

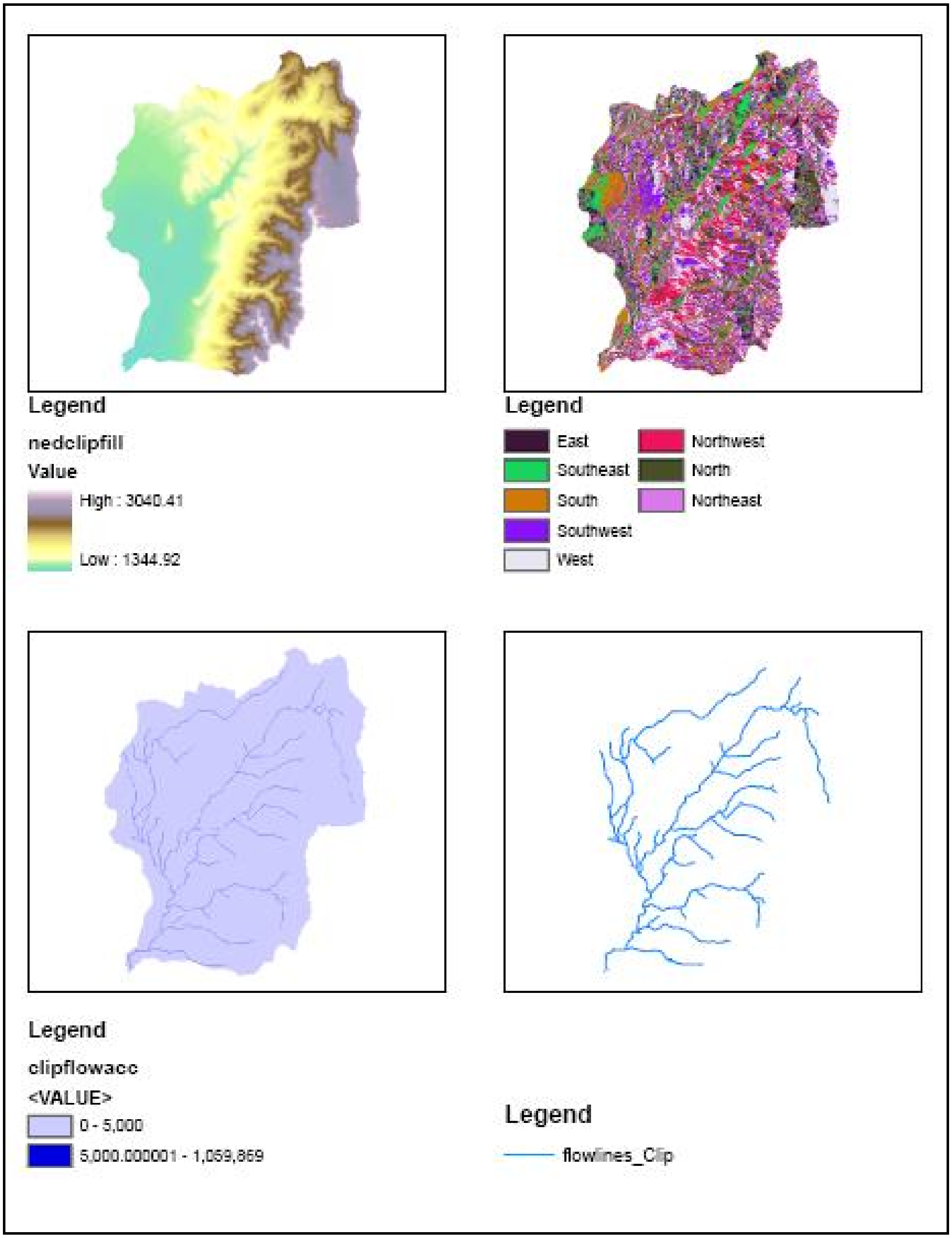

Figure 6. Creation of flow lines using the ArcGIS 9 hydrology toolset.

After all sinks are filled, each 30-meter grid is coded for the drainage direction of each cell on the designated surface. This is accomplished using the Flow Direction command in the ArcGIS hydrology toolset. The Flow Direction command is a focal function that determines the lowest elevation neighbor for every 3 x 3 cell neighborhood. The top right image in figure 6 shows the flow direction raster.

Next, the Flow Accumulation command in the ArcGIS hydrology toolset is used to create a raster showing how many cells are flowing into each down slope cell. Cells with high levels of flow accumulation represent stream networks.

The flow accumulation raster is then used to create a raster stream network by applying threshold values to select cells that have high accumulated flow values. For example, all cells with flow accumulation values greater than 5000 are valued at 1 and everything else has a null value. The bottom left image in figure 6 shows the flow accumulation raster. It has been categorized to show which cells have more than a 5000 flow accumulation value.

Finally, this raster is converted to a feature shapefile representing a linear network. The bottom right image in figure 6 provides a visual representation of the flow line network for the Watershed.

Fields having a portion of the field located within 10 meters of the flow lines are shown in figure 7. There are 661 fields owned by 218 farmers in this selection. Using the export coefficients from table 18, along with corresponding land cover and farm field information, PLOAD calculates total phosphorus loads for each of the 661 farm fields. Aggregating the individual farm field loads results in a combined current total phosphorus load of 17,352 kilograms per year for all 218 farms within 10 meters of a flow line in the Watershed. The calculation of individual farmer loads simply requires the addition of the loads attributable to farm fields owned by each respective farmer (discussed at length below).

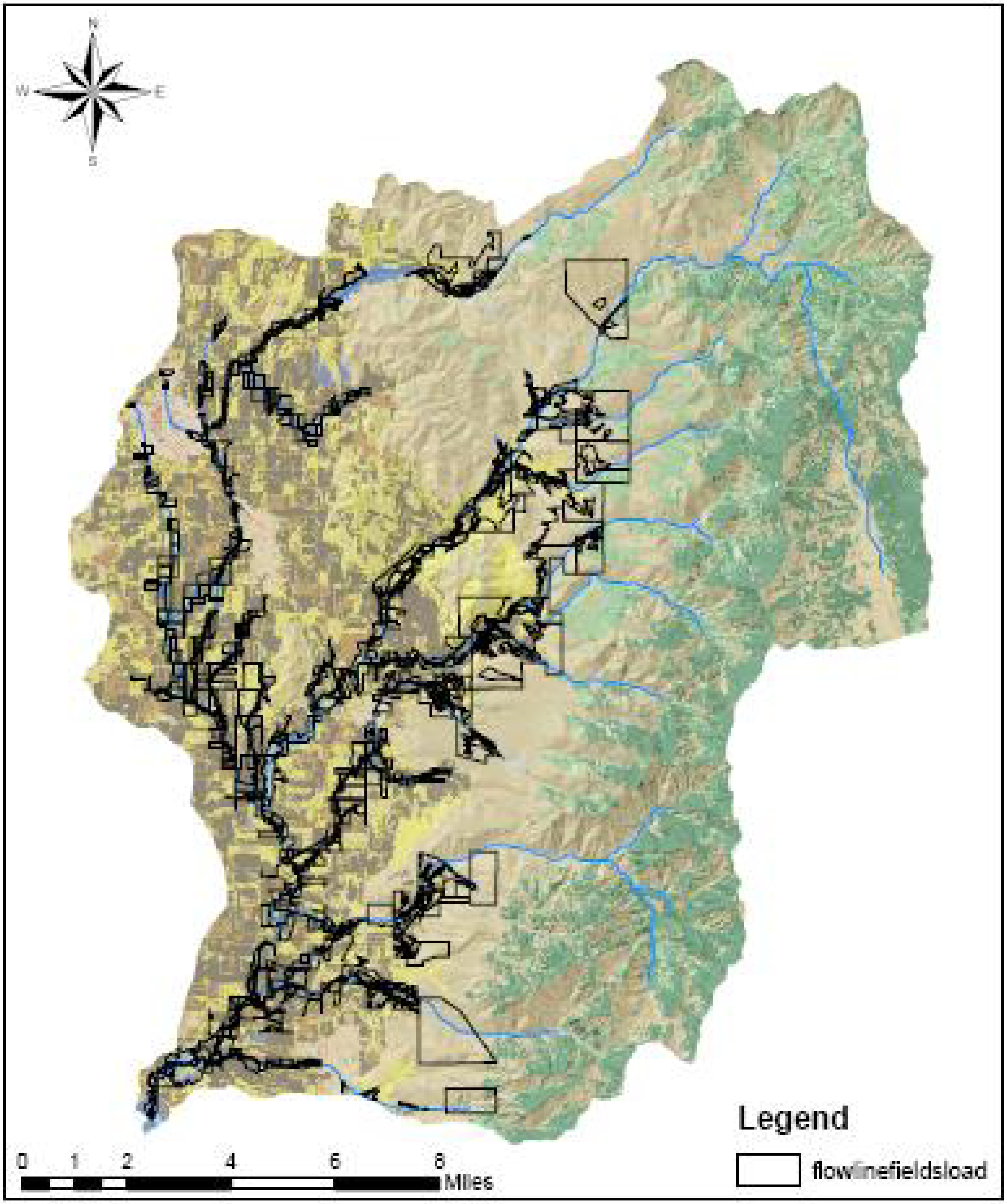

Figure 7. Farm fields having a portion of a field within 10 meters of a flow line.

There are additional non-point source total phosphorus loadings within the Watershed. These include, but are not limited to dairies and animal feeding operations. Information concerning loadings from these non-point sources is scarce and difficult to obtain.

The state of Idaho provides a geographical information system point shapefile of dairies located in the state. Dairies located in Franklin County are selected using ArcGIS 9 and all identifying information, i.e., dairy name, owner, etc., was deleted to conceal identity. There are 104 dairies in Franklin County identified in the shapefile with 36 dairies located within the Watershed.

The National Agricultural Statistics Service provides county level estimates of the number of cattle and calf farms categorized by the size of their inventory. The data is available online at the National Agricultural Statistics Service website. According to 2002 National Agricultural Statistics Service data, Franklin County has 366 cattle and calf farms with a combined inventory of 39,886. The data are further broken down according to the size of inventory as shown in Table 19.

Table 19. 2002 National Agricultural Statistic Service Cattle and Calf Farms by Inventory in Franklin County, Idaho

Inventory size	1 to 9	10 to 19	20 to 49	50 to 99	100 to 199	200 to 499	500 plus
Farms	92	53	74	47	44	43	13
Total Inventory	414	705	2,204	3,347	5,956	13,204	14,056
Average Inventory	5	13	30	71	135	307	1,081
Percentage of Total Farms	25	14	20	13	12	12	4

The 104 dairies identified in Franklin County from the shapefile are randomly assigned an average inventory based on the National Agricultural Statistics Service data percentage breakdown. Thus, 26 dairies (25%) have an average inventory of 5, 15 dairies (14%) have an average inventory of 13, 21 dairies (20%) have an average inventory of 30, 13 dairies (13%) have an average inventory of 71, 13 dairies (12%) have an average inventory of 135, 12 dairies (12%) have an average inventory of 307, and 4 dairies (4%) have an average inventory of 1,081.

The Utah plan provides a total phosphorus export coefficient of 0.018 kg per cow per day (6.57 kg per cow per year). There are 36 dairies located within the Idaho portion of the Watershed, however, only the 7 dairies that are within 100 meters of a flow line field will be examined in this analysis because they pose a higher loading risk. The 7 dairies have a combined estimated total phosphorus load of 5,117.[21] Adding this load estimate to the total flow line field load of 17,352 kilograms per year provides an annual non-point source load of 22,469 kilograms.

Two alternative non-point source regulatory strategies are considered in this study. The first strategy (henceforth, strategy 1) assumes the politically expedient non-regulation of non-point sources. This strategy does not set non-point source target loads, and thus equates each reduction unit by a non-point source as a potential credit for sale to a point source. An effective ceiling on credit creation is therefore based on the credits demanded by point sources. With respect to the Watershed, if the waste water treatment plants decide not to implement control technologies on their own and instead purchase credits from non-point sources, the maximum amount of credits demanded by the waste

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[21] Dairies 1, 2, 3, 4, 5, 6, and 7 have estimated average inventories of 30, 30, 71, 135, 307, 135, and 71, respectively, and estimated current loads of 197, 197, 466, 887, 2,017, 887, and 466, respectively.

water treatment plants will equal 2,416 kilograms per year. Obviously, strategy 1 will not induce compliance with the Watershed's target load.

The second strategy (henceforth, strategy 2) regulates non-point sources by establishing individual non-point source target loads. Unlike the establishment of target loads for point sources, target loads for non-point sources are allocated in an inherently arbitrary manner. Below a simple allocation, i.e., "grandfathering," mechanism is proposed that is based on relative farm loadings.[22] Grandfathering refers to a system of marketable emission permits where pollution permits are distributed to polluters in proportion to their emissions at an agreed date. An alternative system would be the auctioning of pollution permits (Hanley, Shogren, and White 1997). It is assumed that permits cannot be sold to the general public and retired. Irrespective of which allocation mechanism is used, this strategy allows for non-point source to point source, and non-point source to non-point source trading. Under strategy 2 it is possible to induce full compliance for the Watershed.

We begin with strategy 1, i.e., where non-point sources are unregulated. Table A1 located in the Appendix compiles pertinent information for each farmer having a flow line field. Farmers are provided with an identifying number. Current yearly loads estimated by PLOAD are listed. Each farmer's total acreage is also provided.

Based on U.S. Environmental Protection Agency (2003a), Haith and Loehr (1979), Johnes and Heathwaite (1997), Hamlett and Epp (1994), Beasley et al. (1985), Sharpley et al. (2002), Mostaghimi et al. (1997), and Walter et al. (2001), conservation tillage is assumed to result in a 66% reduction of the current total phosphorus load for

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[22] Alternative allocation mechanisms might be based on relative farm size or simple egalitarianism instead of being based on relative farm loadings.

any given farm at a cost of $2.77 per acre. In other words, if a farmer is currently loading 1 kilogram per acre, he can reduce the loading by 0.66 kilogram per acre at a cost of $2.77 per acre. In Table A2, Farmer 1 has a current total phosphorus load of 38.475 kilograms per year from total acreage of 33.633. Conservation tillage would therefore reduce the farmer's TP load by 25.393 kilograms per year at an annualized cost of $93.16. This results in a cost per unit of reduction (i.e., average control cost) of $3.67.[23]

Nutrient planning is assumed to result in a 45% reduction of the current total phosphorus load at a cost of $7.13 per acre. Table A3 shows that if Farmer 1 implements a nutrient management plan he could reduce his total phosphorus loads by 17.314 kilograms per year at an annualized cost of $239.67. This results in a cost per unit of reduction of $13.84.

Grass filter strips are assumed to result in a 50% reduction of the current load at a cost of $17.31 per acre. For this study, a maximum of 5% of any given farmer's total acreage is assumed to be planted in grass filter strips. As shown in the Table A4, the planting of grass filter by Farmer 1 results in a total phosphorus load of 19.237 kilograms per year at an annualized cost of $29.10. Cost per unit of reduction for grass filter strips is thus $1.51. For simplicity it is assumed that farmers can implement more than one best management practice and obtain additively separable reductions.

Haith and Loehr (1979), Beasley et al. (1985), Johnes and Heathwaite (1997), and Mostaghimi et al. (1997) show that implementing packages of best management practices

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[23] For this thesis we assume that no farmers have implemented best management practices because to our knowledge current data is unavailable. Future research will entail documenting which farmers have implemented best management practices via the National Resource Conservation Service's Environmental Quality Improvement Program.

increase reductions obtained compared to implementing only one best management practice, however, it is unclear if diminishing returns to scale are present.

Based on Sharpley et al. (2002) and Mostaghimi et al. (1997) an animal waste system is assumed to result in a 30% reduction of the current total phosphorus load for any given dairy. Fallert, Weimar, and Crawford (1993) have shown that in the United States there are economies of size in waste management. According to estimates done by Outlaw et al. (1993), the annual cost per cow to comply with waste management rules would be $400 per cow from a 50 head farm, compared to $288 per cow from a 175 head farm. For this analysis assume that an animal waste system will cost dairies having less than 50 head $400 per cow per year and dairies having more than 50 head $288 per cow. Dairies 1, 2, 3, 4, 5, 6, and 7 have estimated abatement costs of $12,000, $12,000, $20,448, $38,880, $88,416, $38,880, and $20,448, respectively.

Turning focus to strategy 2, recall that the target load for the entire Watershed is 5,114 kilograms per year. Subtracting the total phosphorus target loads for the Preston, Franklin, and Richmond plants of 52, 1, and 30 kilograms per year, respectively, from the Watershed's overall target load, results in a total non-point source target load of 5,031 kilograms per year. For this study, we assume that individual non-point source target loads are determined as their respective proportion of the overall non-point source target load, based on each non-point source's total phosphorus contribution to the overall current non-point source loadings in the Watershed.

Tables A2, A3, and A4, which are located in the Appendix, show the calculated individual farmer target loads and the reductions obtained from implementing the various best management practices. For example, Farmer 1 has a current total phosphorus load of

38.5 kilograms per year based on 33.6 acres. Farmer 1 is responsible for 0.0017% of the total non-point source load and therefore has a target load of 8.6 kilograms per year. Thus, Farmer 1 has a necessary reduction of 29.9 kilograms per year. Implementation of conservation tillage practices on the entire acreage could reduce Farmer 1's current load by 25.4 kilograms per year at a cost of $93.16. This results in a cost per unit of reduction of $3.67. A nutrient management plan on the entire acreage could reduce Farmer 1's total phosphorus load by 17.3 kilograms per year at an annualized cost of $239.67. This results in a cost per unit of reduction of $13.84.

Planting of grass filter strips by Farmer 1 reduces the total phosphorus load by 19.2 kilograms per year at an annualized cost of $29.10. Cost per unit of reduction for grass filter strips is therefore $1.51. It is therefore evident that when non-point sources are allocated a target load they will likely need to implement more than one best management practice in order to meet and potentially reduce their loads below their target loads, i.e. to potentially create credits for sale either to the waste water treatment plants or to other non-point sources.

Dairies 1, 2, 3, 4, 5, 6, and 7's estimated current loads, target loads, potential reduction from implementing animal waste systems and the associated cost is shown in table 20. It is evident that dairies implementing animal waste systems will still need to purchase reduction credits from other non-point sources in order to be meet their target loads. Based on the given assumptions, dairies will be unable to create reduction credits.

Table 20. Estimated Load and Cost Information for Dairies

Dairy	Average Inventory	Current Load	% of non-point load	Target load	Necessary Reduction	Potential Reduction from Animal Waste System	Total Annual Cost	Cost per unit of reduction
1	30	197	1%	44	153	59	$12,000	$203
2	30	197	1%	44	153	59	$12,000	$203
3	71	466	2%	104	362	140	$20,448	$146
4	135	887	4%	199	688	266	$38,880	$146
5	307	2,017	9%	452	1,565	605	$88,416	$146
6	135	887	4%	199	688	266	$38,880	$146
7	71	466	2%	104	362	140	$20,448	$146

CHAPTER IV

ANALYSIS

This chapter demonstrates how specific non-point source to point source and non-point source to non-point source trades might emerge in the Watershed and thus sets forth the method we might use to assess the overall financial feasibility of trading in the Bear River Watershed. Two possible trading scenarios are examined. The first scenario focuses on the potential for non-point source to point source trading between farmers and a nearby waste water treatment plant. The second scenario focuses on non-point source to non-point source trading among farmers. Because non-point source to non-point source trading is possible only under strategy 2 (see Chapter III), we restrict the ensuing analysis to this strategy. Table A1 in the Appendix reveals the vast potential for non-point sources to implement best management practices in order to create credits for sale to the waste water treatment plants, as well as to other non-point sources that choose not to implement best management practices.

With respect to the first trading scenario, figure 8 displays a 2004 National Agriculture Imagery Program image of the portion of the Watershed surrounding the City of Richmond, Utah near the Utah/Idaho Stateline. Flow lines are displayed in blue and flow from the top of the image toward the bottom, with the Cherry Creek and City Creek flow lines converging with the Cub River flow line. Farm fields located within 10 meters of a flow line are outlined in black. Three fields with the owning farmer listed are highlighted in yellow. The Richmond waste water treatment plant is shown in the lower portion of the image, with a WTP symbol.

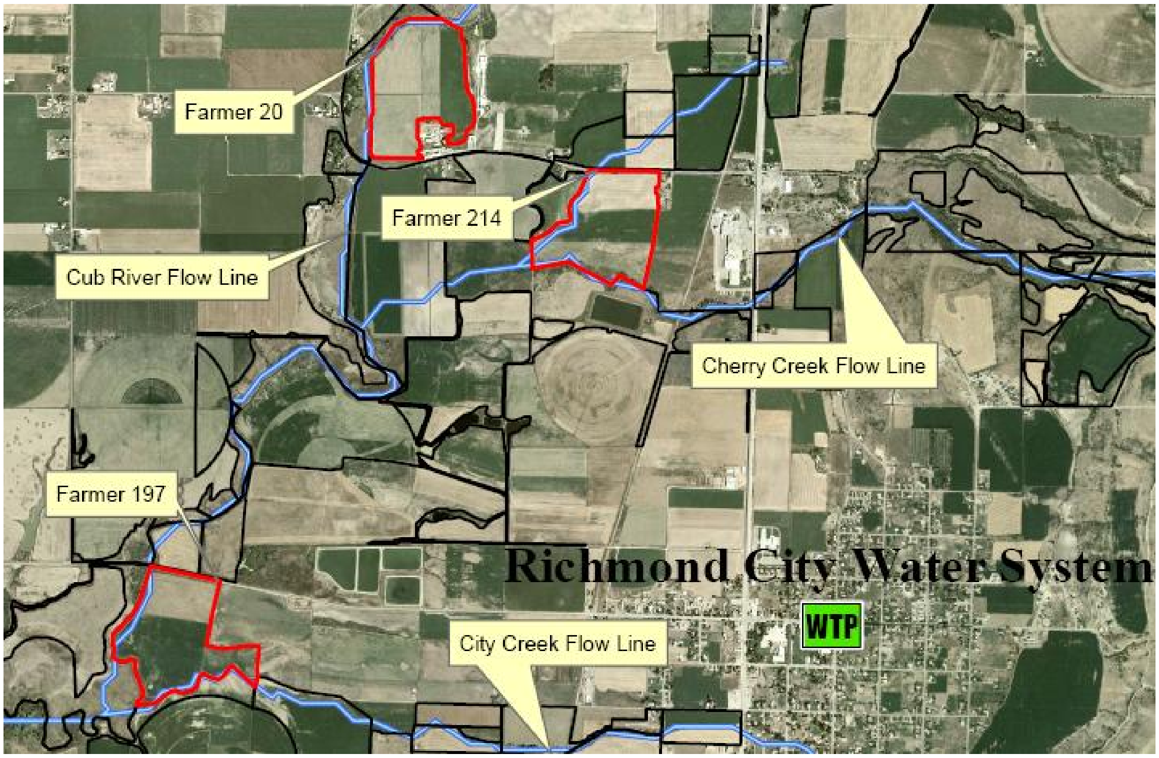

Figure 8. Trading scenario 1: The Watershed near Richmond, Utah.

Recall from table 17 that the Richmond waste water treatment plant has an estimated current total phosphorus load of 840 kilograms per year, with a target load of 30 kilograms per year, and thus a necessary reduction of 810 kilograms per year. Also from table 17, we note that application of a tier 2 control technology results in a reduction of 554.4 kilograms per year at an annual cost of $186,503, resulting in an average control cost for this technology of $336.40. After application of the tier 2 technology, the Richmond plant therefore needs a further reduction of 255.6 kilograms per year to be in compliance. Application of tier 3 technology results in the needed reduction at an additional annual cost of $105,098, resulting in an average control cost of $411.18 for this technology. The overall “weighted” average control cost equals $360 for both technology tiers.

As shown in tables A1-A4, which are located in the Appendix, Farmers 20, 197, and 214 have current total phosphorus loads of 125.8, 92.3, and 110.4 kilograms per year and corresponding target loads of 29.8, 21.9, and 26.2 kilograms per year, respectively. Implementing conservation tillage on his field having a portion within 10 meters of a flow line (henceforth “flow line field”) reduces Farmer 20’s current load by 83 kilograms per year at an annual cost of $201.93. This results in an average control cost of $2.43. To meet his target load, Farmer 20 therefore needs a further reduction of 13 kilograms per year. If Farmer 20 implements a nutrient management plan to complement conservation tillage on his flow line field, he can expect to further reduce his total phosphorus load by 42.8 kilograms per year (i.e., he can completely eliminate total phosphorus loading from this field) at an additional annual cost of $519.48, resulting in an average control cost of $12.14. In the process, Farmer 20 creates 29.8 total phosphorus credits with an overall weighted average control cost of $5.73.

If we assume that Farmer 197 decides to allocate 5% of his flow line field to grass filter strips, the result would be a total phosphorus load reduction of 46.2 kilograms per year at an annual cost of $62.45, implying an average control cost of $1.35. A reduction of 24.2 kilograms per year is still required of Farmer 197 to meet his target load. Assuming he implements conservation tillage on the remaining 95% of his flow line field, Farmer 197 can expect to achieve an additional reduction of 46.1 kilograms per year at an annual cost of $187.29, resulting in an average control cost per for conservation tillage of $4.06. Using this combination of best management practices, Farmer 197 therefore creates 21.9 total phosphorus credits. For Farmer 197, implementation of grass filter strips on 5% of his land and conservation tillage on the other 95% of his land results in a weighted average control cost of $2.71.

Finally, we assume that Farmer 214 also allocates 5% of his flow line field to grass filter strips. He obtains a total phosphorus load reduction of 55.2 kilograms per year at an annual cost of $56.72, resulting in an average cost of $1.03. Farmer 214 therefore requires an additional reduction of 29 kilograms per year in order to meet his target load. Implementation of a nutrient management plan on the remaining 95% of his field results in an additional reduction of 47.2 kilograms per year at an annual cost of $443.99, resulting in an average control cost for the nutrient management plan of $9.41. This allows Farmer 214 to create 18.2 total phosphorus credits with a weighted average control cost of $4.89.[24]

Similar to table 3, table 21 compiles this information. The table demonstrates the potential gains to non-point source to point source trading, as the farmers' weighted average control costs are much less than the Richmond waste water treatment plants. The Richmond waste water treatment plant can reduce its control costs by purchasing reduction credits from the farmers. However, it is apparent that similar to Farmers 20, 197, and 214, additional farmers would need to create total phosphorus credits in order for the waste water treatment plants to reach its target load through trading as opposed to applying tier 2 and 3 technologies itself. The results in table 21 also show the scope for non-point source to non-point source trading due to the differences in weighted average

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[24] Although in this scenario each farmer has only one flow line field, many farmers have more than one. Out of the 218 farmers in the Watershed with flow line fields, 74 farmers own 1flowline field, 52 farmers own 2 flow line fields, 38 farmers own 3 flow line fields, 19 farmers own 4 flow line fields, 7 farmers own 5 flow line fields, 8 farmers own 6 flow line fields, 6 farmers own 7 flow line fields, 2 farmers own 8 flow line fields, 4 farmers own 9 flow line fields, 1 farmer own 10 flow line fields, 2 farmers own 11 flow line fields, 1 farmer owns 12 flow line fields, 1 farmer owns 14 flow line fields, 2 farmers own 18 flow line fields, and 1 farmer owns 22 flow line fields.

Table 21. Trading Scenario 1: Watershed Profile with Cost Information

Source	Current Load	Target Load	Necessary Reduction	Control Technology	Reduction Achieved	Credits (Remaining Reduction Needed)	Average Control Cost ($)	Weighted Average Control Cost ($)
Richmond WWTP	840.0	30.0	810.0	Tier 2	554.4	(255.6)	336.40	360.00
				Tier 3	255.6	0.0	411.18	
Farmer 20	125.8	29.8	96.0	Cons. Tillage	83.0	(13.0)	2.43	5.73
				Nutrient Mngt.	42.8	29.8	12.14	
Farmer 197	92.3	21.9	70.4	Filter Strips	46.2	(24.2)	1.35	2.71
				Cons. Tillage	46.1	21.9	4.06	
Farmer 214	110.4	26.2	84.2	Filter Strips	55.2	(29.0)	1.03	4.89
				Nutrient Mngt.	47.2	18.2	9.41	

control costs across Farmers 20, 197, and 214. However, these cost differentials are not as great as between the waste water treatment plant and the farmers. Thus, the scope for non-point source to non-point source trading is perhaps not as large.

Scenario 2 is similar to Scenario 1, but examines the potential for non-point source to non-point source trading among farmers themselves. Figure 9 is a National Agriculture Imagery Program image showing the portion of the Watershed near Franklin, Idaho. In this figure, it can be seen that the Maple Creek and Spring Creek flow lines converge with the Cub River flow line. Flow lines fields are outlined in black. Four flow line fields are highlighted in yellow with the owning farmer listed. The Franklin waste

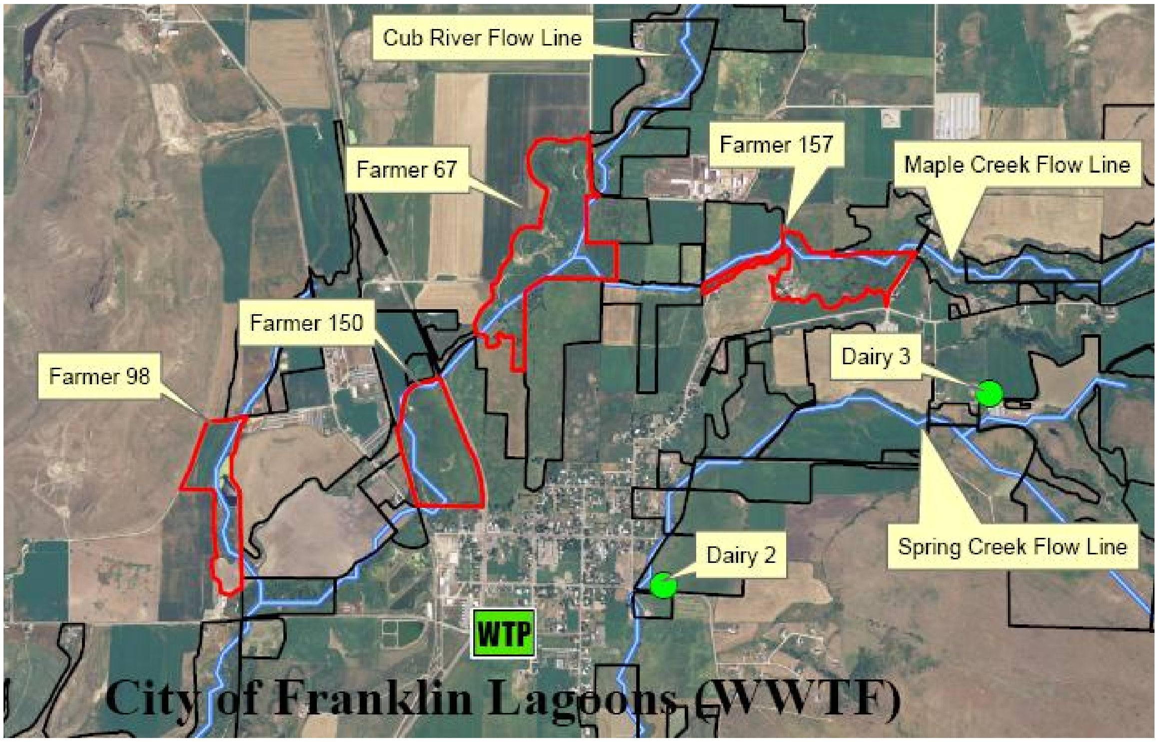

Figure 9. Trading scenario 2: The Watershed near Franklin, Idaho.

water treatment plant is designated by the WTP icon in the lower portion of the image. Dairies 2 and 3 are shown as green dots.

Recall from table 17 that the Franklin waste water treatment plant has an estimated current total phosphorus load of 43 kilograms per year, with a target load of 1 kilogram per year, and thus a necessary reduction of 42 kilograms per year. Also note that application of a tier 2 control technology results in a reduction of 21.5 kilograms per year at an annual cost of $64,531, resulting in an average control cost for this technology of $3,001. After application of the tier 2 technology, the Franklin waste water treatment plant therefore needs a further reduction of 20.5 kilograms per year to be in compliance. Application of tier 3 technology results in the needed reduction of 20.5 kilograms per year at an additional annual cost of $192,163, resulting in an average control cost of

$9,374 for this technology. The overall "weighted" average control cost for the Franklin waste water treatment plant equals $6,112.

As shown in the Appendix, Farmers 67, 98, 150, and 157 have current total phosphorus loads of 111.6, 16.6, 42.2, and 58.4 kilograms per year and corresponding target loads of 26.5, 3.9, 10.0, 13.9 kilograms per year, respectively. Implementing conservation tillage on his entire flow line field reduces Farmer 67's current load by 73.7 kilograms per year at an annual cost of $189.48, resulting in an average control cost of $2.57. To meet his target load, Farmer 67 needs a further reduction of 11.4 kilograms per year. Farmer 67 can implement a nutrient management plan that further reduces his load by 37.9 kilograms per year at a total cost of $487.44, resulting in an average control cost of $12.86. In the process, Farmer 67 has created 26.5 total phosphorus credits. Implementing conservation tillage and a nutrient management plan therefore result in a weighted average control cost of $6.07 for Farmer 67.

Farmer 98 can allocate 5% of his flow line field to grass filter strips, resulting in a total phosphorus load reduction of 8.3 kilograms per year at an annual cost of $26.12. His average control cost for the grass filter strips is therefore $3.15. A reduction of 4.4 kilograms per year is still required by Farmer 98 in order to meet his target load. A nutrient management plan can be implemented on the reaming 95% of Farmer 98's flow line field, resulting in a reduction of 7.1 kilograms per year at a cost of $204.45. His corresponding average control cost is thus $28.80. Using this combination of best management practices, Farmer 98 therefore creates 2.7 reduction credits. Planting grass filter strips on 5% of his field and implementing conversation tillage on the remaining 95% results in a weighted average control cost of $14.97.

Assume Farmer 150 also plants 5% of his field in grass filter strips. He obtains a total phosphorus load reduction of 21.1 kilograms per year at an annual cost of $35.48, resulting in an average control cost of $1.68. Farmer 150 therefore requires an additional reduction of 11.1 kilograms per year in order to meet his target load. Implementing conservation tillage on the 95% of his land remaining results in a reduction of 21.1 kilograms per year at an annual cost of $107.89, resulting in an average control cost of $5.11. In the process Farmer 150 has created 10 total phosphorus credits. Thus, grass filter strips on 5% of the land and implementation of a nutrient management plan on the remainder results in a weighted average control cost of $3.40.

Finally assume that Farmer 157 decides to allocate 5% of his flow line field to grass filter strips. He obtains a total phosphorus load reduction of 29.2 kilograms per year at an annual cost of $30.35, resulting in an average control cost of $1.04. Farmer 157 still needs a further reduction of 15.3 kilograms per year in order to meet his target load. Implementation of a nutrient management plan on the 95% of the remaining flow line filed results in a reduction of 29.2 kilograms per year at a cost of $237.61, resulting in an average control cost of $8.14 and therefore enabling Farmer 150 to create 13.9 total phosphorus credits. Grass filter strips on 5% of the land and implementation of a nutrient management plan on the remaining flow line field results in a weighted average control cost of $4.59.

Dairies 2 and 3 have current loads of 197 and 466 kilograms per year and corresponding target loads of 44 and 104 kilograms per year, respectively. If Dairy 2 decides to implement an animal waste system it can obtain a total phosphorus load reduction of 59 kilograms per year at an annual cost of $12,000, resulting in an average control cost of $203. Dairy 2 still needs a reduction of 94 kilograms per year to meet its target load. If Dairy 3 decides to implement an animal waste system it can obtain a total phosphorus load reduction of 140 kilograms per year at an annual cost of $20,448, resulting in an average control cost of $146. Dairy 3 still needs a reduction of 222 kilograms per year in order to meet its target load. The dairies will need to purchase the needed reductions from other non-point sources.

Similar to trading scenario 1, gains from point source to non-point source trading are evident in this scenario (see table 22). Also, gains from non-point source to non-point source trading are present. The dairies have the incentive to seek out farmers from which to purchase reduction credits. After comparing his weighted average control cost to other farmers, Farmer 98 may decide that it is in his best interest to purchase total phosphorus credits from the other farmers. This is because his weighted average cost of control is rather high compared to the other farmers.

These two trading scenarios are indicative of an infinite number of potential point source to non-point source and non-point source to non-point source trading scenarios that likely exist in the Watershed. Chapter V discusses how future research might refine the results presented here and thus more accurately assess the financial feasibility of water quality trading throughout the entire Bear River Basin.

Table 22. Trading Scenario 2: Watershed Profile with Cost Information

Source	Current Load	Target Load	Necessary Reduction	Control Technology	Reduction Achieved	Credits (Remaining Reduction Needed)	Average Control Cost ($)	Weighted Average Control Cost ($)
Franklin WWTP	43.0	1.0	42.0	Tier 2	21.5	(20.5)	3,001.43	6,112.00
				Tier 3	20.5	0.0	9,373.82	
Dairy 2	197.0	44.0	153.0	Animal Waste System	59.0	(94.0)	203.00	203.00
Dairy 3	466.0	104.0	362.0	Animal Waste System	140.0	(222.0)	146.00	146.00
Farmer 67	111.6	26.5	85.1	Cons. Tillage	73.7	(11.4)	2.57	6.07
				Nutrient Mngt.	37.9	26.5	12.86	
Farmer 98	16.6	3.9	12.7	Filter Strips	8.3	(4.4)	3.15	14.97
				Nutrient Mngt.	7.1	2.7	28.80	
Farmer 150	42.2	10.0	32.2	Filter Strips	21.1	(11.1)	1.68	3.40
				Cons. Tillage	21.1	10.0	5.11	
Farmer 157	58.4	13.9	44.5	Filter Strips	29.2	(15.3)	1.04	4.59
				Nutrient Mngt.	29.2	13.9	8.14	

CHAPTER V

CONCLUSION AND RECOMMENDED FURTHER RESEARCH

Chapters III and IV have shown U.S. Environmental Protection Agency (2004), also known as the water quality trading guidelines, can be applied to specific watersheds with the aid of analytical tools such as a geographical information system. The feasibility of point source to non-point source and non-point source to non-point source trades can be assessed once the necessary water profile and control cost information has been obtained and organized as shown in tables 21 and 22. For example, in Chapter IV we examine two of what is potentially an infinite number of trading scenarios between farmers, dairies, and waste water treatment plants under strategy 2 assumptions (i.e., where non-point sources are regulated similar to point sources).

Based on our assumptions, waste water treatment plants will need to implement tiers 2 and 3 control technologies in order to comply with their target loads on their own, and they will be unable to create total phosphorus credits in the process. Dairies can construct animal waste systems to reduce a portion of their total phosphorus loads; however they must purchase from farmers the remaining total phosphorus reductions needed to meet their target loads. Some dairies might find it beneficial to forgo construction of a holding pond altogether and instead purchase their entire reductions needed from farmers. Farmers will need to implement more than one best management practice in order to meet their target loads and to potentially create total phosphorus credits.

The analysis has also shown that for non-point source to non-point source trading to emerge, economies of scale will have to differ among the non-point sources. In other words there must exist in the Watershed at least some non-point sources with relatively low current loads (relative to other non-point sources on similarly sized acreages), which translates into relatively low reductions achieved, which then translates into relatively high average control costs. For example, in trading scenario 2 of Chapter IV Farmers 98, 150, and 157 have similar acreages. However, Farmer 98 has a relatively low current load compared to Farmers 150 and 157. The difference in total phosphorus loads is attributable to the fact that according to the National Land Cover Dataset land cover file, Farmer 98's flow line field is mainly composed of grasslands having a relatively low export coefficient, while Farmers150 and 157 have flow line fields composed mainly of croplands having relatively high export coefficients. As is expected, Farmer 98 therefore has a relatively high weighted average control cost compared to Farmers 150 and 157 because he is restricted to using the same set of best management practices as these two farmers.

In order to successfully implement a water quality trading program in the Bear River Basin further research is necessary. To begin, the analysis conducted in this thesis for the Cub River Sub-Watershed needs to be extended to the entire basin, shown in figure 1. Specifically, the analysis needs to be extended to include the Little Bear River Sub-Watershed as well as the Middle Bear River Sub-Watershed from the Oneida Reservoir to the Cutler Reservoir.

"Hotspots" can potentially become prominent as the trading area expands because transport coefficients only consider water quality at a receptor point, leaving room for hotspots to occur along river stretches between traders. Therefore, potential hotspots need to be assessed as part of any water quality trading program. U.S. Environmental Protection Agency (2004) defines hotspots as “localized areas with high levels of pollution within a watershed” that can potentially emerge in a water quality trading program. For example, if a relatively large source of pollution, such as a waste water treatment plant, located upstream purchases all its needed credits from relatively smaller, scattered non-point sources located downstream or in another sub-watershed altogether a hotspot could arise along the stretch of river between the waste water treatment plant and the non-point sources (within a given sub-watershed) or between the waste water treatment plant and the sub-watershed’s receptor point (with inter-sub-watershed trading). Thus it may be necessary to limit the size of credit purchases by the waste water treatment plant.

Next, the dynamic water quality model being created by the Utah State University Water Lab needs to be interfaced with the watershed profile information presented in this thesis. Specifically, the dynamic model needs to establish the environmental equivalence or final trading ratios, discussed in Chapter II. U.S. Environmental Protection Agency (2004) explains that equivalence ratios can have a profound effect on the financial attractiveness of trading. Once calculated, these final trading ratios will likely alter the trading scenarios presented in Chapter IV because as the final trading ratio increases for a potential purchaser of credits, the amount of purchased reductions necessary to maintain compliance increases (see Chapter II). This effectively increases the purchase price of credits. As the ratio between buyer and seller gets smaller, the purchase price falls (U.S. Environmental Protection Agency 2004). Recall that in Chapter II we calculated final trading ratios for our example sources. In that example, if WWTP #2 decides to purchase all of its necessary reduction from Bob’s Farm, it will have to purchase 3.87 credits for each unit of reduction it needs because it has a more soluble discharge and is spatially closer to the receptor point. To correctly evaluate the potential for trade, Bob’s Farm’s weighted average control cost of $1.97 from table 5 is multiplied by the final trading ratio of 3.87, for an adjusted minimum purchase price of $7.62 per unit of total phosphorus reduced by Bob’s Farm.[25] This is compared with Waste Water Treatment Plant #2’s weighted average control cost of $17.72. The cost differential has somewhat eroded and, depending on WWTP #2’s pricing strategy, may completely erode the financial attractiveness of trading between the two parties.

Third, uncertainty in estimating non-point source loads and in the effectiveness of best management practices needs to be addressed. PLOAD provides a user-friendly approach to estimating non-point source total phosphorus loads; however, more sophisticated models should be developed to account for this type of uncertainty. Baker, Weller, and Jordan (2006) provides an example of reducing uncertainty in estimating the effectiveness of riparian buffers by developing effective landscape metrics based on a clear conceptual model and quantified at an appropriate scale. Landscape metrics specifically developed for the Bear River Watershed could therefore help to reduce uncertainty.

Fourth, improved water quality and economic data for feedlots and dairies in Utah and Idaho must be obtained. There are numerous feedlots and dairies throughout the study area representing potential trading participants.

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[25] Again, by “equivalent unit” we mean that for every unit of total phosphorus that it does not reduce itself, WWTP #2 must purchase 3.87 units of reduction from Bob’s Farm. Therefore, this unit not reduced effectively costs WWTP #2 $7.62 when purchased from Bob’s Farm.

Fifth, an online trading room providing internet-based infrastructure and support for the water trading program might be developed and supported by the Utah and Idaho Department of Environmental Quality. An online trading room would enable potential traders to communicate with one another as well as with the Department of Environmental Quality in a highly efficient manner. It would also allow potential traders to evaluate potential trades as efficiently as possible. The online trading room can also be used to auction off permits to the general public. An online trading room developed by the World Resources Institute acts as a useful benchmark for the Bear River Watershed at www.nutrientnet.org.

Sixth, a matching algorithm that can fully characterize an optimal trading scenario for the basin needs to be designed. An optimal trading scenario would identify the specific menu of trades that would minimize the overall cost of controlling total phosphorus loads basin-wide. The algorithm could be made using a linear programming model.

Finally, the last two guidelines in U.S. Environmental Protection Agency (2004)-assessing the potential market infrastructure and evaluating stakeholder readiness-need to be addressed. In our opinion Ross & Associates Environmental Consulting (2000) provides a useful benchmark as it contains numerous legal documents that quantify and monitor trading, and thus ensure adequate compliance with regulations. Total phosphorus reductions derive value only with regulations that support and legalize them. As in Ross & Associates Environmental Consulting (2000) potential stakeholders in the Bear River Basin need to be educated about water quality trading. They need to understand how a market supporting point source to non-point source and non-point source to non-point source trading to meet regulations will function, and the potential social benefits associated with trading.

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APPENDIX

Table A1. Individual Total Phosphorus Loads, Potential Reductions, and Cost Information for Farms with Flow Line Fields in the Watershed

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
1	38.5	33.6	25.4	$93.16	$3.67	17.3	$239.67	$13.84	19.2	$29.10	$1.51
2	31.0	17.4	20.5	$48.18	$2.36	13.9	$123.94	$8.89	15.5	$15.05	$0.97
3	23.4	13.6	15.4	$37.60	$2.44	10.5	$96.73	$9.20	11.7	$11.75	$1.01
4	14.7	11.8	9.7	$32.81	$3.37	6.6	$84.41	$12.72	7.4	$10.25	$1.39
5	12.4	12.6	8.2	$35.03	$4.29	5.6	$90.12	$16.18	6.2	$10.94	$1.77
6	51.6	35.6	34.1	$98.64	$2.90	23.2	$253.76	$10.92	25.8	$30.81	$1.19
7	42.0	23.4	27.7	$64.93	$2.34	18.9	$167.04	$8.84	21.0	$20.28	$0.97
8	33.1	28.4	21.8	$78.77	$3.61	14.9	$202.64	$13.62	16.5	$24.61	$1.49
9	98.6	56.8	65.1	$157.47	$2.42	44.4	$405.10	$9.13	49.3	$49.19	$1.00
10	87.3	46.8	57.6	$129.58	$2.25	39.3	$333.36	$8.49	43.6	$40.48	$0.93
11	1.1	3.1	0.7	$8.47	$11.99	0.5	$21.78	$45.23	0.5	$2.64	$4.94
12	138.6	83.5	91.5	$231.29	$2.53	62.4	$595.01	$9.54	69.3	$72.25	$1.04
13	75.9	98.0	50.1	$271.54	$5.42	34.2	$698.55	$20.45	38.0	$84.82	$2.23
14	20.3	64.4	13.4	$178.34	$13.29	9.1	$458.78	$50.15	10.2	$55.71	$5.48
15	27.3	31.8	18.0	$88.20	$4.90	12.3	$226.89	$18.49	13.6	$27.55	$2.02
16	112.8	429.5	74.4	$1,189.67	$15.99	50.7	$3,060.50	$60.32	56.4	$371.63	$6.59
17	93.5	71.0	61.7	$196.74	$3.19	42.1	$506.14	$12.03	46.7	$61.46	$1.32
18	36.1	20.8	23.8	$57.65	$2.42	16.3	$148.30	$9.12	18.1	$18.01	$1.00
19	28.3	21.6	18.7	$59.73	$3.19	12.7	$153.66	$12.05	14.2	$18.66	$1.32
20	125.8	72.9	83.0	$201.93	$2.43	56.6	$519.48	$9.18	62.9	$63.08	$1.00
21	239.1	163.1	157.8	$451.69	$2.86	107.6	$1,162.01	$10.80	119.6	$141.10	$1.18
22	47.4	29.6	31.3	$82.05	$2.62	21.3	$211.08	$9.89	23.7	$25.63	$1.08
23	34.6	61.5	22.8	$170.38	$7.46	15.6	$438.33	$28.14	17.3	$53.23	$3.08
24	266.3	822.5	175.8	$2,278.26	$12.96	119.8	$5,860.96	$48.90	133.2	$711.69	$5.34
25	94.2	84.2	62.1	$233.22	$3.75	42.4	$599.98	$14.16	47.1	$72.85	$1.55
26	39.9	22.9	26.3	$63.37	$2.41	18.0	$163.03	$9.08	19.9	$19.80	$0.99
27	13.3	32.8	8.8	$90.99	$10.33	6.0	$234.07	$38.99	6.7	$28.42	$4.26
28	46.0	35.6	30.3	$98.65	$3.25	20.7	$253.78	$12.27	23.0	$30.82	$1.34
29	19.7	13.9	13.0	$38.54	$2.96	8.9	$99.15	$11.17	9.9	$12.04	$1.22

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
30	11.8	11.2	7.8	$31.12	$4.00	5.3	$80.06	$15.07	5.9	$9.72	$1.65
31	14.7	10.7	9.7	$29.64	$3.06	6.6	$76.25	$11.54	7.3	$9.26	$1.26
32	3.8	11.8	2.5	$32.61	$12.95	1.7	$83.89	$48.87	1.9	$10.19	$5.34
33	7.8	4.9	5.1	$13.69	$2.67	3.5	$35.23	$10.07	3.9	$4.28	$1.10
34	10.3	21.4	6.8	$59.41	$8.73	4.6	$152.84	$32.95	5.2	$18.56	$3.60
35	1.1	3.3	0.7	$9.12	$12.95	0.5	$23.46	$48.87	0.5	$2.85	$5.34
36	48.3	26.1	31.9	$72.18	$2.26	21.7	$185.69	$8.55	24.1	$22.55	$0.93
37	49.5	27.9	32.7	$77.38	$2.37	22.3	$199.07	$8.93	24.8	$24.17	$0.98
38	85.4	45.2	56.4	$125.12	$2.22	38.4	$321.89	$8.37	42.7	$39.09	$0.92
39	107.4	69.5	70.9	$192.65	$2.72	48.3	$495.59	$10.26	53.7	$60.18	$1.12
40	40.7	27.7	26.9	$76.60	$2.85	18.3	$197.06	$10.75	20.4	$23.93	$1.18
41	50.0	91.7	33.0	$254.00	$7.70	22.5	$653.43	$29.05	25.0	$79.34	$3.17
42	4.1	4.6	2.7	$12.63	$4.71	1.8	$32.50	$17.77	2.0	$3.95	$1.94
43	13.2	6.5	8.7	$17.95	$2.06	5.9	$46.18	$7.78	6.6	$5.61	$0.85
44	83.2	66.0	54.9	$182.88	$3.33	37.4	$470.48	$12.56	41.6	$57.13	$1.37
45	124.0	67.0	81.9	$185.50	$2.27	55.8	$477.20	$8.55	62.0	$57.95	$0.93
46	108.6	58.0	71.7	$160.73	$2.24	48.9	$413.50	$8.46	54.3	$50.21	$0.92
47	15.6	22.2	10.3	$61.39	$5.95	7.0	$157.93	$22.45	7.8	$19.18	$2.45
48	9.6	7.6	6.4	$21.02	$3.31	4.3	$54.08	$12.49	4.8	$6.57	$1.37
49	7.9	6.3	5.2	$17.48	$3.36	3.5	$44.96	$12.67	3.9	$5.46	$1.38
50	1.3	3.4	0.8	$9.50	$11.36	0.6	$24.45	$42.86	0.6	$2.97	$4.68
51	71.4	86.6	47.2	$239.85	$5.09	32.2	$617.04	$19.19	35.7	$74.93	$2.10
52	109.4	60.5	72.2	$167.50	$2.32	49.2	$430.91	$8.76	54.7	$52.32	$0.96
53	7.4	3.9	4.9	$10.93	$2.23	3.3	$28.13	$8.43	3.7	$3.42	$0.92
54	19.3	14.6	12.7	$40.40	$3.18	8.7	$103.94	$12.00	9.6	$12.62	$1.31
55	16.1	49.7	10.6	$137.70	$12.95	7.2	$354.23	$48.88	8.1	$43.01	$5.34
56	180.5	96.3	119.1	$266.70	$2.24	81.2	$686.09	$8.45	90.2	$83.31	$0.92
57	7.9	10.8	5.2	$29.86	$5.72	3.6	$76.81	$21.59	4.0	$9.33	$2.36
58	156.3	147.8	103.1	$409.32	$3.97	70.3	$1,053.00	$14.97	78.1	$127.86	$1.64
59	9.0	5.1	5.9	$14.26	$2.40	4.0	$36.69	$9.07	4.5	$4.46	$0.99
60	6.0	11.6	3.9	$32.22	$8.17	2.7	$82.88	$30.84	3.0	$10.06	$3.37

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
61	8.2	25.2	5.4	$69.71	$12.95	3.7	$179.33	$48.87	4.1	$21.78	$5.34
62	11.8	40.6	7.8	$112.32	$14.40	5.3	$288.96	$54.32	5.9	$35.09	$5.94
63	9.3	5.0	6.2	$13.75	$2.23	4.2	$35.38	$8.43	4.7	$4.30	$0.92
64	189.5	112.1	125.1	$310.41	$2.48	85.3	$798.55	$9.36	94.8	$96.97	$1.02
65	151.1	347.1	99.7	$961.38	$9.64	68.0	$2,473.22	$36.38	75.5	$300.32	$3.98
66	9.5	6.4	6.3	$17.83	$2.83	4.3	$45.86	$10.69	4.8	$5.57	$1.17
67	111.6	68.4	73.7	$189.48	$2.57	50.2	$487.44	$9.71	55.8	$59.19	$1.06
68	9.0	5.0	6.0	$13.87	$2.33	4.1	$35.67	$8.77	4.5	$4.33	$0.96
69	116.0	96.8	76.5	$268.22	$3.50	52.2	$690.03	$13.22	58.0	$83.79	$1.45
70	36.6	20.2	24.1	$56.06	$2.32	16.5	$144.22	$8.76	18.3	$17.51	$0.96
71	55.3	29.2	36.5	$80.79	$2.22	24.9	$207.85	$8.36	27.6	$25.24	$0.91
72	14.3	8.9	9.5	$24.57	$2.60	6.4	$63.20	$9.80	7.2	$7.67	$1.07
73	83.8	51.8	55.3	$143.49	$2.60	37.7	$369.14	$9.79	41.9	$44.82	$1.07
74	4.4	3.3	2.9	$9.22	$3.18	2.0	$23.73	$12.01	2.2	$2.88	$1.31
75	72.9	48.5	48.1	$134.37	$2.79	32.8	$345.69	$10.54	36.5	$41.98	$1.15
76	103.1	70.4	68.0	$195.01	$2.87	46.4	$501.69	$10.82	51.5	$60.92	$1.18
77	72.3	51.8	47.7	$143.41	$3.00	32.5	$368.94	$11.33	36.2	$44.80	$1.24
78	71.3	42.9	47.1	$118.94	$2.53	32.1	$305.98	$9.54	35.6	$37.15	$1.04
79	101.5	316.0	67.0	$875.19	$13.07	45.7	$2,251.48	$49.32	50.7	$273.39	$5.39
80	85.2	55.1	56.3	$152.73	$2.72	38.4	$392.92	$10.24	42.6	$47.71	$1.12
81	39.8	27.6	26.2	$76.42	$2.91	17.9	$196.59	$10.99	19.9	$23.87	$1.20
82	238.1	253.8	157.2	$703.07	$4.47	107.1	$1,808.69	$16.88	119.1	$219.63	$1.84
83	339.2	437.2	223.8	$1,211.09	$5.41	152.6	$3,115.60	$20.41	169.6	$378.32	$2.23
84	53.9	230.1	35.6	$637.45	$17.92	24.3	$1,639.87	$67.61	27.0	$199.13	$7.39
85	18.7	15.6	12.4	$43.33	$3.51	8.4	$111.48	$13.23	9.4	$13.54	$1.45
86	0.9	2.5	0.6	$7.03	$11.61	0.4	$18.10	$43.80	0.5	$2.20	$4.79
87	5.0	3.2	3.3	$8.93	$2.70	2.3	$22.97	$10.17	2.5	$2.79	$1.11
88	134.7	102.3	88.9	$283.37	$3.19	60.6	$728.98	$12.02	67.4	$88.52	$1.31
89	177.2	168.1	116.9	$465.75	$3.98	79.7	$1,198.17	$15.03	88.6	$145.49	$1.64
90	224.6	150.1	148.2	$415.69	$2.80	101.1	$1,069.38	$10.58	112.3	$129.85	$1.16
91	10.5	7.8	7.0	$21.64	$3.11	4.7	$55.67	$11.75	5.3	$6.76	$1.28

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
92	12.7	27.8	8.4	$77.05	$9.20	5.7	$198.22	$34.71	6.3	$24.07	$3.79
93	28.7	18.2	18.9	$50.36	$2.66	12.9	$129.56	$10.04	14.3	$15.73	$1.10
94	5.1	3.7	3.4	$10.38	$3.09	2.3	$26.70	$11.66	2.5	$3.24	$1.27
95	4.0	3.0	2.6	$8.19	$3.11	1.8	$21.08	$11.74	2.0	$2.56	$1.28
96	47.1	32.6	31.1	$90.29	$2.91	21.2	$232.29	$10.97	23.5	$28.21	$1.20
97	70.6	112.7	46.6	$312.31	$6.70	31.8	$803.43	$25.30	35.3	$97.56	$2.76
98	16.6	30.2	11.0	$83.61	$7.63	7.5	$215.09	$28.80	8.3	$26.12	$3.15
99	203.7	169.5	134.4	$469.64	$3.49	91.6	$1,208.18	$13.18	101.8	$146.71	$1.44
100	222.4	132.6	146.8	$367.39	$2.50	100.1	$945.14	$9.45	111.2	$114.77	$1.03
101	14.9	10.0	9.9	$27.82	$2.82	6.7	$71.58	$10.65	7.5	$8.69	$1.16
102	515.3	424.4	340.1	$1,175.71	$3.46	231.9	$3,024.60	$13.04	257.6	$367.27	$1.43
103	49.0	30.9	32.3	$85.65	$2.65	22.0	$220.33	$10.00	24.5	$26.75	$1.09
104	81.4	60.4	53.7	$167.39	$3.11	36.6	$430.62	$11.75	40.7	$52.29	$1.28
105	226.4	133.1	149.4	$368.79	$2.47	101.9	$948.74	$9.31	113.2	$115.20	$1.02
106	50.5	34.6	33.3	$95.78	$2.87	22.7	$246.40	$10.84	25.2	$29.92	$1.19
107	144.4	280.9	95.3	$778.17	$8.16	65.0	$2,001.90	$30.80	72.2	$243.09	$3.37
108	7.1	8.1	4.7	$22.55	$4.81	3.2	$58.02	$18.16	3.6	$7.05	$1.98
109	34.0	141.4	22.4	$391.74	$17.45	15.3	$1,007.78	$65.85	17.0	$122.37	$7.20
110	34.3	122.2	22.6	$338.42	$14.96	15.4	$870.60	$56.44	17.1	$105.72	$6.17
111	23.3	16.7	15.4	$46.36	$3.01	10.5	$119.27	$11.35	11.7	$14.48	$1.24
112	196.8	123.7	129.9	$342.61	$2.64	88.5	$881.37	$9.95	98.4	$107.02	$1.09
113	13.6	11.0	9.0	$30.58	$3.40	6.1	$78.68	$12.82	6.8	$9.55	$1.40
114	24.6	18.0	16.3	$49.87	$3.07	11.1	$128.30	$11.58	12.3	$15.58	$1.27
115	70.7	39.2	46.7	$108.57	$2.33	31.8	$279.29	$8.77	35.4	$33.91	$0.96
116	166.7	98.9	110.0	$274.05	$2.49	75.0	$705.01	$9.40	83.4	$85.61	$1.03
117	20.5	27.5	13.5	$76.16	$5.63	9.2	$195.92	$21.23	10.3	$23.79	$2.32
118	10.4	5.9	6.8	$16.43	$2.40	4.7	$42.26	$9.05	5.2	$5.13	$0.99
119	106.7	66.3	70.4	$183.60	$2.61	48.0	$472.33	$9.84	53.3	$57.35	$1.08
120	81.3	55.4	53.7	$153.51	$2.86	36.6	$394.92	$10.79	40.7	$47.95	$1.18
121	810.9	608.0	535.2	$1,684.26	$3.15	364.9	$4,332.85	$11.87	405.4	$526.13	$1.30
122	117.4	75.0	77.5	$207.81	$2.68	52.8	$534.60	$10.12	58.7	$64.92	$1.11

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
123	47.6	29.7	31.4	$82.40	$2.62	21.4	$211.97	$9.90	23.8	$25.74	$1.08
124	27.1	64.3	17.9	$178.00	$9.94	12.2	$457.92	$37.50	13.6	$55.60	$4.10
125	169.8	175.2	112.1	$485.17	$4.33	76.4	$1,248.14	$16.34	84.9	$151.56	$1.79
126	73.0	42.9	48.2	$118.70	$2.46	32.8	$305.35	$9.30	36.5	$37.08	$1.02
127	397.4	265.8	262.3	$736.13	$2.81	178.9	$1,893.74	$10.59	198.7	$229.95	$1.16
128	144.9	80.5	95.7	$222.98	$2.33	65.2	$573.62	$8.80	72.5	$69.65	$0.96
129	117.0	111.7	77.2	$309.37	$4.01	52.6	$795.87	$15.12	58.5	$96.64	$1.65
130	232.4	723.0	153.4	$2,002.75	$13.06	104.6	$5,152.21	$49.27	116.2	$625.63	$5.38
131	179.3	107.5	118.4	$297.65	$2.51	80.7	$765.73	$9.49	89.7	$92.98	$1.04
132	86.0	235.5	56.8	$652.35	$11.49	38.7	$1,678.21	$43.35	43.0	$203.78	$4.74
133	102.2	61.8	67.5	$171.08	$2.54	46.0	$440.10	$9.57	51.1	$53.44	$1.05
134	444.1	335.7	293.1	$929.76	$3.17	199.9	$2,391.86	$11.97	222.1	$290.44	$1.31
135	1.6	1.6	1.1	$4.37	$4.16	0.7	$11.25	$15.71	0.8	$1.37	$1.72
136	35.8	31.3	23.6	$86.69	$3.67	16.1	$223.03	$13.84	17.9	$27.08	$1.51
137	49.7	26.9	32.8	$74.44	$2.27	22.4	$191.51	$8.56	24.8	$23.25	$0.94
138	11.7	9.9	7.7	$27.33	$3.53	5.3	$70.31	$13.32	5.9	$8.54	$1.46
139	53.5	40.9	35.3	$113.35	$3.21	24.1	$291.60	$12.12	26.7	$35.41	$1.32
140	6.9	4.8	4.6	$13.25	$2.91	3.1	$34.09	$10.98	3.5	$4.14	$1.20
141	21.9	15.3	14.4	$42.32	$2.93	9.8	$108.88	$11.06	10.9	$13.22	$1.21
142	31.0	52.2	20.5	$144.46	$7.06	13.9	$371.62	$26.65	15.5	$45.13	$2.91
143	17.8	15.8	11.8	$43.82	$3.73	8.0	$112.74	$14.06	8.9	$13.69	$1.54
144	7.6	17.0	5.0	$47.21	$9.43	3.4	$121.45	$35.57	3.8	$14.75	$3.89
145	150.6	91.4	99.4	$253.20	$2.55	67.8	$651.38	$9.61	75.3	$79.10	$1.05
146	463.5	291.9	305.9	$808.58	$2.64	208.6	$2,080.13	$9.97	231.8	$252.59	$1.09
147	1.7	5.2	1.1	$14.42	$12.95	0.8	$37.09	$48.87	0.8	$4.50	$5.34
148	8.8	10.6	5.8	$29.24	$5.05	3.9	$75.22	$19.06	4.4	$9.13	$2.08
149	1.4	2.1	0.9	$5.74	$6.32	0.6	$14.76	$23.85	0.7	$1.79	$2.61
150	42.2	41.0	27.8	$113.57	$4.08	19.0	$292.17	$15.39	21.1	$35.48	$1.68
151	18.7	14.0	12.3	$38.82	$3.15	8.4	$99.86	$11.89	9.3	$12.13	$1.30
152	15.9	8.6	10.5	$23.85	$2.28	7.1	$61.35	$8.60	7.9	$7.45	$0.94
153	239.8	356.8	158.3	$988.39	$6.24	107.9	$2,542.71	$23.56	119.9	$308.76	$2.57

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
154	660.8	782.5	436.1	$2,167.40	$4.97	297.4	$5,575.78	$18.75	330.4	$677.06	$2.05
155	103.9	65.6	68.6	$181.59	$2.65	46.8	$467.16	$9.99	52.0	$56.73	$1.09
156	46.9	26.6	31.0	$73.55	$2.37	21.1	$189.22	$8.96	23.5	$22.98	$0.98
157	58.4	35.1	38.6	$97.17	$2.52	26.3	$249.98	$9.51	29.2	$30.35	$1.04
158	14.6	9.2	9.6	$25.36	$2.64	6.6	$65.25	$9.96	7.3	$7.92	$1.09
159	6.5	3.4	4.3	$9.53	$2.23	2.9	$24.51	$8.43	3.2	$2.98	$0.92
160	2.3	2.5	1.5	$6.85	$4.52	1.0	$17.62	$17.05	1.1	$2.14	$1.86
161	27.2	19.9	18.0	$55.24	$3.07	12.3	$142.11	$11.60	13.6	$17.26	$1.27
162	468.5	1109.4	309.2	$3,072.94	$9.94	210.8	$7,905.34	$37.49	234.3	$959.93	$4.10
163	34.3	20.5	22.6	$56.82	$2.51	15.4	$146.17	$9.48	17.1	$17.75	$1.04
164	37.1	22.4	24.5	$62.04	$2.54	16.7	$159.61	$9.57	18.5	$19.38	$1.05
165	36.3	21.6	23.9	$59.79	$2.50	16.3	$153.80	$9.42	18.1	$18.68	$1.03
166	20.4	11.8	13.4	$32.68	$2.43	9.2	$84.06	$9.18	10.2	$10.21	$1.00
167	115.0	72.1	75.9	$199.79	$2.63	51.8	$513.98	$9.93	57.5	$62.41	$1.09
168	14.2	24.2	9.4	$66.94	$7.12	6.4	$172.20	$26.87	7.1	$20.91	$2.94
169	0.5	0.4	0.3	$1.02	$3.24	0.2	$2.63	$12.22	0.2	$0.32	$1.33
170	3.2	2.9	2.1	$8.10	$3.81	1.4	$20.85	$14.38	1.6	$2.53	$1.57
171	95.8	172.3	63.2	$477.38	$7.55	43.1	$1,228.09	$28.49	47.9	$149.13	$3.11
172	34.4	44.5	22.7	$123.31	$5.43	15.5	$317.22	$20.49	17.2	$38.52	$2.24
173	194.5	116.2	128.4	$321.90	$2.51	87.5	$828.11	$9.46	97.3	$100.56	$1.03
174	8.2	6.5	5.4	$17.97	$3.31	3.7	$46.22	$12.49	4.1	$5.61	$1.36
175	11.4	13.1	7.5	$36.35	$4.83	5.1	$93.50	$18.24	5.7	$11.35	$1.99
176	2.8	4.3	1.8	$11.95	$6.46	1.3	$30.74	$24.38	1.4	$3.73	$2.66
177	42.1	38.7	27.8	$107.22	$3.86	19.0	$275.82	$14.55	21.1	$33.49	$1.59
178	79.0	47.5	52.1	$131.66	$2.53	35.5	$338.69	$9.53	39.5	$41.13	$1.04
179	23.5	14.4	15.5	$39.90	$2.57	10.6	$102.65	$9.70	11.8	$12.46	$1.06
180	0.1	0.1	0.1	$0.21	$3.24	0.0	$0.55	$12.24	0.1	$0.07	$1.34
181	30.1	17.6	19.9	$48.76	$2.45	13.5	$125.43	$9.26	15.1	$15.23	$1.01
182	14.0	19.6	9.2	$54.21	$5.88	6.3	$139.47	$22.19	7.0	$16.94	$2.43
183	11.0	9.3	7.3	$25.72	$3.54	5.0	$66.16	$13.37	5.5	$8.03	$1.46
184	44.4	43.0	29.3	$118.97	$4.06	20.0	$306.07	$15.32	22.2	$37.17	$1.67

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
185	12.9	9.9	8.5	$27.34	$3.22	5.8	$70.34	$12.14	6.4	$8.54	$1.33
186	15.8	9.2	10.4	$25.62	$2.45	7.1	$65.90	$9.26	7.9	$8.00	$1.01
187	76.6	46.7	50.6	$129.42	$2.56	34.5	$332.94	$9.66	38.3	$40.43	$1.06
188	148.4	235.5	98.0	$652.26	$6.66	66.8	$1,677.97	$25.13	74.2	$203.75	$2.75
189	6.8	13.0	4.5	$35.95	$8.07	3.0	$92.48	$30.45	3.4	$11.23	$3.33
190	3.2	5.7	2.1	$15.76	$7.51	1.4	$40.55	$28.35	1.6	$4.92	$3.10
191	31.5	30.9	20.8	$85.70	$4.12	14.2	$220.47	$15.55	15.8	$26.77	$1.70
192	104.2	64.7	68.8	$179.12	$2.60	46.9	$460.79	$9.83	52.1	$55.95	$1.07
193	34.4	21.8	22.7	$60.36	$2.66	15.5	$155.28	$10.04	17.2	$18.86	$1.10
194	28.4	16.4	18.7	$45.45	$2.42	12.8	$116.93	$9.15	14.2	$14.20	$1.00
195	14.4	12.5	9.5	$34.63	$3.65	6.5	$89.09	$13.77	7.2	$10.82	$1.50
196	13.2	15.2	8.7	$42.21	$4.86	5.9	$108.59	$18.34	6.6	$13.19	$2.00
197	92.3	72.2	60.9	$199.92	$3.28	41.5	$514.30	$12.38	46.2	$62.45	$1.35
198	84.0	102.5	55.4	$283.82	$5.12	37.8	$730.16	$19.32	42.0	$88.66	$2.11
199	175.3	147.8	115.7	$409.39	$3.54	78.9	$1,053.18	$13.35	87.6	$127.89	$1.46
200	86.1	288.4	56.8	$798.95	$14.06	38.7	$2,055.35	$53.07	43.0	$249.58	$5.80
201	16.4	12.9	10.8	$35.70	$3.30	7.4	$91.85	$12.43	8.2	$11.15	$1.36
202	56.9	37.2	37.6	$103.09	$2.74	25.6	$265.20	$10.35	28.5	$32.20	$1.13
203	142.5	95.6	94.1	$264.74	$2.81	64.1	$681.06	$10.62	71.3	$82.70	$1.16
204	116.6	205.0	76.9	$567.81	$7.38	52.5	$1,460.73	$27.85	58.3	$177.37	$3.04
205	26.4	16.9	17.4	$46.68	$2.68	11.9	$120.10	$10.12	13.2	$14.58	$1.11
206	218.0	259.6	143.9	$719.05	$5.00	98.1	$1,849.80	$18.86	109.0	$224.62	$2.06
207	277.0	210.4	182.8	$582.74	$3.19	124.7	$1,499.14	$12.03	138.5	$182.04	$1.31
208	27.5	14.8	18.1	$40.89	$2.26	12.4	$105.18	$8.51	13.7	$12.77	$0.93
209	82.9	63.4	54.7	$175.70	$3.21	37.3	$451.99	$12.12	41.4	$54.88	$1.32
210	23.3	17.4	15.4	$48.06	$3.13	10.5	$123.63	$11.81	11.6	$15.01	$1.29
211	18.3	12.5	12.1	$34.61	$2.87	8.2	$89.03	$10.81	9.1	$10.81	$1.18
212	155.9	107.5	102.9	$297.78	$2.89	70.2	$766.05	$10.92	78.0	$93.02	$1.19
213	43.6	34.0	28.8	$94.22	$3.27	19.6	$242.40	$12.35	21.8	$29.43	$1.35
214	110.4	65.5	72.9	$181.57	$2.49	49.7	$467.10	$9.40	55.2	$56.72	$1.03
215	131.8	81.2	87.0	$225.06	$2.59	59.3	$578.98	$9.76	65.9	$70.30	$1.07

Table A1-*Continued*

Farmer	Current Load	Total Acreage	Pot. Red. From Cons. Til.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. From Nut. Mngt. Plan.	Total Annual Cost	Cost per Unit of Reduction	Pot. Red. from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
216	28.4	27.2	18.8	$75.21	$4.01	12.8	$193.49	$15.12	14.2	$23.50	$1.65
217	230.7	135.1	152.3	$374.27	$2.46	103.8	$962.84	$9.27	115.4	$116.92	$1.01
218	32.1	30.3	21.2	$83.86	$3.96	14.5	$215.73	$14.93	16.1	$26.20	$1.63

Table A2. Individual Current Loads, Target Loads, Potential Reduction from Conservation Tillage and Corresponding Cost Information

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
1	38.5	33.6	0.0017	8.6	29.9	25.4	$93.16	$3.67
2	31.0	17.4	0.0014	6.9	24.0	20.5	$48.18	$2.36
3	23.4	13.6	0.0010	5.2	18.1	15.4	$37.60	$2.44
4	14.7	11.8	0.0007	3.3	11.4	9.7	$32.81	$3.37
5	12.4	12.6	0.0006	2.8	9.6	8.2	$35.03	$4.29
6	51.6	35.6	0.0023	11.6	40.1	34.1	$98.64	$2.90
7	42.0	23.4	0.0019	9.4	32.6	27.7	$64.93	$2.34
8	33.1	28.4	0.0015	7.4	25.7	21.8	$78.77	$3.61
9	98.6	56.8	0.0044	22.1	76.5	65.1	$157.47	$2.42
10	87.3	46.8	0.0039	19.5	67.7	57.6	$129.58	$2.25
11	1.1	3.1	0.0000	0.2	0.8	0.7	$8.47	$11.99
12	138.6	83.5	0.0062	31.0	107.6	91.5	$231.29	$2.53
13	75.9	98.0	0.0034	17.0	58.9	50.1	$271.54	$5.42
14	20.3	64.4	0.0009	4.6	15.8	13.4	$178.34	$13.29
15	27.3	31.8	0.0012	6.1	21.2	18.0	$88.20	$4.90
16	112.8	429.5	0.0050	25.2	87.5	74.4	$1,189.67	$15.99
17	93.5	71.0	0.0042	20.9	72.5	61.7	$196.74	$3.19
18	36.1	20.8	0.0016	8.1	28.0	23.8	$57.65	$2.42
19	28.3	21.6	0.0013	6.3	22.0	18.7	$59.73	$3.19
20	125.8	72.9	0.0056	28.2	97.6	83.0	$201.93	$2.43
21	239.1	163.1	0.0106	53.5	185.6	157.8	$451.69	$2.86
22	47.4	29.6	0.0021	10.6	36.8	31.3	$82.05	$2.62
23	34.6	61.5	0.0015	7.7	26.9	22.8	$170.38	$7.46
24	266.3	822.5	0.0119	59.6	206.7	175.8	$2,278.26	$12.96
25	94.2	84.2	0.0042	21.1	73.1	62.1	$233.22	$3.75
26	39.9	22.9	0.0018	8.9	31.0	26.3	$63.37	$2.41
27	13.3	32.8	0.0006	3.0	10.4	8.8	$90.99	$10.33
28	46.0	35.6	0.0020	10.3	35.7	30.3	$98.65	$3.25
29	19.7	13.9	0.0009	4.4	15.3	13.0	$38.54	$2.96
30	11.8	11.2	0.0005	2.6	9.2	7.8	$31.12	$4.00
31	14.7	10.7	0.0007	3.3	11.4	9.7	$29.64	$3.06
32	3.8	11.8	0.0002	0.9	3.0	2.5	$32.61	$12.95

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
33	7.8	4.9	0.0003	1.7	6.0	5.1	$13.69	$2.67
34	10.3	21.4	0.0005	2.3	8.0	6.8	$59.41	$8.73
35	1.1	3.3	0.0000	0.2	0.8	0.7	$9.12	$12.95
36	48.3	26.1	0.0021	10.8	37.5	31.9	$72.18	$2.26
37	49.5	27.9	0.0022	11.1	38.4	32.7	$77.38	$2.37
38	85.4	45.2	0.0038	19.1	66.3	56.4	$125.12	$2.22
39	107.4	69.5	0.0048	24.0	83.3	70.9	$192.65	$2.72
40	40.7	27.7	0.0018	9.1	31.6	26.9	$76.60	$2.85
41	50.0	91.7	0.0022	11.2	38.8	33.0	$254.00	$7.70
42	4.1	4.6	0.0002	0.9	3.2	2.7	$12.63	$4.71
43	13.2	6.5	0.0006	3.0	10.2	8.7	$17.95	$2.06
44	83.2	66.0	0.0037	18.6	64.6	54.9	$182.88	$3.33
45	124.0	67.0	0.0055	27.8	96.3	81.9	$185.50	$2.27
46	108.6	58.0	0.0048	24.3	84.3	71.7	$160.73	$2.24
47	15.6	22.2	0.0007	3.5	12.1	10.3	$61.39	$5.95
48	9.6	7.6	0.0004	2.2	7.5	6.3	$21.02	$3.31
49	7.9	6.3	0.0004	1.8	6.1	5.2	$17.48	$3.36
50	1.3	3.4	0.0001	0.3	1.0	0.8	$9.50	$11.36
51	71.4	86.6	0.0032	16.0	55.4	47.2	$239.85	$5.09
52	109.4	60.5	0.0049	24.5	84.9	72.2	$167.50	$2.32
53	7.4	3.9	0.0003	1.7	5.8	4.9	$10.93	$2.23
54	19.3	14.6	0.0009	4.3	14.9	12.7	$40.40	$3.18
55	16.1	49.7	0.0007	3.6	12.5	10.6	$137.70	$12.95
56	180.5	96.3	0.0080	40.4	140.1	119.1	$266.70	$2.24
57	7.9	10.8	0.0004	1.8	6.1	5.2	$29.86	$5.72
58	156.3	147.8	0.0070	35.0	121.3	103.1	$409.32	$3.97
59	9.0	5.1	0.0004	2.0	7.0	5.9	$14.26	$2.40
60	6.0	11.6	0.0003	1.3	4.6	3.9	$32.22	$8.17
61	8.2	25.2	0.0004	1.8	6.3	5.4	$69.71	$12.95
62	11.8	40.6	0.0005	2.6	9.2	7.8	$112.32	$14.40
63	9.3	5.0	0.0004	2.1	7.2	6.2	$13.75	$2.23
64	189.5	112.1	0.0084	42.4	147.1	125.1	$310.41	$2.48
65	151.1	347.1	0.0067	33.8	117.2	99.7	$961.38	$9.64

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
66	9.5	6.4	0.0004	2.1	7.4	6.3	$17.83	$2.83
67	111.6	68.4	0.0050	25.0	86.6	73.6	$189.48	$2.57
68	9.0	5.0	0.0004	2.0	7.0	6.0	$13.87	$2.33
69	116.0	96.8	0.0052	26.0	90.0	76.5	$268.22	$3.50
70	36.6	20.2	0.0016	8.2	28.4	24.1	$56.06	$2.32
71	55.3	29.2	0.0025	12.4	42.9	36.5	$80.79	$2.22
72	14.3	8.9	0.0006	3.2	11.1	9.5	$24.57	$2.60
73	83.8	51.8	0.0037	18.8	65.0	55.3	$143.49	$2.60
74	4.4	3.3	0.0002	1.0	3.4	2.9	$9.22	$3.18
75	72.9	48.5	0.0032	16.3	56.6	48.1	$134.37	$2.79
76	103.1	70.4	0.0046	23.1	80.0	68.0	$195.01	$2.87
77	72.3	51.8	0.0032	16.2	56.1	47.7	$143.41	$3.00
78	71.3	42.9	0.0032	16.0	55.3	47.1	$118.94	$2.53
79	101.5	316.0	0.0045	22.7	78.7	67.0	$875.19	$13.07
80	85.2	55.1	0.0038	19.1	66.1	56.3	$152.73	$2.72
81	39.8	27.6	0.0018	8.9	30.9	26.2	$76.42	$2.91
82	238.1	253.8	0.0106	53.3	184.8	157.1	$703.07	$4.47
83	339.2	437.2	0.0151	75.9	263.2	223.8	$1,211.09	$5.41
84	53.9	230.1	0.0024	12.1	41.8	35.6	$637.45	$17.92
85	18.7	15.6	0.0008	4.2	14.5	12.4	$43.33	$3.51
86	0.9	2.5	0.0000	0.2	0.7	0.6	$7.03	$11.61
87	5.0	3.2	0.0002	1.1	3.9	3.3	$8.93	$2.70
88	134.7	102.3	0.0060	30.2	104.6	88.9	$283.37	$3.19
89	177.2	168.1	0.0079	39.7	137.5	116.9	$465.75	$3.98
90	224.6	150.1	0.0100	50.3	174.3	148.2	$415.69	$2.80
91	10.5	7.8	0.0005	2.4	8.2	7.0	$21.64	$3.11
92	12.7	27.8	0.0006	2.8	9.8	8.4	$77.05	$9.20
93	28.7	18.2	0.0013	6.4	22.3	18.9	$50.36	$2.66
94	5.1	3.7	0.0002	1.1	4.0	3.4	$10.38	$3.09
95	4.0	3.0	0.0002	0.9	3.1	2.6	$8.19	$3.11
96	47.1	32.6	0.0021	10.5	36.5	31.1	$90.29	$2.91
97	70.6	112.7	0.0031	15.8	54.8	46.6	$312.31	$6.70
98	16.6	30.2	0.0007	3.7	12.9	11.0	$83.61	$7.63

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
99	203.7	169.5	0.0091	45.6	158.1	134.4	$469.64	$3.49
100	222.4	132.6	0.0099	49.8	172.6	146.8	$367.39	$2.50
101	14.9	10.0	0.0007	3.3	11.6	9.9	$27.82	$2.82
102	515.3	424.4	0.0229	115.4	399.9	340.1	$1,175.71	$3.46
103	49.0	30.9	0.0022	11.0	38.0	32.3	$85.65	$2.65
104	81.4	60.4	0.0036	18.2	63.2	53.7	$167.39	$3.11
105	226.4	133.1	0.0101	50.7	175.7	149.4	$368.79	$2.47
106	50.5	34.6	0.0022	11.3	39.2	33.3	$95.78	$2.87
107	144.4	280.9	0.0064	32.3	112.1	95.3	$778.17	$8.16
108	7.1	8.1	0.0003	1.6	5.5	4.7	$22.55	$4.81
109	34.0	141.4	0.0015	7.6	26.4	22.4	$391.74	$17.45
110	34.3	122.2	0.0015	7.7	26.6	22.6	$338.42	$14.96
111	23.3	16.7	0.0010	5.2	18.1	15.4	$46.36	$3.01
112	196.8	123.7	0.0088	44.1	152.7	129.9	$342.61	$2.64
113	13.6	11.0	0.0006	3.1	10.6	9.0	$30.58	$3.40
114	24.6	18.0	0.0011	5.5	19.1	16.3	$49.87	$3.07
115	70.7	39.2	0.0031	15.8	54.9	46.7	$108.57	$2.33
116	166.7	98.9	0.0074	37.3	129.4	110.0	$274.05	$2.49
117	20.5	27.5	0.0009	4.6	15.9	13.5	$76.16	$5.63
118	10.4	5.9	0.0005	2.3	8.1	6.8	$16.43	$2.40
119	106.7	66.3	0.0047	23.9	82.8	70.4	$183.60	$2.61
120	81.3	55.4	0.0036	18.2	63.1	53.7	$153.51	$2.86
121	810.9	608.0	0.0361	181.6	629.3	535.2	$1,684.26	$3.15
122	117.4	75.0	0.0052	26.3	91.1	77.5	$207.81	$2.68
123	47.6	29.7	0.0021	10.7	36.9	31.4	$82.40	$2.62
124	27.1	64.3	0.0012	6.1	21.1	17.9	$178.00	$9.94
125	169.8	175.2	0.0076	38.0	131.8	112.1	$485.17	$4.33
126	73.0	42.9	0.0032	16.3	56.6	48.2	$118.70	$2.46
127	397.4	265.8	0.0177	89.0	308.5	262.3	$736.13	$2.81
128	144.9	80.5	0.0065	32.5	112.5	95.7	$222.98	$2.33
129	117.0	111.7	0.0052	26.2	90.8	77.2	$309.37	$4.01
130	232.4	723.0	0.0103	52.0	180.4	153.4	$2,002.75	$13.06
131	179.3	107.5	0.0080	40.2	139.2	118.4	$297.65	$2.51

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
132	86.0	235.5	0.0038	19.3	66.8	56.8	$652.35	$11.49
133	102.2	61.8	0.0046	22.9	79.3	67.5	$171.08	$2.54
134	444.1	335.7	0.0198	99.4	344.7	293.1	$929.76	$3.17
135	1.6	1.6	0.0001	0.4	1.2	1.1	$4.37	$4.16
136	35.8	31.3	0.0016	8.0	27.8	23.6	$86.69	$3.67
137	49.7	26.9	0.0022	11.1	38.6	32.8	$74.44	$2.27
138	11.7	9.9	0.0005	2.6	9.1	7.7	$27.33	$3.53
139	53.5	40.9	0.0024	12.0	41.5	35.3	$113.35	$3.21
140	6.9	4.8	0.0003	1.5	5.4	4.6	$13.25	$2.91
141	21.9	15.3	0.0010	4.9	17.0	14.4	$42.32	$2.93
142	31.0	52.2	0.0014	6.9	24.0	20.4	$144.46	$7.06
143	17.8	15.8	0.0008	4.0	13.8	11.8	$43.82	$3.73
144	7.6	17.0	0.0003	1.7	5.9	5.0	$47.21	$9.43
145	150.6	91.4	0.0067	33.7	116.9	99.4	$253.20	$2.55
146	463.5	291.9	0.0206	103.8	359.7	305.9	$808.58	$2.64
147	1.7	5.2	0.0001	0.4	1.3	1.1	$14.42	$12.95
148	8.8	10.6	0.0004	2.0	6.8	5.8	$29.24	$5.05
149	1.4	2.1	0.0001	0.3	1.1	0.9	$5.74	$6.32
150	42.2	41.0	0.0019	9.4	32.7	27.8	$113.57	$4.08
151	18.7	14.0	0.0008	4.2	14.5	12.3	$38.82	$3.15
152	15.9	8.6	0.0007	3.6	12.3	10.5	$23.85	$2.28
153	239.8	356.8	0.0107	53.7	186.1	158.3	$988.39	$6.24
154	660.8	782.5	0.0294	148.0	512.8	436.1	$2,167.40	$4.97
155	103.9	65.6	0.0046	23.3	80.7	68.6	$181.59	$2.65
156	46.9	26.6	0.0021	10.5	36.4	31.0	$73.55	$2.37
157	58.4	35.1	0.0026	13.1	45.3	38.6	$97.17	$2.52
158	14.6	9.2	0.0006	3.3	11.3	9.6	$25.36	$2.64
159	6.5	3.4	0.0003	1.4	5.0	4.3	$9.53	$2.23
160	2.3	2.5	0.0001	0.5	1.8	1.5	$6.85	$4.52
161	27.2	19.9	0.0012	6.1	21.1	18.0	$55.24	$3.07
162	468.5	1109.4	0.0209	104.9	363.6	309.2	$3,072.94	$9.94
163	34.3	20.5	0.0015	7.7	26.6	22.6	$56.82	$2.51
164	37.1	22.4	0.0016	8.3	28.8	24.5	$62.04	$2.54

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
165	36.3	21.6	0.0016	8.1	28.2	23.9	$59.79	$2.50
166	20.4	11.8	0.0009	4.6	15.8	13.4	$32.68	$2.43
167	115.0	72.1	0.0051	25.8	89.3	75.9	$199.79	$2.63
168	14.2	24.2	0.0006	3.2	11.1	9.4	$66.94	$7.12
169	0.5	0.4	0.0000	0.1	0.4	0.3	$1.02	$3.24
170	3.2	2.9	0.0001	0.7	2.5	2.1	$8.10	$3.81
171	95.8	172.3	0.0043	21.4	74.3	63.2	$477.38	$7.55
172	34.4	44.5	0.0015	7.7	26.7	22.7	$123.31	$5.43
173	194.5	116.2	0.0087	43.6	151.0	128.4	$321.90	$2.51
174	8.2	6.5	0.0004	1.8	6.4	5.4	$17.97	$3.31
175	11.4	13.1	0.0005	2.6	8.8	7.5	$36.35	$4.83
176	2.8	4.3	0.0001	0.6	2.2	1.8	$11.95	$6.46
177	42.1	38.7	0.0019	9.4	32.7	27.8	$107.22	$3.86
178	79.0	47.5	0.0035	17.7	61.3	52.1	$131.66	$2.53
179	23.5	14.4	0.0010	5.3	18.3	15.5	$39.90	$2.57
180	0.1	0.1	0.0000	0.0	0.1	0.1	$0.21	$3.24
181	30.1	17.6	0.0013	6.7	23.4	19.9	$48.76	$2.45
182	14.0	19.6	0.0006	3.1	10.8	9.2	$54.21	$5.88
183	11.0	9.3	0.0005	2.5	8.5	7.3	$25.72	$3.54
184	44.4	43.0	0.0020	9.9	34.5	29.3	$118.97	$4.06
185	12.9	9.9	0.0006	2.9	10.0	8.5	$27.34	$3.22
186	15.8	9.2	0.0007	3.5	12.3	10.4	$25.62	$2.45
187	76.6	46.7	0.0034	17.2	59.5	50.6	$129.42	$2.56
188	148.4	235.5	0.0066	33.2	115.2	98.0	$652.26	$6.66
189	6.8	13.0	0.0003	1.5	5.2	4.5	$35.95	$8.07
190	3.2	5.7	0.0001	0.7	2.5	2.1	$15.76	$7.51
191	31.5	30.9	0.0014	7.1	24.4	20.8	$85.70	$4.12
192	104.2	64.7	0.0046	23.3	80.9	68.8	$179.12	$2.60
193	34.4	21.8	0.0015	7.7	26.7	22.7	$60.36	$2.66
194	28.4	16.4	0.0013	6.4	22.0	18.7	$45.45	$2.42
195	14.4	12.5	0.0006	3.2	11.2	9.5	$34.63	$3.65
196	13.2	15.2	0.0006	2.9	10.2	8.7	$42.21	$4.86
197	92.3	72.2	0.0041	20.7	71.6	60.9	$199.92	$3.28

Table A2-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Conservation Tillage	Total Annual Cost	Average Cost per Unit of Reduction
198	84.0	102.5	0.0037	18.8	65.2	55.4	$283.82	$5.12
199	175.3	147.8	0.0078	39.2	136.0	115.7	$409.39	$3.54
200	86.1	288.4	0.0038	19.3	66.8	56.8	$798.95	$14.06
201	16.4	12.9	0.0007	3.7	12.7	10.8	$35.70	$3.30
202	56.9	37.2	0.0025	12.7	44.2	37.6	$103.09	$2.74
203	142.5	95.6	0.0063	31.9	110.6	94.1	$264.74	$2.81
204	116.6	205.0	0.0052	26.1	90.5	76.9	$567.81	$7.38
205	26.4	16.9	0.0012	5.9	20.5	17.4	$46.68	$2.68
206	218.0	259.6	0.0097	48.8	169.2	143.9	$719.05	$5.00
207	277.0	210.4	0.0123	62.0	215.0	182.8	$582.74	$3.19
208	27.5	14.8	0.0012	6.1	21.3	18.1	$40.89	$2.26
209	82.9	63.4	0.0037	18.6	64.3	54.7	$175.70	$3.21
210	23.3	17.3	0.0010	5.2	18.1	15.4	$48.06	$3.13
211	18.3	12.5	0.0008	4.1	14.2	12.1	$34.61	$2.87
212	155.9	107.5	0.0069	34.9	121.0	102.9	$297.78	$2.89
213	43.6	34.0	0.0019	9.8	33.8	28.8	$94.22	$3.27
214	110.4	65.5	0.0049	24.7	85.7	72.9	$181.57	$2.49
215	131.8	81.2	0.0059	29.5	102.3	87.0	$225.06	$2.59
216	28.4	27.2	0.0013	6.4	22.1	18.8	$75.21	$4.01
217	230.7	135.1	0.0103	51.7	179.0	152.3	$374.27	$2.46
218	32.1	30.3	0.0014	7.2	24.9	21.2	$83.86	$3.96

Table A3. Individual Farmer Current Loads, Target Loads, Potential Reductions from Nutrient Management Planning, and Cost Information

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
1	38.5	33.6	0.0017	8.6	29.9	17.3	$239.67	$13.84
2	31.0	17.4	0.0014	6.9	24.0	13.9	$123.94	$8.89
3	23.4	13.6	0.0010	5.2	18.1	10.5	$96.73	$9.20
4	14.7	11.8	0.0007	3.3	11.4	6.6	$84.41	$12.72
5	12.4	12.6	0.0006	2.8	9.6	5.6	$90.12	$16.18
6	51.6	35.6	0.0023	11.6	40.1	23.2	$253.76	$10.92
7	42.0	23.4	0.0019	9.4	32.6	18.9	$167.04	$8.84
8	33.1	28.4	0.0015	7.4	25.7	14.9	$202.64	$13.62
9	98.6	56.8	0.0044	22.1	76.5	44.4	$405.10	$9.13
10	87.3	46.8	0.0039	19.5	67.7	39.3	$333.36	$8.49
11	1.1	3.1	0.0000	0.2	0.8	0.5	$21.78	$45.23
12	138.6	83.5	0.0062	31.0	107.6	62.4	$595.01	$9.54
13	75.9	98.0	0.0034	17.0	58.9	34.2	$698.55	$20.45
14	20.3	64.4	0.0009	4.6	15.8	9.1	$458.78	$50.15
15	27.3	31.8	0.0012	6.1	21.2	12.3	$226.89	$18.49
16	112.8	429.5	0.0050	25.2	87.5	50.7	$3,060.50	$60.32
17	93.5	71.0	0.0042	20.9	72.5	42.1	$506.14	$12.03
18	36.1	20.8	0.0016	8.1	28.0	16.3	$148.30	$9.12
19	28.3	21.6	0.0013	6.3	22.0	12.7	$153.66	$12.05
20	125.8	72.9	0.0056	28.2	97.6	56.6	$519.48	$9.18
21	239.1	163.1	0.0106	53.5	185.6	107.6	$1,162.01	$10.80
22	47.4	29.6	0.0021	10.6	36.8	21.3	$211.08	$9.89
23	34.6	61.5	0.0015	7.7	26.9	15.6	$438.33	$28.14
24	266.3	822.5	0.0119	59.6	206.7	119.8	$5,860.96	$48.90
25	94.2	84.2	0.0042	21.1	73.1	42.4	$599.98	$14.16
26	39.9	22.9	0.0018	8.9	31.0	18.0	$163.03	$9.08
27	13.3	32.8	0.0006	3.0	10.4	6.0	$234.07	$38.99
28	46.0	35.6	0.0020	10.3	35.7	20.7	$253.78	$12.27
29	19.7	13.9	0.0009	4.4	15.3	8.9	$99.15	$11.17
30	11.8	11.2	0.0005	2.6	9.2	5.3	$80.06	$15.07
31	14.7	10.7	0.0007	3.3	11.4	6.6	$76.25	$11.54

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
32	3.8	11.8	0.0002	0.9	3.0	1.7	$83.89	$48.87
33	7.8	4.9	0.0003	1.7	6.0	3.5	$35.23	$10.07
34	10.3	21.4	0.0005	2.3	8.0	4.6	$152.84	$32.95
35	1.1	3.3	0.0000	0.2	0.8	0.5	$23.46	$48.87
36	48.3	26.1	0.0021	10.8	37.5	21.7	$185.69	$8.55
37	49.5	27.9	0.0022	11.1	38.4	22.3	$199.07	$8.93
38	85.4	45.2	0.0038	19.1	66.3	38.4	$321.89	$8.37
39	107.4	69.5	0.0048	24.0	83.3	48.3	$495.59	$10.26
40	40.7	27.7	0.0018	9.1	31.6	18.3	$197.06	$10.75
41	50.0	91.7	0.0022	11.2	38.8	22.5	$653.43	$29.05
42	4.1	4.6	0.0002	0.9	3.2	1.8	$32.50	$17.77
43	13.2	6.5	0.0006	3.0	10.2	5.9	$46.18	$7.78
44	83.2	66.0	0.0037	18.6	64.6	37.4	$470.48	$12.56
45	124.0	67.0	0.0055	27.8	96.3	55.8	$477.20	$8.55
46	108.6	58.0	0.0048	24.3	84.3	48.9	$413.50	$8.46
47	15.6	22.2	0.0007	3.5	12.1	7.0	$157.93	$22.45
48	9.6	7.6	0.0004	2.2	7.5	4.3	$54.08	$12.49
49	7.9	6.3	0.0004	1.8	6.1	3.5	$44.96	$12.67
50	1.3	3.4	0.0001	0.3	1.0	0.6	$24.45	$42.86
51	71.4	86.6	0.0032	16.0	55.4	32.1	$617.04	$19.19
52	109.4	60.5	0.0049	24.5	84.9	49.2	$430.91	$8.76
53	7.4	3.9	0.0003	1.7	5.8	3.3	$28.13	$8.43
54	19.3	14.6	0.0009	4.3	14.9	8.7	$103.94	$12.00
55	16.1	49.7	0.0007	3.6	12.5	7.2	$354.23	$48.88
56	180.5	96.3	0.0080	40.4	140.1	81.2	$686.09	$8.45
57	7.9	10.8	0.0004	1.8	6.1	3.6	$76.81	$21.59
58	156.3	147.8	0.0070	35.0	121.3	70.3	$1,053.00	$14.97
59	9.0	5.1	0.0004	2.0	7.0	4.0	$36.69	$9.07
60	6.0	11.6	0.0003	1.3	4.6	2.7	$82.88	$30.84
61	8.2	25.2	0.0004	1.8	6.3	3.7	$179.33	$48.87
62	11.8	40.6	0.0005	2.6	9.2	5.3	$288.96	$54.32
63	9.3	5.0	0.0004	2.1	7.2	4.2	$35.38	$8.43
64	189.5	112.1	0.0084	42.4	147.1	85.3	$798.55	$9.36

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
65	151.1	347.1	0.0067	33.8	117.2	68.0	$2,473.22	$36.38
66	9.5	6.4	0.0004	2.1	7.4	4.3	$45.86	$10.69
67	111.6	68.4	0.0050	25.0	86.6	50.2	$487.44	$9.71
68	9.0	5.0	0.0004	2.0	7.0	4.1	$35.67	$8.77
69	116.0	96.8	0.0052	26.0	90.0	52.2	$690.03	$13.22
70	36.6	20.2	0.0016	8.2	28.4	16.5	$144.22	$8.76
71	55.3	29.2	0.0025	12.4	42.9	24.9	$207.85	$8.36
72	14.3	8.9	0.0006	3.2	11.1	6.4	$63.20	$9.80
73	83.8	51.8	0.0037	18.8	65.0	37.7	$369.14	$9.79
74	4.4	3.3	0.0002	1.0	3.4	2.0	$23.73	$12.01
75	72.9	48.5	0.0032	16.3	56.6	32.8	$345.69	$10.54
76	103.1	70.4	0.0046	23.1	80.0	46.4	$501.69	$10.82
77	72.3	51.8	0.0032	16.2	56.1	32.5	$368.94	$11.33
78	71.3	42.9	0.0032	16.0	55.3	32.1	$305.98	$9.54
79	101.5	316.0	0.0045	22.7	78.7	45.7	$2,251.48	$49.32
80	85.2	55.1	0.0038	19.1	66.1	38.4	$392.92	$10.24
81	39.8	27.6	0.0018	8.9	30.9	17.9	$196.59	$10.99
82	238.1	253.8	0.0106	53.3	184.8	107.1	$1,808.69	$16.88
83	339.2	437.2	0.0151	75.9	263.2	152.6	$3,115.60	$20.41
84	53.9	230.1	0.0024	12.1	41.8	24.3	$1,639.87	$67.61
85	18.7	15.6	0.0008	4.2	14.5	8.4	$111.48	$13.23
86	0.9	2.5	0.0000	0.2	0.7	0.4	$18.10	$43.80
87	5.0	3.2	0.0002	1.1	3.9	2.3	$22.97	$10.17
88	134.7	102.3	0.0060	30.2	104.6	60.6	$728.98	$12.02
89	177.2	168.1	0.0079	39.7	137.5	79.7	$1,198.17	$15.03
90	224.6	150.1	0.0100	50.3	174.3	101.1	$1,069.38	$10.58
91	10.5	7.8	0.0005	2.4	8.2	4.7	$55.67	$11.75
92	12.7	27.8	0.0006	2.8	9.8	5.7	$198.22	$34.71
93	28.7	18.2	0.0013	6.4	22.3	12.9	$129.56	$10.04
94	5.1	3.7	0.0002	1.1	4.0	2.3	$26.70	$11.66
95	4.0	3.0	0.0002	0.9	3.1	1.8	$21.08	$11.74
96	47.1	32.6	0.0021	10.5	36.5	21.2	$232.29	$10.97
97	70.6	112.7	0.0031	15.8	54.8	31.8	$803.43	$25.30

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
98	16.6	30.2	0.0007	3.7	12.9	7.5	$215.09	$28.80
99	203.7	169.5	0.0091	45.6	158.1	91.6	$1,208.18	$13.18
100	222.4	132.6	0.0099	49.8	172.6	100.1	$945.14	$9.45
101	14.9	10.0	0.0007	3.3	11.6	6.7	$71.58	$10.65
102	515.3	424.4	0.0229	115.4	399.9	231.9	$3,024.60	$13.04
103	49.0	30.9	0.0022	11.0	38.0	22.0	$220.33	$10.00
104	81.4	60.4	0.0036	18.2	63.2	36.6	$430.62	$11.75
105	226.4	133.1	0.0101	50.7	175.7	101.9	$948.74	$9.31
106	50.5	34.6	0.0022	11.3	39.2	22.7	$246.40	$10.84
107	144.4	280.9	0.0064	32.3	112.1	65.0	$2,001.90	$30.80
108	7.1	8.1	0.0003	1.6	5.5	3.2	$58.02	$18.16
109	34.0	141.4	0.0015	7.6	26.4	15.3	$1,007.78	$65.85
110	34.3	122.2	0.0015	7.7	26.6	15.4	$870.60	$56.44
111	23.3	16.7	0.0010	5.2	18.1	10.5	$119.27	$11.35
112	196.8	123.7	0.0088	44.1	152.7	88.5	$881.37	$9.95
113	13.6	11.0	0.0006	3.1	10.6	6.1	$78.68	$12.82
114	24.6	18.0	0.0011	5.5	19.1	11.1	$128.30	$11.58
115	70.7	39.2	0.0031	15.8	54.9	31.8	$279.29	$8.77
116	166.7	98.9	0.0074	37.3	129.4	75.0	$705.01	$9.40
117	20.5	27.5	0.0009	4.6	15.9	9.2	$195.92	$21.23
118	10.4	5.9	0.0005	2.3	8.1	4.7	$42.26	$9.05
119	106.7	66.3	0.0047	23.9	82.8	48.0	$472.33	$9.84
120	81.3	55.4	0.0036	18.2	63.1	36.6	$394.92	$10.79
121	810.9	608.0	0.0361	181.6	629.3	364.9	$4,332.85	$11.87
122	117.4	75.0	0.0052	26.3	91.1	52.8	$534.60	$10.12
123	47.6	29.7	0.0021	10.7	36.9	21.4	$211.97	$9.90
124	27.1	64.3	0.0012	6.1	21.1	12.2	$457.92	$37.50
125	169.8	175.2	0.0076	38.0	131.8	76.4	$1,248.14	$16.34
126	73.0	42.9	0.0032	16.3	56.6	32.8	$305.35	$9.30
127	397.4	265.8	0.0177	89.0	308.5	178.9	$1,893.74	$10.59
128	144.9	80.5	0.0065	32.5	112.5	65.2	$573.62	$8.80
129	117.0	111.7	0.0052	26.2	90.8	52.6	$795.87	$15.12
130	232.4	723.0	0.0103	52.0	180.4	104.6	$5,152.21	$49.27

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
131	179.3	107.5	0.0080	40.2	139.2	80.7	$765.73	$9.49
132	86.0	235.5	0.0038	19.3	66.8	38.7	$1,678.21	$43.35
133	102.2	61.8	0.0046	22.9	79.3	46.0	$440.10	$9.57
134	444.1	335.7	0.0198	99.4	344.7	199.9	$2,391.86	$11.97
135	1.6	1.6	0.0001	0.4	1.2	0.7	$11.25	$15.71
136	35.8	31.3	0.0016	8.0	27.8	16.1	$223.03	$13.84
137	49.7	26.9	0.0022	11.1	38.6	22.4	$191.51	$8.56
138	11.7	9.9	0.0005	2.6	9.1	5.3	$70.31	$13.32
139	53.5	40.9	0.0024	12.0	41.5	24.1	$291.60	$12.12
140	6.9	4.8	0.0003	1.5	5.4	3.1	$34.09	$10.98
141	21.9	15.3	0.0010	4.9	17.0	9.8	$108.88	$11.06
142	31.0	52.2	0.0014	6.9	24.0	13.9	$371.62	$26.65
143	17.8	15.8	0.0008	4.0	13.8	8.0	$112.74	$14.06
144	7.6	17.0	0.0003	1.7	5.9	3.4	$121.45	$35.57
145	150.6	91.4	0.0067	33.7	116.9	67.8	$651.38	$9.61
146	463.5	291.9	0.0206	103.8	359.7	208.6	$2,080.13	$9.97
147	1.7	5.2	0.0001	0.4	1.3	0.8	$37.09	$48.87
148	8.8	10.6	0.0004	2.0	6.8	3.9	$75.22	$19.06
149	1.4	2.1	0.0001	0.3	1.1	0.6	$14.76	$23.85
150	42.2	41.0	0.0019	9.4	32.7	19.0	$292.17	$15.39
151	18.7	14.0	0.0008	4.2	14.5	8.4	$99.86	$11.89
152	15.9	8.6	0.0007	3.6	12.3	7.1	$61.35	$8.60
153	239.8	356.8	0.0107	53.7	186.1	107.9	$2,542.71	$23.56
154	660.8	782.5	0.0294	148.0	512.8	297.4	$5,575.78	$18.75
155	103.9	65.6	0.0046	23.3	80.7	46.8	$467.16	$9.99
156	46.9	26.6	0.0021	10.5	36.4	21.1	$189.22	$8.96
157	58.4	35.1	0.0026	13.1	45.3	26.3	$249.98	$9.51
158	14.6	9.2	0.0006	3.3	11.3	6.5	$65.25	$9.96
159	6.5	3.4	0.0003	1.4	5.0	2.9	$24.51	$8.43
160	2.3	2.5	0.0001	0.5	1.8	1.0	$17.62	$17.05
161	27.2	19.9	0.0012	6.1	21.1	12.3	$142.11	$11.60
162	468.5	1109.4	0.0209	104.9	363.6	210.8	$7,905.34	$37.49
163	34.3	20.5	0.0015	7.7	26.6	15.4	$146.17	$9.48

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
164	37.1	22.4	0.0016	8.3	28.8	16.7	$159.61	$9.57
165	36.3	21.6	0.0016	8.1	28.2	16.3	$153.80	$9.42
166	20.4	11.8	0.0009	4.6	15.8	9.2	$84.06	$9.18
167	115.0	72.1	0.0051	25.8	89.3	51.8	$513.98	$9.93
168	14.2	24.2	0.0006	3.2	11.1	6.4	$172.20	$26.87
169	0.5	0.4	0.0000	0.1	0.4	0.2	$2.63	$12.22
170	3.2	2.9	0.0001	0.7	2.5	1.4	$20.85	$14.38
171	95.8	172.3	0.0043	21.4	74.3	43.1	$1,228.09	$28.49
172	34.4	44.5	0.0015	7.7	26.7	15.5	$317.22	$20.49
173	194.5	116.2	0.0087	43.6	151.0	87.5	$828.11	$9.46
174	8.2	6.5	0.0004	1.8	6.4	3.7	$46.22	$12.49
175	11.4	13.1	0.0005	2.6	8.8	5.1	$93.50	$18.24
176	2.8	4.3	0.0001	0.6	2.2	1.3	$30.74	$24.38
177	42.1	38.7	0.0019	9.4	32.7	19.0	$275.82	$14.55
178	79.0	47.5	0.0035	17.7	61.3	35.5	$338.69	$9.53
179	23.5	14.4	0.0010	5.3	18.3	10.6	$102.65	$9.70
180	0.1	0.1	0.0000	0.0	0.1	0.0	$0.55	$12.24
181	30.1	17.6	0.0013	6.7	23.4	13.5	$125.43	$9.26
182	14.0	19.6	0.0006	3.1	10.8	6.3	$139.47	$22.19
183	11.0	9.3	0.0005	2.5	8.5	4.9	$66.16	$13.37
184	44.4	43.0	0.0020	9.9	34.5	20.0	$306.07	$15.32
185	12.9	9.9	0.0006	2.9	10.0	5.8	$70.34	$12.14
186	15.8	9.2	0.0007	3.5	12.3	7.1	$65.90	$9.26
187	76.6	46.7	0.0034	17.2	59.5	34.5	$332.94	$9.66
188	148.4	235.5	0.0066	33.2	115.2	66.8	$1,677.97	$25.13
189	6.8	13.0	0.0003	1.5	5.2	3.0	$92.48	$30.45
190	3.2	5.7	0.0001	0.7	2.5	1.4	$40.55	$28.35
191	31.5	30.9	0.0014	7.1	24.4	14.2	$220.47	$15.55
192	104.2	64.7	0.0046	23.3	80.9	46.9	$460.79	$9.83
193	34.4	21.8	0.0015	7.7	26.7	15.5	$155.28	$10.04
194	28.4	16.4	0.0013	6.4	22.0	12.8	$116.93	$9.15
195	14.4	12.5	0.0006	3.2	11.2	6.5	$89.09	$13.77
196	13.2	15.2	0.0006	2.9	10.2	5.9	$108.59	$18.34

Table A3-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Nutrient Management Planning	Total Annual Cost	Cost per Unit of Reduction
197	92.3	72.2	0.0041	20.7	71.6	41.5	$514.30	$12.38
198	84.0	102.5	0.0037	18.8	65.2	37.8	$730.16	$19.32
199	175.3	147.8	0.0078	39.2	136.0	78.9	$1,053.18	$13.35
200	86.1	288.4	0.0038	19.3	66.8	38.7	$2,055.35	$53.07
201	16.4	12.9	0.0007	3.7	12.7	7.4	$91.85	$12.43
202	56.9	37.2	0.0025	12.7	44.2	25.6	$265.20	$10.35
203	142.5	95.6	0.0063	31.9	110.6	64.1	$681.06	$10.62
204	116.6	205.0	0.0052	26.1	90.5	52.5	$1,460.73	$27.85
205	26.4	16.9	0.0012	5.9	20.5	11.9	$120.10	$10.12
206	218.0	259.6	0.0097	48.8	169.2	98.1	$1,849.80	$18.86
207	277.0	210.4	0.0123	62.0	215.0	124.7	$1,499.14	$12.03
208	27.5	14.8	0.0012	6.1	21.3	12.4	$105.18	$8.51
209	82.9	63.4	0.0037	18.6	64.3	37.3	$451.99	$12.12
210	23.3	17.3	0.0010	5.2	18.1	10.5	$123.63	$11.81
211	18.3	12.5	0.0008	4.1	14.2	8.2	$89.03	$10.81
212	155.9	107.5	0.0069	34.9	121.0	70.2	$766.05	$10.92
213	43.6	34.0	0.0019	9.8	33.8	19.6	$242.40	$12.35
214	110.4	65.5	0.0049	24.7	85.7	49.7	$467.10	$9.40
215	131.8	81.2	0.0059	29.5	102.3	59.3	$578.98	$9.76
216	28.4	27.2	0.0013	6.4	22.1	12.8	$193.49	$15.12
217	230.7	135.1	0.0103	51.7	179.0	103.8	$962.84	$9.27
218	32.1	30.3	0.0014	7.2	24.9	14.5	$215.73	$14.93

Table A4. Individual Farmer Current Loads, Target Loads, Potential Reductions from Grass Filter Strips, and Cost Information

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
1	38.5	33.6	0.0017	8.6	29.9	19.2	$29.10	$1.51
2	31.0	17.4	0.0014	6.9	24.0	15.5	$15.05	$0.97
3	23.4	13.6	0.0010	5.2	18.1	11.7	$11.75	$1.01
4	14.7	11.8	0.0007	3.3	11.4	7.4	$10.25	$1.39
5	12.4	12.6	0.0006	2.8	9.6	6.2	$10.94	$1.77
6	51.6	35.6	0.0023	11.6	40.1	25.8	$30.81	$1.19
7	42.0	23.4	0.0019	9.4	32.6	21.0	$20.28	$0.97
8	33.1	28.4	0.0015	7.4	25.7	16.5	$24.61	$1.49
9	98.6	56.8	0.0044	22.1	76.5	49.3	$49.19	$1.00
10	87.3	46.8	0.0039	19.5	67.7	43.6	$40.48	$0.93
11	1.1	3.1	0.0000	0.2	0.8	0.5	$2.64	$4.94
12	138.6	83.5	0.0062	31.0	107.6	69.3	$72.25	$1.04
13	75.9	98.0	0.0034	17.0	58.9	38.0	$84.82	$2.23
14	20.3	64.4	0.0009	4.6	15.8	10.2	$55.71	$5.48
15	27.3	31.8	0.0012	6.1	21.2	13.6	$27.55	$2.02
16	112.8	429.5	0.0050	25.2	87.5	56.4	$371.63	$6.59
17	93.5	71.0	0.0042	20.9	72.5	46.7	$61.46	$1.32
18	36.1	20.8	0.0016	8.1	28.0	18.1	$18.01	$1.00
19	28.3	21.6	0.0013	6.3	22.0	14.2	$18.66	$1.32
20	125.8	72.9	0.0056	28.2	97.6	62.9	$63.08	$1.00
21	239.1	163.1	0.0106	53.5	185.6	119.6	$141.10	$1.18
22	47.4	29.6	0.0021	10.6	36.8	23.7	$25.63	$1.08
23	34.6	61.5	0.0015	7.7	26.9	17.3	$53.23	$3.08
24	266.3	822.5	0.0119	59.6	206.7	133.2	$711.69	$5.34
25	94.2	84.2	0.0042	21.1	73.1	47.1	$72.85	$1.55
26	39.9	22.9	0.0018	8.9	31.0	19.9	$19.80	$0.99
27	13.3	32.8	0.0006	3.0	10.4	6.7	$28.42	$4.26
28	46.0	35.6	0.0020	10.3	35.7	23.0	$30.82	$1.34
29	19.7	13.9	0.0009	4.4	15.3	9.9	$12.04	$1.22
30	11.8	11.2	0.0005	2.6	9.2	5.9	$9.72	$1.65
31	14.7	10.7	0.0007	3.3	11.4	7.3	$9.26	$1.26

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
32	3.8	11.8	0.0002	0.9	3.0	1.9	$10.19	$5.34
33	7.8	4.9	0.0003	1.7	6.0	3.9	$4.28	$1.10
34	10.3	21.4	0.0005	2.3	8.0	5.2	$18.56	$3.60
35	1.1	3.3	0.0000	0.2	0.8	0.5	$2.85	$5.34
36	48.3	26.1	0.0021	10.8	37.5	24.1	$22.55	$0.93
37	49.5	27.9	0.0022	11.1	38.4	24.8	$24.17	$0.98
38	85.4	45.2	0.0038	19.1	66.3	42.7	$39.09	$0.92
39	107.4	69.5	0.0048	24.0	83.3	53.7	$60.18	$1.12
40	40.7	27.7	0.0018	9.1	31.6	20.4	$23.93	$1.18
41	50.0	91.7	0.0022	11.2	38.8	25.0	$79.34	$3.17
42	4.1	4.6	0.0002	0.9	3.2	2.0	$3.95	$1.94
43	13.2	6.5	0.0006	3.0	10.2	6.6	$5.61	$0.85
44	83.2	66.0	0.0037	18.6	64.6	41.6	$57.13	$1.37
45	124.0	67.0	0.0055	27.8	96.3	62.0	$57.95	$0.93
46	108.6	58.0	0.0048	24.3	84.3	54.3	$50.21	$0.92
47	15.6	22.2	0.0007	3.5	12.1	7.8	$19.18	$2.45
48	9.6	7.6	0.0004	2.2	7.5	4.8	$6.57	$1.37
49	7.9	6.3	0.0004	1.8	6.1	3.9	$5.46	$1.38
50	1.3	3.4	0.0001	0.3	1.0	0.6	$2.97	$4.68
51	71.4	86.6	0.0032	16.0	55.4	35.7	$74.93	$2.10
52	109.4	60.5	0.0049	24.5	84.9	54.7	$52.32	$0.96
53	7.4	3.9	0.0003	1.7	5.8	3.7	$3.42	$0.92
54	19.3	14.6	0.0009	4.3	14.9	9.6	$12.62	$1.31
55	16.1	49.7	0.0007	3.6	12.5	8.1	$43.01	$5.34
56	180.5	96.3	0.0080	40.4	140.1	90.2	$83.31	$0.92
57	7.9	10.8	0.0004	1.8	6.1	4.0	$9.33	$2.36
58	156.3	147.8	0.0070	35.0	121.3	78.1	$127.86	$1.64
59	9.0	5.1	0.0004	2.0	7.0	4.5	$4.46	$0.99
60	6.0	11.6	0.0003	1.3	4.6	3.0	$10.06	$3.37
61	8.2	25.2	0.0004	1.8	6.3	4.1	$21.78	$5.34
62	11.8	40.6	0.0005	2.6	9.2	5.9	$35.09	$5.94
63	9.3	5.0	0.0004	2.1	7.2	4.7	$4.30	$0.92
64	189.5	112.1	0.0084	42.4	147.1	94.8	$96.97	$1.02

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
65	151.1	347.1	0.0067	33.8	117.2	75.5	$300.32	$3.98
66	9.5	6.4	0.0004	2.1	7.4	4.8	$5.57	$1.17
67	111.6	68.4	0.0050	25.0	86.6	55.8	$59.19	$1.06
68	9.0	5.0	0.0004	2.0	7.0	4.5	$4.33	$0.96
69	116.0	96.8	0.0052	26.0	90.0	58.0	$83.79	$1.45
70	36.6	20.2	0.0016	8.2	28.4	18.3	$17.51	$0.96
71	55.3	29.2	0.0025	12.4	42.9	27.6	$25.24	$0.91
72	14.3	8.9	0.0006	3.2	11.1	7.2	$7.67	$1.07
73	83.8	51.8	0.0037	18.8	65.0	41.9	$44.82	$1.07
74	4.4	3.3	0.0002	1.0	3.4	2.2	$2.88	$1.31
75	72.9	48.5	0.0032	16.3	56.6	36.5	$41.98	$1.15
76	103.1	70.4	0.0046	23.1	80.0	51.5	$60.92	$1.18
77	72.3	51.8	0.0032	16.2	56.1	36.2	$44.80	$1.24
78	71.3	42.9	0.0032	16.0	55.3	35.6	$37.15	$1.04
79	101.5	316.0	0.0045	22.7	78.7	50.7	$273.39	$5.39
80	85.2	55.1	0.0038	19.1	66.1	42.6	$47.71	$1.12
81	39.8	27.6	0.0018	8.9	30.9	19.9	$23.87	$1.20
82	238.1	253.8	0.0106	53.3	184.8	119.1	$219.63	$1.84
83	339.2	437.2	0.0151	75.9	263.2	169.6	$378.32	$2.23
84	53.9	230.1	0.0024	12.1	41.8	27.0	$199.13	$7.39
85	18.7	15.6	0.0008	4.2	14.5	9.4	$13.54	$1.45
86	0.9	2.5	0.0000	0.2	0.7	0.5	$2.20	$4.79
87	5.0	3.2	0.0002	1.1	3.9	2.5	$2.79	$1.11
88	134.7	102.3	0.0060	30.2	104.6	67.4	$88.52	$1.31
89	177.2	168.1	0.0079	39.7	137.5	88.6	$145.49	$1.64
90	224.6	150.1	0.0100	50.3	174.3	112.3	$129.85	$1.16
91	10.5	7.8	0.0005	2.4	8.2	5.3	$6.76	$1.28
92	12.7	27.8	0.0006	2.8	9.8	6.3	$24.07	$3.79
93	28.7	18.2	0.0013	6.4	22.3	14.3	$15.73	$1.10
94	5.1	3.7	0.0002	1.1	4.0	2.5	$3.24	$1.27
95	4.0	3.0	0.0002	0.9	3.1	2.0	$2.56	$1.28
96	47.1	32.6	0.0021	10.5	36.5	23.5	$28.21	$1.20
97	70.6	112.7	0.0031	15.8	54.8	35.3	$97.56	$2.76

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
98	16.6	30.2	0.0007	3.7	12.9	8.3	$26.12	$3.15
99	203.7	169.5	0.0091	45.6	158.1	101.8	$146.71	$1.44
100	222.4	132.6	0.0099	49.8	172.6	111.2	$114.77	$1.03
101	14.9	10.0	0.0007	3.3	11.6	7.5	$8.69	$1.16
102	515.3	424.4	0.0229	115.4	399.9	257.6	$367.27	$1.43
103	49.0	30.9	0.0022	11.0	38.0	24.5	$26.75	$1.09
104	81.4	60.4	0.0036	18.2	63.2	40.7	$52.29	$1.28
105	226.4	133.1	0.0101	50.7	175.7	113.2	$115.20	$1.02
106	50.5	34.6	0.0022	11.3	39.2	25.2	$29.92	$1.19
107	144.4	280.9	0.0064	32.3	112.1	72.2	$243.09	$3.37
108	7.1	8.1	0.0003	1.6	5.5	3.6	$7.05	$1.98
109	34.0	141.4	0.0015	7.6	26.4	17.0	$122.37	$7.20
110	34.3	122.2	0.0015	7.7	26.6	17.1	$105.72	$6.17
111	23.3	16.7	0.0010	5.2	18.1	11.7	$14.48	$1.24
112	196.8	123.7	0.0088	44.1	152.7	98.4	$107.02	$1.09
113	13.6	11.0	0.0006	3.1	10.6	6.8	$9.55	$1.40
114	24.6	18.0	0.0011	5.5	19.1	12.3	$15.58	$1.27
115	70.7	39.2	0.0031	15.8	54.9	35.4	$33.91	$0.96
116	166.7	98.9	0.0074	37.3	129.4	83.4	$85.61	$1.03
117	20.5	27.5	0.0009	4.6	15.9	10.3	$23.79	$2.32
118	10.4	5.9	0.0005	2.3	8.1	5.2	$5.13	$0.99
119	106.7	66.3	0.0047	23.9	82.8	53.3	$57.35	$1.08
120	81.3	55.4	0.0036	18.2	63.1	40.7	$47.95	$1.18
121	810.9	608.0	0.0361	181.6	629.3	405.4	$526.13	$1.30
122	117.4	75.0	0.0052	26.3	91.1	58.7	$64.92	$1.11
123	47.6	29.7	0.0021	10.7	36.9	23.8	$25.74	$1.08
124	27.1	64.3	0.0012	6.1	21.1	13.6	$55.60	$4.10
125	169.8	175.2	0.0076	38.0	131.8	84.9	$151.56	$1.79
126	73.0	42.9	0.0032	16.3	56.6	36.5	$37.08	$1.02
127	397.4	265.8	0.0177	89.0	308.5	198.7	$229.95	$1.16
128	144.9	80.5	0.0065	32.5	112.5	72.5	$69.65	$0.96
129	117.0	111.7	0.0052	26.2	90.8	58.5	$96.64	$1.65
130	232.4	723.0	0.0103	52.0	180.4	116.2	$625.63	$5.38

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
131	179.3	107.5	0.0080	40.2	139.2	89.7	$92.98	$1.04
132	86.0	235.5	0.0038	19.3	66.8	43.0	$203.78	$4.74
133	102.2	61.8	0.0046	22.9	79.3	51.1	$53.44	$1.05
134	444.1	335.7	0.0198	99.4	344.7	222.1	$290.44	$1.31
135	1.6	1.6	0.0001	0.4	1.2	0.8	$1.37	$1.72
136	35.8	31.3	0.0016	8.0	27.8	17.9	$27.08	$1.51
137	49.7	26.9	0.0022	11.1	38.6	24.8	$23.25	$0.94
138	11.7	9.9	0.0005	2.6	9.1	5.9	$8.54	$1.46
139	53.5	40.9	0.0024	12.0	41.5	26.7	$35.41	$1.32
140	6.9	4.8	0.0003	1.5	5.4	3.5	$4.14	$1.20
141	21.9	15.3	0.0010	4.9	17.0	10.9	$13.22	$1.21
142	31.0	52.2	0.0014	6.9	24.0	15.5	$45.13	$2.91
143	17.8	15.8	0.0008	4.0	13.8	8.9	$13.69	$1.54
144	7.6	17.0	0.0003	1.7	5.9	3.8	$14.75	$3.89
145	150.6	91.4	0.0067	33.7	116.9	75.3	$79.10	$1.05
146	463.5	291.9	0.0206	103.8	359.7	231.8	$252.59	$1.09
147	1.7	5.2	0.0001	0.4	1.3	0.8	$4.50	$5.34
148	8.8	10.6	0.0004	2.0	6.8	4.4	$9.13	$2.08
149	1.4	2.1	0.0001	0.3	1.1	0.7	$1.79	$2.61
150	42.2	41.0	0.0019	9.4	32.7	21.1	$35.48	$1.68
151	18.7	14.0	0.0008	4.2	14.5	9.3	$12.13	$1.30
152	15.9	8.6	0.0007	3.6	12.3	7.9	$7.45	$0.94
153	239.8	356.8	0.0107	53.7	186.1	119.9	$308.76	$2.57
154	660.8	782.5	0.0294	148.0	512.8	330.4	$677.06	$2.05
155	103.9	65.6	0.0046	23.3	80.7	52.0	$56.73	$1.09
156	46.9	26.6	0.0021	10.5	36.4	23.5	$22.98	$0.98
157	58.4	35.1	0.0026	13.1	45.3	29.2	$30.35	$1.04
158	14.6	9.2	0.0006	3.3	11.3	7.3	$7.92	$1.09
159	6.5	3.4	0.0003	1.4	5.0	3.2	$2.98	$0.92
160	2.3	2.5	0.0001	0.5	1.8	1.1	$2.14	$1.86
161	27.2	19.9	0.0012	6.1	21.1	13.6	$17.26	$1.27
162	468.5	1109.4	0.0209	104.9	363.6	234.3	$959.93	$4.10
163	34.3	20.5	0.0015	7.7	26.6	17.1	$17.75	$1.04

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
164	37.1	22.4	0.0016	8.3	28.8	18.5	$19.38	$1.05
165	36.3	21.6	0.0016	8.1	28.2	18.1	$18.68	$1.03
166	20.4	11.8	0.0009	4.6	15.8	10.2	$10.21	$1.00
167	115.0	72.1	0.0051	25.8	89.3	57.5	$62.41	$1.09
168	14.2	24.2	0.0006	3.2	11.1	7.1	$20.91	$2.94
169	0.5	0.4	0.0000	0.1	0.4	0.2	$0.32	$1.33
170	3.2	2.9	0.0001	0.7	2.5	1.6	$2.53	$1.57
171	95.8	172.3	0.0043	21.4	74.3	47.9	$149.13	$3.11
172	34.4	44.5	0.0015	7.7	26.7	17.2	$38.52	$2.24
173	194.5	116.2	0.0087	43.6	151.0	97.3	$100.56	$1.03
174	8.2	6.5	0.0004	1.8	6.4	4.1	$5.61	$1.36
175	11.4	13.1	0.0005	2.6	8.8	5.7	$11.35	$1.99
176	2.8	4.3	0.0001	0.6	2.2	1.4	$3.73	$2.66
177	42.1	38.7	0.0019	9.4	32.7	21.1	$33.49	$1.59
178	79.0	47.5	0.0035	17.7	61.3	39.5	$41.13	$1.04
179	23.5	14.4	0.0010	5.3	18.3	11.8	$12.46	$1.06
180	0.1	0.1	0.0000	0.0	0.1	0.0	$0.07	$1.34
181	30.1	17.6	0.0013	6.7	23.4	15.1	$15.23	$1.01
182	14.0	19.6	0.0006	3.1	10.8	7.0	$16.94	$2.43
183	11.0	9.3	0.0005	2.5	8.5	5.5	$8.03	$1.46
184	44.4	43.0	0.0020	9.9	34.5	22.2	$37.17	$1.67
185	12.9	9.9	0.0006	2.9	10.0	6.4	$8.54	$1.33
186	15.8	9.2	0.0007	3.5	12.3	7.9	$8.00	$1.01
187	76.6	46.7	0.0034	17.2	59.5	38.3	$40.43	$1.06
188	148.4	235.5	0.0066	33.2	115.2	74.2	$203.75	$2.75
189	6.8	13.0	0.0003	1.5	5.2	3.4	$11.23	$3.33
190	3.2	5.7	0.0001	0.7	2.5	1.6	$4.92	$3.10
191	31.5	30.9	0.0014	7.1	24.4	15.8	$26.77	$1.70
192	104.2	64.7	0.0046	23.3	80.9	52.1	$55.95	$1.07
193	34.4	21.8	0.0015	7.7	26.7	17.2	$18.86	$1.10
194	28.4	16.4	0.0013	6.4	22.0	14.2	$14.20	$1.00
195	14.4	12.5	0.0006	3.2	11.2	7.2	$10.82	$1.50
196	13.2	15.2	0.0006	2.9	10.2	6.6	$13.19	$2.00

Table A4-*Continued*

Farmer	Current Load	Acreage	Portion of Total NPS Load	Target Load	Necessary Reduction	Potential Reduction from Grass Filter Strips	Total Annual Cost	Cost per Unit of Reduction
197	92.3	72.2	0.0041	20.7	71.6	46.2	$62.45	$1.35
198	84.0	102.5	0.0037	18.8	65.2	42.0	$88.66	$2.11
199	175.3	147.8	0.0078	39.2	136.0	87.6	$127.89	$1.46
200	86.1	288.4	0.0038	19.3	66.8	43.0	$249.58	$5.80
201	16.4	12.9	0.0007	3.7	12.7	8.2	$11.15	$1.36
202	56.9	37.2	0.0025	12.7	44.2	28.5	$32.20	$1.13
203	142.5	95.6	0.0063	31.9	110.6	71.3	$82.70	$1.16
204	116.6	205.0	0.0052	26.1	90.5	58.3	$177.37	$3.04
205	26.4	16.9	0.0012	5.9	20.5	13.2	$14.58	$1.11
206	218.0	259.6	0.0097	48.8	169.2	109.0	$224.62	$2.06
207	277.0	210.4	0.0123	62.0	215.0	138.5	$182.04	$1.31
208	27.5	14.8	0.0012	6.1	21.3	13.7	$12.77	$0.93
209	82.9	63.4	0.0037	18.6	64.3	41.4	$54.88	$1.32
210	23.3	17.3	0.0010	5.2	18.1	11.6	$15.01	$1.29
211	18.3	12.5	0.0008	4.1	14.2	9.1	$10.81	$1.18
212	155.9	107.5	0.0069	34.9	121.0	78.0	$93.02	$1.19
213	43.6	34.0	0.0019	9.8	33.8	21.8	$29.43	$1.35
214	110.4	65.5	0.0049	24.7	85.7	55.2	$56.72	$1.03
215	131.8	81.2	0.0059	29.5	102.3	65.9	$70.30	$1.07
216	28.4	27.2	0.0013	6.4	22.1	14.2	$23.50	$1.65
217	230.7	135.1	0.0103	51.7	179.0	115.3	$116.92	$1.01
218	32.1	30.3	0.0014	7.2	24.9	16.1	$26.20	$1.63