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NUTRIENT TRADING IN THE MRB

A Feasibility Study for Using Large-Scale Interstate Nutrient Trading in the Mississippi River Basin to Help Address Hypoxia in the Gulf of Mexico

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U.S. Environmental Protection Agency Targeted Watershed Grant

Photo on cover: A pelican drying its feathers with a shrimp boat trawling in the background.

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i. About WRI

The World Resources Institute is a global environmental think tank that goes beyond research to put ideas into action. We work with governments, companies, and civil society to build solutions to urgent environmental challenges. Our mission is to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations.

This study was conducted by Michelle Perez, Sara Walker, and Cy Jones who are members of the Water Quality Team. The goal of the Water Quality Team is to reduce eutrophication in coastal zones and lakes by helping stakeholders develop and adopt effective strategies for controlling nutrient pollution, including performance-based and market-based policies.

ii. Acknowledgements

This study was made possible by a U.S. Environmental Protection Agency (USEPA) Targeted Watershed Grant and a grant from the Wells Fargo Foundation in May 2009. WRI sub-contracted with engineering and consulting firms, Symbiont and HydroQual, to conduct the wastewater utility analysis and the nutrient criteria and delivery factor analyses. WRI provided a sub-grant to Dr. Andrew Sharpley of the University of Arkansas to provide agricultural expertise. WRI also collaborated with Dr. Robert Kroger of Mississippi State University to conduct a best management practice (BMP) literature review for the Lower Mississippi Alluvial Valley. WRI entered into a Cooperative Agreement with the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) to conduct the agricultural credit supply and cost analysis. Special thanks to NRCS staff Lee Norfleet and Jay Atwood at the Texas AgriLife Blackland Research and Extension Center for their modeling efforts.

WRI wishes to thank the Metropolitan Water Reclamation District of Greater Chicago and Sanitation District No. 1 of Northern Kentucky for sharing their waste water utility master planning data with us and for their feedback on the study. Thank you also to the many agricultural and environmental state and federal agencies as well as non-government organizations from Arkansas, Illinois, Kentucky, and Mississippi that shared their feedback on the study with us.

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EXECUTIVE SUMMARY

The purpose of this feasibility study was to determine if large-scale interstate nutrient trading in the Mississippi River Basin (MRB) can be an economically and environmentally feasible tool for reducing hypoxia in the Gulf of Mexico (Gulf). Nutrient trading may be economically viable because regulated wastewater utilities may be able to purchase credits (delivered pounds of a nutrient) from the unregulated agricultural sector at prices that are significantly less than the utilities' onsite technology upgrade costs but still enough to interest farmers in generating sufficient credit supply. In addition, interstate nutrient trading across the large MRB could, in theory, benefit from advantageous delivery factors; that is, differences in the percentage of discharged nutrient loads from buyer and seller locations actually reaching the Gulf due to natural attenuation.

WRI completed this feasibility study using a case study approach with two wastewater utilities serving as hypothetical credit buyers and six agricultural watersheds serving as hypothetical credit sellers within a hypothetical nutrient trading framework. WRI chose to use the 2007 U.S. Environmental Protection Agency (USEPA) Science Advisory Board's (SAB) recommendation of a 45% reduction in the delivered nitrogen (N) and phosphorus (P) loads to the Gulf as the project's water quality goal. A simplifying assumption was made that both nutrient sources in the project, the wastewater and the agricultural sectors, would receive this same overall cleanup goal. Thus, the wastewater utilities would have to reduce their existing nutrient loads delivered to the Gulf by 45% or satisfy that goal through purchase of an equivalent amount of credits.

The assumption for agricultural credit sellers was that before they can sell credits, sellers must first achieve their individualized portion of the project's 45% water quality goal reflecting a "trading eligibility standard" (TES). That is, sellers would have to reduce their existing, average per acre nutrient loads below their watershed's average allowable per acre nutrient load (which was calculated by reducing delivered loads from each watershed to the Gulf by 45%). This TES ensures that credits (defined as delivered to the Gulf pounds of N or P reduced) are "additional" to the nutrient reductions that satisfy the farmer's portion of his watershed's project reduction goal, thereby ensuring that trading transactions result in progress toward the policy goal.

WRI partnered with Symbiont, an engineering and consulting firm, to conduct the wastewater utility nutrient reduction cost analysis. Two wastewater treatment plant (WWTP) utilities, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) and Sanitation District No. 1 (SD1) of northern Kentucky, provided Symbiont with data from their 20-year Master Planning documents for two and three plants, respectively. Using standard engineering cost analysis, Symbiont determined the:

- Total pounds of N and P reductions necessary to meet the potential future effluent limits onsite based on plant design capacity to account for future population growth,
- Cost per pound of N and P reduced by these technology upgrades, and
- Quantity of potential credits, measured in pounds delivered to the Gulf, that could satisfy the new discharge requirements via trading.

WRI used Symbiont's estimates of onsite technology costs to satisfy the project's Gulf water quality goal to estimate the utilities' hypothetical willingness to pay for credits. Without knowing if the utilities would engage in trading or how much they would be willing to offer for credit prices, WRI made the simplifying assumption that utilities might offer prices that are 75%, 50%, or 25% of their onsite costs.

WRI partnered with the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Conservation Effects Assessment Project (CEAP) modeling team to estimate the potential nutrient credit supply and associated costs in six "delta area" watersheds in Arkansas and Mississippi. Using a subset of CEAP–Natural Resource Inventory (NRI) conservation datasets for the six project watersheds, the Agricultural Policy Extender (APEX) model, and a "cost-minimization model" as well as a "profit-maximization model," NRCS determined the:

- Total pounds of N and P needed to be reduced to meet each watershed's TES,
- Most cost-effective conservation treatments (suites of practices) to achieve the standard,
- Average costs per pound of N and P reduced, and
- Quantity of potential credit supply generated beyond the TES in response to a variety of potential credit prices.

Without knowing what trading policies or market prices might materialize if a future trading program were developed, 18 different policy-price combinations were analyzed to determine their effects on agricultural credit supply and associated costs. The variations in policies include:

- Three scenarios for trading eligibility standards (N-only TES, P-only TES, and both N and P TES),
- Two scenarios for additionality (with and without additionality enforced), and
- Three market price signals (N-only prices, P-only prices, and both N and P prices) ranging between $1 to $50/lb N and $1 to $100/lb P.

The study also examined other factors that could constrain nutrient trading such as potential for local water concerns (hotspots) and the adoption of local instream numeric nutrient criteria. WRI partnered with HydroQual to study the effect that hypothetical numeric criteria, set in the receiving waters of the project's wastewater utilities, could have on the utilities' potential demand for credits.

The findings of the study are as follows:

1. Nutrient trading in the MRB is an economically feasible approach to reduce the costs of meeting water quality goals in the Gulf of Mexico

A significant cost differential exists between the nutrient reduction costs faced by the project's two wastewater utilities to reduce their loads onsite by 45% and the costs to achieve the same level of reduction through implementing agricultural best management practices. Under selected trading policy rules which required that both N and P TES had to be met and additionality was enforced, at an N credit price of $3, which is less than both utilities' 20-year net present value (NPV) onsite costs to reduce a pound of nitrogen ($4.69/credit for MWRDGC and $11.89/credit for SD1), the utilities could save nearly $900 million over 20 years by solely trading to achieve the goal (see Figure A). This amount is equivalent to a cost savings of 63%. While the project watersheds had sufficient N supply to meet the two utilities' demand, they did not have sufficient P supply for MWRDGC, the larger of the two utilities, under the selected trading policy rules.

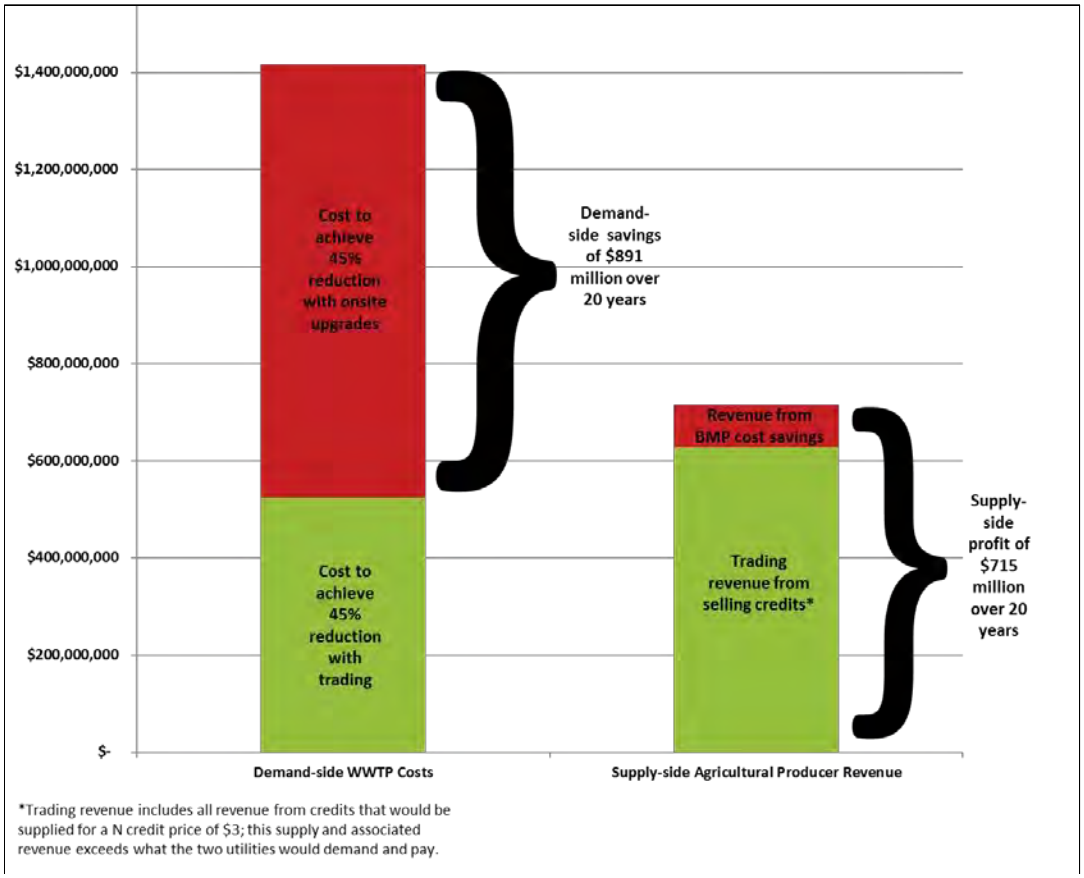


FIGURE A. 20-YEAR DEMAND-SIDE SAVINGS AND SUPPLY-SIDE PROFIT POTENTIAL OF NITROGEN TRADING TO ACHIEVE 45% REDUCTION IN NITROGEN LOADS TO GULF OF MEXICO

Should nutrient trading materialize, there will be far more buyers in the marketplace than the two project buyers and far more sellers than the six project agricultural watersheds. However, given this case study's constraints, it is still interesting to note that if both utilities were interested in trading to satisfy 100% of their hypothetical N reduction target, the average potential N credit supply from the agricultural watersheds would be nearly twice their N credit demand (see Figure B). In contrast, the average potential supply of P credits from the six project watersheds is between 25 and 44% of the potential P demand from the two project utilities, depending on whether only a P credit price is offered or both N and P credit prices are offered (see Figure C). Figures B and C illustrate this supply and demand comparison broken down for each utility under the selected trading policy rules.[1]

[1] The supply estimates are based on a policy scenario in which both the N and the P TES must be met before credits can be sold, additionality is enforced, and there is an N-only price signal at $3 when N is supplied and a P-only price signal at $15 when P is supplied.

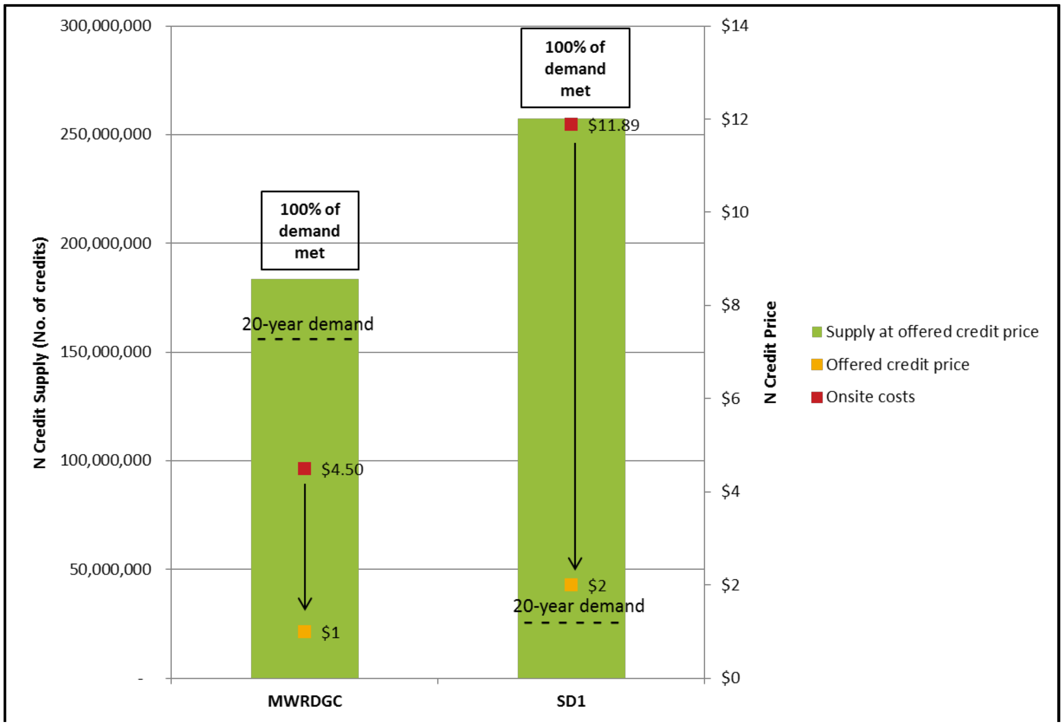


FIGURE B. NITROGEN CREDIT SUPPLY POTENTIAL WITH MWRDGC AND SD1 EACH OFFERING A CREDIT PRICE THAT IS 25% OF THEIR ONSITE COSTS

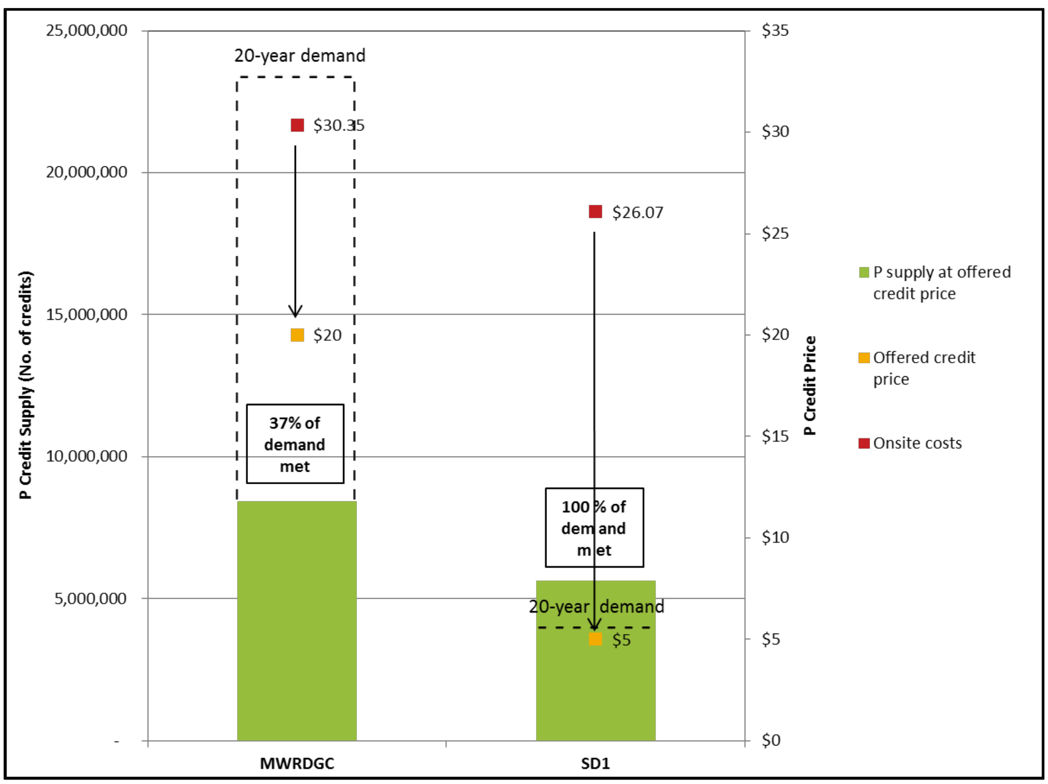


FIGURE C. PHOSPHORUS CREDIT SUPPLY POTENTIAL WITH MWRDGC OFFERING A CREDIT PRICE THAT IS 75% OF ITS ONSITE COSTS AND SD1 OFFERING A CREDIT PRICE THAT IS 25% OF ITS ONSITE COSTS

MWRDGC could trade to achieve the entire 45% N reduction goal; however, based on the supply from the project watersheds, there would be only enough P supply to offset 37% of its demand. SD1, on the other hand, would find enough N and P credits from the agricultural watersheds to satisfy 100% of its demand for both nutrient credits.

Note that when there is a market for only one nutrient, credits for the other nutrient are also generated. For example, if only N credit prices are offered, P credits are also generated because conservation practices selected for reducing N also end up achieving P reductions as co-benefits. Thus, when a $3/N credit price is offered, for example, the six project watersheds generate 14 million N credits annually beyond the N TES for sale, but 445,000 P credits are also generated beyond the P TES every year. Given that these nutrient co-benefits are produced even without a price signal for that nutrient, there are actually many more pounds total nutrients reduced and credits generated at any given price point for a single nutrient.

2. Conservation practices can be profitable, with or without trading

The agricultural project watersheds are poised to generate significant profit from selling nutrient credits in a trading market. To model the maximum profit potential for these agricultural producers, WRI used willingness to pay thresholds representing 75%, 50%, and 25% of average utility onsite costs ($8.09/lb N reduced and $28.42/lb P reduced). At each of these potential credit prices, WRI simulated potential profit at various policy scenarios. Depending on the policy scenario and credit price, the agricultural watersheds could receive about $25 to $61 per acre from the sale of nitrogen credits (see Figure D) and between $18 and $42 per acre from the sale of phosphorus credits.

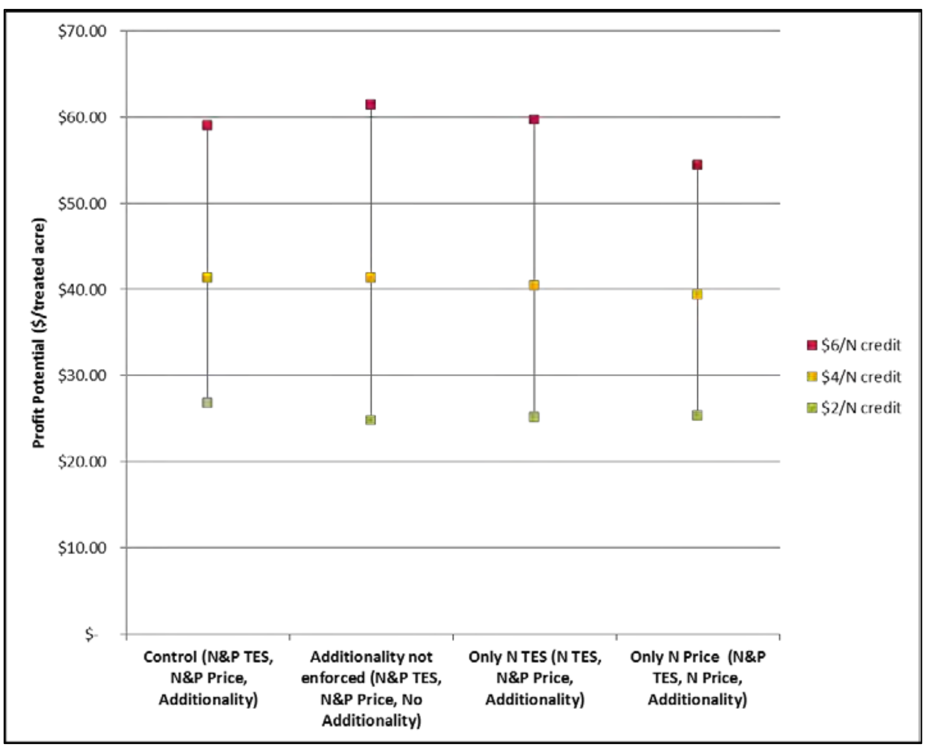


FIGURE D. RANGE OF AGRICULTURAL SECTOR PROFIT POTENTIAL PER TREATED ACRE ACROSS VARIOUS POLICY SCENARIOS AT AVERAGE UTILITY N CREDIT PRICE POSSIBILITIES

One surprising finding was that even when there were no credit prices at play in the model, the profit-maximization equation found that between 12 and 19% of the 4.7 million-acre, six project watershed area could achieve a net savings from implementing conservation practices that achieved both N and P TES or the P-only TES, respectively. These net savings appeared as negative net costs because fertilizer savings and/or increases in crop yield resulting from the conservation practices outweighed the practice costs on these modeled acres.

When relatively low credit prices were introduced (i.e., up to $3/N credit, up to $15/P credit and up to both $3/N and $15/P credits), the model found that between 16 and 38% of the agricultural project area experienced negative net costs (i.e., net savings) from generating credits, even before selling the credits.

Thus, for a portion of the project area, it may be profitable for farmers to implement conservation practices that achieve a greater than 45% reduction in nitrogen and/or phosphorus loads with or without a trading program. This finding should be treated cautiously given the model's limitations. First, this analysis modeled only six 8-digit agricultural watersheds, not the entire MRB. Second, while the model uses various survey points representing a variety of agricultural operations, the data from each survey point is then statistically extrapolated to the rest of the cropland acres in each watershed. As a result of this approach, some of the subtle factors associated with conservation net savings calculations may not be captured.

Finally, there are a variety of reasons why the producers who are located on these acres exhibiting net savings may not have already invested in conservation practices to realize the associated profit. These reasons may include a lack of upfront funds to implement conservation practices, a lack of awareness or understanding of the opportunity, concern that reducing fertilization may reduce yields, lack of on-the-ground evidence that such net savings are possible, and technical challenges assessing whether their operation may be among those that might experience net savings from conservation practice adoption.

3. The study found that when both N and P credit prices are offered in a trading market, more acres are used to generate credits, larger quantities of both N and P credits are generated, and higher profits materialize than when only one credit price is offered. If only one credit price is offered, an N price stimulates more credit generation than a P price. And the larger the credit price, the larger the quantity of credits generated. Regarding TES policy, having both N and P TES requirements yields more credits than just one TES requirement. Finally, as would be expected with the additionality policy, a larger quantity of credits is generated if additionality is not enforced than if it is (though the water quality goal may be compromised).

4. The study did not find any current water quality conditions, state policies, or utility-specific permitting issues that would hamper nutrient trading for either of the project's utilities. However, there are new instream P standards being discussed in Illinois that may constrain the geographic scope of P nutrient trading for the MWRDGC in the future.

5. The study modeled the effect of future instream numeric nutrient criteria on trading and found that, depending on the criteria, instream standards could prevent nutrient trading from occurring with downstream suppliers. Nevertheless, nutrient trading might still remain a viable option for helping to attain local numeric nutrient criteria in the most cost-effective way possible if there is sufficient agricultural credit supply upstream and within the applicable watershed.

6. After reviewing the study's findings, the project utilities found N trading to be a potential alternative to investing in more expensive onsite technologies—should a Gulf-related N reduction goal materialize—and they did not foresee local N water quality policies as forthcoming. MWRDGC was less interested in P trading due to commitments they have made to reduce P onsite and the likelihood that a local instream numeric P criterion might materialize. SD1 was open to investigating the favorability of P trading at some of their plants should a Gulf P goal occur, as they did not foresee a local P goal being developed for the fast-moving Ohio River, where some of their plants discharge. Both utilities, however, were unable to identify a specific willingness to pay, indicating that a thorough cost analysis would have to be conducted to determine potential economic benefits. Both utilities would also have to vet any plans to trade through their ratepayers, review boards, and regulatory agencies, as well as take into account the opinions of other area stakeholders such as watershed and environmental groups.

7. After reviewing the study's findings, most of the agricultural stakeholders in the project watersheds were interested in trading as a potential additional revenue source for farm producers. The study's estimated profits were believed to be attractive to at least some producers. Ultimately, a producer's decision to engage in trading would depend on how commodity prices compare to credit prices, confidence in the buyers and the stability of the market, how risky or onerous contract obligations appeared, and how trading activities may affect their potential future regulatory obligations.

Overall, the study's findings suggest that, although credit generation costs and potential supply and demand would vary somewhat with respect to credit prices and program policies, nutrient trading would be a cost-effective mechanism for helping to achieve clean water goals for the Gulf of Mexico.

While trading on a large interstate scale in the MRB will likely not come to pass unless there is a strong policy driver, states and stakeholders could be taking steps toward enabling trading if and when it occurs. Should USEPA, state regulatory agencies, and stakeholders conclude that nutrient trading is a cost-effective approach to help achieve water quality goals in the MRB, WRI offers three recommendations for moving forward.

1. Identify local watersheds where trading may be feasible due to local water quality concerns.

2. Federal and state agencies, environmental groups, the agricultural community, wastewater community, and other stakeholders should collaborate in defining key trading program elements.

3. All relevant stakeholders should collaborate to identify and develop the necessary data and tools for quantifying nutrient reductions.

The main report that follows provides details on the utility cost and agricultural credit supply analyses and illustrates the likely effects on trading supply and demand under various policy scenarios.

I. INTRODUCTION

A. Study Purpose

The purpose of this feasibility study is to assess the *technical* and *economic* feasibility of large-scale interstate nutrient trading in the Mississippi River Basin (MRB) to address hypoxia in the Gulf of Mexico. The feasibility study is simply intended to examine the economics of trading between upstream buyers and downstream sellers, the effects that various trading program policy decisions could have on supply, demand, and costs, and the constraints that could occur due to local water quality concerns. This study is not a trading design or implementation exercise, but it does provide useful information that informs stakeholders of the issues to consider if and when a trading market for nutrient credits is developed.

To assess the feasibility of nutrient trading in the MRB, the study:

- Evaluated potential nitrogen (N) and phosphorus (P) end-of-pipe discharge reduction requirements to meet the project water quality goal for one wastewater utility in the Upper Mississippi Basin and one utility in the Ohio River Basin,
- Estimated the capital and operations and maintenance costs required to achieve these reductions through wastewater treatment plant (WWTP) upgrades,
- Evaluated the potential for N and P edge-of-field agricultural load reductions in three 8-digit hydrologic unit code (HUC) watersheds in Arkansas and three 8-digit HUC watersheds in Mississippi,[2]
- Estimated the capital and operations and maintenance costs required to produce these agricultural nutrient load reductions,
- Evaluated existing baseline load (see Box 1.1) reduction requirements that credit sellers would have to meet before producing additional reductions to sell as credits,
- Calculated the number of credits utilities potentially would need and agricultural producers potentially could generate by applying watershed-specific delivery ratios, and
- Determined the potential economic feasibility of trading by comparing buyer and seller credit costs.

Box 1.1. Defining the term "baseline load" for this study

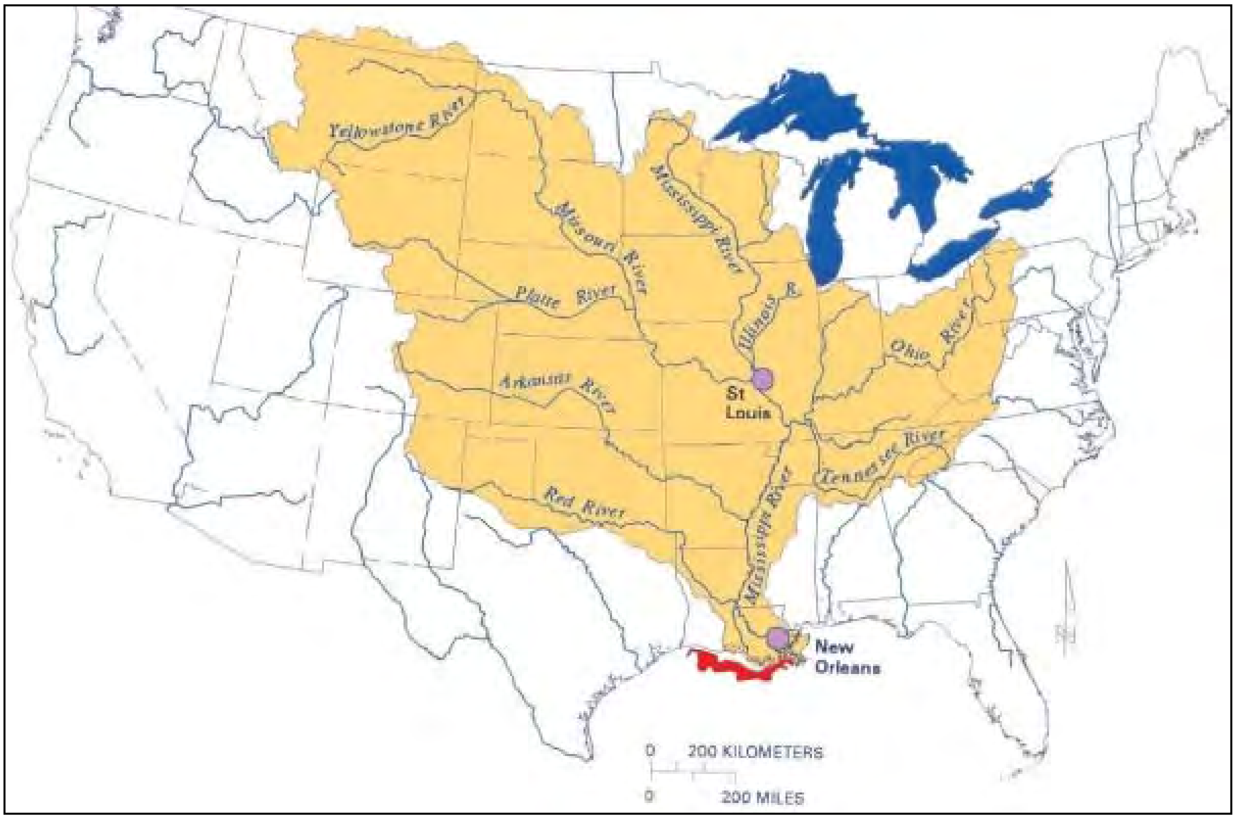
The term "baseline load" in nutrient trading policy circles and in the U.S. Environmental Protection Agency's Water Quality Trading Policy from 2003 is different than the term used by the Natural Resources Conservation Service (NRCS).* In this study, WRI decided to use "baseline load" the same way NRCS uses the term. In NRCS's Conservation Effects Assessment Project (CEAP), baseline load refers to the "existing" annual average nutrient loss levels estimated by the CEAP models to occur from 2003 to 2006, when the Natural Resource Inventory (NRI)–CEAP farmer surveys were conducted. Because this report used the CEAP datasets and models, we retained CEAP's use of the term "baseline." In contrast, in the trading community, baseline load refers to what this report is calling the "trading eligibility standard," that is, the load at which credit suppliers must reduce to before they can trade additional nutrient reductions.

*Source: USEPA 2003.

[2] HUCs provide information regarding the size category for watersheds. Watersheds with larger HUC numbers drain into watersheds with smaller HUC numbers (USGS n.d.)

B. Nutrient Pollution Problem in the Gulf

The Mississippi River Basin drains about 40% of the land area in the continental United States, including most of the area between the Rocky Mountains and the Appalachian Mountains (see Figure 1.1). From northern Minnesota to southern Louisiana, the Mississippi River carries nutrients (i.e., N and P) from agricultural fields, urban and suburban areas, wastewater treatment plants, atmospheric deposition from energy combustion, and eroding stream banks. Eventually, the River empties into the Gulf of Mexico about 100 miles south of New Orleans.[3]



Map credit: Louisiana Marine Consortiums (LUMCON), http://www.gulfhypoxia.net

FIGURE 1.1. THE MISSISSIPPI RIVER DRAINAGE BASIN AND GULF OF MEXICO "DEAD ZONE" (IN RED)

The Mississippi River's nutrient concentrations have increased significantly over the past half-century. These high loads of N and P cause an over enrichment of nutrients, or eutrophication, in the northern Gulf of Mexico.[4] Every summer, when waters are stratified, the warmer freshwater from the River forms a layer on top of the colder, more saline Gulf water. As a result, the deeper Gulf waters are cut off from the more oxygenated surface waters. In this surface layer, the excess nutrients cause the growth of algal blooms. When these algae die, they sink to the bottom of the Gulf and decompose. The decomposition process consumes the already limited oxygen supplies in these bottom waters, and areas become

[3] See Mississippi River Gulf of Mexico Watershed Nutrient Task Force 2012.
[4] See World Resources Institute 2012.

hypoxic, meaning they have dissolved oxygen levels less than 2 parts per million (ppm), which are unsuitable for most aquatic life.[5]

This seasonal phenomenon results in an oxygen "dead zone" in the northern Gulf of Mexico every summer. In the summer of 2011, the dead zone was 6,765 square miles in area, larger than average and about the size of the state of Connecticut.[6]

FIGURE **1.1** provides an illustration of the entire MRB drainage and the dead zone (in red). The U.S. Environmental Protection Agency (USEPA) Science Advisory Board (SAB) has recommended a 45% reduction in N and P loads to reduce the dead zone to 5,000 square kilometers (km^2) on a five-year rolling average.[7]

C. Nutrient Trading as a Potential Solution

The purpose of this study is to examine the cost-effectiveness of using water quality trading of total N and P credits (i.e., nutrient trading) to meet nutrient load reduction targets needed to shrink Gulf hypoxia. For readability's sake, the report uses the abbreviation "N" to represent total nitrogen and "P" to mean total phosphorus. A credit is defined as a pound of N or P reduction as measured in terms of delivered pounds to the Gulf.

Nutrient trading is a market-based mechanism that helps both regulated and unregulated entities cost-effectively meet water quality goals. When a waterbody receives a cap on N or P pollutant loads, such as from a Total Maximum Daily Load (TMDL), the cap limits the amount of pollution that can continue to enter the waterbody. Trading helps to achieve the cap in the most cost-effective manner by enabling high-cost entities such as wastewater utilities to purchase nutrient credits from other utilities with lower abatement costs or from agricultural producers that may be able to reduce nutrient loads more cost effectively. Trading thus provides flexibility to regulated point sources as they consider options for complying with their portion of the cap that would become incorporated into their National Pollutant Discharge Elimination System (NPDES) permit. Trading also provides economic incentives to the agricultural sector, which remains largely unregulated, to reduce pollution further to generate credits that can be sold to regulated buyers.

Water quality trading can occur between two regulated point sources such as wastewater utilities or industrial facilities (point-point trading) or between a regulated point source and a non-regulated nonpoint source like agriculture (point-nonpoint trading). In point-point trading, utilities or industries with low abatement costs are incentivized to reduce nutrients below their permitted limit to generate credits that can be sold in the market. Utilities or industries with high abatement costs may choose to purchase these credits in lieu of paying for expensive upgrades.

Point-nonpoint source trading is when a regulated point source purchases credits from an unregulated nonpoint source, such as the agricultural sector. Agricultural producers can, on average, reduce nutrient runoff at lower costs on a per pound basis than point sources. Thus, trading between point and agricultural nonpoint sources may offer the most cost-effective means for a point source to meet its permit limit. When trading programs also include trading eligibility standards (TES) that represent

[5] See Louisiana University Marine Consortium 2012.
[6] See Schleifstein 2011.
[7] See USEPA 2007.

voluntary cleanup goals for the unregulated sector, trading can serve as an incentive to meet and go beyond the standard to generate credits in the market.

Taking advantage of location differences between credit buyers and sellers can also help maximize the efficiency of a nutrient trading program trying to achieve water quality goals in a downstream waterbody of concern. Natural attenuation processes (e.g., denitrification and P burial, which occurs as nutrients are transported downstream) mean that, generally, nutrient discharges that occur farther upstream have less impact than nutrient discharges that happen near the waterbody of concern. In a nutrient trading program, delivery factors are applied to nutrient reductions to estimate the actual impact of those reductions (or discharges) on the waterbody of concern, ensuring "equivalence" between the reduction efforts of the credit buyers and sellers.

For example, a credit seller located in a watershed with a high N delivery factor of say, 90%, only has 10% of its emitted N lost during transport, while 90% of the N reaches the waterbody of concern. Thus, if that credit seller were to reduce 100 pounds of N, it would generate 90 pounds for sale (100 lbs * 90% delivery). Likewise, if a credit buyer were located farther upstream in a watershed with a 70% N delivery factor, this buyer would need to purchase 70 credits for achieving the same effect on the waterbody of concern (100 lbs * 70% delivery). Thus, using delivery factors to quantify location differences helps trading programs achieve equivalence in the effect that nutrient reduction efforts have on the downstream waterbody of concern.

To highlight how awareness of these delivery factors can increase the economic efficiency of a trading program, imagine a trade between two regulated point sources: " A," a point source with a high delivery factor and "B," a point source with a low delivery factor. The greatest reduction of delivered pollution per dollar spent would occur at point source A (with the higher delivery factor) because most of its reductions will benefit the downstream waterbody. In general, nutrient discharges from the lower reaches of a watershed and those occurring near large, fast moving rivers have higher delivery factors than discharges from the upper reaches of a watershed or those occurring farther away from large, fast moving rivers. Thus, point source A with the higher delivery factor would benefit from being a credit seller; it can price its credits competitively because the pounds reduced are not heavily discounted by a low delivery factor. In contrast, point source B with a low delivery factor may benefit from purchasing credits instead of investing onsite. If credits are purchased as delivered pounds, point source B could purchase only the amount of delivered pounds it needs to reduce as opposed to the number of pounds it would otherwise have to reduce onsite.

Box 1.2. Nitrogen trading is a success in Long Island Sound

The Connecticut Long Island Sound Nitrogen Trading Program was established in 2001 and is the largest nutrient trading program in geographic scale between point sources to date. The program encompasses the Connecticut portion of the Long Island Sound watershed and uses the principle of applying the most cost-effective actions first as its fundamental strategy for achieving total maximum daily load (TMDL) nitrogen waste load allocations (WLA). In the Connecticut program, nitrogen delivery ratios are a key factor in determining cost-effectiveness and the priority order of wastewater treatment plant upgrades. Approximately 79 wastewater treatment plants in the Sound are close to meeting their N cleanup goal through a combination of facility upgrades and trades. The Connecticut Department of Environment estimates that nitrogen trading has helped lower compliance costs by 30%.

Source: Connecticut Department of Environment 2009.

Many states in the Chesapeake Bay watershed have developed nutrient trading programs as part of their strategy to meet a 2025 TMDL for nutrients in the Bay. Pennsylvania, Maryland, and Virginia have nutrient trading programs for point and nonpoint sources. West Virginia allows trades of nutrients on a case-by-case basis, and Delaware is considering developing a program. The existing trading programs are designed to provide flexibility to wastewater treatment plants to meet their nutrient discharge permit limits.[8]

Recent WRI analysis in the Chesapeake Bay indicates that cost savings for meeting the upcoming Bay TMDL nitrogen permit caps through trading with agricultural sources may be on the order of 60% for WWTPs and 25 to 60% for stormwater utilities. Depending on credit price, WRI estimates that point to non-point source trading could provide funding for the installation and maintenance of agricultural best management practices (BMPs) on the order of $45 to $300 million per year, depending on credit prices, as compared to current public federal and state cost-share funding of $180 million per year.[9]

WRI also estimated the potential profitability to six hypothetical crop and livestock farms in Maryland, Virginia, and Pennsylvania from trading. Given a nitrogen credit price of $20/acre and the many other variables affecting the analysis, including cost methods, policy assumptions, data, and estimation tools, the average estimated farm profitmaking potential from trading was $11,000/year, ranging from $300/year to $30,000/year.[10,11,12] These analyses by WRI in the Bay region suggest that not only does trading provide cost savings to regulated point sources with nutrient load reduction requirements, it can also serve as an additional revenue source to unregulated nonpoint agricultural sources that generate the credits.

Across the Unites States, there are 24 active point-nonpoint source trading programs, all with similar goals of providing a flexible and cost-effective option for improving water quality.[13,14] This study examines the feasibility for MRB states to adopt a point-nonpoint source nutrient trading strategy to address Gulf hypoxia.

D. The Study: Large-Scale Interstate Nutrient Trading in the MRB–Gulf of Mexico

Geographic Scope

WRI set the geographic scope for the study as the entire MRB, focusing on the upper MRB for the hypothetical credit buyers and the lower MRB for the credit sellers. WRI designed the study this way because watersheds in the upper reaches of a basin generally tend to have lower delivery ratios than watersheds in the lower basin, providing advantageous delivery ratios to the buyers and sellers. Therefore, producers would be able to sell more of their reductions as credits, and utilities could purchase credits reflecting the utilities' discounted delivered load to the Gulf.

[8] See Branosky et al. 2011.
[9] See Jones et al. 2010.
[10] See Talberth et al. 2010a.
[11] See Talberth et al. 2010b.
[12] See Talberth et al. 2010c.
[13] See Willamette Partnership et al. 2012.
[14] See USEPA 2012a.

The large scale of this study allows us to examine if the differences in delivery factors between distant and proximate sources result in highly beneficial trades that achieve the objective of reducing nutrient loads entering the Gulf in a cost-effective manner.

Buyer and Seller Identification

Due to the potential advantages of trading between sources downstream and upstream, we identified potential credit buyers in Chicago, Illinois, and northern Kentucky. These upstream point sources were selected because of their significant differences in plant capacity. The Chicago Metropolitan Water Reclamation District (MWRDGC) is one of the largest wastewater utilities in the country, and Sanitation District No. 1 of Northern Kentucky (SD1) operates on a much smaller scale. These variations in capacity allow for credit demand estimates on different orders of magnitudes. WRI and its project team worked with these two utilities to assess possible future nutrient discharge requirements, along with the cost to comply with them through the installation of nutrient removal technologies. This information was used to derive the utilities' potential credit needs and credit cost considerations to inform a discussion about the possibility for nutrient trading to become a preferred option for satisfying the project's water quality goal.

Likewise, we identified agricultural producers in the lower MRB as potential credit sellers due to the higher delivery factors in the lower MRB. We identified six 8-digit HUC watersheds in the Mississippi River Delta areas for nutrient reduction. These six watersheds include three in Arkansas—Cache, L'Anguille, and Lower St. Francis—and three in Mississippi—Big Sunflower, Deer-Steele, and Upper Yahoo (see

FIGURE 1.2). The agricultural watersheds were selected for this project because they have relatively high delivered loads of nutrients to the Gulf, according to the U.S. Geological Survey (USGS). Their delivered loads are, in part, why they are participating in several U.S. Department of Agriculture (USDA) conservation programs and targeting initiatives (e.g., Mississippi River Basin Healthy Watersheds Initiatives and USEPA's nonpoint source "319" watershed program).

E. Policy Framework and Assumptions for this Nutrient Trading Feasibility Study

To assess the economic and environmental feasibility of large-scale interstate nutrient trading in the MRB, several policy choices and simplifying assumptions were made. These decisions were made in order to conduct an analysis that represents the most likely conditions under which a nutrient trading program would develop. The decisions also reflect the purpose of such a nutrient trading program: to help minimize the costs of meeting water quality goals that reduce hypoxia in the Gulf of Mexico.

Project Waterbody of Interest

The waterbody of interest in this nutrient trading study is the Gulf of Mexico hypoxic zone. All delivery factors used in this study are a measure of nutrient attenuation from the point of origin of the nutrient load, or the nutrient reduction in the MRB to the Gulf.

FIGURE 1.2. LOCATIONS OF THE WASTEWATER UTILITIES AND AGRICULTURAL WATERSHEDS USED AS CASE STUDIES FOR NUTRIENT TRADING FEASIBILITY ASSESSMENT

Project Water Quality Goal

The water quality goal that this nutrient trading study aims to achieve is the 45% reduction in delivered loads of both N and P to the Gulf.[15] A future trading program would likely involve development of a TMDL for the Gulf that would require scientific and political deliberations about how to allocate the required loads to regulated and unregulated sources of nutrients in the MRB. For this project, WRI decided to make the simplifying assumption that each nutrient source (i.e., utilities and agriculture) would receive a 45% reduction target for N and P delivered load to the Gulf. In addition, so-called, "uncontrollable loads" from forest, barren, and shrub lands and from atmospheric deposition in each project watershed were apportioned into the existing baseline loads for both the utility and the agricultural sources.

[15] See USEPA 2007.

Project Assumptions for Wastewater Utility Credit Buyers

WRI assumed that the project's MRB-Gulf hypoxia reduction goal would require wastewater utilities to reduce their nutrient discharges by 45% or achieve an equivalent amount of reduction from credit purchases that accounted for delivery factors. To estimate the N and P load from which a 45% reduction would be needed at each utility, Symbiont employed the standard wastewater engineering approach to multiply the design flow for each utility's wastewater treatment plant by the plant's current N and P annual average effluent concentrations.

Project Trading Eligibility Standard for Agricultural Credit Sellers

The TES for individual, unregulated agricultural credit sellers in this project is achievement of the 45% N and P delivered load reduction goal before additional reductions can be sold as credits. Thus, for each of the six credit supply watersheds in our project, we determined current baseline N and P loads reaching the Gulf, subtracted the 45% reduction that is needed to meet the water quality goal in the Gulf, and divided the remaining N and P loads into the number of cropland acres in the watershed. The TES, expressed as a maximum N and P loss rate per acre, represents to producers in each watershed the performance-based standard they must achieve before they can qualify to sell the reductions achieved beyond the 45% goal as credits. WRI developed this approach for establishing a TES for credit sellers by scanning protocols from various nutrient trading programs and, in particular, relied on the Maryland Nutrient Trading Program.[16] Note that individual producers interested in engaging in trading need to attain only the TES on their own farm before generating credits and do not have to wait for the rest of the producers in their watershed to achieve the TES standard before trading. Requiring credit sellers to achieve a trading eligibility standard before they can sell credits ensures that trading will help meet the established water quality goal.

Three Types of Trading Eligibility Standards

Though the SAB report called for both N and P reduction goals, a future MRB-Gulf trading program might call for an N-only TES (where a producer must meet only the N TES before being eligible to trade), a P-only TES (where a producer must meet only the P TES before being eligible to trade), or both an N and a P TES (where a producer cannot trade unless he has met both the N and the P TES). WRI decided to analyze what effect each of these trading policy options would have on credit supply and associated costs.

Additionality and Uncertainty

Another important concept in market-based programs relates to the principle of additionality, or the requirement that only new and additional load reductions in excess of the seller's TES can be counted as credits. WRI analyzed the effect that enforcing additionality or not enforcing additionality would have on credit supply and associated costs. For example, in the case of a producer whose existing loads are already below his watershed's TES, if additionality were enforced the difference between his current load and the TES would not count toward credit generation. He would be required to implement new, additional practices to generate reductions that are eligible to sell as credits. If additionality were not enforced, the difference between his current load and the TES would be eligible to sell as credits even though the producer implemented no additional BMPs.

[16] See Maryland Department of Agriculture 2008.

In addition, many trading programs use trade ratios to account for the uncertainty associated with nonpoint source reductions and to provide insurance for trades in case any credits default. The effects of uncertainty will be discussed; however, no assumptions about such policies were made and no trade ratios were incorporated into the core analysis because of the scientific and political nature of these decisions.

Addressing Local Waterbody Concerns

Though the nutrient trading project is designed to achieve potential future water goals in the Gulf of Mexico, USEPA's "Final Water Quality Trading Policy" states that credit buyers will not be allowed to engage in nutrient trading to meet a downstream goal if doing so violates the local water quality standards of their receiving waters.[17] Thus, if a wastewater utility's receiving waters have local water quality standards for either or both N or P that are more stringent than the downstream trading goal, the utility must achieve the local standard discharge requirements before trading to achieve the downstream goal. In such a case, trading might still be an option to help achieve the local water quality standards, but credits would have to be purchased upstream from the utility and within the utility's watershed so that the reductions benefit its local water quality.

F. Project Partners

WRI collaborated with numerous partners to conduct this feasibility study. First and foremost, the partners included on the grant were: Symbiont as a contractor on the wastewater utility credit analysis, HydroQual as a sub-contractor on the instream nutrient criteria and delivery factor analyses, and Dr. Andrew Sharpley of University of Arkansas as a contractor on the agricultural supply side analysis.

Other partners included the two wastewater utilities, MWRDGC and SD1, which provided the utility data used in the credit demand analysis. Dr. Robert Kroger of Mississippi State University helped WRI conduct a BMP literature review in the lower Mississippi Alluvial Valley.

WRI entered into a Collaborative Agreement with the USDA's Natural Resources Conservation Service (NRCS) to conduct agricultural credit supply modeling. WRI worked with NRCS staff, Dr. Lee Norfleet and Dr. Jay Atwood of Texas AgriLife Blackland Research Labs.

G. Stakeholder Engagement

In addition to working with partners and collaborators, WRI also worked with a variety of stakeholders. WRI held kickoff meetings in Arkansas and Mississippi, where we met with over 30 agricultural, environmental, government, and non-government stakeholders. The purpose of these meetings was to introduce the project and learn from the local stakeholder groups. Generally, the agricultural stakeholders were very concerned about nutrient trading and its implications, as they see it as accompanying a future nutrient reduction goal for the Gulf of Mexico and regulations for producers in the MRB.

WRI also held kickoff meetings in Illinois and met with MWRDGC, SD1, Illinois Environmental Protection Agency (IEPA), and USEPA. The purpose of these meetings was to introduce the project and discuss data needs with the utilities and the policymakers. WRI learned that water quality standards and the concept of nutrient trading is still very new in Illinois, and there are differing opinions on how to qualify waters

[17] See USEPA 2003.

as impaired for nutrients. Generally, the agencies were interested in learning more about nutrient trading.

After completing the study, WRI met again with the agricultural and wastewater utility stakeholders and presented the study findings, gained feedback, and answered questions. WRI posed five interview questions to the stakeholders at these meetings and provides summary highlights of those responses throughout the report and in Section VII, subsections B and C. The interview questions included: opinions of the study's methods, data, and approaches; opinions on nutrient trading; willingness to pay for or accept credits; regulatory and other non-monetary factors involved in decision-making about engagement in trading; ideas for next steps and possible roles in potential future trading programs.

H. Overview of the Report and Appendices

This report provides five main sections of analysis: (1) a discussion of the potential credit demand and costs from the two project wastewater utilities; (2) a discussion of the potential credit supply and costs from the project's agricultural watersheds; (3) a comparison of the potential credit demand, supply, and cost differentials; (4) a discussion of the impact of existing and potential future water quality policies on trading; and (5) a discussion of important scientific and policy factors that should be considered when developing a future nutrient credit market.

The report's Appendix provides two sample case studies of the range of costs farm producers might experience in regards to nutrient trading. Finally, eight tables from the NRCS modeling exercises are provided.

The following reports which informed this analysis are available upon request: Symbiont's wastewater utility demand and cost analysis, HydroQual's nutrient criteria and delivery factor analysis, and the peer-reviewed journal article on best management practices that are applicable to the Lower Mississippi Alluvial Valley.

II. POTENTIAL CREDIT DEMAND AND COSTS FROM WWTPs

The credit demand analysis was conducted to estimate the potential for the two project utilities to engage in nutrient trading to achieve a hypothetical discharge limit that is 45% below their current N and P discharges. The analysis that was conducted was not a typical business demand analysis (i.e., investigating the relationship between price and quantity demanded), rather it was a simple analysis based on fixed costs to achieve the study's nutrient reduction goal. The analysis involved estimating costs to achieve the reduction goal onsite through technological upgrades and estimating the amount of N and P that would need to be reduced. Based on this nutrient reduction target and corresponding costs, the potential buyer credit price ceiling, or "maximum willingness to pay" for credits was determined. In Section IV, WRI made the simplifying assumption that the project utilities might be interested in nutrient trading to satisfy the project goals if they perceived sufficient cost savings from offering credit prices that were 25%, 50%, or 75% of their onsite costs.

A. Background

The potential credit buyers in this study are representative publicly owned treatment works that treat wastewater from the public sewer. The seven plants at the MWRDGC currently discharge over 1 billion gallons of wastewater per day, while the two plants at SD1 discharge over 50 million gallons per day. Of MWRDGC's seven plants, three constitute the 2nd, 7th, and 11th largest average daily discharge loads of N into the MRB among nearly 32,000 identified point sources. In comparison, only the SD1 Dry Creek plant placed in the top 50, registering as the 47th largest average daily discharge load of N into the MRB.[18] The participation of these two utilities allows for assessment of the needs of differently sized credit buyers.

MWRDGC provides wastewater treatment services to 10.35 million customers in Chicago and Cook County, Illinois, in an 883.5 square mile sewershed. MWRDGC's facilities discharge into the Chicago Waterway System (CWS), a manmade system with input sources from the Great Lakes, though about 70% of the flow comes from the utility's discharge.[19] MWRDGC's plants therefore have a significant impact on the water quality in the CWS. Due to its location next to Lake Michigan, the utility's sewershed is dominated by urban and suburban land uses.

SD1 has over 100,000 customers in Campbell, Kenton, and Boone Counties in northern Kentucky in a 176 square mile sewershed. SD1's discharge from the Dry Creek plant makes up far less than 1% of the 90,000 cubic feet per second (cfs) flow of the large Ohio River. SD1's Eastern Regional plant is located on a small stream, Brush Creek, which has intermittent flow. At certain times of the year, the plant's effluent makes up the entire stream flow.

B. Policy Framework and Assumptions

To provide the policy framework for this hypothetical trading market, WRI had to make a few simplifying assumptions about the requirements for wastewater utility credit buyers and the lifetime of a unit of pollutant reduction. Neither of these policy considerations have an effect on the methods used to estimate costs to meet future Gulf water quality goals. More details on setting the requirements for credit buyers are discussed in Section V. The existing water quality standards affecting the two project

[18] USEPA 2006.
[19] See Metropolitan Water Reclamation District of Greater Chicago Research and Development Department 2008.

utilities and the likely impact of potential future instream numeric nutrient criteria is also discussed in that section. The lifetime of pollutant reduction units is discussed in Section VI.

C. Methods

To estimate the potential costs of the two wastewater utilities associated with achieving the 45% N and P reduction, the following information was collected and analyzed: (a) the utilities' operating data, (b) expected changes in nutrient loads from a variety of existing and potential future policy developments, and (c) permit information and potential future effluent limits. This information was used to estimate the potential future reductions that could be required and associated costs. The Results section summarizes options for meeting these potential future limits either through upgrades or nutrient trading. All of the data and analysis that was used to conduct the demand-side analysis can be found in the Symbiont report (see Appendix A for a link to that report).

The demand analysis for MWRDGC is based on data from two of its plants, Calumet and Northside, which are the second and third largest of the utility's plants. These plants were selected because they had the most comprehensive Master Plans for nutrient removal options and because the Calumet Master Plan had costs broken out for N and P. Because the Northside plant is nearly identical in flow to Calumet, Calumet's cost information could be apportioned into Northside's costs for N and P. The Calumet and Northside plants developed these detailed plans and nutrient cost analyses in 2006 and 2007, respectively, in response to discussions of potential regulations for N and P.

For SD1's credit demand analysis, data from both of its existing plants and its planned third plant were used. In 2008, SD1 undertook a planning analysis similar to that conducted by MWRDGC, which provided N- and P-specific costs for implementing onsite technology upgrades.

Supplemental Cost Data

The utilities' cost information was used to estimate costs to upgrade the treatment plants to meet potential future nutrient reduction requirements. However, the utilities had only upgrade cost estimates for expected treatment levels of 8 milligrams per liter (mg/L) of N and 1 mg/L of P. For this reason, upgrade costs for other possible treatment levels were estimated using data from outside sources. Wastewater utility databases from Maryland, Virginia, and Pennsylvania were used because these states have requirements for treating N and P, many of which are more stringent than the planning levels the project utilities used. These data include individual plant cost estimates for achieving various levels of nutrient treatment in each state. Data from plants in Pennsylvania, which on average have roughly the same level of nutrient treatment as those included in MWRDGC's and SD1's planning studies, were used as references to check the utilities' data.

Amortization and Discounting

The capital costs for nutrient reduction technologies were annualized over the expected lifetime of the technology, approximately 20 years, using an opportunity cost for capital of 7%. Next, annual operating and maintenance costs were added to the annualized costs. The sum of the full cost stream—annualized capital costs plus operation and maintenance—was calculated using USEPA's recommended consumption rate of interest of 3%. The resulting value was then divided by the 20-year total reductions achieved for each nutrient to establish final values in dollars per pound of reduction.

D. Current and Planned Operating Conditions and Policies

This section summarizes the current operating conditions and potential future nutrient load reductions for MWRDGC and SD1. This information was used to develop the cost estimates, as discussed in the Results section that follows.

MWRDGC

Current Permit Requirements and Operating Conditions

Currently, MWRDGC has no NPDES permit limits for N or P, but it does have limits for biochemical oxygen demand ($cBOD_5$; which is harmful to aquatic life because it depresses oxygen concentration), total suspended solids (TSS; to avoid sedimentation buildup that would harm aquatic life), and two seasonally related limits for ammonia nitrogen (NH_3-N; known to be toxic to certain aquatic species). The District uses activated sludge technology as its secondary treatment process to achieve these permit limits. However, this treatment process does produce some nutrient co-benefits by reducing N and P concentrations by 68% and 80%, respectively. See TABLE 2.1 for current N and P concentrations in the plants' influent and effluent.

TABLE 2.1. NUTRIENT CONCENTRATION DATA FOR MWRDGC TREATMENT PLANTS, 2006–2008 (MG/L)

	Stickney	Calumet	North-side	Kirie	Egan	Hanover Park	Lemont
Influent N	39.3	19.5	20.3	25.1	29.3	31.0	26.3
Effluent N	10.4	10.0	10.3	8.1	16.0	14.5	18.2
Load Reduction	*73%*	*49%*	*49%*	*68%*	*45%*	*53%*	*31%*
Influent P	7.9	4.8	2.9	4.2	6.1	5.5	4.2
Effluent P	1.0	2.4	1.4	0.9	1.2	3.0	2.6
Load Reduction	*87%*	*50%*	*52%*	*79%*	*80%*	*46%*	*38%*

Table 2.1's values represent averages over three years. Actual concentrations for any given day, month, or year vary widely at each plant because they are not currently designed to consistently reduce N or P. In order to meet any proposed future nutrient limits, the plants would need additional technology upgrades for specifically treating N and P. (For more, please see the Symbiont report's Tables 3 and 4 and corresponding text.)

Potential Future Permit Limits for Nutrients

There are a number of potential political and regulatory changes on the horizon for MWRDGC that could have an effect on the future of nutrient discharge limits for the utility. These issues are described in Section 4 of the Symbiont report. Here, the focus is on the utility's anticipated permit requirements for nutrients under the most likely scenario.

MWRDGC is planning for nutrient concentration limits for its plants. However, with no numeric nutrient limits yet for Illinois, the District must look elsewhere to estimate likely limits to its receiving waters. In its Master Plans, the District uses effluent limits of 6 to 8 mg/L N and 0.5 mg/L P as anticipated nutrient concentration limits. MWRDGC derived these values after conversations with IEPA and after inventorying nutrient limits in other parts of the country. The District used these estimates to develop planning-level cost estimates for Calumet and Northside, the two plants used in this study's demand-side analysis.

To meet these potential future permit limits, the MWRDGC anticipates needing to implement a two-step biological treatment system for N reduction: converting ammonia to nitrate through nitrification and then converting to nitrogen gas through denitrification. For P reduction, the District plans to use chemical processes that would mix metal salts with wastewater to change P into an insoluble precipitate that would settle down into the activated sludge, where it can be easily removed. The District estimates that implementing these upgrades at Calumet and Northside would cost $966 million in upfront capital costs, plus another $32.5 million annually in operations and maintenance (O&M) costs.

These process improvements to treat N and P equate to a 20 to 40% reduction in N concentrations and a 64 to 79% reduction in P concentrations. Note that for N, these percentage reductions are slightly less than the 45% reduction that would be required under this project's hypothetical trading program, suggesting that credit purchases might help meet the goal. The P reductions for meeting future permit limits, on the other hand, are much greater than the 45% reduction needed for trading (see TABLE 2.2).

TABLE 2.2. COMPARISON OF CURRENT, PLANNING LEVEL, AND POLICY GOAL NUTRIENT LEVELS FOR MWRDGC's Northside and Calumet WWTPs

	Total Nitrogen			Total Phosphorus		
	Current	**Planning Level**	**Project Policy Goal***	**Current**	**Planning Level**	**Project Policy Goal[a]**
Effluent Concentration (mg/L)[b]	10 & 10.3	6–8	5.6	2.4 & 1.4	0.5	1.05
Mass Load[c] (lbs/day)	58,129	34,377	31,971	10,973	2,865	6.035
Load Reduction	---	*20–40%*	*45%*	---	*64–79%*	*45%*

[a] The 45% nutrient load reduction values, expressed as concentration values, represent an average value for the utility based on the combined total design average flows of the treatment plants. The total flow is 354 million gallons per day (MGD) for Calumet plus 333 MGD for North Side.

[b] The current effluent concentration values reflect each treatment plant. The first value is for Calumet and the second value is for North Side.

[c] Mass loads based on design average flow rate of 354 MGD for Calumet and 333 MGD for North Side. Current N load based on 2006–2008 annual average concentrations of 10 mg/L at Calumet and 10.3 mg/L at North Side. Planning-level N load based on a long-term planning anticipated concentration of 6 mg/L N. Current P load based on 2006–2008 annual average concentrations of 2.4 mg/L P at Calumet and 1.4 mg/L P North Side.

Because the planning-level N effluent values are nearly identical to the policy goal, Symbiont used the MWRDGC's planning-level plant improvements as estimates for the capital and O&M costs of meeting the 45% reduction policy goal. For P, however, the project's policy goal is not as stringent as the utility's anticipated planning level and thus costs were adjusted to account for this discrepancy. The capital cost to meet the project's goal is estimated at $556 million, with $28.1 million per year in O&M costs, down from $966 million in capital and $32.5 million in O&M to meet the planning-level targets. These savings are a result of needing less P treatment to achieve the project's hypoxia goal than the planning scenario.

SD1

Current Permit Requirements and Operating Conditions

SD1's Eastern Regional WWTP discharges into an intermittent stream, Brush Creek, and has a P NPDES discharge permit limit of 1.0 mg/L P but no N limit. SD1's Dry Creek plant discharges into the Ohio River and does not have any nutrient permit limits. It is anticipated that the upcoming Western Regional plant will not have any nutrient limits as it will also discharge into the Ohio River, where the plant's impact is miniscule. Like MWRDGC, SD1's plants also have permit limits for $cBOD_5$, TSS, and NH_3-N and use activated sludge for treatment, with chemical additions available if needed to further reduce P, as in the case of Eastern Regional. SD1's current treatment methods also show some ancillary nutrient reductions, as demonstrated in TABLE 2.3.

TABLE 2.3. NUTRIENT CONCENTRATION DATA FOR SD1 TREATMENT PLANTS (MG/L)		
	Dry Creek	**Eastern**
Influent N	21.0[a]	44.7[b]
Effluent N	14.0	7.2
Load Reduction	33%	84%
Influent P	5.2	10.9
Effluent P	2.7	0.7
Load Reduction	48%	94%

[a] The value shown is an average composite estimate based on the average influent ammonia concentration of 20.1 mg/L plus an average nitrate concentration of 0.6 mg/L rounded to the nearest whole number. Dry Creek does not test influent N.

[b] The value shown in the table represents the Total Kjehldahl Nitrogen measurement. Eastern Regional does not currently test N in the influent.

Potential Future Permit Limits for Nutrients

Like MWRDGC, SD1 also faces a number of potential policy changes that could affect the future of nutrient discharge limits at the utility. These issues are described in Symbiont's report in Section 4. Here, the focus is on the utility's anticipated permit requirements for nutrients under the most likely scenario. While awaiting numeric nutrient limits from Kentucky Department of Water, SD1 hired Malcolm Pirnie, an engineering consulting firm to analyze the costs to achieve potential future nutrient limits. SD1 shared these plans for use in this report.

For the Eastern Regional plant, which discharges into Brush Creek, SD1 used ecoregion values as a guide to estimate potential future nutrient limits. Ecoregion values are instream water quality standards for areas of similar ecosystems and with similar natural resources. The ecoregion in which SD1 falls has values of 0.69 mg/L N and 1 mg/L P. Because Eastern Regional plant effluent discharges make up the majority of Brush Creek's flow, Eastern Regional's effluent limits would likely need to mimic any instream numeric criteria. However, these ecoregion values are well beyond the limit of technology for N, commonly accepted to be 3 mg/L N and 0.3 mg/L P. Therefore, SD1 anticipates that Eastern Regional may be faced with the limit of technology nutrient removal requirement.

SD1's Dry Creek and planned Western Regional plants discharge into the Ohio River, making up less than 1% of the river's flow. For this reason, SD1 does not anticipate any future N or P permit limits for these plants. Regardless, SD1 worked with its consultant, Malcolm Pirnie, to determine potential nutrient limits for planning purposes. SD1 has determined that if its plants receive permit limits based on the 45% reduction goal, they are likely to be 8 mg/L N and 1 mg/L P, treatment levels that can be achieved by simply improving conventional biological treatment processes.

In order for SD1 to meet these potential future N and P discharge limits, it expects that all plants will need to achieve complete nitrification, add stages for denitrification, implement biological and/or chemical P removal systems, and expand handling systems for biosolids. Eastern Regional would also need filtration. To meet these potential discharge limits, SD1 estimates capital costs to be $228.4 million and annual O&M costs to be $4.95 million for all three plants.

The treatment upgrades to reduce N and P concentrations in plant effluent would result in a 43 to 58% reduction in N and a 55 to 63% reduction in P. Note that these planning-level reductions are very close to the study's policy goal of a 45% reduction in N and P (see TABLE 2.4).

TABLE 2.4. COMPARISON OF CURRENT, PLANNING LEVEL, AND POLICY GOAL NUTRIENT LEVELS FOR SD1

	Total Nitrogen			Total Phosphorus		
	Current	**Planning Level**	**Project Policy Goal***	**Current[a]**	**Planning Level**	**Project Policy Goal[a]**
Effluent Concentration[b]	14 & 7.2	8 & 3	7.4	2.7 & 0.65	1 & 0.3	1.4
Mass Load[c] (lbs/day)	8,005	4,540	4,380	1,519	565	841
Load Reduction	---	*43–58%*	*45%*	---	*55–63%*	*45%*

[a] The 45% nutrient load reduction values, expressed as concentration values, represent an average value for the utility based on the combined total design average flows of the treatment plants. The total flow is 46.5 MGD for Dry Creek, plus 20 MGD for Western, plus 4 MGD for Eastern.

[b] The current effluent concentration values reflect each treatment plant. The first value is for Dry Creek and the second value is for Eastern. It has been assumed that effluent concentrations for Western Regional would be the same as Dry Creek.

[c] Mass load based on the design average flow of 46.5 MGD for Dry Creek, 20 MGD for Western Regional, and 4 MGD for Eastern Regional. All flows have been combined together to determine mass loads.

Similar to MWRDGC, SD1's planning-level N effluent concentration is almost the same as the 45% nutrient reduction goal in effluent concentration. Therefore, the analysis was conducted using SD1's planning-level plant improvements as estimates for capital and O&M costs to meet the 45% reduction policy goal. For P, the planning-level concentrations are more stringent than the policy goal would require, so again, the P portion of the cost was adjusted to account for the difference in treatment needed. The capital costs to meet the policy goal would be $208 million and $3.32 million in annual O&M costs, down from the planning level's $216.5 million in capital costs and $4.84 million in O&M costs. This lower cost to meet the policy goal is solely a result of needing less P removal treatment than would be needed at the planning level.

E. Results

The cost calculations above for meeting the project's 45% nutrient reduction policy goal were necessary to estimate the cost per pound of nutrient reduced, the typical unit of analysis for a nutrient trading program. These unit costs were calculated using USEPA's two-stage discounting procedure.[20] More detail on the cost calculation methods and results can be found in Symbiont's report in Section 9 and Table 23. WRI translated these onsite statistics into delivered pounds and costs per delivered pounds in order to understand what they could mean in the context of a trading scenario. TABLE 2.5 summarizes the total necessary reductions and associated costs of delivered pounds to the Gulf.

TABLE 2.5. ESTIMATED ONSITE AND DELIVERED-TO-GULF WWTP REDUCTIONS AND CREDITS DEMANDED TO ACHIEVE A 45% N AND P LOAD REDUCTION GOAL				
	MWRDGC (Calumet & Northside)		SD1 (All Plants)	
Annual Average (Delivered To Gulf)				
	N	P	N	P
Annual Average Reduction (lbs)	7,733,613	1,153,517	1,020,365	203,703
Annual Average Cost	$46,782,390	$47,057,332	$16,303,184	$7,139,900
Annual Average Cost/lb	$6.05	$40.79	$15.98	$35.05
20-Year Present Value (Delivered To Gulf)				
	N	P	N	P
Nutrients Removed Over 20 Years (lbs)	154,672,254	23,070,336	20,407,296	4,074,057
20-Year Present Value (Capital Cost Payments and O&M)	$696,003,835	$700,094,268	$242,550,205	$106,223,682
20-Year Present Value Cost/lb	$4.50	$30.35	$11.89	$26.07

Because utilities tend to plan for changes 20 years into the future, the most important values for this study are the 20-year present value costs per pound of N and P. The values in the last row of TABLE 2.5 reflect the utilities' credit price ceiling. Credits would need to be priced lower than this amount for utilities to find trading more cost effective than investing in upgrades onsite. These results demonstrate that the unit costs to reduce P are very similar for both MWRDGC and SD1. Costs to reduce N are much lower than costs to reduce P at both plants, but costs at SD1 are more than 2.5 times those faced by MWRDGC.

These calculations suggest that based on the costs to reduce nutrients, SD1 may have more to gain from N trading than MWRDGC, as its unit costs for N are higher. However, this simplified credit price ceiling calculation does not consider the cost savings that utilities would aim to achieve through trading, additional costs they would incur by purchasing credits such as transaction costs, or other non-monetary factors that may impact a utility's willingness to trade. Ultimately, the utilities' interest in engaging in nutrient trading to meet nutrient reduction targets will depend on economic suitability and all of these factors. More about how these factors affect willingness to pay can be found in Section VI.E.

[20] See USEPA 2011a.

The next section of the report will provide more context for all of these price points by estimating the costs for agricultural producers to generate credits.

III. POTENTIAL CREDIT SUPPLY AND COSTS FROM AGRICULTURE

The credit supply analysis estimated the quantity and costs of credits from two predominantly agricultural watersheds in two states in the Lower Mississippi River Basin—the delta areas of Arkansas and Mississippi. Although the scale of the credit supply area is relatively small and the maximum potential supply from the entire Mississippi River Basin cannot be estimated from this analysis, the eligibility criteria and cost estimations provide insight into agriculture's potential to participate in nutrient trading. This section provides an overview of the findings.

A. Background

Approach

WRI partnered with USDA's NRCS Conservation Effects Assessment Project (CEAP) Team to develop the agricultural credit supply and cost analysis using NRCS scientific datasets and models: Natural Resources Inventory (NRI)–CEAP farmer survey from 2003 to 2006 and the field-scale, biodynamic Agricultural Policy EXtender (APEX) model. NRCS also used "cost-minimization" and "profit-maximization" economic models to select the most cost-effective conservation treatments to achieve the TES and generate credits. Specifically, NRCS modeled the TES needed in each watershed before credits sales were allowed, the total pounds of N and P reductions needed in each of the six watersheds to meet the TES, the quantity of available credit supply given various trading policies and N and/or P market prices, and the average net cost per pound of N and P reductions to generate these credits. NRCS and WRI prepared a sub-report entitled "Agricultural Credit Supply Analysis." The most pertinent highlights from the NRCS analysis, which includes over 90 data tables and charts in Excel spreadsheets, are provided in this report's Results section.

Three 8-digit project watersheds were selected for analysis in Arkansas and three 8-digit watersheds were selected for Mississippi. All six watersheds comprise what is known as the "delta areas" of both states, because they are topographically low-lying areas that are part of an alluvial plain known as the Mississippi Alluvial Valley. See Figure 3.1 for the names, HUC numbers, and locations for each of the six project watersheds.

Although the analysis was conducted within each of the 8-digit watersheds, results are not statistically significant at the 8-digit level due to limitations of available sample points. For that reason, the data for the three 8-digit project watersheds in Arkansas were aggregated into one larger area WRI refers to as the "Arkansas project area." Likewise, data from the three HUC 8 project watersheds in Mississippi were aggregated into one larger area referred to in this report as the "Mississippi project area." Both of these project areas make up a portion of the 4-digit watershed called the "Lower Mississippi Sub-region" in Arkansas (HUC 0802) and the "Lower Mississippi-Yazoo Sub-region" in Mississippi (HUC 0803; see Figure 3.1).

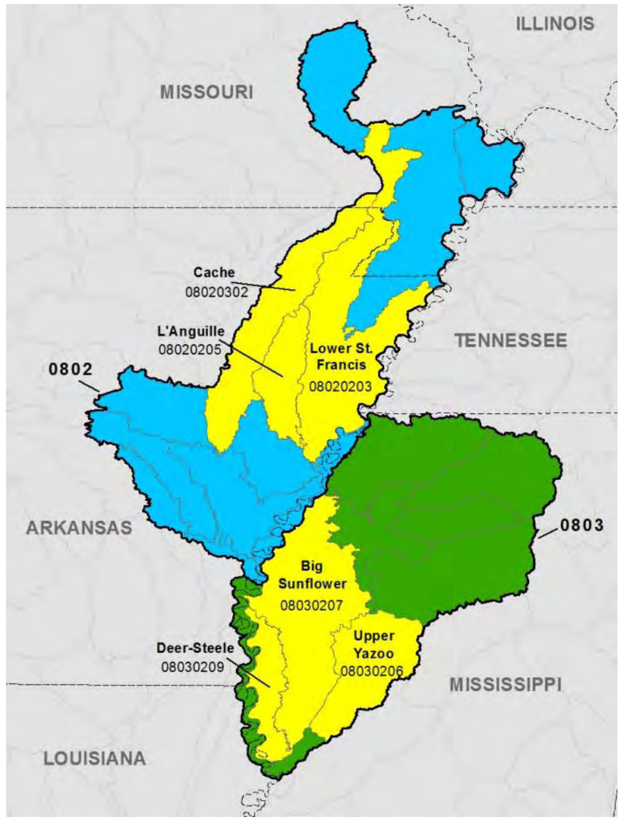


FIGURE 3.1 MAP OF THE LOCATIONS OF THE SIX 8-DIGIT PROJECT WATERSHEDS WITHIN THEIR RESPECTIVE TWO 4-DIGIT WATERSHEDS IN ARKANSAS AND MISSISSIPPI

Land Use in the Project Credit Supply Watersheds

Cultivated cropland dominates land use in the six project watersheds, comprising 75% of the Arkansas project watersheds and 63% of the Mississippi project watersheds. Other major categories of land use occupying the project watersheds include forest land (11.1% in Arkansas and 18.8% in Mississippi) and "urban and built up areas" (2.6% in Arkansas and 1.7% in Mississippi). Regarding proportion of the project cropland acreage by location, of the 4.8 million acres of cultivated cropland studied in this project, 60% are located in Arkansas watersheds and 40% are located in Mississippi watersheds. Note that 6% of the Arkansas watershed is located in Missouri, which was included in the Arkansas analysis.

Crop Production

Five commodity crops comprise the predominant crops grown in the project watersheds. In descending order of acreage, these crops are soybeans, cotton, rice, corn, and wheat. In terms of crop rotations, about a third of the cropland acreage is in a rice-soybean rotation, and a fifth is in soybeans only. Overall, there are very small differences in crop rotations and soil classes between the Arkansas and the Mississippi project watersheds.

Hydrologic and Management Conditions

Table 3.1 displays the variations observed between the two project watersheds in natural conditions (such as precipitation), management choices (conservation practice implementation), and outcomes (e.g., N efficiency, N losses, and crop yield). The CEAP modeling suite found that the Mississippi watersheds receive more precipitation, have a higher intensity of rainfall, have greater sediment losses, use less conservation practices, have lower N use efficiency and thus higher N losses, and tend to have lower crop yields on some crops than the Arkansas watersheds (during crop years 2003 to 2006). These differences are important to keep in mind when considering the current loads from Arkansas and Mississippi watersheds, which will be discussed in the next section.

Note that the CEAP-NRI data set for crop years 2003 to 2006 did observe differences in crops acreage and rotations between the two state project areas. For example, as a percentage of total cropland, the Arkansas watersheds grew more soybeans (52.4 % v. 35.3% in Mississippi), more rice (23.4% v. 6.7% in Mississippi), and less cotton (10.7% v. 42.7% in Mississippi). Crop rotations were also different as soybeans were grown about every other year for Arkansas but only one out of three years for Mississippi and cotton was grown nearly every other year for Mississippi but only about one year out of nine for Arkansas. Despite these differences, when the overall N use efficiency and N losses are calculated for all crops and all crop rotations on all cropland , the Arkansas watersheds show higher N use efficiency and lower N losses than the Mississippi watersheds.

CEAP Estimation of Conservation and Nutrient Management Treatment Needed

To provide a comparison for the findings of this study, NRCS reviewed the results of their nationwide CEAP analysis.[21] CEAP characterized over half the cropland acres in the six project watersheds as in need of a "moderate" level of conservation treatment and over a third as in need of a "high" level of treatment to achieve an average level of "acceptable loss" of nutrients *and* sediment per acre. Thus, both project watersheds are in need of greater conservation treatment to achieve CEAP's defined levels of acceptable loss, though a greater portion of Mississippi's project acres (94%) are in need of moderate or high treatment than Arkansas's acres (83%).

Regarding nutrient management alone, CEAP found that just 18% of the acreage in both states' project watersheds has attained moderate-high or high levels of both N and P management simultaneously. In contrast, 32% of acres in both states' project watersheds are operating at low and moderate levels of both N and P management simultaneously. Thus, both project watersheds are in need of greater nutrient management.

[21] The CEAP report for the Lower Mississippi River Basin has not yet been published, but for more details on these methods see Chapter 5, page 72 of the CEAP Chesapeake Bay report (USDA NRCS 2011).

TABLE 3.1. HYDROLOGIC AND MANAGEMENT DIFFERENCES BETWEEN PROJECT WATERSHEDS		
	Arkansas Project Areas	**Mississippi Project Areas**
Hydrologic and Field Conditions		
Precipitation (inches)	48.5	54.3
Rainfall intensity (USLE R factor)	275.4	349.1
Slope length (in field – feet)	115.8	161.9
Sediment Load (tons/ac)	1.6	6.3
Conservation Practice Implementation		
Conventional Tillage	17.9%	33.5%
No Till	22.6%	13.9%
No Structural Conservation Practices Except Drainage	85.7%	92.5%
Both Overland & Concentrated Flow Control	2.6%	1.6%
Average Nitrogen Balance (lbs N/ac/yr for all crops & crop rotations on all cropland		
Applied N + Legume Fixed N	145.0	144.5
N Loss Edge-of-Field (EOF)	23.5	60.3
N Removal with Crop Harvest	105.9	82.9
N use Efficiency (Harvest N/Applied N + Fixed N)	73%	57%
N Losses via Runoff, Leaching, & Volatilization (1 – N Use Efficiency)	27%	43%
Crop Yield		
Corn (bu/ac)	169.5	159.5
Winter Wheat (bu/ac)	57.5	48.3
Cotton (bales/ac)	2.2	1.7
Soybeans (bu/ac)	45.6	44.1
Rice (lbs/ac)	6,912.0	7,727.4

B. Methods

The Models

WRI worked with NRCS to conduct the supply-side analysis using the CEAP suite of datasets and models. The CEAP Assessment involves a special survey conducted with the USDA National Agricultural Statistics Service (NASS) on 10% of the NRI sample points. NASS enumerators met with farm managers for each selected sample point to complete the 40-page detailed questionnaire.

NRCS used a subset the NRI-CEAP survey dataset that had over 400 sample points of data from producers located in the six project watersheds to reflect the “baseline” field conditions, that is, existing crop management and conservation practice adoption from the available crop years. Each sample point is then statistically extrapolated to larger areas of similar hydrology and crop management conditions.

Next, the NRI points were modeled using the APEX model. APEX is a field-scale, biodynamic model that can simulate flow, nutrient fluxes, sediment fluxes, carbon fluxes, and yield based on information about crop management, soil, and weather. APEX was able to model the nutrient loads for each NRI-CEAP sample point and their statistically extended acres at the edge of the field (EOF) as well as transport of nutrients from the edge of field to the 8-digit watershed outlet. During NRCS’s own CEAP analyses, APEX was linked to the Soil and Water Assessment Tool (SWAT) model to simulate the transport of nutrients from the 8-digit watershed outlet farther downstream (see Figure 3.2). However, for this trading study, SWAT was not used because it has not been calibrated for this region. Instead, delivery factor data was obtained from the USGS Spatially Referenced Regression on Watershed Attributes (SPARROW) model and applied to each watershed to estimate the amount of nutrients that are transported from the 8-digit watershed outlet to the Gulf of Mexico (for more information, see the Delivery Ratios sub-section in Section VI).

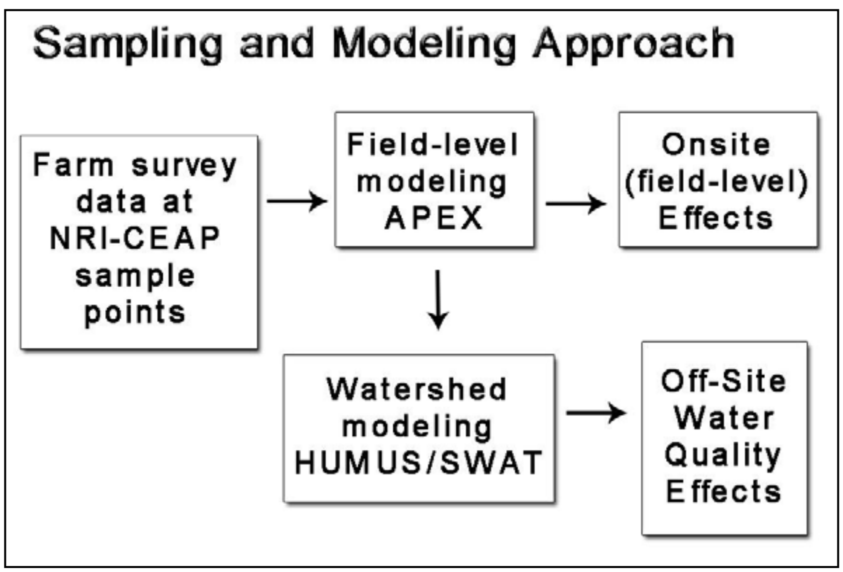


FIGURE 3.2. DIAGRAM OF NRCS’S SAMPLING AND MODELING APPROACH FOR CEAP ANALYSES

Note: For this MRB trading study, the SWAT model was not used.

Source: USDA NRCS 2010.

For this project, NRCS also made use of the General Algebraic Modeling Systems (GAMS) software to develop a “cost-minimization” model that selected the most cost-effective practices in each project watershed to achieve the watershed’s trading eligibility standard and a “profit-maximization” model to select the most profitable practices in response to market prices.

All of these models were used to estimate the per acre loading rate necessary to achieve the TES, the nutrient reduction effects of implementing conservation practices to achieve the TES and to generate credits, and the potential supply of credits and their associated costs, as well as the profitability of trading under various trading policy options and credit price scenarios.

Estimating Baseline Nutrient Loads from Project Watersheds

The results of the APEX-SWAT model run of baseline conditions (reflecting 2003 to 2006 or "existing conditions") are displayed in TABLE 3.2. Overall, Mississippi project watersheds exhibit greater N and P loading at both the edge of the field and delivered to the Gulf than do project watersheds in Arkansas. The annual average edge-of-field N load from the Mississippi watersheds is 60.3 lbs/acre, 2.6 times the average N load from the Arkansas watersheds of 23.5 lbs/acre. Mississippi's annual average P load of 5.6 lbs/acre is also greater than Arkansas's average load of 3.1 lbs/acre. As reviewed in TABLE 3.1, the states exhibit differences in hydrologic factors, use of conservation practices, nutrient application rates, and crop yields, all of which help to explain the differences between the watersheds' baseline nutrient load levels.

TABLE 3.2. CURRENT AND NATURAL BACKGROUND NUTRIENT LOADS (LBS/AC/YR)

	Current Baseline Loads		**Natural Background**	
	Arkansas Project Areas	**Mississippi Project Areas**	**Arkansas Project Areas**	**Mississippi Project Areas**
Nitrogen (EOF)	23.5	60.3	0.42	0.63
Nitrogen (Del)	18.0	48.3	0.32	0.52
Phosphorus (EOF)	3.1	5.6	0.21	0.29
Phosphorus (Del)	1.8	2.6	0.12	0.14

Note: EOF stands for edge of field while Del stands for delivered to Gulf.

To determine the degree to which natural versus management factors impact the average loading rates of the two states' project watersheds, a model scenario was run to simulate natural, background conditions of all native vegetation. This scenario reflects historic conditions before crop production or other manmade land uses. The result of this model run suggests that natural factors do cause Mississippi to have a slightly elevated loading rate, on average, compared to Arkansas (see Table 3.2). However, the difference in magnitude is very small under natural conditions, indicating that management factors exacerbate the naturally higher nutrient loss rates in Mississippi.

Establishing the Trading Eligibility Standard for Seller Watersheds

The TES for credit sellers is based on the study's policy goal of a 45% reduction in N and P loads delivered to the Gulf. To allocate a portion of this reduction target to the agricultural project watersheds, WRI made the simplifying assumption that all contributing sectors (wastewater, agriculture, etc.) across the Mississippi River watershed would bear this reduction goal equally. To operationalize this assumption for agriculture, WRI established a multi-step approach.

First, it was assumed that to achieve a 45% reduction in delivered nutrient loads to the Gulf, each watershed in the MRB would have to reduce its existing baseline nutrient loads delivered to the Gulf by 45. Second, WRI decided to account for the so-called "uncontrollable loads" identified by USGS SPARROW and distribute those loads into the agricultural sector in proportion to land use. The addition of a portion of the “uncontrollable loads” to agriculture’s allocation increased the baseline load by negligible amounts.[22]

Third, each project watershed’s 45% nutrient reduction goal from baseline loads was turned into a per-acre trading eligibility standard. That is, the per-acre TES represents the average allowable level of nutrient loss that must be met on a per acre basis in order to achieve the 45% nutrient reduction goal. Thus, each cropland acre, in order to participate in trading, would have to attain reductions sufficient to get below the per-acre TES to qualify to trade. Only once the TES was met could a farmer sell reductions achieved below the TES as credits.

WRI decided to estimate this per-acre trading eligibility standard for the two larger project areas, Arkansas and Mississippi, rather than for each of the six 8-digit watersheds. This approach approximates a basin-wide standard, which is the standard established in the state nutrient trading programs in the Chesapeake Bay watershed. Thus, the TES for each of the three Arkansas project watersheds within the Arkansas project area are identical, and represents a 45% reduction from the area-wide average. The same goes for Mississippi. Table 3.3 compares the allowable TES loading rates per acre to the baseline loading rates per acre both at the field’s edge and delivered to the Gulf for the Arkansas project area and the Mississippi project area.

TABLE 3.3. AVERAGE BASELINE LOADS COMPARED TO TRADING ELIGIBILITY STANDARD LOAD TARGET (LBS/AC/YR)

	Edge of Field		**Delivered to Gulf**	
	Arkansas Project Area	**Mississippi Project Area**	**Arkansas Project Area**	**Mississippi Project Area**
	Nitrogen			
Baseline load[a]	23.48	60.31	18.02	48.83
Uncontrollable load allocation[b]	0.92	1.06	0.70	0.88
Baseline + Uncontrollable Load	24.40	61.37	18.71	49.71
Trading eligibility standard[c]	13.45	33.78	10.29	27.34
Reductions needed to achieve TES[d]	10.95	27.59	8.42	22.37
	Phosphorus			
Baseline load[a]	3.08	5.61	1.84	2.60
Uncontrollable load allocation[b]	0.12	0.07	0.07	0.03
Baseline + Uncontrollable Load	3.20	5.68	1.91	2.63
Trading eligibility standard[c]	1.76	3.13	1.05	1.45
Reductions needed to achieve TES	1.44	2.55	0.86	1.18

[22] “Uncontrollable” loads, as defined by the USGS SPARROW model, are loads that come from forests, barren land, shrub land, and atmospheric deposition, which are not included in the SPARROW model in any other source sector. Because the CEAP APEX model already accounts for atmospheric deposition onto cropland, the remaining atmospheric deposition loads on forest, barren, and shrub land were apportioned to both the wastewater sector and to agriculture based on land area. Agriculture received 83% of the uncontrollable load burden because it comprises 83% of the land use in the MRB. An additional 3.7 million lbs of N and 263,000 lbs of P were added to the six project watersheds’ cultivated cropland sector as baseline loads before the TES was calculated. This additional reduction quantity was negligible, as it amounted to just a fraction of the N and P reduction needed to achieve the trading eligibility standard.

[a] Baseline load refers to the "existing" level of nutrient losses estimated to be occurring from the 2003 to 2006 NRI-CEAP dataset divided into the cropland acres in each project area to achieve the average baseline load/acre.
[b] Uncontrollable load is the portion of the SPARROW "uncontrollable sources" that WRI decided to apportion to the projects' cropland acres which was divided into each project area's acres for the uncontrollable loads/acre estimate.
[c] Trading eligibility standard refers to the per acre nutrient limit that producers in each watershed must achieve before generating credits; represents 55% of baseline + uncontrollable loads/acre.
[d] Average reductions/acre needed to achieve the TES represents 45% of baseline + uncontrollable loads/acre.

Most of the references to the trading eligibility standard in this report display loads and costs with EOF values while references to credits reflect delivered-to-gulf (Del) values. Readers can move between both EOF and Del values by multiplying or dividing by the appropriate delivery factor if desired (see Table 6.3 for the delivery factors used by NRCS). Note that by meeting the edge-of-field TES the required Gulf TES is also met.

Conservation Treatment Options to Achieve the TES and Generate Credits

The CEAP modeling system is able to analyze the use of six conservation treatment scenarios to generate nutrient reductions necessary to meet and exceed the TES. These six conservation treatment scenarios are listed in Table 3.4 and involve single or multiple practices as well as management or structural conservation practices.

TABLE 3.4. DEFINITIONS OF THE APEX MODEL CONSERVATION TREATMENTS

APEX Conservation Treatment	Six Conservation Treatment Scenarios	Explanation	Number & type of practice[a] & practice timeframe
Base	*Baseline Scenario*	*Baseline 2003–2006 condition based on CEAP NRI surveys*	
B_DWM	Drainage water management (DWM)	Drainage water management practice added to the baseline for selected sample points	1 annual practice
B_CC	Cover Crops (CC)	Cover crop practice added to the baseline for selected sample points	1 annual practice
SEC	Structural Erosion Control (SEC)	Model inputs constructed, starting with baseline but then adding structural practices for erosion and water flow control (NRCS calls this "full treatment" or FT)	Structural practices (1–20 years)
ENM	Erosion & Nutrient Management (ENM)	SEC plus Nutrient Management Planning practices[b] (NRCS calls this the "Erosion and Nutrient Management" CEAP scenario)	Structural practices (1–20 years) + 1 annual practice

E_DWM	Erosion & Nutrient Management & Drainage Water Management (E-DWM)	ENM plus DWM practices on same set of points as receiving the drainage water management	Structural practices (1–20 years) + 2 annual practices
E_CC	Erosion & Nutrient Management & Cover Crops (E-CC)	ENM plus cover crops on same set of points as receiving cover crops	Structural practices (1–20 years) + 2 annual practices

[a] For each conservation treatment alternative, the actual practices applied to each sample point vary according to point characteristics; some points are unchanged relative to baseline.
[b] The nutrient management planning practices includes various individual practices, such as soil testing, manure nutrient content testing, split nutrient applications, etc.

Box 3.1 discusses the range of potential preferences producers may have for certain practices.

Box 3.1. Feedback from the project's agricultural stakeholders about farmer preferences for annual management or multi-year structural practices

WRI interviewed various agricultural community stakeholders in Arkansas and Mississippi about this study's approach and findings (see Section IV.C). Several stakeholders offered conflicting opinions about whether farmers would be more interested in annual management practices or multi-year structural practices. On the one hand, several Mississippi farm trade association staff and University of Arkansas staff thought management practices like cover crops and no till (not modeled in this study) may be difficult for a variety of reasons. Many farmers find that heavy harvesting machinery will cut ruts in their mostly clay soil fields which then must be tilled in the spring to smooth out the field for planting. Farmers also worry about the timing constraints from the weather in the fall on their ability to get their crops out in time to plant cover crops and in the spring to kill down the cover crop to prepare the field for planting. Furthermore, market prices will influence farmer decisions about what to plant year to year, which increases the difficulty of including cover crops or no till into an uncertain crop rotation.

Staff also thought that 10-year structural erosion control practices within a field or at the edge of fields may not be a problem as long as a farmers can dedicate some land to take out of production and know all they need to do every year is maintain the grass or trees in the conservation practice. However, on land a farmer is leasing, structural practices may be more difficult if they have an absentee or uninterested landowner. Arkansas NRCS staff pointed out that many farmers and landowners are able to come to agreement on Conservation Reserve Program (CRP) contracts to take some fields out of production and install long-term structural practices, so nutrient trading may also foster collaboration on leased fields. Future research should investigate the challenges and preferences associated with using either or both management or structural conservation practices to satisfy annual or multi-year nutrient trading contracts.

Conservation Practice Costs

The costs of implementing the conservation treatment scenarios were also estimated by the model effort. NRCS used its Payment Schedule databases for both Arkansas and Mississippi to input practice costs into the model. The costs per acre by practice are listed in Table 3.5. Note that the cost of conservation practices includes the following elements:

1. Practice life span,
2. Typical number of practice units implemented per acre,
3. Installation cost that has been amortized over the life of the practice with a 3% discount rate, and
4. Technical assistance cost, which has also been amortized with the same discount rate.[23]

TABLE 3.5. COSTS OF CONSERVATION PRACTICES

Practice Name	Practice Life (Years)	Units of Practice per Protected Acre[b]	Amortized "INSTALL" Cost/ Protected Acre[c]	Amortized Technical Assistance Cost/ Protected Acre[d]	Amortized Install + Technical Assistance Cost
Drainage Water Management	1	1	$9.09	$0	$9.09
Contouring	1	1	$11.78	$0	$11.78
Nutrient Management Planning	1	1	$33.95	$4.65	$38.60
Cover Crop	1	1	$71.37	$1.52	$72.89
Contour Strip Cropping	2	1	$1.26	$0	$1.26
Terracing[a]	10	215.30	$49.15	$12.33	$61.48
Filter Strip	15	0.09	$10.41	$0.43	$10.84
Field Border	20	0.02	$3.07	$0.01	$3.08
Riparian Buffer-Grass	20	0.09	$8.97	$0.34	$9.31
Riparian Buffer – Forest	20	0.16	$15.90	$0.63	$16.53

[23] Note that farmers, when receiving financial assistance, do not also receive the technical assistance in the form of financial payments but are provided technical assistance for free. Given the importance of technical assistance to the adoption of many practices and the limited federal budget to pay staff to provide this service, WRI and NRCS decided to include the technical assistance component to reflect the true total cost of the conservation practice.

[a] Terracing units are linear feet.
[b] Protected acre refers to the number of acres that are "protected" by the conservation treatment rather than the number of acres that are actually occupied by the practice. For example, a terrace practice of 10,000 linear feet on a 10-acre knoll within a 40-acre "land planning unit" or "farm field" would be reported as 250 linear feet per protected acre (10,000 linear feet/40 acres). In another example, suppose a 1,300-foot-wide by 1,600-foot-long field has a 40-foot-wide buffer along one of the 1,300-foot sides. The total field acreage is 47.75 acres ((1300*1600)/43560). The buffer area is 1.19 acres ((40*1300)/43560). Therefore, 1.19 acres is protecting 47.75 acres, or stated another way, 2.5% of the field is in conserving area, or 0.025 acres of buffer per acre of protected area.
[c] Installation costs include all costs except the Technical Assistance component.
[d] Technical Assistance is the cost to the government agency of assisting the producer with the practice; cost may be incurred directly or paid as a reimbursement to a Technical Service Provider.

Estimating Net Costs

In this trading feasibility study, WRI and NRCS decided to reflect the net costs—not just the conservation practice costs—to achieve the trading eligibility standard. Net costs include four elements:

1. Conservation practice installation, maintenance, and technical assistance costs (Table 3.5),
2. Changes in fertilizer application and cost,
3. Changes in diesel fuel use and cost, and
4. Changes in crop revenue.

One interesting finding in this study is that many acres achieve negative net costs—that is, net savings or profits—from the implementation of conservation practices. Because the Nutrient Management Treatments can, for some sample points, decrease fertilizer costs and increase crop yield and thus crop revenue, these changes can be larger than the cost of the conservation practice and result in net savings. The Structural Erosion Control Treatment can also result in net savings from increased crop yields but can also decrease yields if a portion of cropland is removed from production for a conservation practice. The Cover Crop Treatment, in contrast, tends to consistently result in a small increase in diesel fuel costs associated with the planting operation (see Box 3.2 for more about how average net costs are calculated and what they mean).

Box 3.2. Understanding the average net costs per credit

In some instances, especially at no or low credit prices, the credit supply analyses suggest that some agricultural producers could realize net savings by implementing conservation practices. It is important to understand what the term "average net costs per credit" means compared to "marginal costs per credit."

When average net costs per credit are negative, this means net savings are realized because the conservation treatments save the producers money. Savings occur because of reductions in fertilizer application and associated costs and/or because of increases in crop yield and associated revenue. The term "average net cost per credit" simply reflects the mathematical "average," which is the:

> Sum of total net costs from conservation treatments on participating acres divided by the total quantity of credits generated.

Given that the estimation is an *average*, there will be producers who experience net costs/credit that are *lower* than the entire participating group's average costs and producers who experience net costs/credit that are *higher* than the group's average.

In contrast, the marginal cost represents the:

> Cost per credit of the last credit that could be generated cost-effectively (i.e., the credit generated at the highest possible cost).

For example, at a credit price of $1/lb N, about 9.2 million N credits could be generated at an average net cost/lb of -$1.61 (see figure below). This average negative net cost/lb indicates that the participating acreage group, overall, experienced a total net savings from conservation investments. Although some producers experienced net costs, the costs were overwhelmed by the savings the rest of the producers experienced.

The figure below illustrates that each point on the average cost curve represents the average cost for all the credits supplied under each price point. Thus, at a credit price point of $1 for N, -$1.61/N credit is the average cost for generating about 9.2 million N credits. In contrast, the marginal cost curve presents points on the credit supply curve that reflect the per-unit cost for the highest cost credit at each price point. The marginal cost of generating the 9.2 millionth N credit is $1/N credit.

Thus, the marginal cost is equal to the credit price of $1 under market equilibrium. The last producer to find it cost-effective to generate credits at a $1 price would experience an average cost of $1/credit and thus would break even. But the other producers will earn profits of varying degrees by selling credits for $1/credit while generating the reductions for a lesser cost.

Box 3.2 continued

It is important to remember that for any market credit price and credit supply solution, there will be an array of producers, sorted from lowest to highest average net cost per credit, and that it is unlikely that any one producer actually experiences the group's average net cost/credit. Thus, comparing the average agricultural net cost to the average costs for utilities should be done with caution. It must be noted that if a credit price equal to the average net cost/credit were offered, only a portion of the credit supply would materialize from the portion of producers whose costs were equal to or lower than the average.

The figure below illustrates that regardless of the credit price or amount of credits supplied, marginal costs will always be positive and higher than the average costs.

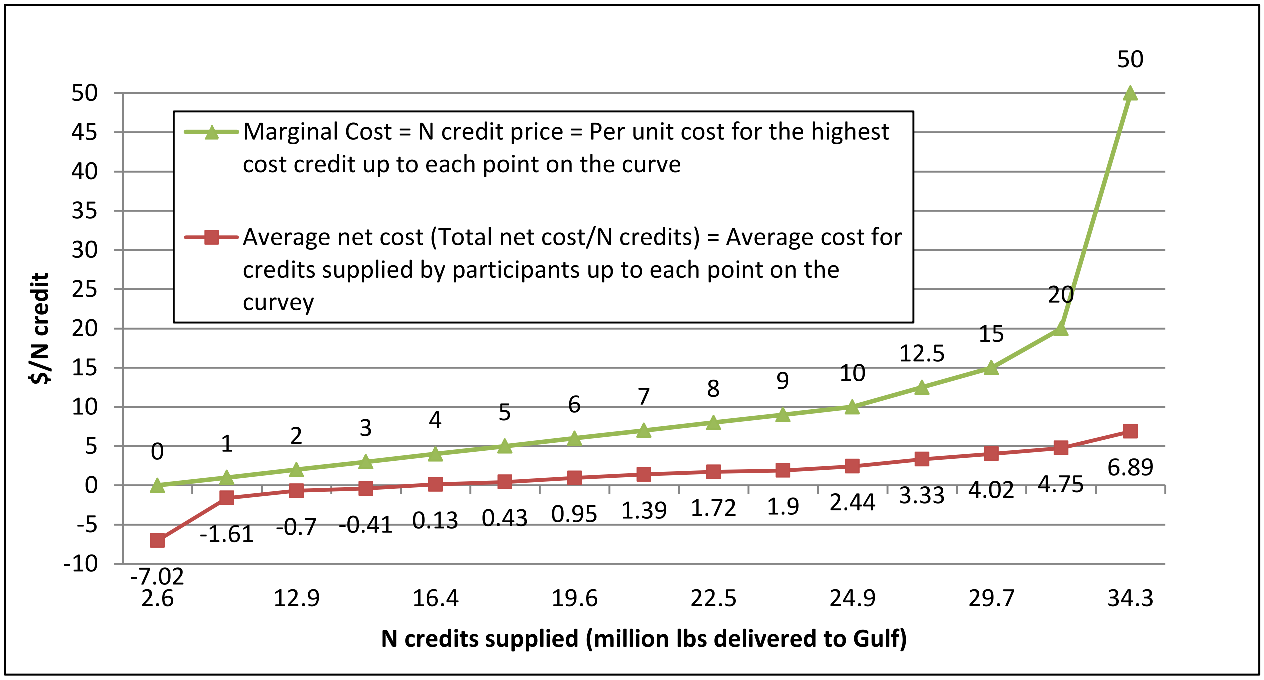


FIGURE FOR BOX 3.2. COMPARING MARGINAL COST (N CREDIT PRICE) AND AVERAGE COST CURVES FOR N UNDER THE N & P TES REQUIREMENT AND WHEN ADDITIONALITY IS ENFORCED

For any quantity of credits supplied, the per unit profit for each credit is found from the difference between the price (a horizontal line intersecting the curve) and the average cost curve. Smaller credit quantities will have a higher per-unit profit while larger credit quantities will have a lower per-unit profit.

Selecting Least-Cost Treatments to Achieve the Trading Eligibility Standard

To estimate the costs of reducing nutrient loads to levels that achieve each field's TES, the APEX model, in conjunction with the cost-minimization model, identified and selected the most cost-effective conservation treatment scenarios. For any given NRI sample point, the selected treatment first had to be appropriate for the sample point's agronomic and hydrologic conditions and then it had to meet both the N and the P TES at the least per-acre *net* cost possible.[24]

Note that the models might find one applicable treatment that does not achieve the amount of N and P reductions needed to achieve the sample point's TES, but the next best treatment exceeds the standard. WRI and the model regard the nutrient reductions to get to the TES as non-additional and not tradable, while the reductions achieved beyond the TES are regarded as additional and tradable. Once delivery factors are applied to the tradable reductions, they can be referred to as credits (see Figure 3.3).

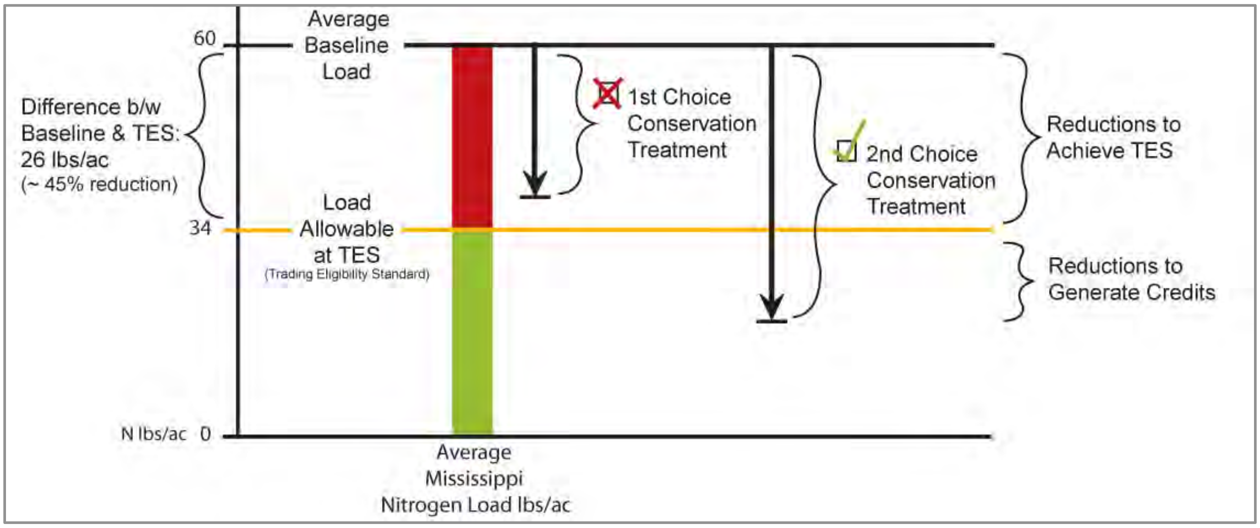


FIGURE 3.3. SELECTION OF CONSERVATION TREATMENTS TO ACHIEVE THE TES AND GENERATE CREDITS THAT ARE ADDITIONAL TO THE TES WHEN BASELINE LOADS ARE ABOVE THE TES

It is important to remember that producers are managing different cropland parcels under different hydrologic, management, and conservation conditions. Given this variation, producers will experience different effort levels for nutrient reduction to reach their watershed's TES (see Figure 3.4).

[24] Regarding applicability, very few points have the right agronomic and hydrologic conditions to receive the Drainage Water Management (DWM) treatment. In addition, sample points that do receive the DWM cannot also receive the Cover Crop Treatment, because the treatments cannot be applied to the same acreage at the same time.

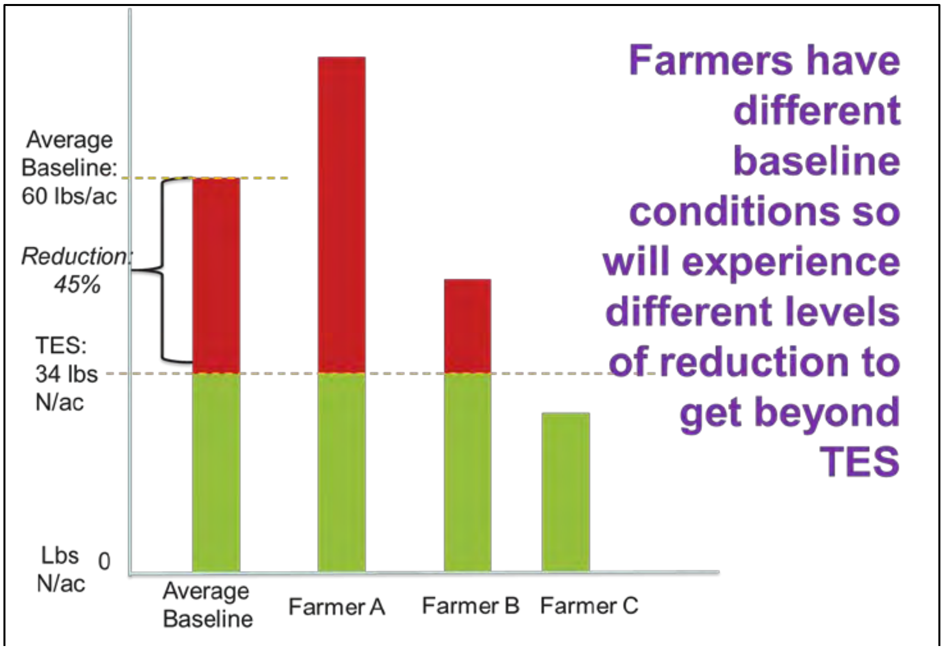


FIGURE 3.4. FARMERS WILL HAVE DIFFERENT LEVELS OF EFFORT TO MEET THE TRADING ELIGIBILITY STANDARD BEFORE BEING ABLE TO SELL CREDITS

Selecting the Most Profitable Treatments to Generate Credits

When N and P credit trading prices are introduced, NRCS used a profit-maximization model to estimate net costs and profits to generate credits. The model selected the conservation treatment that achieves the trading eligibility standard and generates the greatest profit for each sample point.

Profit is defined as the sum of:

- Revenue from selling tradable reduction pounds (quantity multiplied by price),
- Conservation practice costs (sum of sample points and the chosen treatments per-acre costs multiplied by acreage weights), and
- Net costs (sum of the change in per acre value of diesel fuel used at the sample points, fertilizer use, and crop revenue, multiplied by acreage weights).

Attributing Net Costs to Each Nutrient

Note that most conservation practices lower both N and P loads simultaneously, though some practices are better at reducing N loads while others are particularly suited to P loads. This scientific reality makes it difficult to attribute economic costs to one nutrient or the other. Thus, WRI and NRCS decided to simply isolate the net cost and attribute them to each nutrient one at a time. That is, a cost per pound of N reflects the entire cost of all practices within the conservation treatment divided into the number of N pounds reduced, without regard to the P credits generated. The same method was used to attribute the total net costs to pounds of P that were reduced by the suite of practices within the conservation treatment. We refer to these costs as the “isolated net costs per pound of nutrient.” Because this method does not account for the net cost savings when both N and P are reduced by conservation practices, the net costs in reality are likely to be lower (see Figure 3.5).

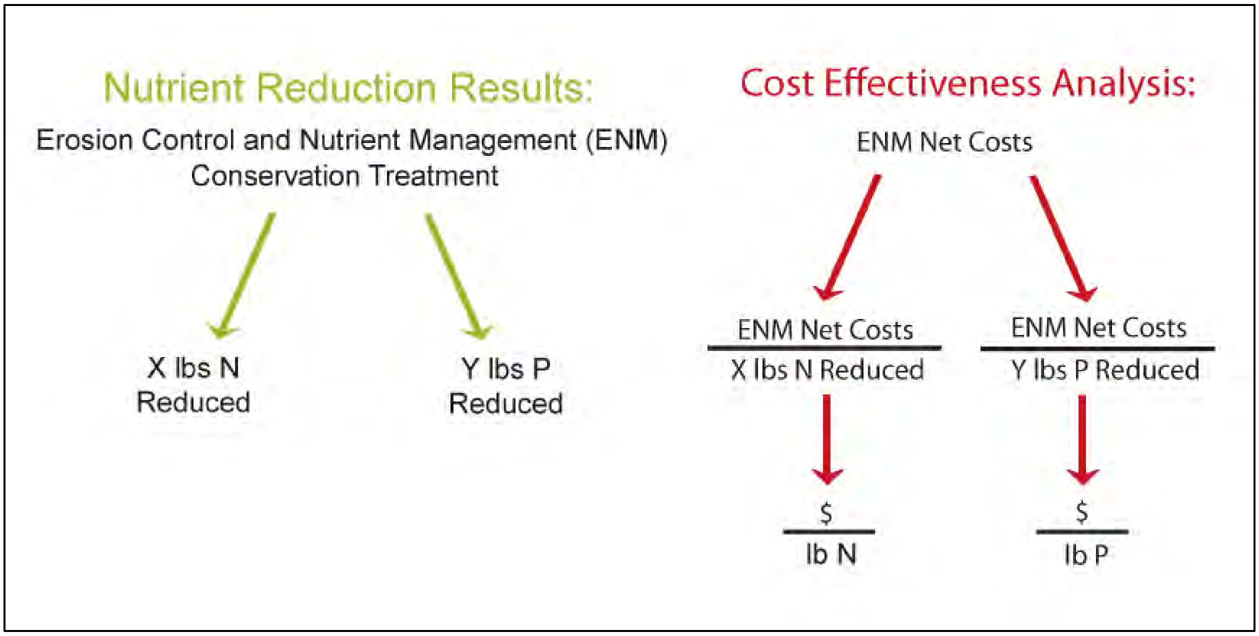


FIGURE 3.5. ISOLATING NET COSTS TO EACH NUTRIENT

Accounting for Trading Program Policies – TES and Additionality

Nutrient trading programs may be designed in a variety of ways depending on the program's goal. For example, a program may require that both the N and P trading eligibility standard must be met before either nutrient can be traded. Alternatively, a trading program may require only the N TES be met if N is determined to be the nutrient of interest and the only marketable credit. Such a decision will be tackled by appropriate policymakers and relevant stakeholders when deliberating development of a trading program to achieve a specific nutrient-reduction goal.

Trading program policies also determine additionality principles. There are two cases in which additionality comes into play in this feasibility study. First, WRI made the simplifying decision that producers whose existing baseline loads were greater than the trading eligibility standard had to first meet that standard before selling credits. In essence, this rule automatically achieves the additionality principle (see Figure 3.6).

The second situation pertains to producers whose existing baseline conditions are lower than the TES. WRI decided to analyze the effect of allowing the difference between the TES and the baseline load to be sold as credits—reflecting a situation where additionality is not enforced—compared to a policy that would require these producers to implement new conservation treatments to generate credits—reflecting enforcement of additionality (see Figure 3.6).

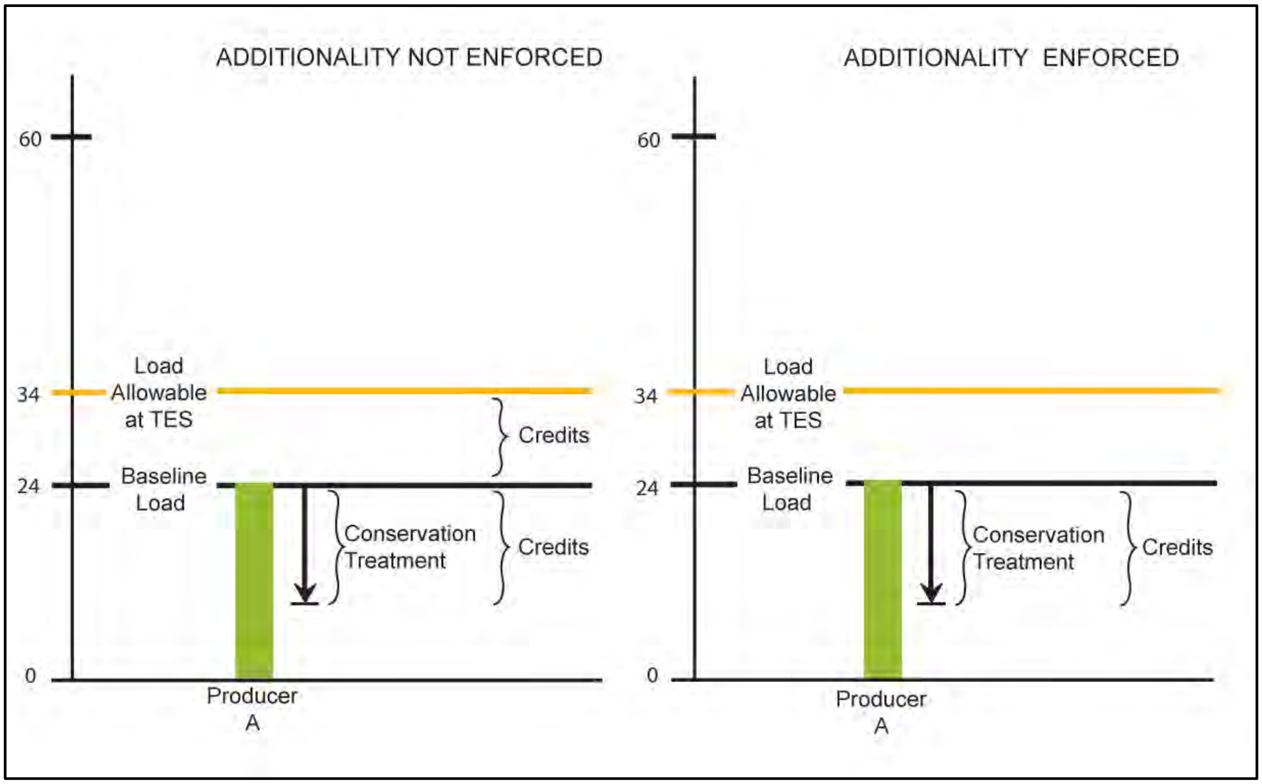


FIGURE 3.6. CREDITS VARY WHEN ADDITIONALITY IS AND IS NOT ENFORCED FOR A PRODUCER WHOSE EXISTING BASELINE LOADS ARE ALREADY BELOW THE TES

In Figure 3.6, when additionality is not enforced, the producer can sell the difference in pounds between the TES and his existing baseline loads (34 lbs/ac TES - 24 lbs/ac baseline = 10 lbs/acre) without having to do any additional conservation treatments. If additionality were enforced, the producer would not be able to sell those 10 lbs N/acre and could sell only the additional reductions achieved from implementation of new conservation treatments.

The purpose of this study is not to design a trading program or to recommend policies but to explore the impacts of various policy scenarios on the net costs and quantity of agricultural credit supply. The policy options include:

- *TES for N-only, for P-only, or for both N and P.* When a TES for both N and P is enforced, a supplier must meet both standards even if he is interested in only selling credits for one pollutant.

- *Additionality enforced or not enforced.* When additionality is enforced, only those credits that are new or "additional" to baseline loads are creditable.

Finally, the credit supply analyses were also conducted under a range of potential market prices for N, P, and for N and P together at pre-determined intervals.

C. Results

1. Achieving the trading eligibility standard – can producers achieve a 45% reduction in delivered nutrient and phosphorus loads to the Gulf?

NRCS found that 84% of the cropland acres in the six project watersheds have existing baseline N and P field losses that are higher than the N and P trading eligibility standard. Thus, 16% of all project cropland acres already meet the N and P TES because their baseline level of nutrient losses are smaller than the TES (see Table 3.6).

TABLE 3.6. ACRES NOT MEETING THE TRADING ELIGIBILITY STANDARD FOR BOTH NITROGEN AND PHOSPHORUS (EDGE OF FIELD)

	Arkansas Project Areas	Mississippi Project Areas	All Six Watersheds
Acres not meeting TES (1,000s)	2,486.2	1,533.7	4,019.9
All Acres (1,000s)	2,859.3	1,938.8	4,798.2
Percentage Acres Not Meeting TES	86.9%	79.1%	83.8%

Though not displayed here, if only an N TES were in place, 38% of the six watersheds' crop acreage would meet that standard; if only a P TES were imposed, 30% of the cropland in the six watersheds would already meet the standard.

Table 3.7 displays the trading eligibility standards for both project areas and the average loads on just the acres exceeding the TES. The per-acre TES for both N and P are much smaller (lower) in Arkansas than those in Mississippi, reflecting the large differences observed in existing baseline loads.

TABLE 3.7. PER ACRE TRADING ELIGIBILITY STANDARDS AND AVERAGE PER ACRE LOADS EXCEEDING THE TES (EDGE OF FIELD)

Project Areas	Trading Eligibility Standard		Loads on Acres Not Meeting the TES	
	N TES (lbs/ac/y)	P TES (lbs/ac/y)	N load (lbs/ac/y)	P load (lbs/ac/y)
Arkansas	13.4	1.8	38.3	4.2
Mississippi	33.8	3.1	71.2	6.5

a. What is the least cost approach to achieving the trading eligibility standard?

Table 3.8 provides the acres, total loads, and loads per acre occurring before and after the conservation treatments needed to meet the TES in both project watersheds.

TABLE 3.8. NUTRIENT LOADS BEFORE AND AFTER TREATMENT ON ACRES THAT ACHIEVE TRADING ELIGIBILITY STANDARD (EDGE OF FIELD)			
	Arkansas Project Area	**Mississippi Project Area**	**All Six Project Watersheds**
Acres needing Treatment (1,000s)	1,826.3	1,452.2	3,278.5
Total Loads (1,000s)			
Baseline N load	38,665.1	102,377.4	141,042.5
N load after treatment	14,407.7	27,137.5	41,545.2
Baseline P load	5,630.9	9,404.7	15,035.6
P load after treatment	2,081.7	2,314.3	4,395.9
Loads Per Acre			
Baseline N load	21.2	70.5	43.0
N Load After Treatment	7.9	18.7	12.7
Baseline P load	3.1	6.5	4.6
P load After Treatment	1.1	1.6	1.3

The least cost approach to achieving the N and P TES resulted in the total annual baseline loads to drop by 71% for both N and P, or by 99.5 million lbs of N and 10.6 million lbs of P (see Table 3.8, and for more information).

Therefore, the least-cost approach to achieving a 45% reduction trading standard exceeds the TES by about 26%. Because the cost-minimization model tries to find the single least-cost treatment option to satisfy a 45% reduction goal, it will almost always end up exceeding the goal because of the discrete nature of the model's treatment choice for each sample point. WRI identifies these pounds reduced in excess of the TES as tradable reductions and counts them as credits once the appropriate delivery factor is applied.

Table 3.9 indicates that the total net cost for the least-cost solution to achieve the watersheds' trading eligibility standards is $145 million each year on 3.3 million acres or 69% of the six watershed project area. The conservation practice costs alone amount to $203 million, but the total net costs are lower due to the $71.7 million in fertilizer savings and the $4 million in crop revenue increases. The fuel cost increase that occurs with cover crops was minor ($735,000). All of the six project watersheds experienced fertilizer savings. Two of the Mississippi watersheds (Deere Steele and Upper Yazoo) experienced net increases in crop revenue from implementing conservation practices, while the remaining four project watersheds experienced crop revenue losses (see Box 3.3 for putting these net costs into context).

TABLE 3.9. NET COSTS TO ACHIEVE THE TRADING ELIGIBILITY STANDARD			
Items (in 1,000s)	**Arkansas Project Area**	**Mississippi Project Area**	**All Six Project Watersheds**
Total Net Cost	$77,227.60	$67,742.70	$144,970.30
Conservation Practice Cost	$89,683.60	$113,218.00	$202,901.50
Fertilizer Cost	-$30,571.30	-$41,203.20	-$71,774.50
Crop Revenue Change	-$17,812.70	$4,704.60	-$13,108.20
Fuel Cost	$302.60	$432.50	$735.10

Box 3.3. Putting the costs for achieving the trading eligibility standard into context

If each acre in the six project watersheds were to be treated with conservation practices to meet the trading eligibility standard (TES), the estimated annual cost of conservation practices (including technical assistance) is $89.7 million in Arkansas and $113 million in Mississippi.[1] To put this cost into context, WRI compiled information from the federal Environmental Quality Incentives Program (EQIP), the single largest working lands program available.

Over the 2003 to 2007 timeframe, the state of Arkansas received, on average, $21 million every year while Mississippi received $19 million per year from EQIP for both technical assistance and financial assistance, which typically covers 75% of installation costs and conservation practices maintenance. Thus, this analysis indicates that paying 100% of the full cost of conservation practices for every eligible acre in just these six project watersheds to meet their portion of a potential, future Gulf cleanup goal, would take over four to five times the amount of EQIP resources available for the entire states of Arkansas and Mississippi. This funding discrepancy underscores the reality that the current voluntary, cost-share-based approach is significantly under-funded to achieve future Gulf hypoxia reduction goals. Thus, alternative policy approaches, such as nutrient trading, are worthy of consideration.

Nutrient trading may offer an additional source of revenue for producers without necessarily taxing the already scarce public conservation program funds. There are at least two possible pathways to help producers get to the TES that do not require financial assistance from public conservation programs. First, producers may be able to negotiate contract agreements with credit aggregators and buyers that provide some or all of the upfront costs to get producers to the TES. Second, this study made the assumption that producers would price their credits based on the full cost of conservation practices. This assumption, in effect, makes credit buyers pay for the costs to get to the TES and to generate credits but allows them to count only the tradable credits. Such an assumption may be tenable given the large cost differentials observed in this study between the wastewater and the agricultural sectors.

[1]Here, conservation practice costs include installation, maintenance, *and* technical assistance costs.

On an acreage basis, net costs to achieve the trading eligibility standard average about $44.22 per acre (see Table 3.10). When the total net cost is applied to the pounds of nutrients reduced in an isolated manner, that is, the entire cost is attributed all at once to just the N reduced, and then the entire cost is attributed to all the P reduced, the unit costs are $1.46/lb of N reduced and $13.63/lb of P reduced. Note that these average costs per pound are much larger than the costs per credit estimated later in Table 3.12 and onwards because in Table 3.10, 69% of the six watershed project area is being treated to achieve both N and P TES in this exercise while much smaller portions of the project area are participating in nutrient trading at credit prices that would likely appeal to this study's credit buyers.

From the state perspective, the average cost per pound of either nutrient is far less expensive in Mississippi than in Arkansas.

TABLE 3.10. NET COSTS PER POUND REDUCED AND PER ACRE TREATED TO ACHIEVE THE NITROGEN AND PHOSPHORUS TRADING ELIGIBILITY STANDARD (EDGE OF FIELD)			
Per-Unit Values	**Arkansas Project Areas**	**Mississippi Project Areas**	**Total**
Net Cost Per lb N reduced	$3.18	$0.90	$1.46
Net Cost Per lb P reduced	$21.76	$9.55	$13.63
Net Cost Per acre treated	$42.29	$46.65	$44.22

Table 3.11 illustrates how many acres received each conservation treatment option to achieve both the N and P trading eligibility standard. The Structural Erosion Control (SEC) treatment was found to be the least-cost solution for the largest number of acres to satisfy the TES across all six watersheds. In Mississippi, however, the largest number of acres received the Enhanced Nutrient Management and Cover Crops (ENM + CC) Treatment. Note that depending on site-specific conditions of each acre of cropland, the most cost effective conservation treatment will vary. No single practice or suite of practices is the most cost effective for all cropland.

TABLE 3.11. ACRES OF LEAST-COST CONSERVATION TREATMENTS TO ACHIEVE THE TRADING ELIGIBILITY STANDARD (EDGE OF FIELD)			
Conservation Treatments (1,000s acres)	**Arkansas Project Areas**	**Mississippi Project Areas**	**Total**
Drainage Water Management (DWM)	22	0	22
Cover Crops (CC)	476	287	762.9
Structural Erosion Control (SEC)	691	311.7	1,002.7
Erosion & Nutrient Management (ENM)	358.2	156.2	514.4
ENM + DWM	60.7	38.8	99.5
ENM + CC	218.5	658.5	877
Total Treated	1,826.3	1,452.2	3,278.5

b. How many acres can and cannot achieve the trading eligibility standard?

NRCS found that about 16% of the acres in the project watersheds have existing baseline conditions that already meet the N and P trading eligibility standard, 15% of the acres cannot meet the TES with any of the modeled conservation practices, and the remaining 69% of acres can reach the TES by adopting conservation practices (see Figure 3.7).

There are 741,000 acres (15% of the 4.8 million acres) in the six project watersheds that have baseline nutrient losses that are so high that none of the available conservation treatment scenarios CEAP modeled can achieve both the N and the P TES simultaneously. This acreage accounts for 17% of total N loads and 16% of total P loads from the overall project area. The average loading rate on this acreage is 42.7 lbs N/ac and 4.3 lbs P/ac, nearly double the TES loading rates of 21.7 lbs N/ac and 2.3 lbs P/ac. It should be noted that some of these acres can achieve either the N or the P TES, but not both together.

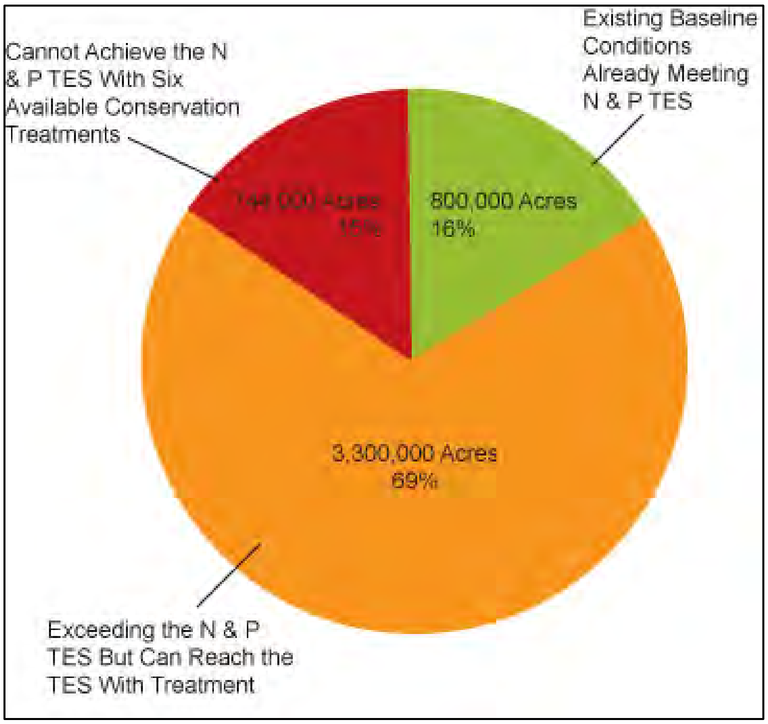


FIGURE 3.7. PORTION OF SIX PROJECT WATERSHEDS THAT ALREADY MEET THE N & P TES, CAN MEET THE TES WITH MODELABLE CONSERVATION TREATMENTS, AND CANNOT MEET THE TES

NRCS did posit that although these acres cannot achieve the TES with NRCS's existing suite of 10 conservation treatments, they could achieve the average overall watershed TES levels using alternative practices not modeled in this study. Examples of alternative practices include additional reductions in fertilizer application rates and converting some small acreage from cropland to perennial crops or natural vegetation.

2. Generating credits – what is the potential quantity of credit supply and corresponding net cost?

The quantity of credits that can be generated from the six project watersheds, and their associated net costs, will depend on the potential future trading program's policies and on the magnitude and availability of credit prices (i.e., how high the prices are and if one or both nutrient credit prices are being offered). In order to estimate potential supply and credit generation costs without assuming any given policies, 18 different policy-price combinations were analyzed. These scenarios reflect three different trading eligibility standards (N only, P only, and N and P together), two additionality rules, and three credit price options for a total of 18 scenarios (i.e., 3 x 2 x 3 = 18; see Appendix for tables and charts reflecting the 18 scenarios).

Under each of these combinations, the profit-maximization model was used to select the most profitable conservation treatments to exceed the trading eligibility standard and generate credits. Credit supply in this section still reflects an annual average number of credits. However, credits are now measured in delivered pounds of N and P reduced to the Gulf, reflecting each of the six project watershed's delivery factors (see Section VI's delivery ratio section for more details). Net costs per credit still reflect the average annual total net costs for exceeding the TES and generating credits and are estimated by dividing the total net cost by the number of N credits and then by the number of P credits.

a. How do trading policies affect credit supply and costs?

This section provides simple examples of how two common trading policies could affect credit supply and net costs. The first policy examines the effect of enforcement or lack of enforcement of the additionality rule. The second policy examines the effects of requiring producers to achieve a single nutrient or both nutrient trading eligibility standards before they can generate credits for either nutrient.

i. How does additionality affect supply and costs?

When producers' existing baseline conditions were greater than the trading eligibility standard, after the model selected a conservation treatment to achieve the TES, WRI counted reductions below the TES as tradable reductions even though they were achieved by the same treatment used to achieve the TES. Other trading programs, which are focused on "practice additionality," would not consider these reductions as satisfying additionality because no additional practices were used to generate the tradable reductions. Because of the discrete nature of the scientific and economic models used in this study, as well as the discrete nature of conservation practices themselves, it was impossible to separate out the practices for every sample point—or the nutrient reductions achieved per practice—from within a multi-practice conservation treatment. Thus, for simplicity's sake, WRI regarded the reductions in excess of the TES as satisfying what we are referring to as "pollution reduction additionality."

When producers' existing baseline conditions are already lower than the trading standard, WRI decided to study the effect of:

a) Enforcing additionality—requiring new conservation treatment to generate credits, and
b) Not enforcing additionality—allowing the differences in pounds between the baseline load levels and the TES to be sold as credits.

In the example below, the effect of additionality is displayed under a trading policy scenario wherein both N and P trading standards have to be attained before credit generation. There is a $3/lb N credit price and a $15/lb P credit price in the market. This price level was selected simply because it represents credit prices that are below both project utilities' onsite technology costs. In order to isolate the impact of the two additionality policies, the TES rules and available prices were held constant while only the additionality rule was varied.

TABLE 3.12. EFFECT OF THE ADDITIONALITY RULE ON CREDITS AND NET COSTS								
Conditions: Both N & P TES are required Both N & P prices are available at a $3/lb N and a $15/lb P level (Credits in 1,000s lbs delivered to the Gulf; Cost in $/lb)								
Additionality Rule	**Scenario[a]**	**Acres (1,000s)**	**Nitrogen**		**Phosphorus**		**Total Net Costs (1,000s)**	**Trade Revenue (1,000s)**
			Credit Supply	**Average Net Cost**	**Credit Supply**	**Average Net Cost**		
No Additionality	6	2,438.6	22,377	-$0.01	884	-$0.23	-$199.5	$80,395.9
Additionality	3	1,660.3	15,207	-$0.09	591	-$2.44	-$1,443.1	$54,488.3

[a] Scenario refers to modeling scenarios prepared by NRCS for WRI.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

As would be expected, when additionality is not enforced, more acres generate credits and more credits are offered for sale than when additionality is enforced. This occurs because the baseline reductions below the TES are counted in the credit supply (Table 3.12).

Total net costs for implementing conservation treatments in both scenarios are negative, meaning there are net savings from adopting conservation practices. The net savings are less when additionality is not enforced ($199,500 versus $1,443,100), because conservation treatments are added to more acres to generate credits (778,300 versus 660,800 acres). These extra acres either cost more to treat or give lower N loss reductions when treated, or both, so as treated acreage expands, the cost per acre increases. In contrast, the net savings are larger when additionality is enforced ($1.4 million), simply because less acreage participates and so the per-acre net benefits are larger. Note that if additionality is not enforced the cost increase on the extra treated acres is sufficient to offset the effect on the average cost calculation of allowing 660,000 acres with baseline management and zero extra conservation cost into the solution.

This finding indicates that the conservation treatments selected by the model to maximize profits in response to the $3/lb N and $15/lb P credit prices actually pay for themselves, on average, in fertilizer savings and/or the increases in crop yield revenue, even before trading occurs. However, since the prices required to induce this supply are $3/lb N and $15/lb P, the implication is that some of the lower-cost participants experience very large net savings, which in the average cost calculation offset the costs that range up to $3/lb N and $15/lb P for the higher-cost participants. It is unlikely that the market design would include profit sharing between the lower-cost and higher-cost participants.

When credits are sold at the available credit prices, trading revenue is larger when additionality is not enforced because of the larger number of credits. Note that total profits are the sum of trade revenue and net savings. Thus profits are larger ($80.6 million) when additionality is not enforced than when additionality is enforced ($55.9 million). On a per-acre or a per-credit basis, profits are very similar regardless of whether additionality is or is not enforced. When additionality is not enforced, profits for participating producers are, on average, $33.05/acre, $3.60/lb N, or $91.17/lb P. When additionality is enforced, profits for participating producers are on average $33.69/acre, $3.68/lb P, and $94.64/lb P.

ii. How do trading eligibility standards affect supply and costs?

Though the 2007 USEPA Science Advisory Board recommended a 45% reduction in both N and P loads delivered to the Gulf, future potential trading program developers might require producers to meet an N-only trading eligibility standard if a producer wishes to only sell N, a P-only TES if a producer wishes to only sell P, or both the N and P TES before either nutrient could be sold. For example, in Maryland's state trading program,[25] program developers chose to allow maximum flexibility to producers, requiring that they achieve only the trading standard for the nutrient they desire to sell.

In this example, to isolate the effect of the three options for a trading eligibility standard, WRI held the following conditions constant: (1) two credit prices are available at the $3/lb N and $15/lb P level, and (2) additionality is enforced in order to see the effect of new conservation treatments only. Table 3.13 is arranged in descending order of N credits.

TABLE 3.13. EFFECT OF THE TRADING ELIGIBILITY STANDARD ON CREDITS AND NET COSTS

Condition: Additionality enforced
Both N & P prices are available at a $3/lb N and a $15/lb P level
(Credits in 1,000s lbs delivered to the Gulf; Cost in $/lb)

Trading Eligibility Standard	Scenario[a]	Acres (1,000s)	Nitrogen		Phosphorus		Total Net Costs (1,000s)	Trading Revenue (1,000s)
			Credit Supply	Average Net Cost	Credit Supply	Average Net Cost		
N TES	3a	1,823.5	15,488	-$0.38	428	-$13.68	-$5,858.50	$52,885.50
N & P TES	3	1,660.3	15,207	-$0.09	591	-$2.44	-$1,443.10	$54,488.30
P TES	3b	1,757.9	14,726	-$0.24	612	-$5.67	-$3,473.40	$53,362.20

[a] Scenario refers to modeling scenarios prepared by NRCS for WRI.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

Table 3.13 shows that the trading eligibility standard policy has a modest effect on N credit supply but a larger effect on P credit supply. For N supply, an N-only TES results in the most N credits followed by the N & P TES and then the P TES. The largest quantity of N credits is just 5% larger than the smallest quantity.

The greatest supply of P credits occurs under the mirror image of TES conditions for N supply. That is, the greatest supply for P credits occurs when producers must achieve a P-only TES, followed by the N and P TES, and then an N-only TES. In this case, the largest quantity of P credits is 30% greater than the smallest quantity.

Note the co-benefits that can occur when trying to meet only one or the other nutrient trading eligibility standard. In Scenario 3a, when producers have to meet only the N TES, they generate 15.5 million N credits as well as 428,000 P credits as co-benefits, because some of those conservation treatments also generate enough P reductions to achieve the P trading eligibility standard simultaneously and are counted as tradable P credits. In Scenario 3b, when producers aim to achieve only the P TES, they

[25] See Maryland Agricultural Nonpoint Trading Advisory Committee 2010.

generate 612,000 P credits while the selected conservation treatments also achieve the N TES on some acres, generating 14.7 million N credits in the process.

Net savings under each of these three trading eligibility standard options and these low credit prices range from $1.4 to $5.9 million before selling credits. The smallest net savings occurs when both the N and P trading eligibility standard must be met, reflecting the fact that more expensive treatments are needed to reach both trading standards and fewer acres are able to do so. About 35 to 38% of the six project watershed acres are able to participate in this trading scenario, depending on the TES requirement.

When credits are sold at the modeled prices ($3 and $15 for N and P, respectively), trading revenue ranges from $52.8 to $54.5 million, with the greatest trade revenue occurring when both N & P TES are required due largely to the higher price offered for P credits. When profits are considered (trade revenue plus net savings), the greatest profits occur with an N-only TES ($58.7 million), then a P-TES ($56.8 million), and the N & P TES ($55.9 million). The smallest profits are associated with the N&P TES despite this scenario having the largest trade revenue. This happens because the N&P TES is also the scenario with the smallest net savings.

On a per unit basis, profits per acre and profits per pound of N, regardless of the TES requirement, are very similar ($32.21 to $33.69/ac and $3.38 to $3.86/lb N), while they are very different for profits per pound of P ($92.87 to $137.25/lb P). This reflects the 30% difference in-between the greatest and smallest quantity of P credits.

c. How do price signals affect credit supply and costs?

To isolate the effect that the availability of credit prices have on credit supply and net costs, WRI selected a simple example that varies the availability of credit prices at the $3/lb N and $15/lb P level while holding constant the additionality rule (enforced) and the trading eligibility standard (both N & P TES).

TABLE 3.14. EFFECT OF THE CREDIT PRICES ON CREDIT SUPPLY AND NET COSTS

Conditions: Both N & P TES required
Additionality enforced
Both N & P prices available at $3/lb N & $15/lb P
(Credits in 1,000s lbs delivered to the Gulf; Cost in $/lb)

Price(s)	Scenario[a]	Acres (1,000s)	Nitrogen		Phosphorus		Total Net Costs (1,000s)	Trading Revenue (1,000s)
			Credit Supply	Average Net Cost	Credit Supply	Average Net Cost		
N & P price	3	1,660.3	15,207	-$0.09	591	-$2.44	-$1,443.10	$54,488.30
N price	1	1,485.9	14,078	-$0.41	445	-$13.11	-$5,830.00	$42,234.50
P price	2	775.9	3,300	-$5.33	345	-$50.92	-$17,573.70	$5,176.40

[a] Scenario refers to modeling scenarios prepared by NRCS for WRI.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

The example in Table 3.14 shows that both trading eligibility standards must be achieved before any credits can be sold and additionality is enforced. When there is both an N and P credit price in this trading market, the greatest number of both N and P credits are generated and there is the highest level of acres generating credits. The second greatest quantity of both N & P credits and trading acreage occurs when there is only an N credit price. Note that the availability of an N-only price generates about 22% more P credits than does a P-only price (Scenario 1 versus 2).

Note that although there would be no *market* driver to generate P reductions if there was only a price signal for N, it is the N and P TES policy that drives generation of P credits before any N credits could be sold. The P supply shown in Scenario 1 represents the P co-benefits when conservation treatments are selected to maximize profits from N trading. The same situation occurs in Scenario 2 where there is a supply of N with only a P price signal.

Under all three price availability scenarios, net savings result from investing in conservation treatments to meet the N and P TES before any credits can be sold. Surprisingly, the greatest net savings occur with the P price and the smallest net savings with the N and P price. This suggests that the profit-maximizing treatments selected to generate P credits only are resulting in very large fertilizer savings and/or crop yield increases. And since the least acreage is treated when there is a P price, on a per pound basis, the greatest savings per pound also occurs when there is only a P price in the market.

As expected, trading revenue experiences the opposite effect from net savings, with the largest trading revenue occurring with both prices present, given the large quantity of both nutrient credits generated in response to both credit prices. Profits reflect the same trend as trade revenue indicating the largest profits from nutrient trading occur when both credit prices are available followed by only an N credit price.

These findings underscore the important economic signals that credit prices send to market actors. The availability of credit prices in a market for N has a moderate effect on N credit supply, but in a market for P has a larger effect on P credit supply.

d. What is the range of credit supply in response to different magnitudes of credit prices?

Table 3.15 displays the range of N and then P credits that could be generated—regardless of additionality or trading eligibility standard policies—in response to three credit price levels:

1. \$1/lb N and \$5/lb P (this is the smallest price combination modeled),
2. \$3/lb N and \$15/lb P (this is the price combination below both project utilities' onsite costs),
3. \$50/lb N and \$100/lb P (this is the largest price combination modeled).

Note that for this example, WRI opted to display only the N credits generated when there is either an N-only price or an N and a P price available and did not display the N credits generated when there is only a P price available. This reflects the reality that the profit-maximization model is selecting treatments in response to available market prices. The same choice was made for P.

Table 3.15. RANGE OF CREDIT SUPPLY IN RESPONSE TO PRICE MAGNITUDE AND THREE MARKETS FOR NUTRIENTS				
Conditions: Three different credit prices displayed (Credits in 1,000 lbs delivered to the Gulf; Total Net Costs & Trade Revenue in $1,000s)				
Prices Available	**Price/lb N**	**$1**	**$3**	**$50**
	Price/lb P	**$5**	**$15**	**$100**
N & P	**N Credits**	8,545 to 17,730	14,726 to 22,685	34,530 to 46,272
	Net Cost/lb N	-$1.97 to -$0.99	-$0.24 to -$0.22	$7.37 to $6.70
	Acres	1,299 to 2,245	1,758 to 2,611	3,255 to 4,285
	P Credits	222 to 673	428 to 906	2,124 to 2,679
	Net Cost/lb P	-$71.35 to -$26.01	-$13.68 to -$2.46	$125.55 to $111.27
	Acres	1,435 to 2,092	1,824 to 2,537	3,506 to 4,033
	Total Net Costs	-$4,233.20 to -$3,647.90 (N credits) & -$3,352.70 to -$4,300.50 (P credits)	-$1,979.00 to -$1,966.80 (N credits) & -$3,352.70 to -$4,300.50 (P credits)	$132,772.00 to $157,104.20 (N Credits) & $144,681.20 to $145,195.00 (P credits)
	Trade Revenue	$10,639.40 to $19,600.50 (N credits) & $12,477.20 to $18,430.40 (P credits)	$53,362.20 to $78,599.20 (N credits) & $52,885.50 to $79,269.90 (P credits)	$1,945,153 to $2,574,096 (N credits) & $2,006,247 to $2,514,220 (P credits)
Price Available	**Price/lb N**	**$1**	**$3**	**$50**
N	**N Credits**	8,262 to 17,294	13,880 to 21,069	34,288 to 45,939
	Net Cost/lb N	-$2.10 to -$1.08	-$0.50 to -$0.55	$6.89 to $6.21
	Acres	1,203 to 2,323	1,540 to 2,554	3,139 to 4,190
	Total Net Costs	-$4,697.40 to -$4,517.00	-$2,171.90 to -$2,725.80	$122,634.80 to $143,001.30
	Trade Revenue	$8,262.10 to $17,293.70	$41,639.40 to $63,207.30	$1,714,417 to $2,296,973
Price Available	**Price/lb P**	**$5**	**$15**	**$100**
P	**P Credits**	240 to 731	333 to 889	1,253 to 1,720
	Net Cost/lb P	-$80.05 to -$30.92	-$54.80 to -$23.57	$26.40 to $15.97
	Acres	709 to 1,959	818 to 2,375	2,2130 to 3,265

	Total Net Costs	-$4,081.30 to -$5,586.80	-$2,464.80 to -$4,415.50	$132,549.90 to $7,262.40
	Trade Revenue	$1,199.50 to $3,653.70	$4,989.10 to $13,337.40	$125,326.40 to $172,047.00

Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

Overall, a large range of credit supply and associated costs occurs in response to the available credit price levels. As would be expected, the larger the magnitude of credit prices in the market, the greater the quantity of credit supply. In addition, total net costs remain net savings until the $50/lb N and $100/lb P price level wherein conservation practice costs exceed the on-farm economic benefits of conservation. A large range of participating acres also occurs in response to each price level.

At the cheapest credit price modeled ($1 per N credit and $5 per P credit), producers find it profitable to generate between 8.5 and 17 million N credits and between 222,000 and 730,000 P credits. Under these conditions, between 1.4 and 2 million acres are part of credit trading and are achieving between $31 and $46 million in profit from the sale of both N and P credits, or about $21/acre in both high and low cases.

These figures increase dramatically at the largest credit price modeled of $50 per N credit and $100 per P credit. In this instance, the potential for N credits reaches a maximum of over 46 million, and the potential for P credits reaches a maximum of over 2.6 million. Under these conditions, profits to producers could exceed $5.3 billion from the sale of both N and P credits. Net costs per credit are now positive, meaning the cost of implementing conservation treatments now exceeds the fertilizer savings and/or the increases in crop revenue. However, conservation is still being implemented because of the profitability of selling credits at the selected prices.

The middle scenario of $3 per N credit and $15 per P credit is the most realistic based on the results of the demand analysis in Section II. This scenario will be explored in greater detail in Section IV, when the results of the demand and supply analyses are directly compared.

i. Which policy combination results in the largest supply of credits?

For N, the largest supply of credits occurs when only an N trading eligibility standard is required, additionality is not enforced, and when there are both N and P prices. Even at only $1/N credit and $5/P credit, producers would find it profitable to generate over 17 million pounds of N reductions under this policy scenario on over 2.3 million project acres (see Table 3.15).

For P credits, the largest supply of credits is generated when only a P trading eligibility standard is required, additionality is not enforced, and there are both N and P prices. Again, at only $1/N credit and $5/P credit under this policy scenario, producers would find it profitable to generate 731,000 pounds of P reductions on over 1.9 million project acres.

ii. Which policy combination results in the smallest supply of credits?

For N credits, the smallest quantity of N credit prices is generated when there is only a P trading standard, additionality is enforced, and there is only an N price.

For P credits, the smallest number of credits occurs when there is only an N trading eligibility standard, additionality is enforced, and there is only a P price.

e. Putting trading into policy context

This section illustrated how trading policies and credit prices affect the quantity of credits and associated net costs. It is important to note that the trading eligibility standards and the additionality rule help to ensure that nutrient trading achieves the overarching water quality goal for the waterbody of concern. That is, these two policy rules ensure that trading fulfills its promise to achieve the policy cap on pollution in the most cost-effective manner possible. However, upholding these trading principles requires tradeoffs, because they do dampen credit supply and raise net costs. Given the many sociopolitical factors that must be taken into account when designing a trading program, it will be challenging to uphold these principles while also considering other important program elements such as fairness, flexibility, and producer participation.

Although this section demonstrated the effects of trading policies on supply and net costs, it is apparent that regardless of the policy decisions in place, there is significant potential supply to be generated, often at a net savings to the producers.

3. Conservation may be profitable on some project acres even without trading

WRI and NRCS decided to run a scenario in which no credit prices were available but the project watersheds were still subjected to combinations of all three trading eligibility standards and the two additionality rules. In this example below, WRI decided to enforce additionality simply to show the results of new conservation treatment implementation. Without credit prices, the profit-maximization model selects the most cost-effective treatments to achieve the specific 45% reduction goal in question and reports out the number of reductions (credits) achieved in excess of the delivered-to-the-Gulf trading standard (see Table 3.16).

Even without credit prices and when additionality is enforced, Table 3.16 and Figure 3.8 show that about 12 to 19% of cropland acres in the six project watersheds can attain net savings from implementing conservation treatments. These conservation treatments result in greater fertilizer savings and/or greater increases in crop yield revenue than the cost of the conservation treatments. Total net savings range from an annual average of about $19 to $22 million per year, or about $24 to $32 per acre, from implementing conservation treatments on 782,000 to 903,000 acres.

TABLE 3.16. EVEN WITHOUT CREDIT PRICES, CONSERVATION MAY BE PROFITABLE

Conditions: No credit prices
Additionality enforced
Arranged in descending order of nitrogen credits
(Credits are in 1,000s lbs delivered to the Gulf; Cost in $/lb)

		Nitrogen		Phosphorus		Area		Net Costs	
Trading Eligibility Standard	Scenario[a]	Credit Supply	Average Net Cost/lb	Credit Supply	Average Net Cost/lb	Acres (1,000s)	Project Area	Total Net Costs (1,000s)	Net Costs/ac
N TES	1a, 2a, 3a	3,035	-$6.39	129	-$150.01	781.5	16%	-$19,385.90	-$24.81
N & P TES	1, 2, 3	2,614	-$7.02	250	-$73.27	581.2	12%	-$18,342.40	-$31.56
P TES	1b, 2b, 3b	0	$0.00	346	-$62.63	902.6	19%	-$21,654.30	-$23.99

[a] Scenario refers to modeling scenarios prepared by NRCS for WRI.

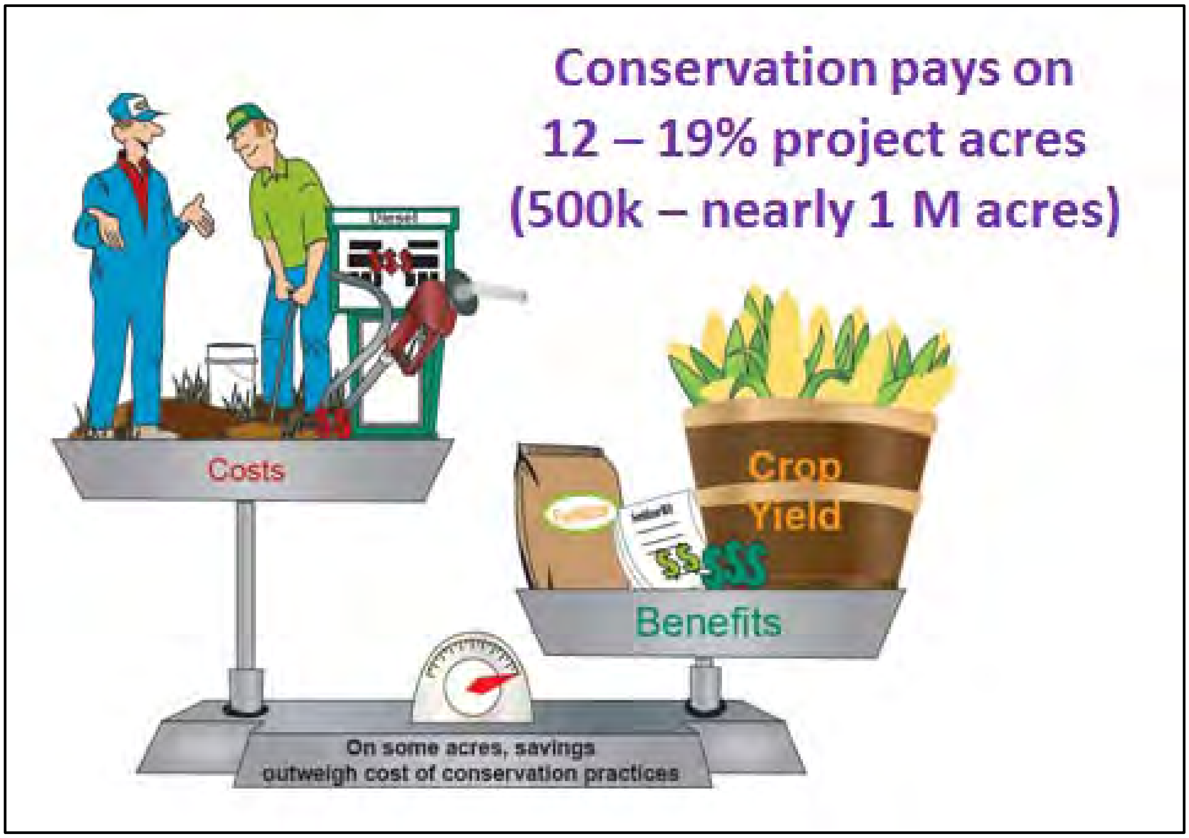


FIGURE 3.8. ON SOME ACRES, INVESTMENTS IN CONSERVATION MAY GENERATE MORE SAVINGS THAN COSTS EVEN WITHOUT TRADING

The greatest N supply occurs with an N TES while the greatest P supply occurs with a P TES. Note that no N credits are counted when there is only a P TES, indicating that the least-cost treatments selected by the model achieved only the 45% reduction in P and did not result in enough simultaneous N reductions to achieve the 45% reduction goal in N.

This analysis demonstrates that, even without a trading market, for a portion of the project area it may be profitable for farmers to implement conservation practices that achieve greater than a 45% reduction in N and/or P loads with or without a trading program.

This finding should be treated cautiously given the model's limitations. First, this analysis was only modeled for six 8-digit agricultural watersheds, not for the entire MRB. Second, extending data from the NRI-CEAP survey points to statistically similar acres assumes homogeneous fields, which may miss some of the subtle factors associated with conservation net savings calculations. Finally, there are a variety of reasons why producers may not have invested in conservation practices to realize the associated profit. These reasons include but are not limited to:

- Lack of upfront funds to implement conservation practices,
- Lack of awareness or understanding of the opportunity,
- Concern that reducing fertilization rates may reduce yields and is too great a risk to take,
- Lack of on-the-ground evidence that such net savings are possible, and
- Technical challenges with helping producers assess whether their operation may be among those that would experience net savings from conservation practice adoption.

Box 3.4. Feedback from project's agricultural stakeholders on finding that conservation, even without trading, may be profitable on some acres

Regarding the study's findings about the profitability of some conservation practices on some acres without trading, University of Arkansas (UAR) staff said that farmers are now recognizing the importance of analyzing crop budgets because they understand they could be losing money on higher nutrient or pesticide applications. Six years ago, they were not concerned about N costs, but they are now due to higher N prices. Other UAR economists said they would have to do some analysis to know if the net savings from conservation found in the study is realistic.

Farm trade representatives in Mississippi concurred that the findings about conservation's profitability were interesting but underscored the fact that farmers tend to focus more on increasing yields rather than on increasing profitability. Staff said that farmers at the coffee shop compare each other's yields as their metrics of success. Staff said they realize that some farmers with lower yields may be making more money than farmers with higher yields; nevertheless, most farmers strive for the highest yields possible per acre. Future research should investigate how conservation planners can provide economic analysis services to producers to help identify which fields and which suites of best management practices may afford net savings.

IV. COMPARING NET COST DIFFERENTIALS, DEMAND, & SUPPLY

A. Comparing Costs and Credits Delivered to the Gulf

1. Is large-scale interstate nutrient trading an economically justifiable option to help achieve clean water goals in the Gulf?

a. Nutrient trading is economically justified

This feasibility study found that large-scale interstate nutrient trading can help achieve Gulf of Mexico hypoxia reduction goals at a lower cost to society than could be achieved via technological plant upgrades. The study determined that given the average of the two project utilities' onsite technology upgrade costs to meet their potential future nutrient limits, the utilities may be able to pay significantly lower prices to achieve the necessary reductions by purchasing credits, depending on trading program rules.

A significant cost differential exists between the nutrient reduction costs faced by the project's two wastewater utilities to reduce their loads onsite by 45% and the costs to achieve the same level of reduction by implementing agricultural best management practices. At an N credit price of $3, which is less than both utilities' 20-year net present value (NPV) onsite costs to reduce a pound of N ($4.69/credit for MWRDGC and $11.89/credit for SD1), the utilities could save nearly $900 million over 20 years by solely trading to achieve the goal (see Figure 4.1). This amount is equivalent to a cost savings of 63%. These figures were estimated under trading program rules that required both N and P TES to be achieved before credits could be sold and that additionality rules were enforced.

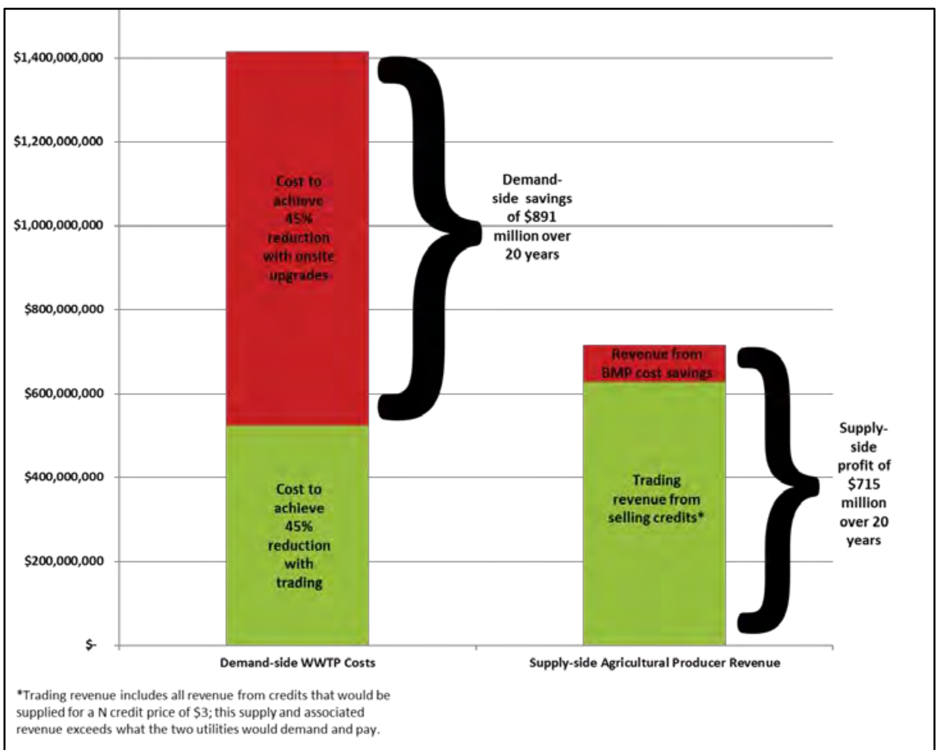


FIGURE 4.1. 20-YEAR DEMAND-SIDE SAVINGS AND SUPPLY-SIDE PROFIT POTENTIAL OF NITROGEN TRADING TO ACHIEVE 45% REDUCTION IN NITROGEN LOADS TO GULF OF MEXICO

While the project watersheds had sufficient N supply to meet the two utilities' demand, they did not have sufficient P supply for MWRDGC, under the aforementioned trading program rules. However, the credits that could be supplied were produced at a net savings to the producer at all possible credit prices before revenue from the credit sales was factored in.

Should nutrient trading materialize, there will be far more buyers in the marketplace than the two project buyers and far more sellers than the six project agricultural watersheds. However, given this case study's constraints, it is still interesting to note that if both utilities were interested in trading to satisfy 100% of their hypothetical N reduction target, the average potential N credit supply from the agricultural watersheds collectively would be nearly twice their N credit demand (see Figure 4.2). In contrast, the average potential supply of P credits from the six project watersheds is between 25 and 44% of the potential P demand from the two project utilities, depending on whether only a P credit price is offered or both N and P credit prices are offered (see Figure 4.3).[26]

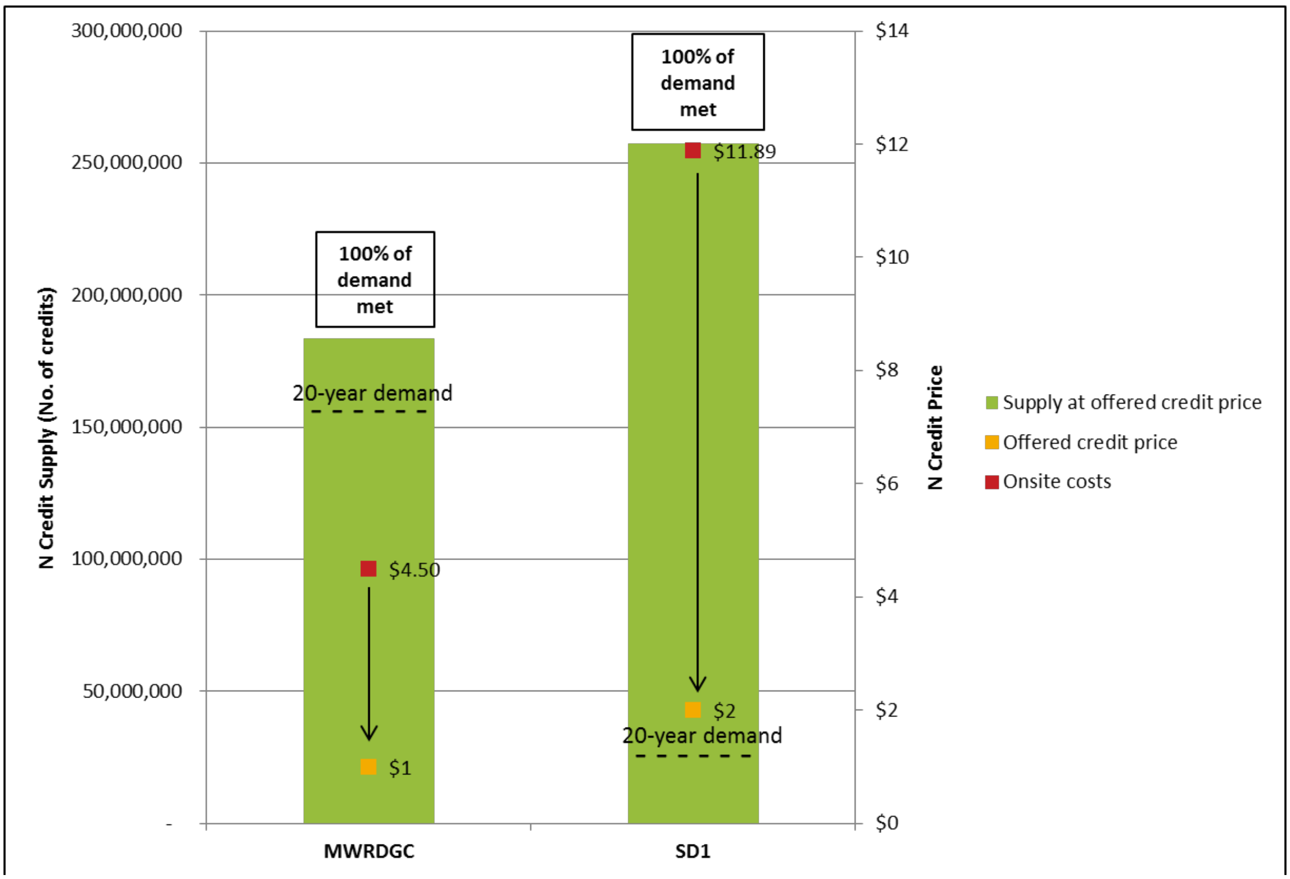


FIGURE 4.2. NITROGEN CREDIT SUPPLY POTENTIAL WITH MWRDGC AND SD1 EACH OFFERING A CREDIT PRICE THAT IS 25% OF THEIR ONSITE COSTS

[26] The supply estimates are based on a policy scenario in which both the N and the P TES must be met before credits can be sold, additionality is enforced, and there is an N-only credit price signal at $3 when N is supplied and a P-only price signal at $15 when P is supplied.

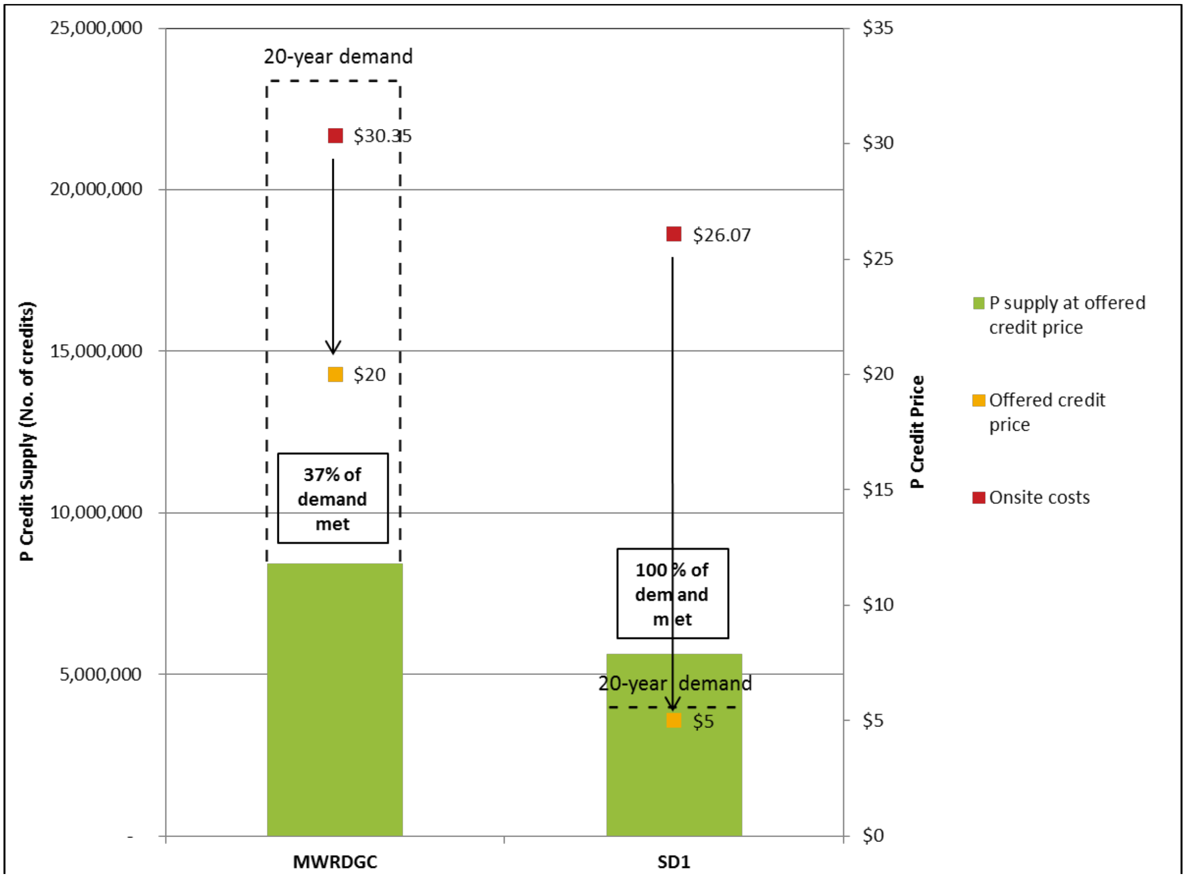


FIGURE 4.3. PHOSPHORUS CREDIT SUPPLY POTENTIAL WITH MWRDGC OFFERING A CREDIT PRICE THAT IS 75% OF ITS ONSITE COSTS AND SD1 OFFERING A CREDIT PRICE THAT IS 25% OF ITS ONSITE COSTS

MWRDGC could trade to achieve the entire 45% N reduction goal; however, based on the supply from the project watersheds, there would only be enough P supply to offset 37% of its demand. SD1, on the other hand, would find enough N and P credits from the agricultural watersheds to satisfy 100% of its demand for both nutrient credits. Note that under different trading program rules – for example if additionality were not enforced and only a P trading eligibility standard were required and both N and P credit prices were in the market, nearly 98% of MWRDGC's demand for P credits could be satisfied if the utility were willing to offer 75% of its onsite P costs.

Note that when there is a market for only one nutrient, credits for the other nutrient are also generated. For example, if only N credit prices are offered, P credits are also generated because conservation practices selected for reducing N also end up achieving P reductions as co-benefits. Thus, for example, when a $3/N credit price is offered, the six project watersheds generate 14 million N credits annually beyond the N TES for sale but 445,000 P credits are also generated beyond the P TES every year. Given that these nutrient co-benefits are produced even without a price signal for that nutrient, there are actually many more pounds total nutrients reduced and credits generated at any given price point for a single nutrient.

b. Large potential financial benefits to both utilities and agriculture from trading

To illustrate the opportunities for profit sharing and for covering transaction costs between the wastewater utility sector and agriculture, see Figure 4.4, which depicts the N credit supply curves when only N credit prices are offered under six policy scenarios (three TES requirements: N-only TES, P-only TES, and N and P TES and two additionality scenarios: when additionality is or is not enforced).

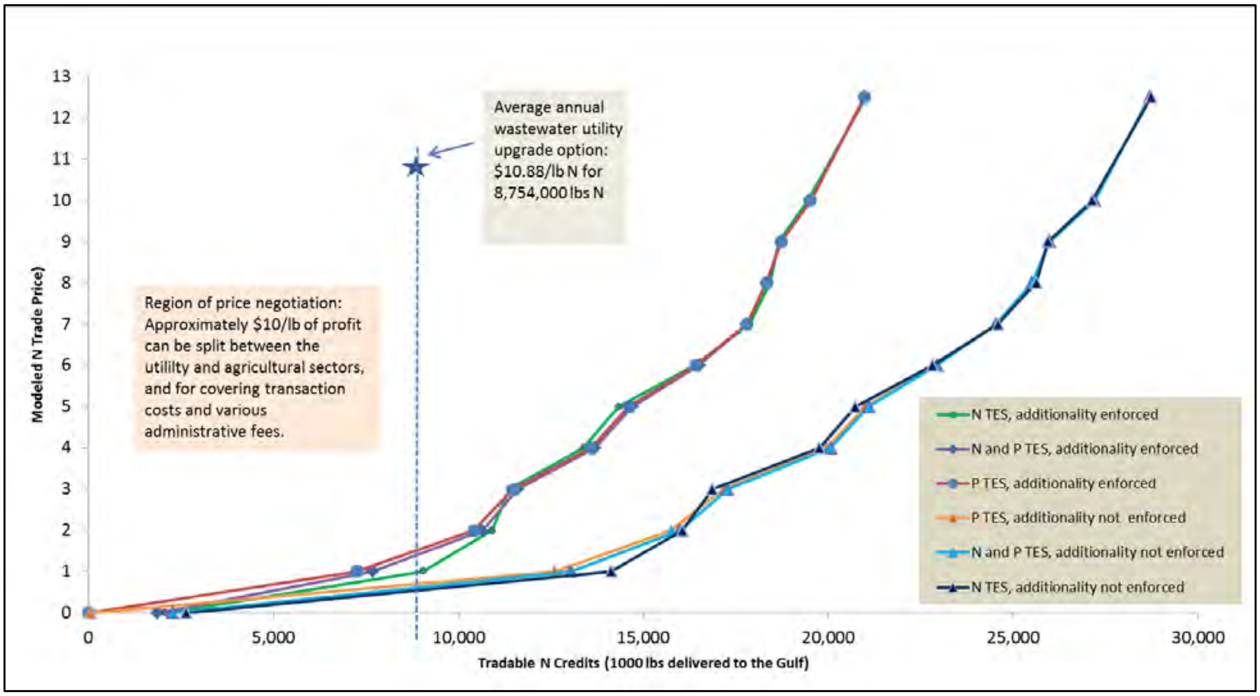


FIGURE 4.4. POTENTIAL MARKET EXCHANGE OF N CREDITS FOR ALTERNATIVE POLICY SCENARIOS IF ONLY N CREDIT PRICES ARE OFFERED AND ONLY N CREDITS ARE TRADED

Given this study's findings that the average of the two project utilities onsite costs are $10.88/lb N (20-year NPV), and together they would need to reduce about 8.8 million lbs of N every year, the utility managers could decide to invest in the onsite technology upgrades or negotiate in an N credit trading market for a similar quantity of reduction from agriculture. If agriculture were to be paid for only the N reductions, Figure 4.4 shows that depending on whether or not additionality were enforced and whether a 45% reduction in P loads was also required for trading eligibility, the quantity of 8.8 million credits would be supplied for any price above about $0.50 to $1 per pound.

This finding implies that the $10 or so difference between what the utilities would pay ($10.88) and what agriculture would require (about $0.50 to $1) would be available as profit to be split between the utility companies and agriculture, depending on the bargaining outcome. In addition, some portion of that surplus could be made available for covering market transaction costs, such as credit aggregator fees, permitting fees, trading program fees, verification of conservation practices, water quality monitoring, administrative costs, etcetera.

In order to more closely examine the profit potential for agricultural producers, WRI looked at the profit maximization model's profit estimates when credits are sold at the two utilities' average willingness to pay thresholds of 75%, 50%, and 25% of their onsite costs. While the low and sometimes negative net costs to implement credit-generating BMPs provide evidence of the cost differential, and therefore economic feasibility of trading, they are only part of the story. The costs represent costs to implement BMPs that will generate credits, but they do not account for the producers' revenue earned from selling those credits. Figures 4.5 and 4.6 display the profit potential per N credit sold and per acre treated by a BMP, respectively, over various policy scenarios.

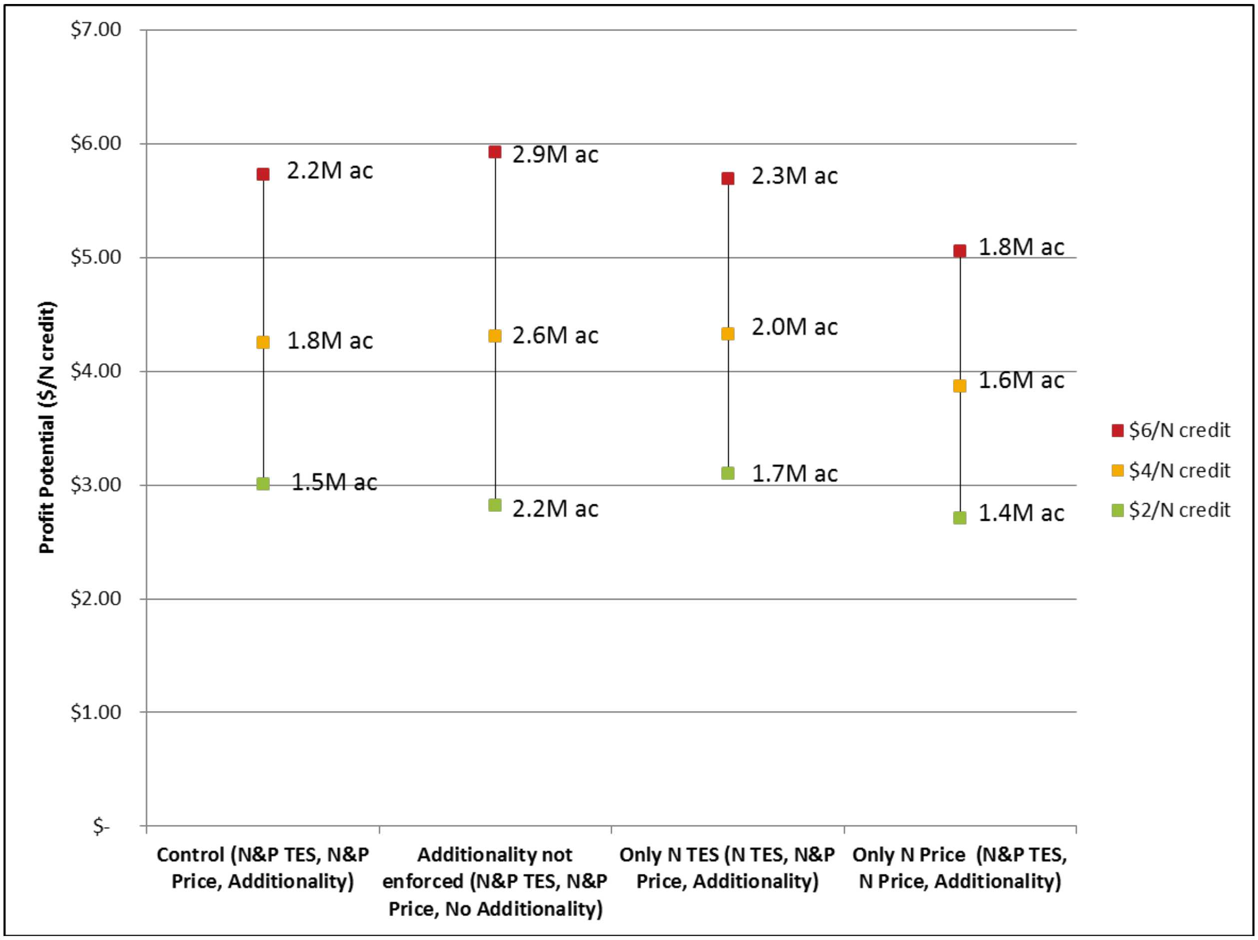


FIGURE 4.5. RANGE OF AGRICULTURAL SECTOR PROFIT POTENTIAL PER N CREDIT ACROSS VARIOUS POLICY SCENARIOS AT AVERAGE UTILITY N CREDIT PRICE POSSIBILITIES

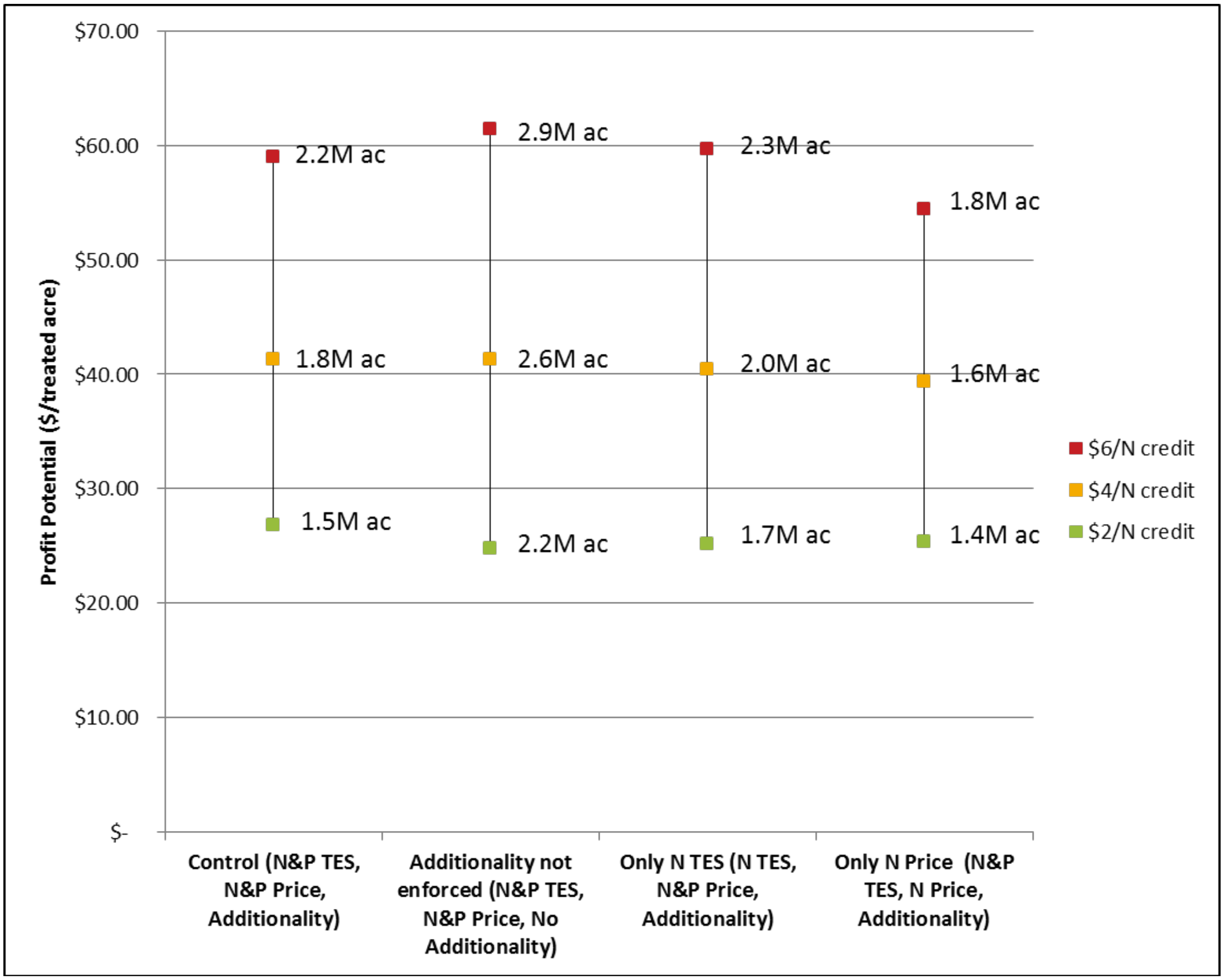


FIGURE 4.6. RANGE OF AGRICULTURAL SECTOR PROFIT POTENTIAL PER TREATED ACRE ACROSS VARIOUS POLICY SCENARIOS AT AVERAGE UTILITY N CREDIT PRICE POSSIBILITIES

Not surprisingly, the profit potential per N credit is close to the credit price. As discussed earlier, at low credit prices ($2 per N credit in this example), there are often cost savings associated with implementing BMPs due to savings in fertilizer and fuel costs and/or increases in crop revenue. So in this scenario, when an N credit is sold for $2, the profit is around $3, which includes the $2 in revenue from the sale as well as about a dollar in cost savings (see Figure 4.5). At $6 per N credit, however, the profit is slightly less than $6 per N credit. In this instance, after most of the low-hanging fruit has been exhausted, more expensive BMPs are implemented, incurring net costs rather than net savings. On a per acre basis, profits range from about $25 per acre to $60 per acre, depending on the credit price and policy scenario (see Figure 4.6).

Changes in policies do not appear to have a significant effect on profit. Compared to the control policy scenario, in which there's both an N and a P price and the most stringent policies are in place (i.e., both the N and P TES have to be met in order to trade either nutrient and additionality is enforced), not enforcing additionality only slightly changes the profit at each credit price. Profits increase slightly at $6/N credit and decreases slightly at $2/N credit. Requiring only the N TES to be met to sell N credits has the opposite effect, slightly decreasing profit at $6/N credit and slightly increasing profit at $2/N credit.

Only offering one price signal for N, not also for P, may have the greatest effect on profit, as it decreases profit more than any other price or policy change across all credit scenarios (see Figure 4.5).

For P, profits per credit are much higher than the credit price (see Figure 4.7). A P credit sold for $10, for example, actually generates between $67 and $81 in profit, in part because of the significant cost savings associated with implementing BMPs that reduce P. Credits sold for $20 can bring in between $58 and $97, depending on the policies in place, and $5 P credits can bring in between $56 and $71 per credit.

Interestingly, profit per P-treated acre is generally less than the per acre profit estimates for N credits (see Figure 4.8). Profits per P-treated acre range from $18 to $42 compared to profits per N-treated acre of $25 to $61. They are likely less than N profits per acre simply because the quantity of P reductions are typically less than N reductions for any given BMP that is designed to treat both.

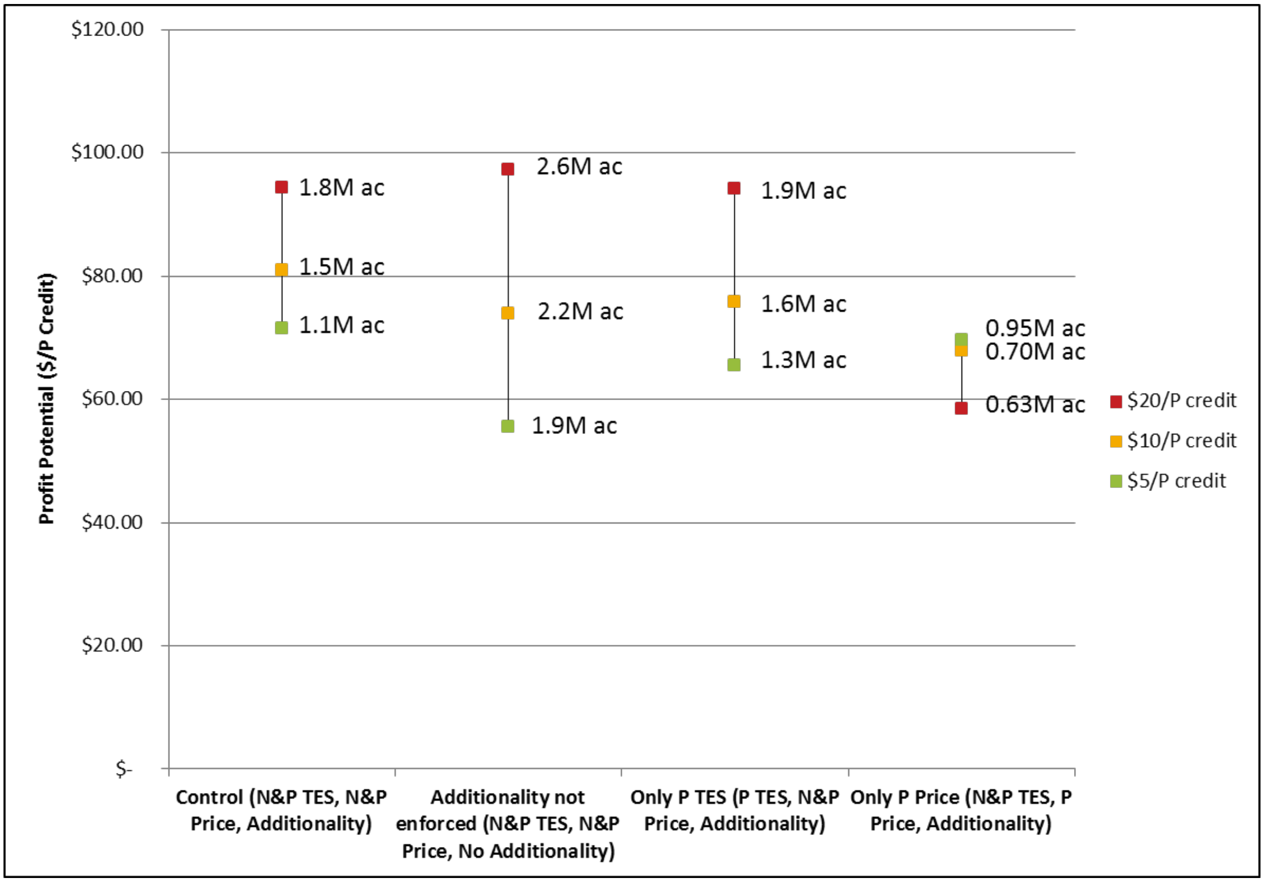


FIGURE 4.7. RANGE OF AGRICULTURAL SECTOR PROFIT POTENTIAL PER P CREDIT ACROSS VARIOUS POLICY SCENARIOS AT AVERAGE UTILITY P CREDIT PRICE POSSIBILITIES

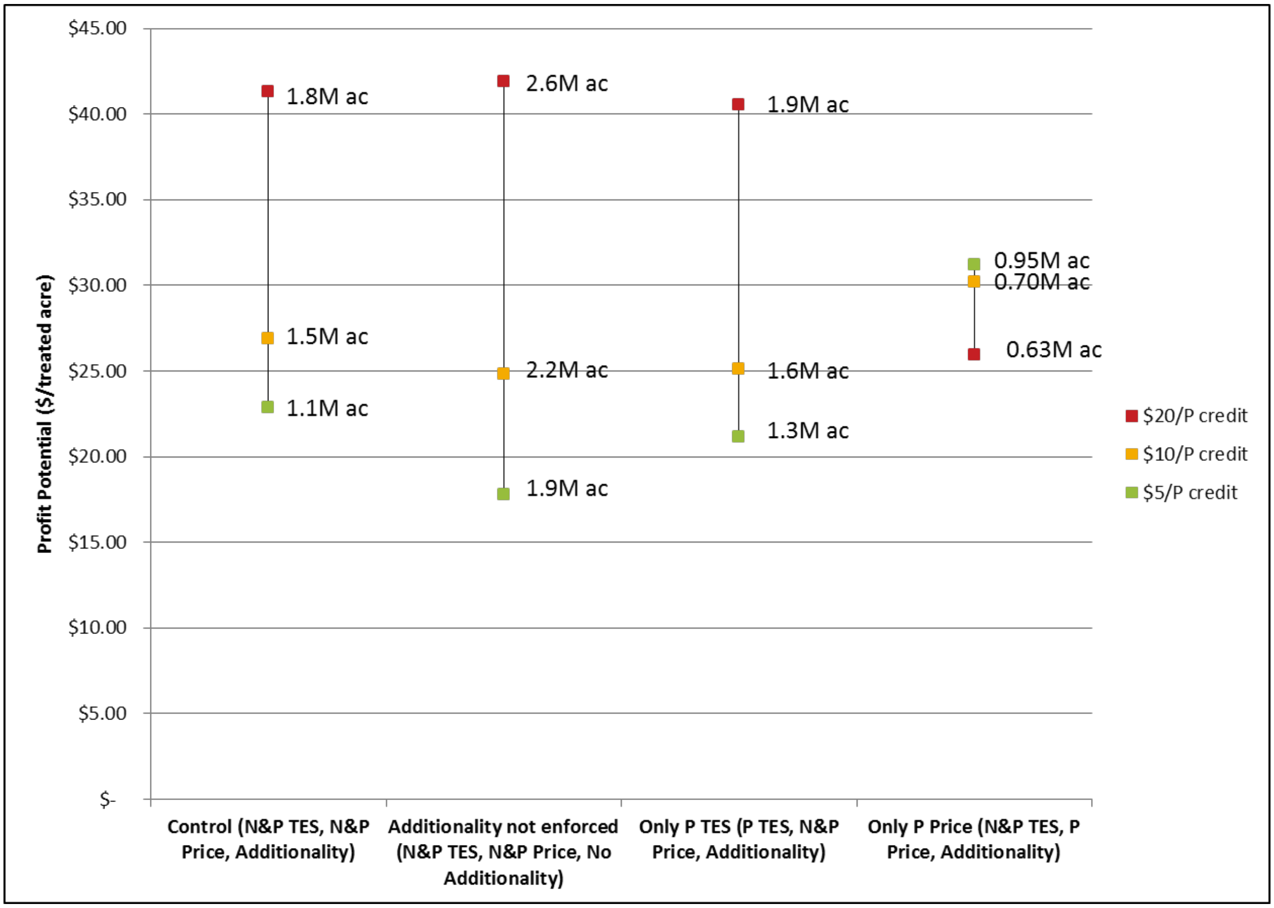


FIGURE 4.8. RANGE OF AGRICULTURAL SECTOR PROFIT POTENTIAL PER TREATED ACRE ACROSS VARIOUS POLICY SCENARIOS AT AVERAGE UTILITY P CREDIT PRICE POSSIBILITIES

When additionality is not enforced, the profit range widens in both directions, resulting in a minimum profit of only $56 at $5 P credit and a slightly higher maximum than when additionality is enforced at $97 for a $20 P credit. When only the P TES is enforced to trade P, profits decrease slightly. When only a P price signal is available, profits significantly decrease, into the $20 to $30 range. When there is only a price signal for P, the profit ceiling is significantly lower. And interestingly, the $20 P credits generate less profit per credit and per acre than the $5 P credits when there's only a P price signal. This finding suggests that the revenue from the sale of P credits alone is not large enough to offset the increase in costs to implement the more expensive practices that the larger credit prices drive.

2. How does potential demand and supply for credits compare between the utilities and the agricultural sector?

To further investigate the opportunity for trading, the following perspectives are investigated:

a) The combined utilities' potential credit price offerings and the combined agricultural sectors' potential credit generation response,
b) MWRDGC's potential credit price offering and the combined agricultural sectors' potential credit generation response,
c) SD1's potential credit price offering and the combined agricultural sectors' potential credit generation response,

d) Arkansas's potential credit generation response to the combined utilities' potential credit price offerings, and
e) Mississippi's potential credit generation response to the combined utilities' potential credit price offerings.

To facilitate analysis of the likely credit price scenarios, WRI examined supply and demand under three potential scenarios that reflect possible demand-side willingness to pay thresholds: 75%, 50%, and 25% of the utility's onsite costs.

Based on these three willingness-to-pay thresholds, potential supply and credit generation costs were examined across the relevant policy scenarios to identify the least and highest average net cost per credit generated and the associated supply.

If trading is to materialize in the Mississippi River Basin, decision-making bodies will have to decide which trading eligibility standards or additionality rules to adopt and whether to allow a market for N and/or P credits to emerge. Given there is no way to predict these decisions ahead of time, this section does not pre-select which of the 18 modeled policy-price combination scenarios to analyze. Instead, this section will identify the likely agricultural credit costs and supplies that could materialize in response to potential credit prices offered by the project utilities and then mention which policy-price scenario the credit costs and supplies stemmed from.

a. Comparing the combined utility estimates to the combined agricultural estimates

The average of the two utilities' onsite technology costs to achieve the project's 45% nutrient reduction goal is $8.09/lb for N and $28.42/lb for P. Three credit prices that are 75%, 50%, and 25% of these onsite costs, rounded down to the nearest whole number were selected for analysis: $6, $4, and $2 per N credit and $20, $10, and $5 per P credit. These percentages were selected to represent various levels of "willingness to pay" that could be expected from the utilities. On the more aggressive end, utilities may be willing to spend up to 75% of their onsite costs on credits in lieu of onsite upgrades. On the more conservative end, utilities may only be willing to spend 25% of their estimated onsite costs on credits in lieu of upgrades.

For Table 4.1, two average net costs are displayed to represent the least average net cost and the highest average net cost. The supply corresponding to these two average net costs is also displayed. The same methods were repeated for P credit costs and supply (see Tables pmChart3-PV for the credit cost data and pmChart4-PV for the credit supply data in the Appendix).

TABLE 4.1. AGRICULTURAL NUTRIENT CREDIT COSTS AND SUPPLY IN RESPONSE TO CREDIT PRICES THAT ARE 75%, 50%, AND 25% OF THE UTILITY COSTS AND POTENTIAL DEMAND (DATA ARE AVERAGES OF BOTH UTILITIES AND AVERAGES OF ALL SIX AGRICULTURAL WATERSHEDS)							
Average Utility Onsite Costs and Demand							
Average Onsite Costs		$8.09/lb N			$28.42/lb P		
Fraction of Costs Utilities May Be Willing to Pay		75%	50%	25%	75%	50%	25%
Credit Prices Utilities May Be Willing to Offer ($/lb)		$6[a]	$4[b]	$2[c]	$20[a]	$10[b]	$5[c]
Annual Utility Credit Demand (1,000 lbs)		8,754			1,357		
20-Year Utility Credit Demand (1,000 lbs)		175,080			27,144		
Average Agricultural Credit Costs and Supply (Six Project Watersheds)							
Least Cost	**NPV Cost/lb**	$0.48	-$0.14	-$0.68	-$30.62	-52.45	-$59.55
	20-Year Supply (1,000 lbs)	555,660	331,160	259,920	8,200	5,380	4,800
Highest Cost	**NPV Cost/lb**	$1.29	$0.48	-$0.33	$10.70	-$8.51	-$18.07
	20-Year Supply (1,000 lbs)	444,660	359,220	394,900	16,180	15,040	12,220

[a] 75% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[b] 50% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[c] 25% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

i. Combined Utilities' Perspectives on Nitrogen

In response to the smallest offered credit price, $2/lb N, representing 25% of the average onsite utility costs ($8.09/lb N), both the least and the highest average agricultural credit generation costs are net savings (negative values in red). If a $2/lb N price were offered, the *lowest* average agricultural N credit cost is -$0.68/lb N. At the $2/lb price, there could be an average of 260 million pounds of N credits generated over 20 years, which is more than enough to meet both utilities' total potential 20-year project demand of 175 million lbs.

There are two policy-price scenarios that yield this *lowest* average net present value cost (-$0.68/lb N). The first occurs with an N trading eligibility standard, an N credit price, and when additionality is enforced (no existing baseline credit trades allowed). The second policy-price scenario occurs with a P trading standard only, an N credit price only, and additionality is enforced.[27] Thus, as long as there is a small N credit price offered, even if additionality is enforced, either an N TES or a P TES will stimulate more than enough supply to satisfy both utilities' N needs.

[27] Note that the supply for the first scenario is 274 million and the supply for the second scenario is 245.8 million; thus, the average credit supply from both scenarios is 260 million pounds.

ii. Combined Utilities' Perspectives on Phosphorus

For P, there are agricultural net savings at 50% and 25% of the buyers' onsite costs. However, at a P market price of $20/lb, which represents 75% of the average combined utility onsite costs ($28.42/lb P), the *highest* average farm net cost is $10.70/lb. At this price, the largest potential supply of 16 million pounds of P is generated, which is just 60% of the 27 million P pounds needed by the two utilities to satisfy their project goal over 20 years.

This highest average net cost of $10.70/lb P and 16 million credits occur when both an N and a P trading eligibility standard are present, both credit prices are offered (i.e., an additional market price of $4/lb N is also needed along with the $20/lb P price), and additionality is enforced (no baseline trades allowed).

b. Comparing MWRDGC's estimates to the combined agricultural estimates

The same methodology used to generate Table 4.1 was repeated for populating Table 4.2, except this time only the MWRDGC's onsite costs to meet the project's 45% nutrient reduction goal is analyzed: $4.29/lb for N and $30.76/lb for P. Thus, at 75%, 50%, and 25% of these onsite costs, credit prices of $3/lb, $2/lb, and $1/lb per N credit and $20/lb, $15/lb, and $5/lb per P credit were evaluated.

TABLE 4.2. AGRICULTURAL NUTRIENT CREDIT COSTS AND SUPPLY IN RESPONSE TO CREDIT PRICES THAT ARE 75%, 50%, AND 25% OF MWRDGC'S COSTS AND POTENTIAL DEMAND

MWRDGC's Onsite Costs and Demand							
Average Onsite Costs		$4.29/lb N			$30.76/lb P		
Fraction of Costs MWRDGC May Be Willing to Pay		75%	50%	25%	75%	50%	25%
Credit Prices MWRDGC May Be Willing to Offer ($/lb)		$3[a]	$2[b]	$1[c]	$20[a]	$15[b]	$5[c]
Annual MWRDGC Credit Demand (1,000 lbs)		7,734			1,154		
20-Year MWRDGC Credit Demand (1,000 lbs)		154,672			23,070		
Average Agricultural Credit Costs and Supply (Six Project Watersheds)							
Least Cost	**NPV Cost/lb**	-$0.57	-$0.68	-$1.56	-$30.62	-$40.76	-$59.55
	20-Year Supply (1,000 lbs)	287,229	259,920	165,242	8,200	6,652	4,800
Highest Cost	**NPV Cost/lb**	-$0.01	-$0.33	-$0.68	$10.70	-$0.17	-$18.07
	20-Year Supply (1,000 lbs)	447,531	394,900	321,053	16,180	17,688	12,220

[a] 75% of MWRDGC's 20-year net present value cost ($4.29/lb N and $30.76/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[b] 50% of MWRDGC's 20-year net present value cost ($4.29/lb N and $30.76/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[c] 25% of MWRDGC's 20-year net present value cost ($4.29/lb N and $30.76/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

i. MWRDGC's Perspective on Nitrogen

At the low N credit prices (\$1/lb to \$3/lb), all of the costs to implement conservation practices are net savings. By paying an N market price of \$1/lb or just 25% of the MWRDGC's onsite costs, the utility would be able to satisfy all of its project needs of 155 million N credits over 20 years, as there is an average of 165 million credits generated by the six agricultural watersheds under the *least* average net cost/lb N (-\$1.56/lb N) policy scenario.

These 165 million N credits are generated when there is only a P trading eligibility standard, an N credit price, and additionality is enforced (no baseline trades allowed). This interesting set of policy and price conditions could conceivably occur when there is an N market signal but the farm producers are required to achieve a P standard before selling credits because of local P water quality concerns. By aiming to meeting the P trading standard, some producers also exceed the N trading eligibility standard and can sell 165 million N credits.

Hence, this situation appears to be a win-win-win for MWRDGC, for producers, and for the environment. MWRDGC achieves a 75% savings in its net costs per pound of N abatement over 20 years. Producers achieve net savings from reductions in fertilizer costs that exceed their conservation practice costs and, in addition, earn profits from engaging in trading. Finally, the environment benefits because requiring additionality ensures that both P and N clean water standards are achieved by these credit suppliers before credits can be generated and sold.

ii. MWRDGC's Perspective on Phosphorus

At 25% and 50% of MWRDGC's onsite P reduction costs, the average credit generation cost for agricultural producers is again a net savings. However, at the highest offered P price of \$20/lb, or 75% of MWRDGC's onsite costs of \$30.76/lb P, the agricultural watersheds would have to incur their highest average net cost of \$10.70/lb P to supply an average of only 16 million of the 23 million pounds of P that MWRDGC needs (70%).

The policy scenario for the \$20/lb P price and the ensuing \$10.70 average P credit cost entails both an N and a P trading eligibility standard, both an N and a P credit price (i.e., an additional market price of \$4/lb N is also needed), and additionality is enforced. The situation is good for the environment because the agricultural producers exceed the N trading standard on some acres along with the P standard, and additionality is achieved.

To satisfy MWRDGC's demand for 23 million pounds of P over 20 years, there are three policy scenarios that supply 25 to 27 million pounds of P at \$25/lb (81% of the utility's onsite costs). However, all three of these scenarios also include a \$5/lb N market price, which is more than it would cost MWRDGC to reduce its load onsite. Therefore, unless there were other N credit buyers in the marketplace willing to offer \$5/lb N, it is not likely that these agricultural watersheds could offer attractive N and P prices for MWRDGC to satisfy all of its P credit demand cost-effectively.

c. Comparing SD1's estimates to the combined agricultural estimates

The methodology used to generate the table for MWRDGC above was repeated for populating Table 4.3 for SD1. To meet the project's 45% nutrient reduction goal, SD1's onsite costs are: \$11.89/lb for N and \$26.07/lb for P. The following credit prices were selected for analysis to represent 75%, 50%, and 25% of

SD1's onsite costs, cost rounded down to the nearest whole credit price: $8/lb, $5/lb, and $2/lb per N credit and $15/lb, $10/lb, and $5/lb per P credit.

TABLE 4.3.AGRICULTURAL NUTRIENT CREDIT COSTS AND SUPPLY IN RESPONSE TO CREDIT PRICES THAT ARE 75%, 50%, AND 25% OF THE SD1'S ONSITE COSTS AND POTENTIAL DEMAND							
SD1's Onsite Costs and Demand							
Average Onsite Costs		$11.89/lb N			$26.07/lb P		
Fraction of Costs SD1 May Be Willing to Pay		75%	50%	25%	75%	50%	25%
Credit Prices SD1 May Be Willing to Offer ($/lb)		$8[a]	$5[b]	$2[c]	$15[a]	$10[b]	$5[c]
Annual SD1 Credit Demand (1,000 lbs)			1,020			204	
20-Year SD1 Credit Demand (1,000 lbs)			20,407			4,074	
Average Agricultural Credit Costs and Supply (Six Project Watersheds)							
Least Cost	**NPV Cost/lb**	$1.11	$0.08	-$0.68	-$40.76	-52.45	-$59.55
	20-Year Supply (1,000 lbs)	641,924	353,109	259,920	6,652	5,380	4,800
Highest Cost	**NPV Cost/lb**	$2.12	$1.02	-$0.33	-$0.17	-$8.51	-$18.07
	20-Year Supply (1,000 lbs)	511,144	417,362	394,900	17,688	15,040	12,220

[a] 75% of SD1's 20-year net present value cost ($11.89/lb N and $26.07/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[b] 50% of SD1's 20-year net present value cost ($11.89/lb N and $26.07/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[c] 25% of SD1's 20-year net present value cost ($11.89/lb N and $26.07/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

i. SD1's Perspective on Nitrogen

By offering a $2/lb N price or just 25% of SD1's onsite costs ($11.89/lb N), SD1 could easily meet its need for 20 million pounds of N over 20 years as an average of 260 million pounds of credits are generated.

At the $2/lb N credit price, the smallest average net cost for credit generation of -$0.68/lb N occurs under the same two policy-price scenarios as discussed in Section a (the combined utility cost comparison). Interestingly enough, both of these least cost scenarios for N also produce enough P credits to meet SD1's P needs of 4 million pounds over 20 years. The policy-price scenarios are:

1. N trading eligibility standard, an N credit price only, and additionality is enforced (generates 4 million P credits), and

2. P trading eligibility standard, an N credit price only, and additionality is enforced (generates 9.1 million P credits).

ii. SD1's Perspective on Phosphorus

By offering a $5/lb P price, or just 25% of SD1's maximum willingness to pay for credits, the scenario that results in the *least* average net cost/lb P to producers of -$59.55/lb generates 4.8 million P pounds. This amount exceeds SD1's potential demand for 4 million pounds over 20 years.

This least-cost scenario occurs with an N trading eligibility standard, a P price, and additionality enforcement. And because the trading standard is for N, 56 million pounds of N are also generated which is nearly triple the N needs of SD1. If SD1 were only interested in purchasing P credits, then the environment experiences a bonus, because while producers are meeting the additionality principle and aiming to exceed the N standard, they are also exceeding the P standard on some acres, so the 45% reduction goal is achieved for both nutrients.

d. Comparing Arkansas's estimates to the combined WWTP estimates

To provide the analysis for just the three Arkansas watersheds (instead of the six combined watersheds), WRI created four new tables from NRCS's tables to reflect only Arkansas's average net costs for credit generation and corresponding credit supply under the 18 policy-price combinations.

The combined utility credit price offerings from Section a are used here to represent the three possible N credit prices and the three possible P credit prices.

TABLE 4.4. ARKANSAS'S SUPPLY OF NUTRIENT CREDITS AND COSTS IN RESPONSE TO CREDIT PRICES FROM UTILITIES (AN AVERAGE OF ONSITE COSTS FROM BOTH PROJECT UTILITIES)

Average Utility Onsite Costs and Demand							
Average Onsite Costs		$8.09/lb N			$28.42/lb P		
Fraction of Costs Utilities May Be Willing to Pay		75%	50%	25%	75%	50%	25%
Credit Prices Utilities May Be Willing to Offer ($/lb)		$6[a]	$4[b]	$2[c]	$20[a]	$10[b]	$5[c]
Annual WWTP Credit Demand (1,000 lbs)		8,754			1,357		
20-Year WWTP Credit Demand (1,000 lbs)		175,080			27,144		
Arkansas's Three Project Watershed's Agricultural Credit Costs and Supply							
Least Cost	**NPV Cost/lb**	$0.13	-$3.87	-$10.56	-$10.40	-$27.44	-$35.65
	20-Year Supply (1,000 lbs)	99,060	77,174	67,591	3,802	2,142	1,717
Highest Cost	**NPV Cost/lb**	$4.17	$0.22	-$0.42	$2.50	-$5.20	-$8.76
	20-Year Supply (1,000 lbs)	85,849	82,445	69,553	7,114	5,585	4,905

[a] 75% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[b] 50% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[c] 25% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

i. Arkansas's Perspective on Nitrogen

If a $6/lb N credit price were offered (75% of the combined utility onsite costs for P), the Arkansas watersheds can generate a maximum of 99 million pounds of N in response or about 56% of the combined utility needs of 175 million pounds. This also happens to be the *least* average net cost/lb N credit generation scenario ($0.13/lb N) and occurs under an N trading eligibility standard, with only an N price available and no enforcement of additionality.

ii. Arkansas's Perspective on Phosphorus

If a $20/lb P credit price were offered (75% of the combined utility onsite costs for P), the *highest* average cost/lb credit generation scenario ($2.50/lb P net cost) generates 7.1 million pounds of P or about 60% of the combined utilities P needs. This occurs when there is both an N and a P trading eligibility standard, the $20/lb P price and a $4/lb N price, and additionality is not enforced. Because of the presence of an N price (and both trading eligibility standards), 84 million pounds of N are also generated from this policy-price scenario.

e. Comparing Mississippi's estimates to the combined WWTP estimates

To provide the Mississippi perspective in Table 4.5, WRI created four new tables to reflect only Mississippi's average net costs for credit generation and corresponding credit supply under the 18 policy-price combinations (see Appendix for these four tables and four corresponding charts named MS pmChart1-PV, MS pmChart2-PV, MS pmChart3-20y, MS pmChart4-20y).

TABLE 4.5. MISSISSIPPI'S SUPPLY OF NUTRIENT CREDITS AND COSTS IN RESPONSE TO CREDIT PRICES FROM UTILITIES (AN AVERAGE OF ONSITE COSTS FROM BOTH PROJECT UTILITIES)							
Average Utility Onsite Costs and Demand							
Average Onsite Costs		$8.09/lb N			$28.42/lb P		
Fraction of Costs Utilities May Be Willing to Pay		75%	50%	25%	75%	50%	25%
Credit Prices Utilities May Be Willing to Offer ($/lb)		$6[a]	$4[b]	$2[c]	$20[a]	$10[b]	$5[c]
Annual WWTP Credit Demand (1,000 lbs)		8,754			1,357		
20-Year WWTP Credit Demand (1,000 lbs)		175,080			27,144		
Mississippi's Three Project Watershed's Agricultural Credit Costs and Supply							
Least Cost	**NPV Cost/lb**	$0.56	-$0.07	-$0.66	-$48.13	-$68.96	-$78.14
	20-Year Supply (1,000 lbs)	456,617	267,867	217,327	4,390	3,244	2,376
Highest Cost	**NPV Cost/lb**	$1.23	$0.54	-$0.30	$14.45	-$10.47	-$24.32
	20-Year Supply (1,000 lbs)	365,793	302,314	325,354	11,265	9,464	7,305

[a] 75% of the utilities' 20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[b] 50% of the utilities'20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
[c] 25% of the utilities'20-year net present value cost ($8.09/lb N and $28.42/lb P) to install onsite technology to meet 45% N and P reduction goals, rounded down to nearest whole credit price increment modeled.
Note: The average net costs reflect the range of costs for each level of credit supply, ranging from very negative (large net savings from practice adoption), to positive, and nearly equal to the N and P prices simulated, for the most costly participant.

i. Mississippi's Perspective on Nitrogen

If a $2/lb N credit price were offered, the *least* average net cost per pound (-$0.66/lb N) credit generation scenario in Mississippi produces 1.2 times (217 million lbs) the amount of N credits needed by the two utilities. This occurs with just an N trading eligibility standard, the $2/lb N price and a $10/lb P price, and when additionality is enforced.

ii. Mississippi's Perspective on Phosphorus

For Mississippi to be able to generate 11.3 million pounds of P credits, which is 42% of the P credits needed by the combined utilities, the $20/lb P credit price (75% of the combined utilities' onsite costs for P) would have to be offered. These credits are supplied under the *highest* cost per pound credit generation scenario ($14.45/lb P), which involves both N and P trading eligibility standards, both N and P prices, and additionality is enforced.

The greatest number of credits from Mississippi in response to a $20/lb P price is actually 15.5 million pounds and occurs under the same scenario except that additionality is no longer enforced. Thus, about 4.2 million pounds of P would not be additional. These credits are supplied when the average net cost per pound is $13.05/lb P (lower than the *highest* average net cost).

3. What is the effect of the most stringent policy scenarios on credit demand and supply?

When a trading program is designed, the policymakers and stakeholders involved will have to make important decisions about the conditions in which credits can be generated. A trading program must walk a fine line between helping to achieve cost-effective nutrient reductions and also upholding environmental standards so that water quality does not degrade. These supply and demand analyses of 18 different policy-price combination scenarios help to demonstrate the effects that policy choices have on costs, supply, and demand. Below, the effects of the most environmentally stringent policy scenarios on the feasibility of trading in the MRB are examined. If trading is still demonstrated to be economically feasible under these stringent standards, it is likely that any future trading program, regardless of its policies, would provide cost savings to permitted facilities and create additional revenue streams for agricultural producers and other credit generators.

The policy combination that sets the highest trading eligibility bar for agricultural producers requires them to meet both the N and the P trading standard simultaneously and enforces the additionality rule. If there were market prices available for both N and P, these two policy requirements have the following effect on the two project utilities.

a. MWRDGC's experience

Nitrogen trading – If MWRDGC were only in the market for obtaining N credits, under these highest trading standards, MWRDGC would have to offer at least \$1/lb N or just 25% of its onsite costs (\$4.29/lb N) to be able to meet 100% of its potential N demand of 155 million pounds over 20 years from the six project watersheds. Agricultural producers' net costs/lb at that price and policy combinations is a net savings between -\$1.20 and -\$1.11/lb N. Thus, producers are making money not only from investing in conservation practices but also from selling credits.

Phosphorus trading – To solely meet its potential demand for 23 million pounds of P over 20 years, MWRDGC would have to offer a P credit price of at least \$30 to \$35/lb P (and there would have to be an N price between \$6 and \$7/lb N in the market) to stimulate between 21.7 and 25.2 million pounds of P. However, this credit price would exceed MWRDGC's onsite costs (\$30.76). Thus, The District would need more sellers in a trading market to satisfy 100% of its P needs through trading.

Nitrogen and Phosphorus trading – Note that within this required policy scenario combination, because of the N:P price combinations chosen for modeling, there is no previously prepared N and P combination that together yields just enough N and P pounds for purchase by MWRDGC. The District would have to rely on other sellers in a future market to satisfy all of its N and P credit needs.

b. SD1's experience

Nitrogen trading – To meet all of its 20.4 million pounds of N potential demand over 20 years, SD1 may need to offer very little money per credit to producers, as more than double SD1's demand quantity can be generated at a cost savings to producers, even before trading revenue is calculated. However, the higher the trading price, the more likely it is that producers will opt to adopt conservation practices in order to generate credits.

Phosphorus trading – To meet all of SD1's demand of 4 million pounds of P over 20 years, no trading price is technically necessary to stimulate production of enough supply, as there is an average net savings of $54.50/lb P to producers in the six project watersheds. Again, some P credit price will likely need to be offered to stimulate interest in generating credits.

Nitrogen and Phosphorus trading – To meet all of SD1's potential N and P reduction targets over 20 years, there is sufficient supply from the six project watersheds without any trading price signal.

These results suggest that even at the most stringent trading requirements—requiring additionality and enforcing both an N and a P trading eligibility standard to trade either nutrient—trading remains a cost-effective option for reducing nutrient loads. However, this supply and demand analysis so far is simply considering costs faced by the utilities onsite and agricultural net costs to generate credits.

To more accurately assess the economics of trading, more factors must be assessed. First, additional transaction costs associated with engaging in trading must be taken into consideration. Second, the supply and price of credits could be affected by trading ratios depending on policy and program design. And third, potential buyers and sellers will consider a number of non-monetary factors such as the risk and liability involved in trading before deciding to enter into the market. These factors could affect the feasibility of trading and a buyer's or seller's willingness to participate in a trading program and are discussed below and in Section VI.

B. Potential Buyers' Willingness to Pay for Credits and Regulatory Agency Input

Since nutrient trading requires a multi-stakeholder process that involves significant buy-in from many parties, WRI sought feedback on this study from the potential study buyers, the buyers' state regulators, and federal agency staff and included highlights of that feedback in the report. After presenting the report findings, WRI conducted in-person and phone interviews with staff at MWRDGC, SD1, IEPA, and USEPA Regions 4, 5, and 7. WRI submitted five overarching questions and sub-questions to these stakeholders in advance of the interviews and recorded responses during the interviews. Below is a summary of the responses regarding opinion of the study and interest in trading, willingness to pay for credits, and regulatory or other non-monetary concerns about trading.

Opinion of the Study and Interest in Trading

Overall, each of the buyer-related stakeholders were generally supportive of WRI's study, had a mixed attitude toward nutrient trading for Gulf water quality goals, and could envision their institution or agency being involved in designing a nutrient trading program in the future.

MWRDGC staff said they may be interested in N trading for meeting potential future Gulf hypoxia reduction goals given the lack of discussion of development of any local N policies. Because the District had recently committed to conduct onsite technology upgrades for P, they might be interested in P trading if a future Gulf goal required more reductions than offered by their onsite upgrades.

SD1 staff also said that they would consider nutrient trading as an option for achieving some or all of potential future N and P permit limits, though one of their plants was an exception as it already had a P discharge limit that they were meeting through onsite technologies.

Staff at IEPA and the regional USEPA offices indicated that they could foresee writing NPDES permits for N and P for regulated point sources in their jurisdiction that linked to a Gulf hypoxia goal. These staff said they could envision becoming involved in trading program development by providing water quality policy and trading program guidance. They were, however, unsure if a TMDL or other regulatory driver would be set for the Gulf of Mexico hypoxia reduction effort.

Willingness to Pay for Credits

MWRDGC staff acknowledged that it would be a challenge to decide whether to engage in trading and how much to offer for credit prices. They said they would conduct a cost comparison between onsite investments and credit purchases for each nutrient to help determine if it made economic sense for them to trade to meet future permit requirements. In addition to the economic analysis, MWRDGC would consider the concerns of their clients, state policymakers, and local environmental and watershed groups. Because the utility is a risk management agency, and therefore risk adverse, they are typically more comfortable with building technology onsite.

MWRDGC staff said if they had to guess, they thought their maximum willingness to pay for nutrient credits would likely be around 25% of their onsite costs. They believed that the significant cost savings achieved through trading at 25% of the onsite costs would be enough to justify to their ratepayers and relevant policymakers that trading was indeed a cost-effective option for achieving regional water quality goals.

SD1 staff said that it was difficult to answer the question about willingness to pay at this time when there were no policy drivers encouraging them to do so. Before deciding whether to engage in trading, the SD1 staff would conduct a business case analysis, or mini-study, with updated data in relation to the actual permit limit to see what would make economic sense. However, at this time, staff believed that SD1 could consider a combination of upgrades and trading as their initial market position. This combination would allow them to realize the benefits of trading while also “selling” the plan to ratepayers who would likely want to see onsite upgrades. This approach also allows for diversification, or mitigating the perceived risks involved with “putting all their eggs in one basket.” SD1 was not able to estimate their willingness to pay at this time.

Regulatory or Other Non-Monetary Concerns About Trading

MWRDGC was willing to engage in dialogue about trading but raised concerns about regulatory and other non-monetary issues associated with trading. MWRDGC finds the concept of trading to be inequitable. Staff pointed out that because the Clean Water Act lacks regulatory authority over nonpoint sources, regulators can only apply pressure on point sources. They regard this situation as unfair since the majority of the nutrient problem in the Gulf of Mexico stems from nonpoint sources. MWRDGC recognized that though mitigating farm runoff issues may be more effective and less expensive than point source mitigation, they regard trading as “a form of extortion that holds the threat of expensive plant upgrades over the heads of utility operators to encourage them to invest in farm runoff solutions.”

MWRDGC also had concerns with its ability to engage in trading without legislative authority. MWRDGC operates under statutory authority of the state of Illinois and thus believed that some legislative authority would likely be needed to allow the District to engage in trading. MWRDGC staff were unclear on whether their funds could be spent outside of the District, let alone outside of the state.[28] In addition, MWRDGC raised a concern that investing in nutrient trading would not provide local environmental benefits that would be realized if they invested in other innovative ideas like a local wetland treatment.

MWRDGC expressed a potential interest in P trading should a local numeric P criterion or a Gulf-related P goal materialize that required additional P reductions to their recent investments in onsite P technologies. The District is investing in biologically based P technologies that will be able to capture P and turn it into a fertilizer product due to an interest in becoming a "resource recovery" agency. They are concerned that if either a local instream numeric P criterion or a Gulf-P goal materializes that requires reductions beyond the limit of their biological technology investments, they will be forced to use a chemical technology approach that will ruin the opportunity to recycle, recapture, and reuse P as a fertilizer product. Thus, they regard P trading as a way to bridge a potential gap between potential future permits for P and the reductions achieved by their onsite biological investments. Should the policy driver be a local instream P criterion, the District is concerned that it would leave them with very few options to trade with farmers given there are only a few farms in the upper portion of the Des Plaines watershed in Wisconsin.

SD1 also raised a concern about spending ratepayer funds outside the Northern Kentucky area. At the moment, SD1 was having difficulty getting their requested rate increases passed by the General Assembly. Staff felt that they have been strictly limited on their resources and cutbacks have occurred. Therefore, staff indicated that making the economic case for trading would be a challenge and would require a lot of education.

IEPA staff said that the numeric nutrient criteria they were developing might limit trading by regulated point sources to within local water bodies receiving the criteria. Staff have been working to develop numeric P criterion for 53 stream segments that are on Illinois's 2012 303(d) Impaired Waters List for excess algae and/or low dissolved oxygen levels.

USEPA regional staff did not see any regulatory barriers to trading because they regard trading as a voluntary program. Given that a trading program would likely be developed in a collaborative fashion by the various point and nonpoint source stakeholders, the state water quality agencies, and environmental groups, they thought all the relevant stakeholders would design a program that meets everyone's needs.

Both utilities raised a concern about government capacity at their state water quality agencies and their regional USEPA office to handle development of new nutrient permits, reporting on those permits, and being able to evaluate new permits that include trading proposals. Both utilities pointed out that they were operating under expired NPDES permits. IEPA and regional USEPA staff acknowledged they were currently underfunded and understaffed and would likely need many new people to write the new nutrient permits and oversee the trading component of the permits.

[28] MWRDGC has *two* sources of revenue: taxpayers and industries. Taxpayers (all residences and commercial business) pay an ad valorem real estate property tax, a portion of which comes to the District. Industrial facilities are charged a fee by MWRDGC based on their discharge loads. MWRDGC also takes care of the local sewers. Residences may pay a wastewater bill to local municipalities, which also cover the sewers.

C. Potential Sellers' Willingness to Sell Credits and Agricultural Agency Input

WRI also sought feedback on the study from the credit seller stakeholders including representatives from farm trade associations, conservation agencies, water quality agencies, and universities in Arkansas and Mississippi and included highlights of that feedback in the report. After presenting the study findings, WRI conducted in-person and phone interviews with farm trade association representatives from Arkansas Farm Bureau, Mississippi Farm Bureau, and Delta F.A.R.M. (based in Mississippi). Other stakeholders at the meetings included staff representing Arkansas-NRCS, Mississippi-NRCS, Arkansas Department of Environmental Quality (ADEQ), Mississippi Department of Environmental Quality (MDEQ), Arkansas Natural Resources Commission (ANRC), Mississippi Soil and Water Conservation Commission (MSWCC), Lower Mississippi River Conservation Committee, the University of Arkansas (UAR), and Mississippi State University (MSU). WRI submitted five overarching questions and sub-questions to these stakeholders in advance of the interviews and recorded responses. Below is a summary of the feedback regarding their opinion of the study and interest in trading, willingness to accept payment for credits, and regulatory or other non-monetary concerns about trading.

Opinion of the Study and Interest in Trading

Overall, most of the credit seller–related stakeholders were supportive of WRI's study, had generally positive attitudes toward nutrient trading as a mechanism to help farmers adopt more conservation practices, and could envision their institutions being involved in helping to design a nutrient trading program in the future.

Representatives from Mississippi's farm trade associations said that if trading should ever materialize in the MRB that the report would be useful as a roadmap to move forward. MDEQ staff thought the study was a good first step to get people thinking about the issues and the information could be used by the State Level Nutrient Reduction Strategies' Technical Advisory Group. AR-NRCS staff said that overall the study lays out a framework for how trading might work and provides staff the ability to engage in trading discussions in the future.

Regarding opinions about trading, Mississippi farm trade association staff said that, "As conservation advocates, we look at trading as a tool and incentive to get additional conservation benefits." AR-NRCS said they thought trading could have a positive and additive effect on what the conservation programs are already accomplishing. UAR staff said they thought trading offers the potential to help delist streams from the Impaired Waters List in Arkansas by giving farmers an incentive to aim for a quantitative and measurable outcome. MSWCC staff said that they were generally opposed to nutrient trading based on their experience with carbon trading not working out in the Delta.

The organizations foresaw playing various roles in the development of a nutrient trading program, should one materialize. ADEQ staff said they could envision being part of the water quality policy discussion to help ensure that a trading program helps achieve local and regional water quality goals and designated uses. Participants thought that ANRC might provide a certification role for verifying credit validity and maintenance, or they could train third parties to do the certification. ANRC staff said that they would be willing to help develop a nutrient trading program only if there is real buy-in from all the players: NRCS, ADEQ, UAR, Farm Bureau, etc. A member of the Lower Mississippi River Conservation Committee said they would likely be involved by conducting outreach with farmers about the trading program and explaining how it might work.

UAR staff view nutrient trading as an opportunity to educate producers about the risks and rewards of nutrient reduction efforts and trading contracts. The UAR economists could provide training on developing legal contracts for landowners and managing risks associated with a trading contract. Staff envisioned setting up a decision framework to help producers make the best choices for their farm. UAR scientists could also be involved in monitoring and setting up water quality data collection systems. UAR would be interested in ensuring that the estimated reductions being used to determine credits are reflective of what the science is telling them about conservation practices from their field experiments. UAR staff said they could be involved in developing the credit calculation tool as well.

AR NRCS said that they would probably proceed with nutrient trading in much the same way they proceeded with carbon trading, simply sharing information about it with farmers but not taking a more active role. MDEQ representatives contend they remain “interested observers” in trading. MSWCC said that “Everyone in this room will be involved in nutrient trading if it materializes in Mississippi because we are involved in anything that has to do with water in the Delta. It’s our jobs.”

Willingness to Accept Payment for Credits

Overall, meeting participants from Mississippi and Arkansas believed that the study’s estimate of average profit, ranging from $21 to $34 per acre per year depending on trading policy and credit prices , would be attractive to many farmers. Mississippi farm association staff said they thought such a profit estimate was large enough for some farmers to build some conservation activities into their farm loans. Several stakeholders cautioned that for any farmer to decide to engage in trading—regardless of the profit-making potential—they would have to be confident that they can trust that estimate of profits and be able to plan a change in management or conservation practices to pursue those profits. AR-NRCS said that landowners are open to any opportunities that benefit their land and resources, so trading at these estimated profits will likely appeal to some.

Several groups offered conflicting opinions about which types of farmers might be interested in trading at these estimated profit margins. One federal conservation agency staff person said that the bigger landowners might be interested in a $20 to 30 per acre profit from trading, while a farm trade association staff person said larger operations might not have time to engage in trading while smaller farms would probably be interested. Future research should look into determining if size of farming operation plays a role in producers’ willingness to participate in nutrient trading.

Other stakeholders tried to put the $20 to $30 per acre profit figure into context. One farm trade association staff person offered that this was about what it costs producers to apply one fungicide treatment, pay their taxes, or take their families on vacation. Thus, farmers motivated to finance these activities through trading may opt to participate. Other staff tried to compare the trading profit estimate in this study (which was generated from adopting working lands conservation practices) to payments for the land retirement conservation programs. MS-NRCS staff said that Conservation Reserve Program (CRP) payments are currently providing $70 to $100 per acre and the Wetlands Reserve Program (WRP) is offering $170 per acre. Despite these high offers, both programs were not seeing much sign-up given high commodity prices, which make it more profitable for farmers to keep marginal lands in production than retire the lands. Future research should look into the various factors farmers will consider when determining whether to participate in trading.

Regulatory or Other Non-Monetary Concerns About Trading

The agricultural stakeholders raised a variety of non-monetary concerns about trading.

A few stakeholders expressed cultural concerns about trading. For example, one person had reservations about the concept of trading, which they saw as a way to "squeeze farmers while allowing big municipalities to continue discharging when we don't know what agriculture is contributing to the problem." Another raised the issue of penalties for early actors. Staff worried that some farmers will step forward to lower their nutrient load to the target goal but then a lawsuit might materialize and force the standard lower than what these farmers had accomplished, punishing them for early action. WRI pointed out that trading programs can be designed to account for these issues through a variety of mechanisms, including grandfather clauses for early actors or allowing flexibility for early actors to meet the new requirements, or certainty agreements that might limit the amount or frequency of additional nutrient reduction effort needed.

Several groups cautioned that though some farmers might find the profit-making potential of trading enticing, many would not pursue trading if there are too many regulatory obligations involved or if trading contracts exceeded their risk tolerance. AR-NRCS staff stated a fundamental challenge to developing a nutrient trading program was developing a "system of trust" where farmers could work with trusted players and have confidence that the market was stable. Given the collapse of the carbon trading market, stakeholders in Mississippi were worried that nutrient trading might also be unreliable.

All of the farm trade association, conservation agency, and university stakeholders emphasized that should a nutrient trading program materialize, the scientific models and technical tools will need to use the best available data during their development to estimate farmer nutrient baseline loads and calculate credits. Staff indicated that the data used in this study, which reflected 2003 to 2006 crop years, do not reflect the agricultural or conservation conditions currently in place in the Delta today. For example, the recent high corn and soybean prices and low cotton prices mean that most producers are growing corn and soybeans and very few are farming cotton.

Staff also pointed out that many producers are adopting new conservation practices that were not captured in the CEAP models. Since 2010, both states have been involved in the Mississippi River Basin Healthy Rivers Initiative (MRBI) projects, and Mississippi and Arkansas stakeholders said that pads and pipes,[29] on-farm water storage reservoirs, and tail water recovery systems are increasingly common in the Delta (though absent from the CEAP models). AR-NRCS said that they had also been encouraging cover crops and nutrient management under the MRBI, which they had not been doing prior to 2010.

Farm trade association and conservation staff in both states asked how individual farmers would estimate their baseline nutrient loads and how much they could reduce and sell credits. WRI responded that there are internet-based tools like USDA's Nutrient Tracking tool (NTT) that can be used to provide this function for farmers. Mississippi is already engaged in a USDA Conservation Innovation Grant (CIG)

[29] "Pads and pipes" refers to a conservation practice that is common in the Mississippi Delta that originated for rice production but now is regarded as having both water conservation and water quality (nutrient and sediment reduction) benefits. Fields are laser-leveled and the edges are built up with soil to create a pad that keeps water in for rice production. When crops other than rice are produced in the field, the area before the pipe at the downslope of the field slows water runoff and allows nutrients, pesticides, and sediment to precipitate out of solution before the runoff is carried via pipe to a drainage ditch or to a tailwater recovery system. Nutrient reduction efficiency values have not yet been published for the pads and pipes system.

project with WRI and the Texas Institute for Applied and Environmental Research (TIAER) to calibrate NTT to Mississippi's Delta conditions for non-trading conservation applications.

Several conservation agency and university staff indicated concern that nutrient trading could increase their workload while they're facing budget cuts. University staff predicated their willingness to engage in various nutrient trading functions upon their ability to find financial support for those activities.

V. IMPACT OF EXISTING AND POTENTIAL WATER QUALITY POLICIES ON TRADING

A. Impact of Existing Water Quality Standards in Buyer and Seller Watersheds on Trading

Buyer Watersheds

Trading facilitates discovery of the most cost-effective means for achieving a specific waterbody's pollution limits, and it enables one pollutant source (i.e., the credit buyer) to acquire credits generated from another pollutant source (i.e., the credit seller) for the purposes of complying with a water quality–based effluent limit. Therefore, concern exists that trades would result in discharges that exceed local water quality standards in the buyer's receiving water.[30] Fortunately, there are many principles and official policies in place that would forbid credit exchanges in such situations.

First and foremost, the Clean Water Act prohibits discharges that would cause violations of water quality standards. Thus, even if states do not have any local TMDLs or pollution discharge or nutrient concentration limits, trades still must ensure water quality standards are maintained.[31] State regulatory agencies will be expected to review any point source discharge permits and requests to include nutrient trading as a means to meet permit standards. This review should ensure that no potential violation of local water quality standards occurs or would occur over time. Such a review should prevent the development of pollution "hotspots."[32] This analysis typically involves using modeling exercises to simulate proposed trades. A proposed trade would not be authorized if it is shown to violate local water quality standards.

Second, if local TMDLs or other local water quality policies did exist, and they were stricter than the nutrient limits on the downstream waterbody of concern, then potential buyers would be required to meet the local policy first before engaging in nutrient trading for the downstream policy.

The following section describes the current status of TMDLs and other local water quality standards in MWRDGC's and SD1's receiving waters. In sum, there are no current policies that would hamper nutrient trading for MWRDGC and SD1. However, there are policy developments underway that may constrain future nutrient trading for MWRDGC and other point sources in Illinois.

MWRDGC's Water Quality Issues

For MWRDGC, the study team (WRI, Symbiont, and HydroQual) pursued investigations directly with state and federal environmental agencies and conducted research on the water quality standards affecting the utility's wastewater treatment plants. USEPA and IEPA are currently deliberating some of the state's 303(d) listings. The state does have some P-impaired waters, including MWRDGC's receiving waters. However, these waters are listed as P-impaired because they have an instream P concentration greater than a non-standard target value (i.e., a non-regulatory reference) of 0.61 mg/L, representing the 85th percentile of P concentration data from 1978 to 1996. States develop non-standard target

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[30] There is another, related scenario where trading could occur in a waterbody that lacks water quality standards. Presumably, any credit purchase would result in higher than usual discharges to that waterbody. However, the absence of water quality standards is not a trading issue; rather it is a listing issue and challenge of state water programs throughout the United States.
[31] See USEPA 2003.
[32] See World Resources Institute 2010.

values to serve as policy discussion points for consideration of development of potential future water quality standards.

Despite MWRDGC's receiving waters having P concentrations greater than 0.61 mg/L, nutrient-related impairments such as low dissolved oxygen or chlorophyll *a* levels are not present. Illinois has postponed writing TMDLs for P because of a lack of data and information on appropriate water quality standards and corresponding numeric targets for P.[33] Therefore, although MWRDGC's receiving waters are listed as impaired for P, the non-standard instream P target is not believed to limit trading at this time, though it could become an instream nutrient criteria standard or result in corresponding effluent limits in the future.

With regard to N, there are no N-caused impairments in MWRDGC's receiving waters. There are N-caused impairments in other waterbodies in the state, but IEPA is trying to delist its N-impaired waters because the science is not well understood.[34,35] Like for P, one particular challenge with writing TMDLs or numeric limits for N is that USEPA uses 16 years of data to compare high versus low nutrient levels, yet some streams deemed to have high concentrations do not have indications of algae or other impairments. As a result, USEPA is currently updating its protocol for developing nutrient TMDLs.

At the time this study was conducted, there was one TMDL for nutrients, sediment, and bacteria that was being prepared for the Illinois River.[36] At this time, the identified TMDL area is estimated to be more than 50 miles downstream from MWRDGC, and the District has not been mentioned as a source of pollution. It is unlikely that this TMDL will have an effect on MWRDGC, but it could have upstream implications.

With regard to permitting, Illinois has a state effluent limit for P affecting new and expanding plants that does not apply to MWRDGC. Otherwise, only Great Lakes states in USEPA Region V have a 1 mg/L permit limit for P. WRI learned that instream nutrient criteria are not expected to be implemented in the near future (see Section V.B. for more information about instream nutrient criteria). IEPA stated that any future N reduction requirements would likely be driven by Gulf hypoxia rather than instream nutrient criteria, which is in line with our study's policy assumption.[37] HydroQual also researched the state's water quality standards and status. It was determined that there are no 303(d) impairment listings for dissolved oxygen in the Chicago Waterway System that would place a new discharge limit on MWRDGC.

SD1's Water Quality Issues

In Kentucky, HydroQual researched the status of water quality in SD1's receiving waters and the water quality standards and policies governing these waters. These receiving waters also do not have listed nutrient impairments. Thus, nutrient reduction policies in the future would likely be driven by Gulf hypoxia rather than local water quality. If local water quality is prioritized, it is likely that Kentucky would require that existing nutrient concentrations be maintained. In this case, instream nutrient concentrations in the Ohio River could be used to set an upper percentile of annual average N and P concentrations. Based on water samples from the Ashland station in the Ohio River from 2000 to 2006, the 90th percentile would be 2.0 mg/L N and 0.22 mg/L P.

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[33] See Willhite 2009.
[34] See Azevedo 2009.
[35] See Willhite 2009.
[36] See Tetra Tech, Inc. 2010.
[37] See Willhite 2009.

Based on this research, it was determined that aside from national policies on maintaining water quality standards, there are no other current standards or policies in Illinois or Kentucky that would affect the ability for MWRDGC or SD1 to trade or that would need to be prioritized over the project's Gulf hypoxia nutrient reduction goal.

Seller Watersheds

The water quality status of the supply-side watersheds in Arkansas and Mississippi was also examined. Although these watersheds would see a decrease in nutrient loads from trading and thus the risk for hotspots would decrease, it is important for water quality standards to be met before credits can be generated and sold. In this trading feasibility study, a 45% reduction guideline is used as the benchmark that interested credit sellers would have to meet before selling credits in order to demonstrate that they are in compliance with the project's water quality standards for Gulf hypoxia. However, if these watersheds are facing local impairments from nutrients that require a greater nutrient load reduction than 45%, the stricter standard must be met to qualify for trading.

WRI found that there is only one TMDL within the six project watersheds that had an impairment or a TMDL related to nutrients from agriculture. In the Big Sunflower Watershed in Mississippi, one of its sub-watersheds named Porter Bayou has a TMDL for nutrients and low dissolved oxygen that calls for an 85% reduction in N and a 95% reduction in P from agricultural sources. Other than recognizing that USEPA Trading Policy would require local water quality goals that are more strict than a downstream water quality goal to be satisfied prior to credit trading for the downstream goal, WRI did not further assess the effect of this TMDL on trading because of a technical reason. Since the Porter Bayou watershed is a 10-digit watershed it is much smaller than the 8-digit Big Sunflower watershed and thus NRCS is not yet able to conduct statistical modeling analysis on such a small scale.

No other water quality standards in the supply-side watersheds were identified that could affect nutrient trading.

B. Impact of Potential Future Numeric Nutrient Criteria on Trading

This study assesses the potential impacts that future instream nutrient criteria could have on the economic feasibility of nutrient trading in the MRB. Nutrient criteria are "numerical values for both causative variables (P and N) and response variables (chlorophyll *a* and turbidity) associated with the prevention and assessment of eutrophic conditions."[38] USEPA first introduced guidance on developing nutrient criteria in 1998. This guidance included proposed nutrient criteria by ecoregions, areas of similar ecosystems and with similar natural resources.[39] USEPA tasked the states to develop statewide and/or site-specific numeric nutrient criteria for rivers, streams, lakes, reservoirs, and estuaries. As of March 2012, states are at various levels of nutrient criteria development.[40]

When in place within the Mississippi River Basin, nutrient criteria would have the effect of moving the waterbody of concern from the large, downstream Gulf of Mexico to each small, local stream that receives numeric criteria. Thus, for both buyers and sellers of nutrient credits, attention to water quality

[38] See USEPA 2002.
[39] See USEPA 2011b.
[40] See USEPA 2012b.

policies would shift from the Gulf policy to the local numeric criteria policy regardless of whether the local policy was more stringent than the Gulf downstream policy.

In general, WRI envisions several ways in which the presence of nutrient criteria could impact trades for both credit buyers and sellers.

Effect of Numeric Nutrient Criteria on Credit Buyers

For wastewater treatment utilities, nutrient criteria would shift the utilities' ability to purchase credits to meet nutrient load limits associated with Gulf hypoxia to credit suppliers located upstream, which would address the local criteria first. Advantageous delivery ratios would no longer be available; in fact, they could be disadvantageous to the buyer because sources upstream are likely to have lower delivery ratios than the downstream buyer, meaning more credits would need to be generated to achieve the necessary delivered load reductions to the Gulf than would need to be generated downstream where delivery ratios are typically higher.

To achieve the numeric criteria affecting a utility's NPDES permit, the utility has the following options:

a) Reduce its end-of-pipe nutrient concentrations and loads,
b) Purchase credits from a supplier *upstream* of its discharge, or
c) Engage in a combination of both options in order to meet the instream limits.

If the local criteria were more stringent than the Gulf policy, achieving the local criteria would thus help achieve the Gulf hypoxia reduction goal as well. If the local criteria were less stringent than the Gulf policy, then the utility could aim first to achieve the Gulf goal by engaging in nutrient trading with credit suppliers downstream within the MRB and in so doing would also attain the less strict local criteria.

Effect of Numeric Nutrient Criteria on Credit Sellers

For credit suppliers, if the instream criteria were more stringent than the Gulf hypoxia reduction goal, the numeric criteria would become the trading eligibility standard for credit suppliers. This scenario could reduce the potential supply of credits, as there would likely be fewer producers able and willing to comply with a more stringent standard. If the numeric criteria were less stringent than the Gulf goal, to participate in trading to meet the Gulf policy goal credit suppliers would still need to meet the more stringent Gulf trading standard before selling credits.

Current and Future Numeric Nutrient Criteria in Project Buyer Watersheds

Illinois currently has some site-specific numeric criteria and has a P criterion for lakes and reservoirs. Neither of these standards applies to MWRDGC's receiving waters. Illinois has been in discussions with USEPA Region V about their criteria and the possibility of moving forward with a narrative standard instead of a numeric standard for more waters in the state. USEPA and IEPA have agreed that Illinois will develop narrative criteria for targeted watersheds (which have not been announced yet) that have the worst water quality first, rather than taking a statewide approach. When narrative criteria are developed for the Chicago Waterway System and converted into water quality–based effluent limits or TMDLs, the effect of nutrient criteria on trading for MWRDGC, specifically, can be appropriately assessed.

Kentucky does not currently have any numeric nutrient criteria in place. However, the state of Ohio and the Ohio River Valley Water Sanitation Commission (ORSANCO) are developing numeric nutrient criteria for the Ohio River, SD1's receiving waterbody.[41] When numeric criteria are in place for the Ohio River, the effect of nutrient criteria on trading for SD1, specifically, can be appropriately assessed.

Assessing the Impact of Varying Nutrient Criteria on the Ability of Project Buyers to Trade

While numeric nutrient criteria are being deliberated in both project states, the study team estimated the impact that different levels of nutrient criteria could have on the ability of the two project utilities to engage in nutrient trading. The ecoregion criteria guidance published by USEPA in 2000 was used as a proxy for future nutrient criteria in Illinois and Kentucky.[42] Data on the flow and nutrient concentrations of the utilities and of the utilities' receiving waters was collected. The data represented mixed concentrations of N and P, reflecting concentrations of N and P after the utilities' wastewater discharge is mixed with upstream river flow. These mixed concentrations were compared to nutrient criteria estimates.

MWRDGC Nutrient Criteria Analysis

For MWRDGC, their seven WWTPs' discharge makes up the majority of the total flow of the Chicago Waterway System. Because MWRDGC's discharge is not well diluted, it could face very stringent discharge limits under nutrient criteria standards. Based on 2009 water quality data from MWRDGC, existing N and P levels in the Chicago Waterway System are 6.6 mg/L N and 0.86 mg/L P. The ecoregion criteria for "sub-ecoregion 54" within ecoregion VI, which is used as a placeholder for Illinois's potential instream criteria, is 2.95 mg/L N and 0.073 mg/L P.[43] If instream nutrient criteria limits were established based on these numbers, it was estimated that the Northside plant of MWRDGC would need to achieve an effluent concentration of no greater than 4.3 mg/L N. To meet the P limit, it was estimated that the effluent concentration would have to be close to the instream P criteria, and there would need to be a reduction in Lake Michigan's P concentration (see HydroQual's report, Section 4, for more information).

However, since the 2000 ecoregion criteria were not derived from cause and effect relationships between nutrient concentrations and biological response, Illinois is unlikely to adopt these guidelines as their numeric standards. Therefore, three alternative levels of potential nutrient criteria standards for MWRDGC's Northside WWTP were developed to illustrate the impacts that the choice of nutrient criteria has on utilities.

The three nutrient criteria studied equate to the completely mixed downstream instream nutrient concentrations:

(1) Of the existing levels of 6.7 mg/L N and 0.95 mg/L P,
(2) After a 22.5% nutrient reduction, which is half of the 45% policy goal reduction, from MWRDGC's discharge, resulting in 5.3 mg/L N and 0.75 mg/L P numeric criteria, and
(3) After a 45% nutrient reduction from MWRDGC's discharge, resulting in a 3.8 mg/L N and 0.56 mg/L P numeric criteria (see FIGURE 5.1).

Absent nutrient reductions from other upstream point and nonpoint sources, these figures present the effect that the plants' nutrient discharges have on instream nutrient concentrations and how these concentrations compare to potential numeric nutrient criteria. By selecting an instream nutrient concentration from the y-axis (i.e., potential nutrient criteria), one can determine the corresponding

[41] See Ohio River Valley Water Sanitation Commission 2012.
[42] See USEPA 2000.
[43] See USEPA 2000.

required effluent concentration that would be needed to meet the nutrient criteria by finding the y-axis value on the solid black line and reading the x-axis value below that point.

For the first alternative criteria, as is expected by definition, the Northside WWTP would meet the sample nutrient criteria at existing discharge concentration levels. Under this scenario, Northside would not need to engage in trading to meet the numeric criteria. For the second alternative criteria, it was estimated that Northside would need to achieve an effluent discharge concentration of 8 mg/L N and 1.1 mg/L P to meet the sample numeric criteria. Northside could trade with upstream sources to meet these nutrient criteria, and once achieved, could trade with downstream sources to meet the more stringent 45% reduction goal. For the third alternative criteria scenario, Northside would have to achieve an N effluent concentration limit of about 6 mg/L N and 0.5 mg/L P. Meeting these criteria—which are also consistent with the Gulf hypoxia goal—through trading, would limit nutrient trading to upstream sellers. Similar results were found for MWRDGC's Calumet WWTP (for more, see HydroQual's report).

It is important to note that these concentration limits to meet instream criteria assume that there are no other sources responsible for meeting the nutrient criteria. In reality, multiple sources of nutrients would share the burden. Regardless of this caveat, this analysis clearly demonstrates that the potential for MWRDGC to trade with downstream sources is highly dependent on the level at which numeric nutrient criteria are set.

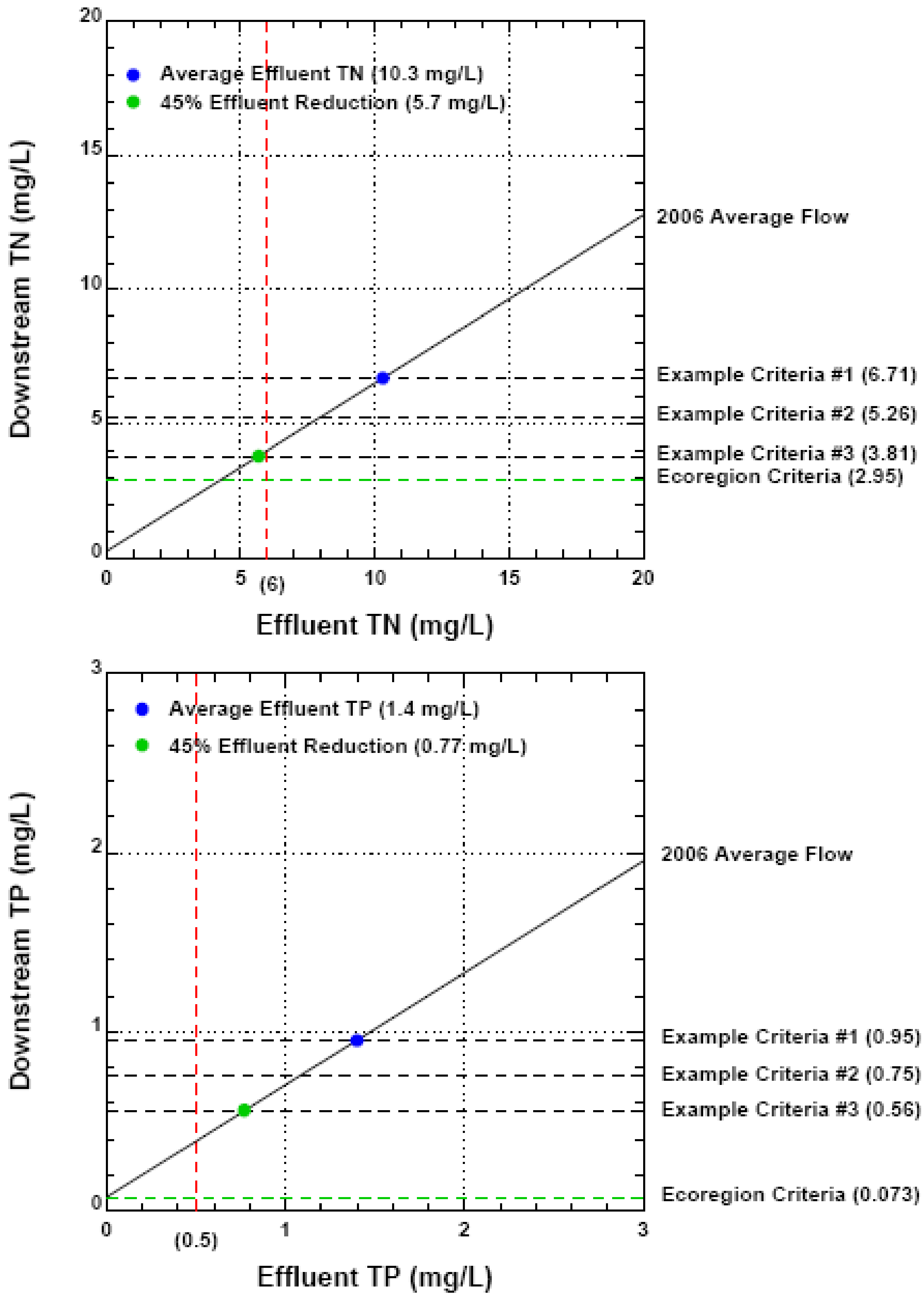

FIGURE 5.1. THE EFFECT OF LOCAL NUTRIENT CRITERIA ON MWRDGC'S NORTHSIDE WWTP[44]

[44] Notes about Figure 5.1: Horizontal dashed green lines represent the example ecoregion criteria;

SD1 Nutrient Criteria Analysis

SD1's Dry Creek and proposed Western Regional Creek WWTPs discharge into the Ohio River. Existing nutrient levels in the Ohio River are 1.5 mg/L N and 0.15 mg/L P, above the 2000 USEPA guidance ecoregion criteria for this area of 0.8 mg/L N and 0.03 mg/L P.[45] These plants are very small sources of nutrients to the large Ohio River (90,000 cfs), so their discharge has a very small effect on Ohio River water quality and is greatly diluted.

Due to these plants' minimal influence on the Ohio River's water quality, there are no discharge nutrient concentration limits that could be placed on Dry Creek or Western Regional WWTPs to meet the ecoregion criteria for this area. In fact, even the elimination of these plants would not result in the guidance ecoregion criteria being attained in the Ohio River. As a result, it is possible that these plants would not be given discharge limits for local instream criteria, potentially enabling them to trade with downstream sources to meet the Gulf hypoxia goal.

In contrast, SD1's Eastern Regional WWTP discharges into Brush Creek and the plant's discharge comprises the majority of the Creek's flow during parts of the year. Brush Creek's nutrient concentrations (1.4 mg/L N and 0.38 mg/L P) are above the ecoregion criteria. Absent reductions from other sources in the watershed, Eastern Regional would need to achieve a maximum effluent limit of 0.77 mg/L N to meet the ecoregion criteria of 0.8 mg/L N.

Eastern Regional would not, on its own, be able to achieve the P ecoregion criteria of 0.030 mg/L (see Figure 5.3). Both the necessary N and P reductions to achieve the ecoregion criteria are beyond present-day wastewater treatment technology limits of 3 mg/L N and 0.3 mg/L P. Should Eastern Regional receive a discharge limit to help meet nutrient criteria, it would likely be at this limit of technology and would restrict trading to upstream suppliers.

These analyses demonstrate the importance of setting appropriate numeric nutrient criteria based on sound science on nutrient source loads and flow. Whether through a TMDL allocation process or a Use Attainability Analysis, various sources of nutrients to the waterbodies of concern must be considered when setting numeric criteria. Once numeric criteria are established, they can greatly limit the geographic scope of trading and the supply of credits to upstream sources if the criteria are set at levels more stringent than existing instream nutrient concentrations.

Vertical red dashed line represents potential nutrient effluent limits based on the utility's long-term planning activities;
Blue circle represents current average effluent concentrations for the WWTP; and
Green circle represents the effluent concentrations needed at the WWTP to achieve the 45% nutrient reduction goal.

[45] See USEPA 2000.

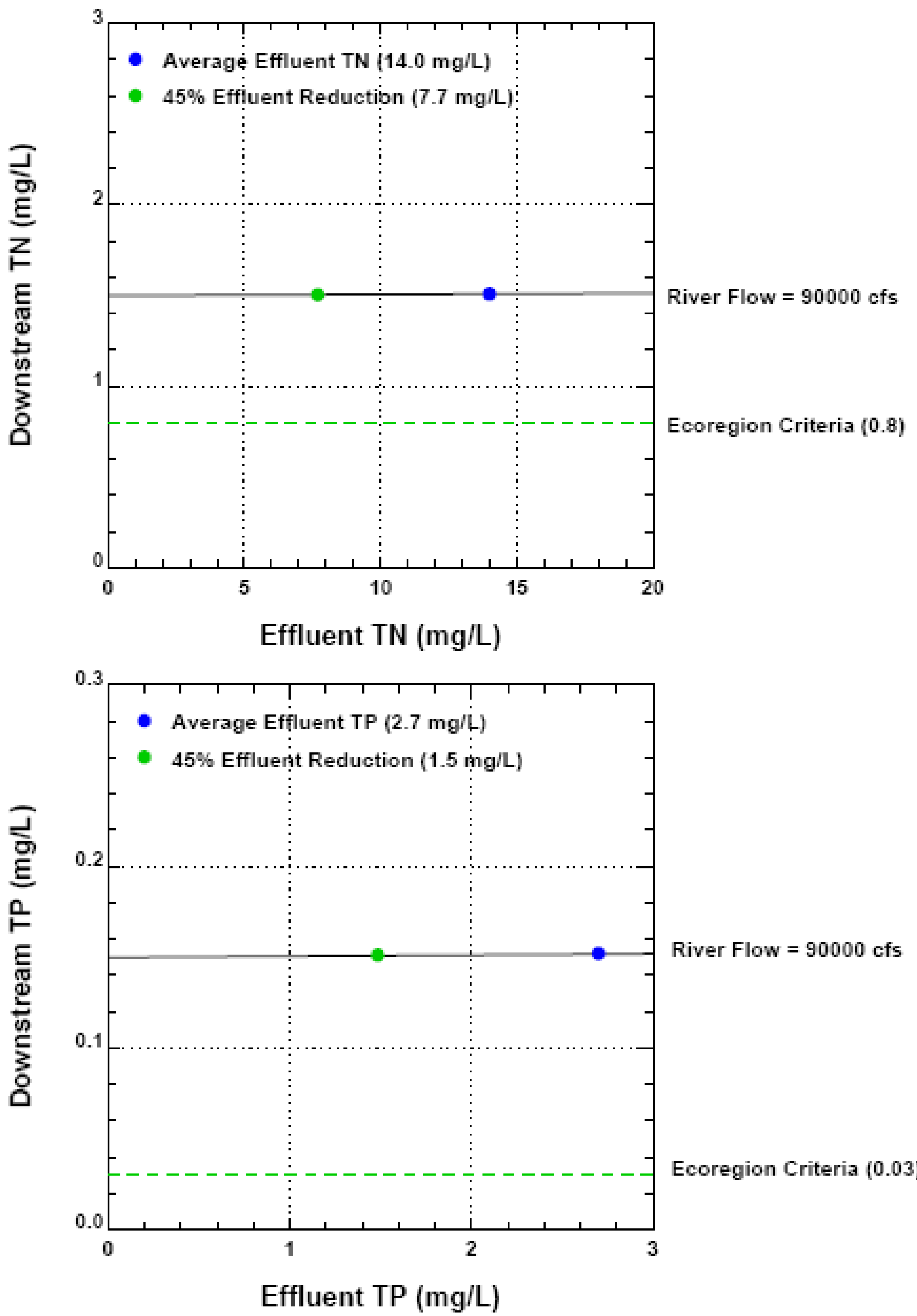

FIGURE 5.2. THE EFFECT OF LOCAL NUTRIENT CRITERIA ON SD1'S DRY CREEK WWTP

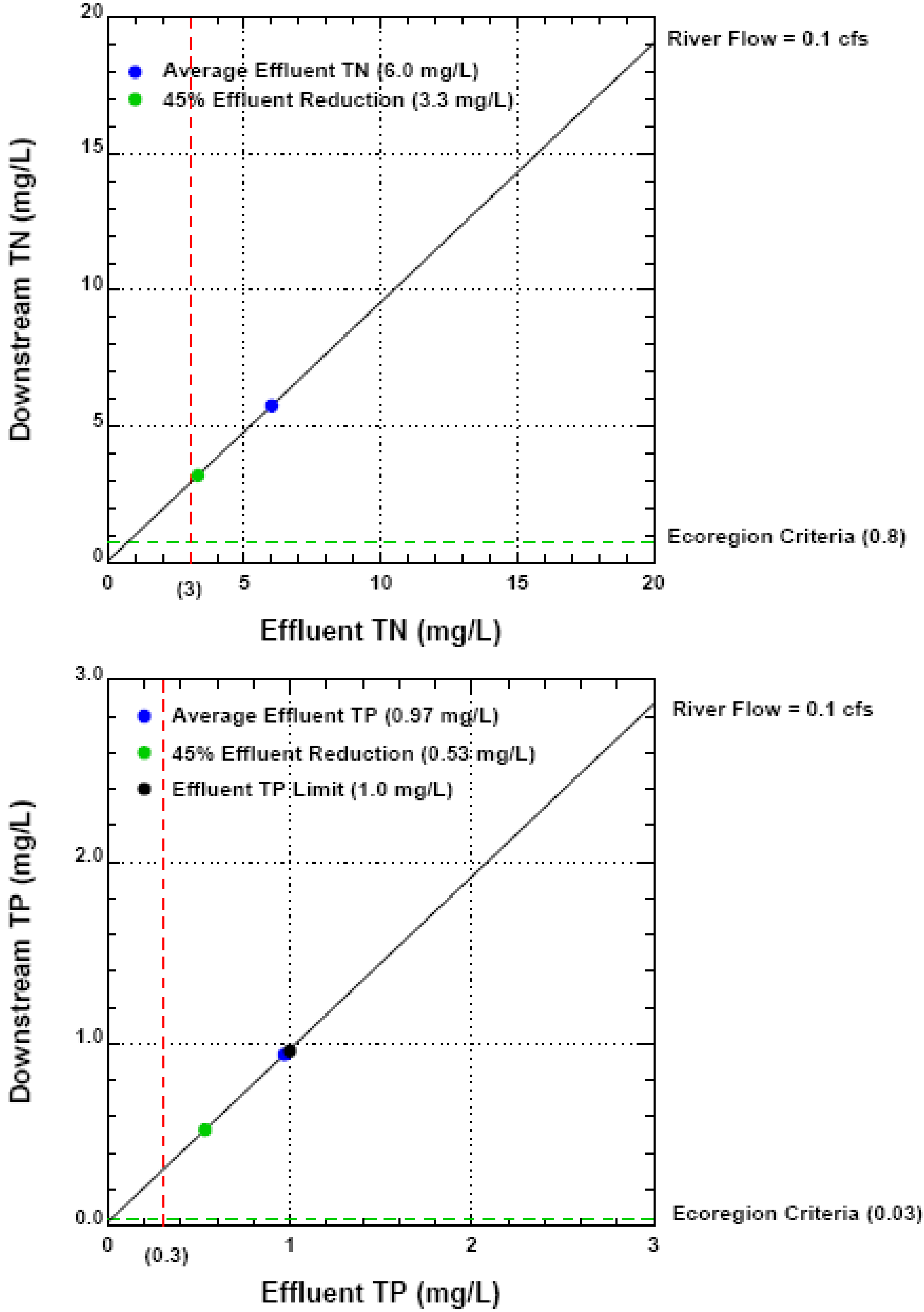

FIGURE 5.3. THE EFFECT OF LOCAL NUTRIENT CRITERIA ON SD1'S EASTERN REGIONAL WWTP

VI. SCIENTIFIC AND POLICY FACTORS THAT AFFECT TRADING

A. Lifetime of a Unit of Pollution Reduction

In any pollutant trading program, it is important that pollutant credits have appropriate lifespans so that the increased loads that they offset affect the waterbody of concern at approximately the same time as the reduced loads. These nutrient credit lifespans typically coincide with permitted dischargers' effluent limit averaging periods (e.g., monthly or annual load limits). Because MWRDGC and SD1 do not currently have permit limits for N and P to address Gulf hypoxia, it was assumed for this feasibility study that a Mississippi River Basin nutrient trading program would have *annual average* permitting limits, and thus, a nutrient credit would represent a one pound reduction in annual load delivered to the Gulf.

A one-year averaging period is likely because this is the lifespan of nutrient credits in the nutrient trading programs in the Chesapeake Bay watershed. The Bay watershed states have developed permitting strategies to address nutrients that are delivered to the Chesapeake Bay. In 2004, USEPA concluded that annual permitting limits are appropriate for the Bay because:

a) "the exposure period of concern is very long,"
b) "the area of concern is far-field rather than near-field," and
c) "the average pollutant load rather than the maximum load is of concern."[46]

USEPA also noted that annual averaging periods would likely be appropriate in other watersheds that share these characteristics and should be supported with appropriate data. During an interview WRI conducted with Dr. Dale Robertson of the USGS, Robertson supported the annual averaging period assumption because the Gulf integrates nutrient loads over a longer timeframe than the Bay. Likewise, the delivery time for nutrients across the MRB is longer than for nutrients in the Bay watershed.[47] Therefore, although analyses would need to be conducted to verify that annual averaging periods are appropriate for the Gulf, the above information is used in the interim as guidance for how an MRB trading program would be designed.

Under annual averaging periods, credits must be sold within the year they were generated. Once purchased, the buyer must also use the credits in the same year that they were generated. This requirement ensures that the trading program will help to meet annual load goals or limits for the Gulf. Though there will be one-year expiration dates on credits, buyers and sellers could enter into contracts for multiple years' worth of credit exchanges, because installed BMPs generate new credits annually in perpetuity. Trading contracts represent agreements to buy or sell a certain number of credits per year for a specific number of years. Under a five-year contract, for example, a buyer could only apply credits generated in Year 1 in the first year of the contract. Year 1 credits cannot be banked for use in later years.[48]

[46] See Hanlon et al. 2004.
[47] See Robertson 2011.
[48] See USEPA 2009.

B. Impact of Trade Ratios

Trading ratios can include delivery ratios, uncertainty ratios, reserve ratios, retirement ratios, and equivalency ratios. Each trading ratio has a different purpose and is applied independently of each other in an additive manner. In addition, trading ratios help account for uncertainty about nutrient removal rates and help to guarantee nutrient reductions or an improvement in water quality. Watersheds will have different needs for various trading ratios depending on the hydrology, data availability, pollutants, or goals.

To obtain guidance on which ratios might be appropriate for a Mississippi River Basin trading program, WRI reviewed USEPA's 2007 Water Quality Trading Toolkit for Permit Writers. In addition, WRI reviewed how existing trading programs apply these ratios.[49]

WRI found that existing nutrient trading programs use a variety of trade ratios. In the Chesapeake Bay watershed, all states use delivery ratios. Pennsylvania and West Virginia use a reserve ratio, and Maryland uses a retirement ratio. Maryland, Virginia, and West Virginia have varying degrees of uncertainty ratios for certain nonpoint source practices.[50] A WRI assessment of trading programs across the world found that of the 26 active water quality trading programs in the United States, 20 programs used some form of trading ratio.[51,52]

Delivery Ratios

A nutrient trading program in the Mississippi River Basin would need to use delivery ratios to account for the difference in delivered loads between sources and the waterbody of concern by adjusting the nutrient loads accordingly. Due to the natural nutrient loss process that occurs during transport, such as denitrification and P burial, less N and P is actually delivered to the Gulf of Mexico than is emitted onsite at point sources such as WWTPs or from nonpoint sources such as farm fields. Delivery ratios account for these location differences between the credit buyer, the credit seller, and the waterbody of concern by accounting

> "for the distance and unique watershed features between a pollutant source and the downstream waterbody (e.g., bay, estuary, lake, reservoir) that the trading program is trying to address (e.g., a hypoxic zone in a waterbody). The location ratio allows credits to be traded between unique sources by converting their loadings or reductions into credits needed or available at the waterbody of concern."[53]

Note that the nutrient loss process is inversely related to the delivery ratio. The higher the natural rate of nutrient loss, the lower the delivered amount of nutrients. Conversely, the lower the natural rate of nutrient loss across a landscape, the greater the delivery factor becomes.

For this nutrient trading feasibility study, the study team obtained delivery factors for the buyer and seller watersheds that reflect the percentage of N and P emitted by these sources that reach the Gulf. For example, according to 2009 USGS SPARROW data, the L'Anguille watershed in Arkansas has a 90% delivery factor for N. In other words, 90% of the N that leaves the L'Anguille watershed is ultimately

[49] See Selman et al. 2009.
[50] See Branosky et al. 2011.
[51] See Selman et al. 2009.
[52] See Branosky et al. 2011.
[53] See USEPA 2009.

delivered to the Gulf of Mexico. This means that if a producer in the L'Anguille watersheds generates credits for the trading market, he would only be able to sell 90% of the N he reduces (see Table 6.1).

On the demand side, the delivery ratios are generally lower because the utilities are located farther upstream from the supply watersheds. SD1, for example, has a 78% delivery factor for N. If SD1 were to purchase credits to meet a Gulf load reduction goal, it would only need to purchase 78% of the amount of N that it would otherwise be required to reduce onsite.

In conducting the demand-side credit analysis, the study team obtained the delivery ratios from the most recent 2009 USGS SPARROW model data, which are presented in TABLE 6.1.

TABLE 6.1. 2009 SPARROW WATERSHED OUTLET DELIVERY FACTORS TO THE GULF

	N Delivery Factor	P Delivery Factor
Credit Buyers		
Chicago, IL (MWRDGC) watershed outlet	0.81	0.64
Licking, KY (SD1) watershed outlet	0.78	0.81
Credit Sellers		
Lower St. Francis, AR	0.86	0.86
L'Anguille, AR	0.90	0.93
Cache, AR	0.80	0.85
Upper Yazoo, MS	0.96	0.97
Big Sunflower, MS	0.94	0.96
Deer-Steele, MS	0.94	0.96
Arkansas (0802) average	*0.85*	*0.88*
Mississippi (0803) average	*0.95*	*0.86*
Aggregated regional average	*0.90*	*0.92*

In the delivery factor sensitivity analysis, HydroQual used a 1997 version of the USGS SPARROW model because it had several important modeling attributes that are not available in the 2009 version. Thus, the delivery factors in Table 6.2 are slightly different than the most recent numbers from 2009.[54]

[54] See Smith et al. 1997.

TABLE 6.2. 1997 SPARROW WATERSHED OUTLET DELIVERY FACTORS TO THE GULF		
	N Delivery Factor	**P Delivery Factor**
	Credit Buyers	
Chicago, IL (MWRDGC) watershed outlet	0.87	0.89
Licking, KY (SD1) watershed outlet	0.92	0.94
	Credit Sellers	
Lower St. Francis, AR	0.76	0.83
L'Anguille, AR	0.82	0.87
Cache, AR	0.76	0.83
Upper Yazoo, MS	0.96	0.97
Big Sunflower, MS	0.87	0.91
Deer-Steele, MS	0.96	0.97

In conducting the supply-side credit analysis, NRCS used a combination of the delivery factors from the APEX model and the delivery factors from the 2009 SPARROW model to determine an edge of field to Gulf delivery factor. NRCS calculated this by multiplying the APEX edge of field to 8-digit delivery factor by the 2009 SPARROW 8-digit watershed to Gulf delivery factor (see Table 6.3).

Note that because the demand-side delivery factors do not account for any losses between the end of pipe and the 8-digit watershed outlet, the actual delivery factors for MWRDGC and SD1 may be slightly less than the ones used in this report. Likewise, when the SPARROW watershed to Gulf delivery factors for P are compared to the edge of field to Gulf delivery factors that NRCS calculated, the NRCS delivery factors are smaller. This is because NRCS captures edge of field to 8-digit HUC losses wherein more nutrient loss occurs in these shallow streams than in large rivers, resulting in smaller delivery factors.[55]

[55] See Alexander et al. 2000.

TABLE 6.3. NRCS DELIVERY RATIOS FOR NITROGEN AND PHOSPHORUS						
	Nitrogen			Phosphorus		
8-digit watershed	**Edge of Field to 8-digit**	**8-digit to Gulf**	**Edge of Field to Gulf**	**Edge of Field to 8-digit**	**8-digit to Gulf**	**Edge of Field to Gulf**
8020203	0.93	0.86	0.80	0.68	0.86	0.58
8020205	0.92	0.90	0.83	0.72	0.93	0.67
8020302	0.77	0.81	0.62	0.66	0.85	0.56
0802 average	*0.89*	*0.85*	*0.76*	*0.68*	*0.87*	*0.59*
8030206	0.75	0.96	0.72	0.42	0.97	0.41
8030207	0.94	0.94	0.89	0.52	0.96	0.50
8030209	0.84	0.94	0.79	0.45	0.96	0.43
0803 average	*0.88*	*0.94*	*0.83*	*0.49*	*0.96*	*0.47*
Regional average	*0.89*	*0.89*	*0.79*	*0.60*	*0.91*	*0.54*
Data source	APEX	2009 SPARROW	Product of APEX * SPARROW	APEX	2009 SPARROW	Product of APEX * SPARROW

The supply and demand analyses described in Sections II and III reflect the appropriate delivery factors for MWRDGC, SD1, and the agricultural watersheds, as the estimates of potential demand and supply are based on delivered pounds to the Gulf.

HydroQual's Delivery Ratio Analysis

HydroQual conducted a sensitivity analysis of delivery ratios using the 1997 SPARROW dataset, which yielded surprisingly high delivery ratios for all project watersheds. The literature on N loss rates indicates greater nutrient losses occur from backwater and impoundment areas and from side channels than USGS SPARROW analysis indicated.[56] Therefore, a sensitivity analysis was conducted to examine how delivery ratios would change if the natural attenuation loss rates were actually higher.

In two scenarios, SPARROW was used to predict the dampening effect on delivered loads if loss rates increased by 50% and 100% delivered loads to the Gulf. To provide some insight into other end of the spectrum, a third scenario was run for each watershed that modeled a 50% decrease in natural loss rates to reflect the potential for even greater nutrient delivery than SPARROW suggests (see HydroQual's report, Tables 7–10 in Section 5 for more information).

The overall results of the sensitivity analysis are illustrated in TABLE 6.4. The percentages of nutrient loads delivered to the Gulf from the two utilities and from the six agricultural watersheds are displayed as ranges, reflecting the sensitivities that increased the loss rates by 50% and 100% and decreased the loss rates by 50%.

[56] See Richardson et al. 2004.

TABLE 6.4. RANGE OF NUTRIENT LOAD DELIVERED TO GULF FROM PROJECT WATERSHEDS AS RESULT OF SENSITIVITY ANALYSIS		
	Total Nitrogen Delivered	**Total Phosphorus Delivered**
Credit Buyers		
MWRDGC	76–93%	79–94%
SD1	84–96%	89–97%
Credit Sellers		
Cache Watershed, AR	58–87%	68–91%
St. Francis Watershed, AR	58–87%	69–91%
L'Anguille Watershed, AR	67–90%	76–93%
Big Sunflower Watershed, MS	76–93%	82–95%
Deer-Steele Watershed, MS	81–95%	87–96%
Upper Yazoo Watershed, MS	91–98%	94–98%

The potential variation of nutrient delivery rates among the watersheds illustrates the watersheds' unique hydrologic and geographic conditions. For example, the Cache Watershed in Arkansas, which is one of the northernmost of all the six watersheds (see FIGURE 6.1), has relatively low nutrient delivery to the Gulf because nutrients from this watershed travel for a longer distance in shallow water where a lot of natural attenuation is occurring. The Upper Yazoo Watershed in Mississippi, on the other hand, is located south of the Cache and is one of the southernmost project watersheds, so it has the highest range of nutrient delivery of all the agricultural project watersheds.

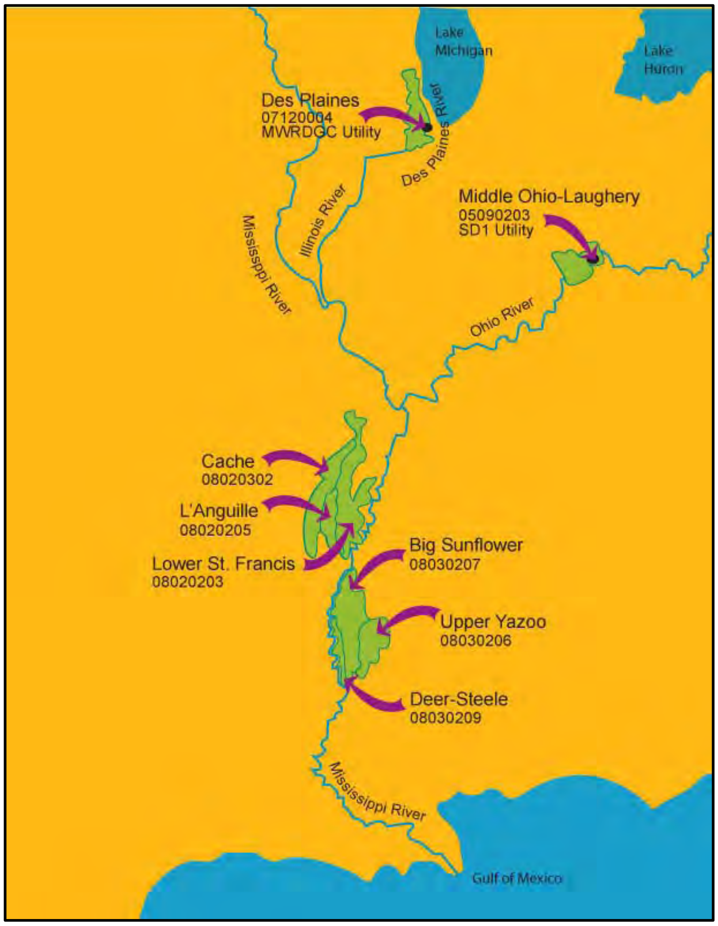

FIGURE 6.1. MAP OF PROJECT WATERSHEDS

In addition to site-specific characteristics, proximity to a large river such as the Mississippi also affects the loss rates of nutrients on their course from the land or end of pipe to the receiving waterbody downstream. This concept is also illustrated for the utilities, with SD1 having a higher range of delivery than MWRDGC because of its closer proximity to the Gulf. During the design of this feasibility study, it was expected that there would be greater differences in delivery ratios between the buyer and seller watersheds, which would make trading between the two areas very advantageous from a cost perspective. Although the buyer watersheds do have smaller delivery factors than the supply watersheds, the difference is not as great as was expected. The greatest gap, and where the most advantageous trades would occur, is between MWRDGC and the Upper Yazoo Watershed.

However, the results of the sensitivity analysis illustrate the potential variability in nutrient delivery from these watersheds to the Gulf. Some of these watersheds' site-specific characteristics (e.g., impoundments, backwater, side channel areas) that affect nutrient loss rates are not considered in SPARROW. A more robust analysis of delivery rates from all sources in the Mississippi River Basin is necessary to set accurate delivery ratios for a basin-wide nutrient trading program.

Uncertainty Ratios

Uncertainty ratios are used in some trading programs to address uncertainty associated with estimating nonpoint source reductions that are not directly measured onsite. For example, Virginia uses a 2:1

nonpoint source to point source trading ratio for its nutrient trading program. To account for the uncertainty surrounding the quantification of nonpoint source nutrient credits that are sold to offset easy-to-measure point source loads, a 2:1 ratio requires that twice as many credits be used than the number of delivered pounds the point source would need to reduce onsite.

This uncertainty ratio could affect only the buyer, only the seller, or both parties. The commonly held assumption is that the burden falls on the buyer. However, this arrangement is not required. Therefore, WRI developed three options for bearing the burden and described the effects on supply and demand as a result of each scenario, using a 2:1 nonpoint source to point source ratio as an example.

Scenario 1: Uncertainty ratio applied to buyer side of the transaction

Under this scenario, the buyer would be responsible for bearing the entire burden of the uncertainty ratio, meaning that they have to buy two credits for every one credit they need to satisfy their potential reduction target. For example, if a buyer needed 100 N credits to offset its load, this scenario would require the buyer to purchase 200 N credits from nonpoint sources to account for uncertainty.

Under this scenario, although WWTPs may generate more demand for credits because they would be required to purchase twice as many as they would need without an uncertainty ratio, their maximum willingness to pay per credit would be cut in half.

Scenario 2: Uncertainty ratio applied to seller side of the transaction

In this scenario, the sellers bear the burden of the uncertainty ratio and are only able to sell half of the nutrient reductions they generate. For example, if an agricultural producer generates 100 delivered pounds of N, the producer could only put 50 N credits on the market. The quantity of credits that a buyer demands is not affected by the uncertainty ratio in this scenario.

If the producers could only sell half of the N generated, they would be cutting their profit in half if credit price is held constant. Alternatively, if the market can bear it, producers could sell those reduced credits at higher costs, which would cover costs to generate all of the reductions.

Scenario 3: Uncertainty ratio applied to both buyer and seller sides of the transaction

The third option for handling the uncertainty ratio burden is to apply it equally to the buyer and to the seller, such that the buyer would have to purchase 50% more credits than would be required otherwise, and the credit supplier would need to generate additional credits equal to the amount that the buyer needs to purchase in excess.

For example, if a buyer needed to purchase 100 N credits, an uncertainty ratio that applied equally to buyers and sellers would mean that the buyer would actually need to purchase 150 credits. The producer in this scenario who offers 150 credits for sale would actually have needed to generate 200 total credits, 50 of which would be retired. This scenario upholds the 2:1 uncertainty ratio requirement, such that 50 credits are purchased in excess in demand and retired, and 50 more credits are generated than can be sold, assuring that for the 100 credits being applied to the WWTP permit, there are 100 additional credits being generated and bought as a safeguard in the face of nonpoint source nutrient reduction uncertainty.

Applying an Uncertainty Ratio to the Project Utilities and Agricultural Watersheds

To examine the effects of an uncertainty ratio on the project utilities' potential credit demand, agricultural supply, and associated costs to purchase and generate credits, Table 4.1 was recreated under three uncertainty ratio scenarios. While an uncertainty ratio of 2:1 was used above as a basic example of how it would affect demand, supply, and costs, such a high ratio is likely unnecessary if there are adequate data and tools in place that already account for some uncertainty when calculating nonpoint source reductions, as is the case with the USEPA Chesapeake Bay Program Water Quality and Watershed Models and WRI's NutrientNet credit calculation tool. Thus, a 1.5:1 uncertainty ratio is used here. Table 6.5 compares the average potential demand and supply and illustrates the associated costs when the buyer bears the entire burden of the uncertainty ratio, the seller bears the entire burden, and the buyer and seller equally share the burden.

TABLE 6.5. EFFECTS OF A 1.5:1 UNCERTAINTY RATIO UNDER THREE DIFFERENT SCENARIOS OF APPLYING THE BURDEN

	Buyer to Seller Uncertainty Ratio Scenario	Average Utility Willingness to Pay Ceiling and Potential Total Demand for Credits		Average Agricultural Net Costs/lb and Potential Total Supply of Credits	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Potential 20-Year Net Present Value Costs/lb	None	$8.09	$28.42	-$1.74	$5.87
	1.5:1	$5.39	$18.95	-$1.74	$5.87
	1:1.5	$8.09	$28.42	-$1.74	$5.87
	1.5 shared	$6.47	$22.74	-$1.74	$5.87
Potential 20-Year Credit Demand or Supply	None	175,079,550	27,144,393	512,133,000	22,758,001
	1.5:1	262,619,325	40,716,590	512,133,000	22,758,001
	1:1.5	175,079,550	27,144,393	341,422,000	15,172,001
	1.5 shared	218,849,438	33,930,491	468,363,113	15,971,903

Under no uncertainty ratio, the average utility willingness to pay per pound ceiling is the same as that found in Table 4.1. This amount represents the average cost the utilities would face if they were to invest in onsite upgrades to achieve the 45% reduction goal. Likewise, the potential demand and supply are also the same as those found in Table 4.1.

In comparison, a 1.5:1 buyer to seller uncertainty ratio reduces the utilities' willingness to pay ceiling by a third. This reduction occurs because the utility would have to purchase credits 1.5 times the pounds that it would otherwise need to reduce onsite, while the total budget (i.e., the average cost to reduce the nutrients onsite) is held constant. The willingness to pay ceiling would drop to $5.39 per N credit—still well above the costs faced by the agricultural producers to generate the reductions. For P, the willingness to pay ceiling would reduce to $18.95, also well above the average cost to reduce a pound of P. This scenario suggests that an uncertainty ratio of 1.5:1, borne solely by the buyer, would still allow for economically viable trades between these utilities and the agricultural credit supply watersheds.

In terms of demand and supply, demand will increase 1.5 times. Supply is unchanged. These agricultural watersheds would still have enough supply to satisfy demand for N credits. However, even under the no uncertainty ratio, the agricultural watersheds did not have quite enough supply to meet the potential P demand. Now with even more P demand but no more supply, the demand is nearly twice as much as the supply for P credits.

The next scenario illustrates the effects of a 1:1.5 buyer to seller uncertainty ratio, in which the entire uncertainty burden is borne by the suppliers. In this scenario, the utility willingness to pay ceiling and demand is the same as under a no uncertainty ratio scenario. The costs to generate a pound of N and P are also held constant. The potential supply, however, decreases. With no uncertainty ratio burden, at an average net savings of $1.74/lb of N reduced, the agricultural watersheds could reduce over 512 million pounds of N. However, the producers could sell only 341 million N credits from these reductions. Even though the producers would still reduce their load by 512 million pounds of N, this amount represents 1.5 times what can be sold as credits to account for risks in uncertainty. Only 15 million P credits would be available, down from nearly 23 million. Under this scenario, the reduced N supply would still be enough to satisfy demand, but there would not be enough P supply.

Many agricultural producers in the project watersheds experience average net savings instead of net costs for generating salable credits. Thus, these producers may be able to share some or the entire burden of the trading ratio and still make a reasonable profit on the credit sales. However, it is likely that this sub-scenario may discourage some of these producers from participating, which would result in less available supply and higher credit prices.

The third scenario illustrates how demand, supply, and costs would change if the buyers and sellers share the uncertainty ratio. The willingness to pay ceiling under a no uncertainty ratio scenario is divided by 1.25, resulting in a shared uncertainty ratio willingness to pay of $6.47/N credit and $22.74/P credit. The costs per pound of nutrient reduced by the agricultural watersheds remain unchanged. The comparison between the demand-side and supply-side costs is again favorable in this scenario.

The no uncertainty ratio scenario demand was increased by 1.25, or about 44 million N credits, to nearly 219 million N credits. To achieve the 1.5:1 uncertainty ratio requirement, 44 million credits must now be retired on the supply side. Therefore, the agricultural suppliers who can reduce the N load by about 512 million pounds can only sell about 468 million N credits. For P, demand increases to nearly 34 million, and supply decreases to about 16 million. Again, N demand can be met by the agricultural supply watersheds under this scenario, but P demand cannot.

Although scientific rationale should be the primary reason for setting an uncertainty ratio, trading program developers should be equally mindful of the effect this ratio can have on the potential supply, demand, and credit prices. Setting a high uncertainty ratio just to provide assurance that water quality will not suffer as a result of trades will likely hinder the cost-effectiveness of trading programs. When a trading program is developed, it will be important to analyze if and how well the proposed methods for estimating nonpoint source reductions account for uncertainty. This will help determine if an uncertainty ratio is necessary and at what level it should be set for achieving assurance that the downstream water quality goal is being fulfilled while avoiding excessive constraints on the trading program's credit supply or demand.

Reserve Ratios

Reserve ratios, or insurance ratios, are sometimes "used to set aside a portion of all generated credits into a reserve pool or insurance fund" to be used if any credits default after they are purchased.[57] Reserve ratios are used when there is no other insurance set up by the seller or the banker. Credits may default if weather conditions prevent producers from implementing conservation practices as scheduled, or if severe weather compromises the effectiveness of the practices. Pennsylvania applies a reserve ratio of 10% to credits that are generated in its trading program. Pennsylvania saves these reserve credits as insurance for regulated entities, should credits default, and the state may also use them to boost market supply if necessary. Reserve credits expire at the same time as the credits that were bought by the buyer. A 10% reserve ratio is likely to have minimal effect on trading supply or demand and could be applied on the buyer or seller side of the transaction.

Retirement Ratios

Retirement ratios "retire a percentage of all credits generated" and "can be applied if a goal of the trading program is to accelerate achievement of water quality standards."[58] The agency administering the trading program owns the retired credits. Once these credits are retired, they cannot be sold again, ensuring that each trade results in a net water quality benefit. Michigan's Water Quality Trading Rules, for example, call for 1:1.1 retirement ratio for trades between point sources, such that 10% of all purchased credits must be retired. A 10% retirement ratio is likely to have minimal effect on trading supply or demand and could be applied to either side of the transaction.

Equivalency Ratios

The last commonly used type of trade ratio is an equivalency ratio. Equivalency ratios would be used when different forms of a pollutant are traded, such as nitrate and nitrite. Equivalency ratios are not employed in this feasibility study because the potential credit supply and credit demand are calculated in terms of total N and total P.

C. Climate Change

Climate change could potentially affect nutrient loads and credit supply and demand under a nutrient trading program. In many areas around the world, climate change is thought to result in increased precipitation and warmer temperatures. The study team conducted a literature review on the potential effects of climate change on watershed hydrology (for more information, see HydroQual's report, Section 2).

The literature suggests, through a combination of modeling exercises and historical data analyses, that there is likely to be an increase in severe weather events but not an increase in annual precipitation amounts. Although conclusions about climate change's effects on nutrient runoff were inconclusive, the majority of studies did indicate that runoff would increase, resulting in increased nutrient loads to waterbodies.

[57] See Selman et al. 2009.
[58] See USEPA 2009.

Moreover, increases in air temperatures will result in increases in water temperatures, though to a lesser degree than air. Any increases in water temperature, however, could cause more algal growth and other water quality impairments from nutrients. Increases in air temperatures could result in longer growing seasons, which could mean an increase in nutrient inputs to the land and an increase in nutrient runoff from the land, exacerbating waterbodies' vulnerability to nutrient-caused impairments. Such conditions could mean higher demand for nutrient credits to offset loads. They could also mean a lower supply of nutrient credits, because these increased impairments could equate to more stringent trading eligibility standards to meet more stringent local or downstream water quality goals.

WRI attempted to gain more information on climate change's impact on the supply side watersheds through its partnership with NRCS, but at this time, NRCS cannot simulate the potential effects of climate change projections with its CEAP models.

The USEPA Science Advisory Board stated that: "studies have suggested that climate change will create conditions for which larger nutrient reductions, e.g., 50 to 60% for N, would be required to reduce the size of the hypoxic zone."[59] Should these predictions come to fruition, the policy driver for nutrient reductions from permitted facilities would require a 50 to 60% reduction and the trading eligibility standard would also require a 50 to 60% reduction to ensure that water quality standards were met before any additional reductions were sold as credits to offset other pollution sources.

Although there's reason to believe that climate change could impact the supply and demand of nutrient credits, more research is needed to better understand the complexity of its effects on watershed hydrology, nutrient dynamics, and the economic feasibility of nutrient trading.

D. Setting the Trading Program's Nutrient Reduction Goal

As mentioned at the beginning of the report, this trading feasibility study is based on the assumption that a large-scale Mississippi River Basin nutrient trading program would be implemented to cost-effectively reduce Gulf hypoxia. Using Gulf hypoxia as the policy driver for a nutrient trading program, WRI researched nutrient reduction recommendations to address hypoxia. In 2007, the USEPA SAB released a report, *Hypoxia in the Northern Gulf of Mexico,* which called for "a target of reducing the five-year running average of N loadings by at least 45%."[60]

The SAB Panel developed this 45% reduction target based on the need to reduce the hypoxic zone to a five-year running average of 5,000 km^2 by 2015 using a 1980 to 1996 baseline of average nutrient flux. Achieving this hypoxic zone reduction equates to reducing N loads to no more than 960,000 tons/year and P loads to no more than 83,000 tons/year.

Because the 45% reduction target is based on achieving maximum loads of N and P to address the hypoxic zone, the latest MRB loading data from SPARROW (through 2010) was used to calculate if the percentage reduction necessary to meet these gross load targets in more recent years would be significantly different from the 45% level that was based on 1980 to 1996 loading levels. The SPARROW results show that the 2006 to 2010 running average for N would require a 37% reduction, and the five-year running average for P would require a 54% reduction to shrink the hypoxic zone to 5,000 km^2. However, the SAB Panel's "best professional judgment is that P reductions will need to be comparable

[59] See USEPA 2007.
[60] See USEPA 2007.

(in percentage terms) to N reductions to reduce the size of the hypoxic zone."[61] When averaged, the combined reduction for both N and P over the more recent timeframes is 46%. Because this revised target is very close to the 45% reduction goal, WRI decided to use the 45% reduction recommendation for both N and P.

It is also important to note that taking a more accurate reduction goal based off of the five-year running average from the project utilities and agricultural watersheds would not necessarily provide for a more accurate analysis. The utility loading data used for the demand-side analysis is from between 2006 and 2009, and the loading data used for the supply-side analysis is from 2003 to 2006. Although the differences in years may slightly affect the total demand or supply, it does not weigh significantly on the economic feasibility of nutrient trading. Likewise, the reduction goal of 45% is currently the best possible nutrient reduction target that has been developed for addressing Gulf hypoxia, which is why it was chosen as the demand driver.

Looking toward the future, it is possible that this 45% reduction could be altered due to a change in nutrient loading, the Gulf's biological response, better data, or climate change. It will be important to use adaptive management principles to set appropriate nutrient reduction targets in years to come. Consequently, an MRB nutrient trading program would also have to be adaptively managed to account for changes in loads, reduction targets, trading eligibility standards, and delivery factors, etcetera.

E. Social and Economic Considerations for an MRB–Gulf of Mexico Nutrient Trading Program

Additional Economic Considerations

There are a number of costs that must be considered when examining the economic feasibility of a nutrient trading program. Trading programs are typically developed and designed by a large group of stakeholders, and they must be administered over time, have protocols for verifying and certifying nutrient reductions, and often rely on the services of third parties known as aggregators to catalyze and facilitate transactions. Although these costs are likely not deal-breakers for the large economic benefits that trading could provide, it is important that they are acknowledged and considered.

Program development and design refers to all components necessary to start a trading program, such as writing trading program policies and guidelines, creating and/or identifying necessary tools and methods for quantifying nonpoint source reductions, and outreach to stakeholders. WRI has played critical roles in the stakeholder process and technical development of state nutrient trading programs in the Chesapeake Bay watershed. Based on this experience, below are some examples of one-time, start-up costs likely to be incurred by individual states during the trading program development and design stages:

- **Stakeholder participation: $100,000**
  Maryland contracted with a third-party facilitator to oversee the stakeholder process of their Maryland Agricultural Nonpoint Nutrient Trading Advisory Committee. These activities included tasks such as creating a work plan for the Committee, scheduling and conducting meetings, drafting trading policies and guidelines, and arranging meetings with the public and key professionals.

[61] See USEPA 2007.

- **Electronic marketplace development: $50,000**
  Online marketplaces provide a meeting place for interested buyers and sellers to post credits needed and offer credits for sale. A marketplace can also be used as a platform for placing bids and catalyzing trades between parties. The cost to develop the marketplace would likely fall upon the program administrator.

- **Credit registry development: $100,000**
  Credit registries are critical components of any trading programs, as they provide the necessary functions of approving and certifying credits, tracking verification of credit-generating practices, approving trades, and retiring and reserving credits. This cost estimate assumes a dynamic, online registry. As an alternative, a static registry could be developed offline as a simple spreadsheet at a minimal cost. The cost to develop the credit registry would likely fall upon the program administrator.

- **Credit calculation protocols and tools: $200,000**
  A variety of options exist for trading programs to estimate credits generated from the implementation of agricultural conservation practices. Some trading programs use water quality monitoring to quantify credits. Others use estimation methods. For example, some programs have developed "look-up" tables through a consensus process of experts who selected appropriate nutrient reduction efficiency estimates for each practice from published literature. Other programs have developed farmer-friendly credit calculation tools such as the USDA's Nutrient Tracking Tool which runs sophisticated field-scale scientific models that first must be calibrated to local agronomic, hydrologic, and conservation conditions. The cost estimate provided pertains to the model-based credit calculation tool approach.[62]

These development elements and associated costs are not meant to be an exhaustive list or to reflect costs for a large-scale interstate MRB trading program. They are simply meant to provide insight into activities and startup costs, based on WRI's experience developing intrastate trading programs. Because these costs are reflective of intrastate programs, costs for a nutrient trading program covering the entire MRB would be significantly more expensive and costs would need to be estimated with the right players at the table. In addition, operational costs will be incurred every year to continue stakeholder engagement activities and conduct outreach as well as to continually maintain and update the marketplace and registry.

Transaction costs are another important consideration for examining the economic feasibility of nutrient trading. Transaction costs include expenses associated with certifying farms, verifying practices, and providing aggregation and transaction services for sellers and buyers. These activities are commonly handled by an aggregator who works as a third party between nonpoint source credit generators, such as producers, and entities purchasing credits, such as wastewater treatment utilities. The cost of these aggregator services makes up the transaction costs of trades.

An aggregator active in the Chesapeake Bay watershed provided WRI with estimates of typical transaction costs and how these costs are borne. When credit sellers work with an aggregator to sell their credits, as typically happens, the aggregator assumes the liability for the credits sold, verifies practices, and continually monitors to confirm that practices are maintained for the length of the contract. These costs are built into the credit price, which the buyer then absorbs, increasing the credit price by about 10%.

[62] Selman et al. 2009.

Social Considerations

The feasibility of nutrient trading relies heavily on the economic rationale of credit transactions. However, there are numerous other non-monetary factors that could affect whether a market actually materializes or is successful. Trading programs require support from the public, acceptance of trading by regulators, confidence from buyers to invest in pollution treatment practices, and willingness of producers to reduce loads to offset point sources and to allow verifiers to monitor the implementation of practices on their land.

Nutrient trading can be a complicated concept to communicate to the public and policy stakeholders and many issues are involved. Some stakeholders in both the point and nonpoint source sectors hold opposing viewpoints about which sector is responsible for the pollution problem and thus regard trading as fostering inequity. For example, some stakeholders in the agricultural community argue that trading "lets polluters continue to pollute." In contrast, some stakeholders in the wastewater utility community argue that "utilities will be held responsible for solving a problem that is largely caused by agricultural sources."

Environmental stakeholders worry that regional trading for a downstream water body could sacrifice local water quality. Public officials may be concerned that tax dollars designated to pay for wastewater treatment are being spent in another state, if credits are purchased out of state. An MRB–Gulf of Mexico trading program will need to include an effective outreach strategy to address these concerns and garner support from the public.

Nutrient trading programs can only be successful if regulators consider trading to be a viable form of pollution reduction that will not result in water quality impairments. More than 50 water quality trading programs have been developed in the United States though only a few have progressed beyond the pilot or early stages.[63] Many explanations abound regarding why this is the case but two hypotheses are plausible:

(1) Several trading programs remain in the "pre-compliance" stage because of a lack of regulatory drivers. Before a trading program is developed for the Mississippi River basin, the interested parties should assess whether regulatory requirements or voluntary goals are likely to stimulate significant nutrient credit demand.

(2) Several trading programs are beyond the pre-compliance stage but are not designed with sufficiently robust standards and protocols. For example, demand may be slow to materialize because risks to the regulatory community surrounding purchase of nonpoint source credits may not be adequately ameliorated through mechanisms such as credit reserves, involvement of aggregators, and credit verification protocols. In addition, trading between point and nonpoint sources may either not be allowed or may be technically challenging due to a lack of necessary nonpoint source credit quantification methods.[64]

The states in the Mississippi River Basin could learn about how trading works with existing regulations and how to incorporate trading into NPDES permits from the ongoing programs. With regard to permits and regulations, permit writers will need to be educated on nutrient trading and consider the potential for trades to occur under permits without degrading water quality in the receiving waters. Incorporating

[63] See Selman et al. 2009.
[64] See Selman et al. 2009.

nutrient trading policies and processes into state regulations and plant operations to get a nutrient trading program up and running smoothly will take financial and human resources.

With proper precautions and modeling exercises in place to approve trades for water quality protection, wastewater treatment utilities may have concerns about the risk of investing their money in "green" infrastructure rather than onsite, technological "gray" infrastructure to meet nutrient reduction goals or permit limits. Creating a nutrient trading program that considers the uncertainty of nonpoint source reductions, has strong conservation practice verification protocols in place, and has a system for recovering from default credits can help to alleviate these concerns.

Concerns about trading may also arise from the nonpoint source sector, which is well positioned to generate credits. Although trading offers the potential to generate additional revenue for agricultural producers from the implementation of conservation practices, producers may be hesitant to allow third parties access to their land to verify practices. Producers may also choose not to participate in a program that enables another source to "continue polluting," while they are reducing their nutrient loads. These are some of the concerns expressed from the agricultural community in Arkansas and Mississippi during stakeholder meetings. It is important that Conservation Districts and other groups that work closely with producers on a regular basis are engaged in nutrient trading dialogues and can help to provide education and outreach to producers on the issues of concern.

All of these concerns warrant careful consideration and responses to ensure the MRB has a robust nutrient trading market that can help to cost-effectively achieve the watershed's collective nutrient reduction goals. The feasibility of an interstate program rests on receiving buy-in from the public and all stakeholders. Early and continued involvement of stakeholders in the program's development phase can help to gain this necessary support.

VII. CONCLUSION & NEXT STEPS

A. Conclusions

Using a case study approach and a hypothetical water quality policy trading framework, this project determined that large-scale interstate nutrient trading in the MRB could be an economically and environmentally feasible tool for helping to reduce hypoxia in the Gulf of Mexico.

The study found that under the most stringent trading program rules which require both N and P trading eligibility standards to be met and require additionality rules to be enforced, if the two utilities offered just 25% of their onsite N technology upgrade costs as an N credit price, the six credit seller watersheds could satisfy their N needs. Such an arrangement would enable these utilities to meet the project's hypothetical N reduction goals, saving MWRDGC 75% or about $522 million and saving SD1 75% or about $182 million in net present value costs (NPV) over 20 years. For P, only SD1 would be able to satisfy its needs from these six project watersheds by offering just 25% of its onsite costs and saving 75% or about $80 million in NPV over 20 years. If MWRDGC were to offer 75% of its on-site P costs ($525 million), the six project utilities would only be able to satisfy 38% of their P needs under these trading program rules and would have to find credit sellers elsewhere.

Potential profit-making opportunities for the farm sector were estimated to range between $21/acre to $33/acre from implementation of conservation practices and sale of credits, depending on which trading policies and credit prices were selected. The study also found that without credit prices or with low credit prices, between 12 and 19% of the 4.7 million study acres could achieve a net savings from implementing conservation practices to achieve both the N and P TES or the P-only TES, respectively. These net savings were due to fertilizer savings and/or increases in crop yield outweighing the conservation practice costs. When relatively low credit prices were introduced (i.e., up to $3/N credit only, up to $15/P credit only, and up to both $3/N and $15/P credits offered simultaneously), the model found that between 16 and 38% of the agricultural study area experienced net savings from generating credits, even before selling the credits.

The study found that, in general, having both an N and P TES to meet before farmers could generate credits resulted in more of both types of credits than when only the N TES or the P TES was required. Having both an N and a P credit price signal in the market also resulted in more farm acres generating credits and higher profits than when only one credit price was available. If only one credit price were available in the market, an N price results in more of both types of credits being generated than when only a P price is available.

Currently, there are no local nutrient TMDLs or numeric nutrient criteria in the receiving waters of the project's buyers. However, if future local water quality policies did materialize and were more stringent than the project's 45% delivered nutrient reduction goal, nutrient trading could be employed to meet that local goal. Credit buyers would then have to find credit sellers upstream or within the local watershed. One of the Mississippi project watersheds has a smaller sub-basin with a TMDL for N and P that is much stricter than the project's 45% reduction goal; thus, farmers in this sub-basin would need to have their trading eligibility standard reflect the stricter local water goal before they are able to sell credits.

The numeric nutrient criteria analysis shed light on the effect that various levels of potential future criteria would have on MWRDGC's and SD1's ability to engage in regional and/or local nutrient trading options and still satisfy those criteria. The delivery factor analysis provided insight into the importance of improving the science and modeling of nutrient delivery for credit buyers to find the best credit sellers to maximize the cost-effectiveness of nutrient trading for Gulf of Mexico water quality goals.

Overall, feedback on the study from the project's WWTP potential buyers and the regulatory water quality agencies as well as the project's potential agricultural credit sellers, agricultural conservation agencies, and universities was generally positive. Many the groups thought the study provided a helpful explanation of nutrient trading concepts and a useful outline of possibilities for trading program design.

The project's wastewater utilities indicated an interest in N trading should an N reduction goal for the Gulf of Mexico materialize, as they did not foresee any local N water quality policies being developed. For P, given both utilities had a P-related permit at one plant, were committing to install P technology upgrades, or anticipated development of local TMDLs or instream numeric P criteria in the near future, they were less interested in trading. However, their interest may increase if a future P goal materialized (Gulf-related, a local TMDL, or a numeric P criterion) that required more reductions than their current P technology commitments. If this happened, they would determine if it would be cost-effective to meet the new goal through onsite investments or through credit purchases. The utilities indicated that the study's use of a credit price that reflected just 25% of their onsite technology costs was a reasonable hypothetical maximum "willingness to pay" for credits. They said they would need to justify significant cost saving to their ratepayers and policy stakeholders to be able to engage in trading to meet required water quality goals. The federal and state water quality regulatory agencies that were associated with the project buyers said they could envision participating in the development of a nutrient trading program for the Gulf of Mexico by providing water quality policy guidance and trading program design input.

The project's agricultural conservation stakeholders also indicated an interest in trading as a way to increase conservation practice implementation. They saw the availability of credit prices as a way to provide voluntary incentives to farmers to achieve specific N and P reduction targets. Given the heterogeneity of farmers, some stakeholders thought that the potential profits per acre estimated would be high enough to elicit interest from some farmers. Several stakeholders stated they could envision getting involved in developing a nutrient trading program in a variety of functions, including: providing outreach and educational assistance to communicate the potential benefits of voluntary participation in a trading program, conservation planning technical assistance to help farmers decide which practices were most cost-effective and profitable, helping to develop trading contracts to minimize risk, providing the latest nutrient reduction efficiency estimates from commonly adopted conservation practices, developing watershed-scale and field-scale nutrient reduction estimation models and tools, and providing verification that adopted conservation practices meet installation and maintenance protocols.

Both buyer and seller stakeholder groups identified several barriers to trading, including policy, political, scientific, technical, capacity, and cultural barriers. Both sets of stakeholders pointed out that without a real policy driver creating demand for credits, it was difficult to engage in trading policy discussions. The potential buyers were uncertain about what legal authorities they may currently have or might have to seek to be able to engage in either local or large-scale interstate trading. The buyers also expressed concern about the political challenge of convincing ratepayers and policymakers to spend funds on credit purchases outside of their jurisdiction and even outside of their states. Finally, one utility raised issues of fairness and appropriateness of policy action. The utility pointed out that though nonpoint sources contribute a larger portion of the Gulf nutrient problem, the Clean Water Act fails to regulate agricultural nonpoint sources and thus they regard trading as a mechanism for increased regulatory pressure only on point sources.

Both sets of state agency stakeholders in the project buyers and sellers watersheds raised concerns about their capacity to assist in various trading program functions given their shrinking budgets and already understaffed working conditions.

The agricultural stakeholders pointed out that should nutrient trading materialize, they would need field-level credit calculation tools developed for their farmers to be able to accurately estimate individual baseline nutrient loads and credit generation possibilities. In addition, both watershed-scale and field-scale models and tools must be updated to accurately reflect current agronomic and conservation practices in a credit seller region. Also, model and tool developers would need to gain producer and other conservation stakeholder buy-in to the new technologies by investing in many educational events to explain how the models and tools work and overcome producer and stakeholder wariness. Finally, a few agricultural stakeholders raised cultural concerns about trading as a mechanism that allows one group of nutrient sources to shoulder the responsibility of reductions for another group of sources. Should nutrient trading materialize for addressing either or both regional or local water quality goals, these and other barriers will have to be effectively addressed and overcome.

In conclusion, nutrient trading would likely be a cost-effective policy option to help achieve a potential future Gulf of Mexico nutrient reduction goal.

B. Next Steps

While trading on a large interstate scale in the MRB will likely not come to pass unless there is a strong policy driver, states and stakeholders could be taking steps toward enabling trading if and when it comes about. Should USEPA, state regulatory agencies, and stakeholders conclude that nutrient trading is a cost-effective approach to help achieve water quality goals in the MRB, WRI offers three recommendations for moving forward.

1. Identify local watersheds where trading may be feasible due to local water quality concerns.

Many states have nutrient-related TMDLs for local waterbodies and are in the process of developing instream numeric nutrient criteria. Though this study focused on the feasibility of trading to achieve regional or downstream waterbody goals, it also noted that nutrient trading could be a helpful policy tool for achieving local water quality goals. USEPA is committed to working with states on nutrient reduction strategies that may include trading.[65] It should continue to demonstrate its support for nutrient trading for helping to achieve both regional and local water quality goals and continue to work with states to make this cost-effective nutrient-reduction option a reality. By allowing trading to be used for achieving both future Gulf of Mexico and local waterbody goals, state water quality and agricultural conservation agencies can confidently engage in watershed planning activities that identify where trading may be most useful to help address nutrient pollution.

As priority watersheds are identified for trading, care must be taken to balance multiple environmental goals. For example, imminent instream numeric criteria could restrict credit buyers to trading only with

[65] See Stoner 2011.

credit sellers located upstream from the waterbody receiving the criteria and within the watershed determined to be contributing nutrient pollution to the impaired waterbody. As a result, credit supply may not be sufficient to meet demand, and the economic efficiency of the market could be compromised. Additionally, should a basin-wide trading program develop, trading must be conducted so as to not compromise local water quality while aiming to achieve Gulf nutrient reduction goals.

2. **Federal and state agencies, environmental groups, the agricultural community, wastewater community, and other stakeholders should collaborate to define key trading program elements.**

Given the multi-stakeholder nature of nutrient trading, significant buy-in needs to occur from each of the relevant stakeholder groups to not only participate in trading but also to lend their expertise and political capital to develop a credible and viable trading program.

While federal and state water quality regulatory agencies develop permits with new N and P limits that correspond to local or regional water goals, they will also need to approve trading as a viable option for regulated point sources to meet some or all of their new permit limits. These agencies will need to develop the analytical capabilities to determine whether a point source can opt to include trading in the permit as a cost-effective means to help satisfy required nutrient reductions. Along with assistance from federal and state water quality research agencies, these stakeholders will need to ensure that trading programs work to achieve local or regional water goals by measuring progress toward those goals through modeling and/or water quality monitoring techniques.

Before regulated point sources can pursue trading to meet some or all of their new N and P permit limits, they will need to clarify and confirm their legal authority to engage in trading. They will also need to conduct the necessary business case analysis to justify to ratepayers and policy stakeholders that that trading makes economic sense over solely investing in onsite technological upgrades.

For the farming community to engage in trading, they need to believe that there is a sufficiently credible policy driver in place that creates a stable and permanent demand for nutrient credits. Producers will need to see sufficiently high N or P credit prices to make their investment in conservation practices to generate credits profitable. And they need to be assured that the aggregators and utilities they contract with will provide a credible, dependable funding commitment through contracts and program requirements that are not too onerous. The federal and state conservation agencies, non-government conservation organizations, and agricultural extension professionals need to be assured that investment of their conservation planning expertise and knowledge of farmer interests and constraints will result in a trading program that is viable, credible, and verifiable.

The environmental and public interest advocacy community needs to be involved in developing a trading program to ensure that it is effectively designed to achieve the trading program's water quality goal. If the trading program is serving a regional goal, they will want to ensure that the program rules prevent violation of local water quality standards while progress is made toward the regional goal.

Given that several concerns were raised by both the point and nonpoint source stakeholders in this study regarding which sector was causing most of the nutrient pollution problem in the Gulf as well as whether trading was a fair mechanism to incentivize action within existing regulatory frameworks, policy stakeholders should foster dialogue between all parties to further discuss these issues.

3. **All relevant stakeholders should collaborate to identify and develop the necessary data and tools for quantifying nutrient reductions.**

For a nutrient trading program to develop, particularly with nonpoint sources, sufficient data must be available on agricultural sector nutrient loading rates, delivery factors within watersheds and to the waterbody of concern, and BMP nutrient reduction effectiveness. These data will be inputted into models and tools that inform trades.

One of the most important scientific and technical hurdles to begin or continue working on right away is the development of the watershed-scale and field-scale models and tools needed for trading. Uses for the watershed-scale tools include specification of the water quality policy goal, which will serve as the policy driver for the development of the trading program; calculation of the program's trading eligibility standard; and identification of high priority watersheds and sub-watersheds that have disproportionate nutrient losses. Improving and calibrating existing models such as USGS's SPARROW model and the USDA / Texas A&M SWAT model for use in watersheds of interest can help develop nutrient trading and watershed prioritization strategies.

Once watersheds well suited for local or regional trading are identified, tools must also be developed or calibrated with local and current agronomic and conservation conditions to estimate farm-scale nutrient losses and credit generation. One such tool is USDA's Nutrient Tracking Tool (NTT) tool, which is currently being calibrated in various regions for use in field-scale nutrient loading assessments, trading programs, and non-trading conservation decision-making applications.

In addition to having the data and tools that are critical to implementing and executing a trading program properly, stakeholders should consider what additional functions will make nutrient trading as efficient as possible. For example, in a Gulf-related nutrient trading program, to increase market efficiency, potential credit buyers will benefit from the development of models and tools that identify the location of potential credit sellers who have advantageous delivery factors. It may also be beneficial to have tools that value credits based on the water quality status of the local watershed in which they were generated.

Modelers and tool developers should conduct educational outreach events to explain the models and tools to agricultural and point source stakeholders and policymakers to ensure that all parties understand how they work, what their strengths are, what their shortcomings are, and if they provide sufficient confidence to move forward.

All of these recommendations will help federal and state agencies and other interested stakeholders prepare for a nutrient trading program that is scientifically and technically sound, efficient, and robust. However, these recommendations need not be limited to development of a trading program. Even if local or basin-wide trading programs are not developed, activities such as watershed prioritization, stakeholder collaboration, and tool development are critical for states' nutrient reduction strategies.

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IX. APPENDICES

A. Sample Case Studies

While the study focuses on "the average" net costs to generate credits, tremendous variation exists above and below the average cost per pound of N or P reduction for farmers in the project watersheds. NRCS selected one high-cost and one low-cost sample point to display this variation in greater detail at the sample point scale. The goal of this analysis is to provide as close to a field-level look at the potential experience by individual producers if they engage in nutrient trading.

NRCS selected a high-cost sample point and a low-cost point to determine the:

a) Average baseline loads,
b) Watershed's trading eligibility standard for that point,
c) Least-cost conservation treatment that would exceed both the trading eligibility standard and still generate credits, and
d) Trading price that would be necessary for the producer to break-even on the net costs per isolated nutrient pound.

These case studies employed the cost-minimization model because no prices were included. No additionality was enforced. The loads reflect annual average reductions at the edge of field. For the tradable reductions estimated in these case studies to become tradable credits, the appropriate delivery factor to the Gulf of Mexico must be applied.

The High-Cost Case Study

Sample point "H" and its extended acres grow a soybean-rice crop rotation. For "H," the existing baseline N and P losses are both greater than the required the edge-of-field trading eligibility standard. In order to meet the TES for both N and P, both the Structural Erosion Control (SEC) and the Erosion and Nutrient Management (ENM) treatments were able to achieve the TES for both N and P.

On a per acre basis, the net costs associated with the SEC treatment are $9.12/acre and 8 pounds of tradable N/acre and 0.9 lbs of tradable P/acre are generated. Isolated nutrient costs are therefore $1.14/lb N and $9.81/lb P reduced. For this sample point and its extended acres, the net costs are positive, meaning that the costs of the treatment exceed any on-farm economic benefits.

The net costs associated with the ENM treatment are also positive and quite large, $74.98/acre with 8.5 lbs of tradable N/ac and 0.93 lbs tradable P/ac being generated. Isolated nutrient costs are $8.87/lb N and $80.62/lb of P.

If a market existed for only N, the breakeven price for this farm would be $1.41, and if the N price is less than $1.14/lb no trades would occur. But, if the N price was $1.14 to $8.87 per lb and the Structural Erosion Control Treatment were installed, then 8 lbs N could be traded per acre. If the price was $8.87/lb N or above, and the Enhanced Nutrient Management Treatment were adopted, then 8.45 lbs of N /ac could be traded.

If a market existed for only P trades, the breakeven price for this sample farm occurs for a P price below $9.81, while 0.93 lbs P/ac are traded for any price at $9.81 or above.

The Low Cost Case Study

Sample point "L" and its statistically extended acres grow continuous rice. The existing baseline loads are already below both the N and P TES, thus if additionality were not enforced, this point has tradable "baseline-below-TES" N and P credits of 9.03 lbs N/ac and 0.59 lbs P/ac.

If additionality were enforced, those credits could not be sold but the following treatments could be applied to this point to achieve additional credits: Drainage Water Management (DWM), SEC, ENM, and ENM plus drainage water management (ENM+DWM) treatments.

The SEC treatment actually has a net cost per acre of -$8.74, due to (a) fertilizer savings from areas converted to a filter or a buffer strip and (b) a slight increase in crop yields. This results in negative net cost of -$0.68/lb for N and -$9.82/lb for P. Thus, even without trading, the structural erosion control treatment results in net savings for these acres.

The next lowest cost treatment is DWM, costing $14.42 per acre and yielding 20.37 lbs N/ac and 0.15 lbs P/ac of reduction. Net costs are $0.71/lb for N and $96.15/lb for P. Drainage water management has a large effect on N reduction and could be profitable at N credit prices greater than $0.71/lb.

B. Eight Key Tables from NRCS CEAP

TABLE A.1.

POTENTIAL ANNUAL SUPPLY OF N CREDITS FOR ALTERNATIVE POLICIES AND VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**N supply (in 1,000s lbs, delivered to Gulf)**														
N & P	Enforced	N	1	2,614	9,181	12,872	14,078	16,356	17,527	19,556	21,303	22,501	23,122	24,871	27,722	29,687	31,380	34,288
N & P	Enforced	P	2	2,614	2,614	2,944	3,300	3,868	4,745	5,577	5,636	5,976	6,554	7,209	9,751	12,797	12,797	12,797
N & P	Enforced	N & P	3	2,614	9,532	13,081	15,207	17,962	20,868	22,283	23,885	25,601	27,836	28,540	30,800	32,268	33,177	34,532
N	Enforced	N	1a	3,035	11,080	13,703	14,361	16,559	17,655	20,050	22,120	23,497	24,226	25,924	28,720	30,463	32,428	35,596
N	Enforced	P	2a	3,035	2,817	3,146	3,274	3,842	4,719	5,552	5,611	5,950	6,542	7,196	9,738	12,785	12,785	12,785
N	Enforced	N & P	3a	3,035	11,368	13,707	15,488	18,447	21,506	22,917	24,664	26,355	28,526	29,366	31,578	33,093	34,170	35,878
P	Enforced	N	1b	0	8,262	12,290	13,880	16,172	17,406	19,435	21,276	22,475	23,096	24,871	27,722	29,687	31,380	34,288
P	Enforced	P	2b	0	0	0	0	367	906	1,061	1,061	1,221	1,778	2,432	4,351	6,452	6,452	6,452
P	Enforced	N & P	3b	0	8,545	12,306	14,726	17,663	20,584	22,183	23,785	25,513	27,778	28,482	30,666	32,136	33,095	34,530
N & P	Not Enforced	N	4	3,316	15,695	19,361	20,957	23,923	25,132	27,232	29,314	31,019	31,723	33,907	37,145	39,251	41,151	44,638
N & P	Not Enforced	P	5	3,316	9,037	9,433	9,789	10,377	11,175	12,019	12,251	12,763	13,408	14,259	17,053	20,515	20,515	20,515
N & P	Not Enforced	N & P	6	3,316	16,053	19,745	22,377	25,582	28,841	30,498	32,533	34,402	37,128	37,853	40,462	42,027	43,083	44,928
N	Not Enforced	N	4a	4,102	17,294	20,020	21,069	24,170	25,306	27,784	30,179	32,096	32,893	35,013	38,177	40,055	42,202	45,939
N	Not Enforced	P	5a	4,102	9,284	9,679	9,764	10,351	11,149	11,993	12,226	12,737	13,395	14,246	17,040	20,502	20,502	20,502
N	Not Enforced	N & P	6a	4,102	17,730	20,384	22,685	26,059	29,480	31,132	33,312	35,156	37,817	38,679	41,253	42,863	44,087	46,272
P	Not Enforced	N	4b	63	14,776	18,779	20,759	23,739	25,011	27,111	29,288	30,992	31,697	33,907	37,145	39,251	41,151	44,638
P	Not Enforced	P	5b	63	3,641	3,721	3,956	4,812	5,271	5,436	5,681	6,249	6,973	7,813	10,238	12,800	12,800	12,800
P	Not Enforced	N & P	6b	63	15,066	18,971	21,895	25,283	28,557	30,398	32,433	34,314	37,070	37,795	40,328	41,895	43,000	44,927

TABLE A.2.

POTENTIAL ANNUAL SUPPLY OF P CREDITS FOR ALTERNATIVE POLICIES AND VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**P supply (in 1,000s lbs, delivered to Gulf)**														
N & P	Enforced	N	1	250	279	420	445	538	604	747	885	962	990	1,124	1,323	1,499	1,659	2,070
N & P	Enforced	P	2	250	281	311	345	422	526	615	624	649	706	738	988	1,256	1,256	1,256
N & P	Enforced	N & P	3	250	357	486	591	809	1,003	1,085	1,259	1,416	1,565	1,627	1,921	2,026	2,092	2,194
N	Enforced	N	1a	129	119	201	209	302	389	558	703	779	819	959	1,163	1,297	1,517	1,952
N	Enforced	P	2a	129	240	269	333	410	514	612	621	646	703	735	985	1,253	1,253	1,253
N	Enforced	N & P	3a	129	222	305	428	698	908	1,011	1,191	1,351	1,507	1,568	1,866	1,977	2,039	2,124
P	Enforced	N	1b	346	352	458	466	560	605	747	886	963	991	1,124	1,323	1,499	1,659	2,070
P	Enforced	P	2b	346	438	541	598	669	761	794	818	842	871	907	1,131	1,362	1,362	1,362
P	Enforced	N & P	3b	346	419	536	612	817	1,016	1,103	1,277	1,432	1,584	1,646	1,946	2,044	2,112	2,196
N & P	Not Enforced	N	4	289	531	673	713	829	899	1,049	1,217	1,325	1,354	1,513	1,737	1,912	2,093	2,543
N & P	Not Enforced	P	5	289	534	569	606	683	784	876	894	937	1,000	1,047	1,323	1,629	1,629	1,629
N & P	Not Enforced	N & P	6	289	611	752	884	1,132	1,355	1,438	1,644	1,808	1,988	2,051	2,361	2,474	2,545	2,676
N	Not Enforced	N	4a	121	152	364	430	571	661	837	1,013	1,119	1,160	1,325	1,554	1,688	1,928	2,399
N	Not Enforced	P	5a	121	472	507	593	671	772	873	891	934	997	1,044	1,320	1,626	1,626	1,626
N	Not Enforced	N & P	6a	121	374	549	703	1,019	1,260	1,364	1,576	1,743	1,930	1,992	2,305	2,424	2,491	2,605
P	Not Enforced	N	4b	498	604	711	734	851	899	1,049	1,218	1,326	1,355	1,513	1,737	1,912	2,093	2,543
P	Not Enforced	P	5b	498	731	782	889	944	1,035	1,060	1,120	1,151	1,186	1,233	1,468	1,720	1,720	1,720
P	Not Enforced	N & P	6b	498	673	803	906	1,140	1,368	1,456	1,662	1,825	2,007	2,070	2,386	2,492	2,564	2,679

TABLE A.3.
AVERAGE ANNUAL NET COST/LB N CREDIT FOR ALTERNATIVE POLICY SCENARIOS WITH VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**Net Costs per Nitrogen Credit ($/lb delivered)**														
N & P	Enforced	N	1	-7.02	-1.61	-0.70	-0.41	0.13	0.43	0.95	1.39	1.72	1.90	2.44	3.33	4.02	4.75	6.89
N & P	Enforced	P	2	-7.02	-6.96	-6.11	-5.33	-4.19	-2.91	-2.05	-1.97	-1.70	-1.18	-0.87	1.02	2.62	2.62	2.62
N & P	Enforced	N & P	3	-7.02	-1.49	-0.63	-0.09	0.65	1.37	1.73	2.28	2.85	3.53	3.78	4.92	5.62	6.14	7.37
N	Enforced	N	1a	-6.39	-1.49	-0.91	-0.76	-0.19	0.11	0.75	1.28	1.64	1.85	2.35	3.20	3.81	4.65	6.89
N	Enforced	P	2a	-6.39	-6.82	-6.04	-5.57	-4.39	-3.06	-2.13	-2.05	-1.78	-1.24	-0.93	0.98	2.59	2.59	2.59
N	Enforced	N & P	3a	-6.39	-1.39	-0.88	-0.38	0.48	1.25	1.63	2.21	2.77	3.43	3.70	4.82	5.54	6.10	7.43
P	Enforced	N	1b		-2.10	-0.91	-0.50	0.06	0.38	0.91	1.38	1.71	1.89	2.44	3.33	4.02	4.75	6.89
P	Enforced	P	2b					-50.57	-18.12	-14.62	-13.92	-11.35	-7.12	-4.51	0.79	3.67	3.67	3.67
P	Enforced	N & P	3b		-1.97	-0.87	-0.24	0.57	1.32	1.73	2.28	2.85	3.54	3.79	4.93	5.61	6.15	7.37
N & P	Not Enforced	N	4	-5.71	-0.99	-0.50	-0.27	0.20	0.41	0.80	1.19	1.54	1.70	2.21	2.98	3.56	4.20	6.20
N & P	Not Enforced	P	5	-5.71	-2.08	-1.97	-1.85	-1.61	-1.29	-0.99	-0.93	-0.76	-0.53	-0.34	0.76	1.96	1.96	1.96
N & P	Not Enforced	N & P	6	-5.71	-0.92	-0.44	-0.01	0.58	1.19	1.49	2.00	2.47	3.11	3.31	4.29	4.89	5.36	6.63
N	Not Enforced	N	4a	-4.93	-1.08	-0.71	-0.55	-0.03	0.18	0.65	1.11	1.49	1.66	2.14	2.88	3.39	4.11	6.21
N	Not Enforced	P	5a	-4.93	-2.16	-2.04	-1.92	-1.68	-1.35	-1.03	-0.96	-0.80	-0.56	-0.37	0.74	1.94	1.94	1.94
N	Not Enforced	N & P	6a	-4.93	-0.99	-0.62	-0.22	0.46	1.10	1.42	1.95	2.41	3.04	3.26	4.23	4.85	5.35	6.70
P	Not Enforced	N	4b	-359.76	-1.22	-0.63	-0.33	0.16	0.38	0.77	1.19	1.54	1.69	2.21	2.98	3.56	4.20	6.20
P	Not Enforced	P	5b	-359.76	-6.21	-5.98	-5.30	-4.15	-3.38	-3.15	-2.68	-2.25	-1.81	-1.33	0.49	2.15	2.15	2.15
P	Not Enforced	N & P	6b	-359.76	-1.16	-0.58	-0.10	0.52	1.15	1.49	1.99	2.47	3.11	3.32	4.30	4.88	5.37	6.63

TABLE A.4.

AVERAGE ANNUAL NET COST/LB P CREDIT FOR ALTERNATIVE POLICY SCENARIOS WITH VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**Net Costs per Phosphorus Credit ($/lb delivered)**														
N & P	Enforced	N	1	-73.27	-52.99	-21.50	-13.11	3.97	12.46	24.81	33.54	40.21	44.37	54.05	69.72	79.72	89.86	114.08
N & P	Enforced	P	2	-73.27	-64.66	-57.85	-50.92	-38.39	-26.23	-18.57	-17.76	-15.70	-10.96	-8.49	10.06	26.66	26.66	26.66
N & P	Enforced	N & P	3	-73.27	-39.70	-17.09	-2.44	14.39	28.59	35.61	43.26	51.56	62.69	66.24	78.89	89.59	97.40	116.00
N	Enforced	N	1a	-150.01	-139.40	-62.26	-52.04	-10.41	5.19	26.96	40.22	49.47	54.62	63.61	79.07	89.53	99.40	125.64
N	Enforced	P	2a	-150.01	-80.05	-70.51	-54.80	-41.16	-28.14	-19.33	-18.50	-16.41	-11.58	-9.07	9.68	26.40	26.40	26.40
N	Enforced	N & P	3a	-150.01	-71.35	-39.37	-13.68	12.69	29.63	37.03	45.71	53.98	64.84	69.31	81.53	92.77	102.28	125.55
P	Enforced	N	1b	-62.63	-49.26	-24.31	-14.99	1.85	11.07	23.68	33.23	39.92	44.08	54.05	69.72	79.72	89.86	114.08
P	Enforced	P	2b	-62.63	-48.94	-38.02	-33.20	-27.72	-21.59	-19.52	-18.04	-16.45	-14.54	-12.08	3.06	17.39	17.39	17.39
P	Enforced	N & P	3b	-62.63	-40.17	-20.00	-5.67	12.28	26.82	34.75	42.40	50.76	61.99	65.53	77.69	88.27	96.44	115.88
N & P	Not Enforced	N	4	-65.47	-29.14	-14.50	-7.87	5.79	11.52	20.70	28.76	36.15	39.78	49.41	63.69	73.05	82.58	108.84
N & P	Not Enforced	P	5	-65.47	-35.18	-32.62	-29.88	-24.47	-18.36	-13.60	-12.68	-10.40	-7.07	-4.62	9.85	24.65	24.65	24.65
N & P	Not Enforced	N & P	6	-65.47	-24.29	-11.44	-0.23	13.09	25.23	31.64	39.52	46.98	58.04	61.09	73.61	83.14	90.76	111.36
N	Not Enforced	N	4a	-166.42	-122.17	-39.12	-27.01	-1.30	6.93	21.56	32.93	42.73	47.05	56.46	70.71	80.51	90.09	118.87
N	Not Enforced	P	5a	-166.42	-42.41	-39.03	-31.62	-25.90	-19.50	-14.12	-13.18	-10.87	-7.49	-5.02	9.56	24.44	24.44	24.44
N	Not Enforced	N & P	6a	-166.42	-47.01	-23.10	-6.95	11.72	25.72	32.48	41.22	48.69	59.59	63.35	75.68	85.67	94.68	118.96
P	Not Enforced	N	4b	-45.72	-29.83	-16.68	-9.21	4.35	10.58	19.90	28.54	35.94	39.58	49.41	63.69	73.05	82.58	108.84
P	Not Enforced	P	5b	-45.72	-30.92	-28.46	-23.57	-21.14	-17.23	-16.17	-13.61	-12.21	-10.62	-8.44	3.39	15.97	15.97	15.97
P	Not Enforced	N & P	6b	-45.72	-26.01	-13.74	-2.46	11.59	23.95	31.04	38.91	46.40	57.53	60.57	72.69	82.10	90.03	111.27

TABLE A.5.
POTENTIAL 20-YEAR SUPPLY OF N CREDITS FOR ALTERNATIVE POLICIES AND VARIOUS N, P, OR N AND P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**N supply (in 1,000s lbs, delivered to Gulf)**														
N & P	Enforced	N	1	52,288	183,622	257,443	281,563	327,122	350,534	391,124	426,054	450,026	462,447	497,421	554,445	593,739	627,606	685,767
N & P	Enforced	P	2	52,288	52,288	58,870	65,992	77,364	94,896	111,548	112,728	119,517	131,089	144,172	195,012	255,949	255,949	255,949
N & P	Enforced	N & P	3	52,288	190,630	261,611	304,143	359,238	417,362	445,662	477,702	512,024	556,720	570,797	615,990	645,362	663,547	690,633
N	Enforced	N	1a	60,693	221,598	274,066	287,230	331,180	353,110	401,001	442,406	469,930	484,520	518,479	574,398	609,265	648,550	711,927
N	Enforced	P	2a	60,693	56,330	62,913	65,476	76,847	94,380	111,032	112,212	119,001	130,834	143,917	194,757	255,694	255,694	255,694
N	Enforced	N & P	3a	60,693	227,351	274,134	309,759	368,931	430,128	458,347	493,288	527,094	570,514	587,327	631,568	661,858	683,400	717,552
P	Enforced	N	1b	0	165,242	245,801	277,596	323,440	348,113	388,703	425,530	449,502	461,922	497,421	554,445	593,739	627,606	685,767
P	Enforced	P	2b	0	0	0	0	7,338	18,128	21,213	21,213	24,420	35,555	48,638	87,015	129,043	129,043	129,043
P	Enforced	N & P	3b	0	170,891	246,119	294,519	353,257	411,673	443,658	475,698	510,264	555,560	569,637	613,312	642,723	661,895	690,602
N & P	Not Enforced	N	4	66,319	313,900	387,226	419,138	478,463	502,642	544,643	586,283	620,371	634,470	678,133	742,901	785,020	823,018	892,765
N & P	Not Enforced	P	5	66,319	180,749	188,667	195,788	207,537	223,497	240,380	245,026	255,264	268,154	285,181	341,063	410,301	410,301	410,301
N & P	Not Enforced	N & P	6	66,319	321,054	394,907	447,532	511,644	576,827	609,960	650,657	688,042	742,550	757,056	809,248	840,535	861,661	898,566
N	Not Enforced	N	4a	82,037	345,874	400,394	421,382	483,407	506,120	555,677	603,585	641,924	657,862	700,265	763,539	801,102	844,050	918,789
N	Not Enforced	P	5a	82,037	185,671	193,588	195,272	207,021	222,981	239,863	244,510	254,748	267,899	284,926	340,808	410,046	410,046	410,046
N	Not Enforced	N & P	6a	82,037	354,608	407,670	453,708	521,183	589,593	622,644	666,243	703,112	756,344	773,585	825,060	857,267	881,750	925,437
P	Not Enforced	N	4b	1,265	295,520	375,584	415,171	474,780	500,221	542,222	585,759	619,847	633,945	678,133	742,901	785,020	823,018	892,765
P	Not Enforced	P	5b	1,265	72,814	74,420	79,130	96,238	105,413	108,729	113,621	124,979	139,462	156,257	204,753	256,002	256,002	256,002
P	Not Enforced	N & P	6b	1,265	301,315	379,415	437,908	505,663	571,138	607,956	648,653	686,282	741,390	755,896	806,569	837,896	860,010	898,535

TABLE A.6.

POTENTIAL 20-YEAR SUPPLY OF P CREDITS FOR ALTERNATIVE POLICIES AND VARIOUS N, P, OR N AND P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**P supply (in 1,000s lbs, delivered to Gulf)**														
N & P	Enforced	N	1	5,007	5,583	8,408	8,891	10,763	12,089	14,933	17,692	19,246	19,803	22,481	26,461	29,974	33,186	41,405
N & P	Enforced	P	2	5,007	5,630	6,218	6,902	8,442	10,527	12,295	12,489	12,975	14,118	14,758	19,765	25,122	25,122	25,122
N & P	Enforced	N & P	3	5,007	7,131	9,712	11,822	16,187	20,053	21,696	25,183	28,311	31,307	32,541	38,419	40,513	41,846	43,874
N	Enforced	N	1a	2,585	2,376	4,017	4,179	6,043	7,777	11,150	14,064	15,588	16,382	19,186	23,264	25,947	30,336	39,031
N	Enforced	P	2a	2,585	4,798	5,386	6,652	8,192	10,277	12,235	12,429	12,914	14,061	14,701	19,708	25,065	25,065	25,065
N	Enforced	N & P	3a	2,585	4,439	6,102	8,562	13,962	18,156	20,212	23,824	27,022	30,146	31,356	37,320	39,539	40,786	42,473
P	Enforced	N	1b	6,915	7,032	9,164	9,311	11,192	12,091	14,935	17,712	19,267	19,823	22,481	26,461	29,974	33,186	41,405
P	Enforced	P	2b	6,915	8,759	10,813	11,962	13,386	15,215	15,884	16,361	16,841	17,410	18,147	22,610	27,242	27,242	27,242
P	Enforced	N & P	3b	6,915	8,379	10,726	12,246	16,338	20,325	22,058	25,545	28,650	31,687	32,920	38,928	40,871	42,231	43,930
N & P	Not Enforced	N	4	5,784	10,623	13,468	14,270	16,586	17,988	20,986	24,337	26,500	27,081	30,260	34,732	38,245	41,866	50,856
N & P	Not Enforced	P	5	5,784	10,683	11,373	12,115	13,667	15,687	17,524	17,881	18,740	19,993	20,946	26,452	32,585	32,585	32,585
N & P	Not Enforced	N & P	6	5,784	12,210	15,048	17,688	22,642	27,096	28,758	32,880	36,156	39,755	41,021	47,213	49,479	50,890	53,521
N	Not Enforced	N	4a	2,428	3,047	7,276	8,605	11,416	13,228	16,740	20,267	22,380	23,198	26,503	31,073	33,755	38,553	47,988
N	Not Enforced	P	5a	2,428	9,442	10,131	11,865	13,417	15,437	17,464	17,821	18,679	19,936	20,889	26,395	32,528	32,528	32,528
N	Not Enforced	N & P	6a	2,428	7,480	10,984	14,057	20,379	25,199	27,273	31,521	34,867	38,593	39,836	46,094	48,486	49,811	52,100
P	Not Enforced	N	4b	9,950	12,072	14,224	14,689	17,015	17,990	20,988	24,358	26,520	27,101	30,260	34,732	38,245	41,866	50,856
P	Not Enforced	P	5b	9,950	14,615	15,631	17,783	18,883	20,702	21,203	22,398	23,029	23,725	24,665	29,353	34,409	34,409	34,409
P	Not Enforced	N & P	6b	9,950	13,459	16,063	18,112	22,793	27,368	29,120	33,242	36,495	40,135	41,401	47,722	49,838	51,276	53,576

TABLE A.7.

AVERAGE PRESENT VALUE NET COST/LB N CREDIT FOR ALTERNATIVE POLICY SCENARIOS WITH VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**Net Costs per Nitrogen Credit ($/lb delivered)**														
N & P	Enforced	N	1	-5.22	-1.20	-0.52	-0.30	0.10	0.32	0.71	1.03	1.28	1.41	1.82	2.48	2.99	3.53	5.13
N & P	Enforced	P	2	-5.22	-5.18	-4.55	-3.96	-3.12	-2.16	-1.52	-1.47	-1.26	-0.88	-0.65	0.76	1.95	1.95	1.95
N & P	Enforced	N & P	3	-5.22	-1.11	-0.47	-0.07	0.48	1.02	1.29	1.70	2.12	2.63	2.81	3.66	4.18	4.57	5.48
N	Enforced	N	1a	-4.75	-1.11	-0.68	-0.57	-0.14	0.08	0.56	0.95	1.22	1.38	1.75	2.38	2.83	3.46	5.13
N	Enforced	P	2a	-4.75	-5.07	-4.49	-4.14	-3.27	-2.28	-1.58	-1.52	-1.32	-0.92	-0.69	0.73	1.93	1.93	1.93
N	Enforced	N & P	3a	-4.75	-1.03	-0.65	-0.28	0.36	0.93	1.21	1.64	2.06	2.55	2.75	3.59	4.12	4.54	5.53
P	Enforced	N	1b	0	-1.56	-0.68	-0.37	0.04	0.28	0.68	1.03	1.27	1.41	1.82	2.48	2.99	3.53	5.13
P	Enforced	P	2b	0	0	0	0	-37.62	-13.48	-10.88	-10.35	-8.44	-5.30	-3.35	0.59	2.73	2.73	2.73
P	Enforced	N & P	3b	0	-1.47	-0.65	-0.18	0.42	0.98	1.29	1.70	2.12	2.63	2.82	3.67	4.17	4.57	5.48
N & P	Not Enforced	N	4	-4.25	-0.74	-0.37	-0.20	0.15	0.30	0.60	0.89	1.15	1.26	1.64	2.22	2.65	3.12	4.61
N & P	Not Enforced	P	5	-4.25	-1.55	-1.47	-1.38	-1.20	-0.96	-0.74	-0.69	-0.57	-0.39	-0.25	0.57	1.46	1.46	1.46
N & P	Not Enforced	N & P	6	-4.25	-0.68	-0.33	-0.01	0.43	0.89	1.11	1.49	1.84	2.31	2.46	3.19	3.64	3.99	4.93
N	Not Enforced	N	4a	-3.67	-0.80	-0.53	-0.41	-0.02	0.13	0.48	0.83	1.11	1.23	1.59	2.14	2.52	3.06	4.62
N	Not Enforced	P	5a	-3.67	-1.61	-1.52	-1.43	-1.25	-1.00	-0.77	-0.71	-0.60	-0.42	-0.28	0.55	1.44	1.44	1.44
N	Not Enforced	N & P	6a	-3.67	-0.74	-0.46	-0.16	0.34	0.82	1.06	1.45	1.79	2.26	2.43	3.15	3.61	3.98	4.98
P	Not Enforced	N	4b	-267.62	-0.91	-0.47	-0.25	0.12	0.28	0.57	0.89	1.15	1.26	1.64	2.22	2.65	3.12	4.61
P	Not Enforced	P	5b	-267.62	-4.62	-4.45	-3.94	-3.09	-2.51	-2.34	-1.99	-1.67	-1.35	-0.99	0.36	1.60	1.60	1.60
P	Not Enforced	N & P	6b	-267.62	-0.86	-0.43	-0.07	0.39	0.86	1.11	1.48	1.84	2.31	2.47	3.20	3.63	3.99	4.93

TABLE A.8.

AVERAGE PRESENT VALUE NET COST/LB P CREDIT FOR ALTERNATIVE POLICY SCENARIOS WITH VARIOUS N, P, OR N & P MARKET PRICES

		N price		0	1	2	3	4	5	6	7	8	9	10	12.5	15	20	50
		P price		0	5	10	15	20	25	30	35	40	45	50	75	100	100	100
TES	**Additionality**	**Price(s)**	**Wksht**	**Net Costs per Phosphorus Credit ($/lb delivered)**														
N & P	Enforced	N	1	-54.50	-39.42	-15.99	-9.75	2.95	9.27	18.46	24.95	29.91	33.01	40.21	51.86	59.30	66.84	84.86
N & P	Enforced	P	2	-54.50	-48.10	-43.03	-37.88	-28.56	-19.51	-13.81	-13.21	-11.68	-8.15	-6.32	7.48	19.83	19.83	19.83
N & P	Enforced	N & P	3	-54.50	-29.53	-12.71	-1.82	10.70	21.27	26.49	32.18	38.35	46.63	49.27	58.68	66.64	72.45	86.29
N	Enforced	N	1a	-111.59	-103.70	-46.31	-38.71	-7.74	3.86	20.05	29.92	36.80	40.63	47.32	58.82	66.60	73.94	93.46
N	Enforced	P	2a	-111.59	-59.55	-52.45	-40.76	-30.62	-20.93	-14.38	-13.76	-12.21	-8.61	-6.75	7.20	19.64	19.64	19.64
N	Enforced	N & P	3a	-111.59	-53.08	-29.29	-10.18	9.44	22.04	27.55	34.00	40.15	48.23	51.56	60.65	69.01	76.08	93.39
P	Enforced	N	1b	-46.59	-36.64	-18.08	-11.15	1.38	8.23	17.61	24.72	29.70	32.79	40.21	51.86	59.30	66.84	84.86
P	Enforced	P	2b	-46.59	-36.41	-28.28	-24.70	-20.62	-16.06	-14.52	-13.42	-12.24	-10.82	-8.99	2.28	12.94	12.94	12.94
P	Enforced	N & P	3b	-46.59	-29.88	-14.88	-4.22	9.13	19.95	25.85	31.54	37.76	46.11	48.75	57.79	65.66	71.74	86.20
N & P	Not Enforced	N	4	-48.70	-21.68	-10.79	-5.85	4.31	8.57	15.40	21.39	26.89	29.59	36.75	47.38	54.34	61.43	80.96
N & P	Not Enforced	P	5	-48.70	-26.17	-24.27	-22.23	-18.20	-13.66	-10.12	-9.43	-7.74	-5.26	-3.44	7.33	18.34	18.34	18.34
N & P	Not Enforced	N & P	6	-48.70	-18.07	-8.51	-0.17	9.74	18.77	23.54	29.40	34.95	43.17	45.44	54.76	61.85	67.51	82.84
N	Not Enforced	N	4a	-123.80	-90.88	-29.10	-20.09	-0.97	5.16	16.04	24.50	31.79	35.00	42.00	52.60	59.89	67.02	88.42
N	Not Enforced	P	5a	-123.80	-31.55	-29.03	-23.52	-19.27	-14.51	-10.50	-9.80	-8.09	-5.57	-3.73	7.11	18.18	18.18	18.18
N	Not Enforced	N & P	6a	-123.80	-34.97	-17.18	-5.17	8.72	19.13	24.16	30.66	36.22	44.33	47.12	56.30	63.73	70.43	88.49
P	Not Enforced	N	4b	-34.01	-22.19	-12.41	-6.85	3.24	7.87	14.80	21.23	26.73	29.44	36.75	47.38	54.34	61.43	80.96
P	Not Enforced	P	5b	-34.01	-23.00	-21.17	-17.53	-15.73	-12.82	-12.03	-10.12	-9.08	-7.90	-6.28	2.52	11.88	11.88	11.88
P	Not Enforced	N & P	6b	-34.01	-19.35	-10.22	-1.83	8.62	17.82	23.09	28.94	34.52	42.80	45.06	54.07	61.07	66.97	82.77