2009

Essays on environmental issues associated with the diary production region in Louisiana

Larry Michael Hall
Louisiana State University and Agricultural and Mechanical College, lmhlsu@cox.net

ESSAYS ON ENVIRONMENTAL ISSUES ASSOCIATED WITH THE DAIRY PRODUCTION REGION IN LOUISIANA

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
Requirements for the degree of
Doctor of Philosophy

in

The Department of Agricultural Economics & Agribusiness

By
Larry Michael Hall
B.S., Northwestern State University of Louisiana, 1971
M.B.A., Northeast Louisiana University, 1977
B.S., Louisiana State University, 1981
May, 2009

ACKNOWLEDGEMENTS

I would to express my gratitude to a number of individuals who have provided assistance during this journey. The first person to acknowledge is the department head, Dr. Gail Cramer. He gave me the initial vote of confidence that I would be able to succeed in the program. In addition, I'd like to thank Dr. Cramer for asking me to teach an undergraduate course in agribusiness management that I found very rewarding.

My committee members, Dr. Steve Henning, Dr. Rex Caffey, Dr. Richard Kazmierczak, Dr. Kayanush Aryana, and Dr. Margaret Reams receive my sincere appreciation for providing their time and thoughtful guidance. In addition, I'd like to thank Dr. Walter Keithly for his suggestions concerning my dissertation proposal.

Appreciation also goes to Dr. Dan Thomas and Dr. Ron Sheffield in the Department of Agricultural Engineering for providing technical guidance concerning BMPs' effectiveness. Former and current graduate students who provided timely assistance and should be mentioned are Dr. Seon-Ae Kim and (soon to be Dr.) Pablo Garcia. Departmental computer assistance came from Mark Christofferson and Robert Boucher. Absolutely crucial support came from Ms. Huizhen (Jane) Niu concerning GIS software that forms the foundation for this research.

I must thank my parents, Mr. and Mrs. Crayton G. "Sparky" Hall for instilling a love of reading and therefore learning. Being the first college graduates in their families, they "lead by example" and always encouraged further education.

Finally, my dissertation advisor Dr. Krishna Paudel receives a heartfelt "thank you." This has been a difficult but rewarding time in my life and this research could not have been accomplished without Dr. Paudel's guidance.

TABLE OF CONTENTS

LIST OF TABLES

.

LIST OF FIGURES

ABSTRACT

The Louisiana dairy production region (LDPR) is located in southeast Louisiana and includes five parishes (Tangipahoa, Washington, Livingston, St. Helena, and St. Tammany). It is home to approximately 90% of the state's dairy industry and is a major contributor to nonpoint source pollution (NPS) in the area's watershed through nitrogen, phosphorus, and sediment effluents. While point source (PS) effluents are easily identified and subject to federal and state regulations, NPS mitigation efforts must address uncertainties such as location of the NPS as well as stochastic parameters such as rainfall and its effect on nutrient and sediment flow. This dissertation presents three strategies to mitigate the effects of the NPS pollution. The first strategy is to identify dairy specific Best Management Practices (BMPs) that best mitigate NPS at the lowest cost. Using geographical information system (GIS) software to simulate nutrient (Nitrogen and Phosphorus) runoff and sediment flow, a suite of seven BMPs are identified that lead to high N reduction with a minimal cost solution. The second strategy uses point source PS/NPS trading to achieve mitigation. A section of the LDPR is identified containing approximately 162 dairy farmers, six point sources, and two weather stations. Using a trading ratio to capture uncertainty inherent with NPS pollution, trading ratios are identified for a range of values for both BMP efficacy and reliability of NPS variance estimates. The less assurance the researcher has in the validity of these parameters, the higher the trading ratio and the more effluent credits the PS will be required to purchase for the NPS in lieu of further PS abatement. The final strategy uses the Hazard model to identify entry and exit BMP adoption characteristics of dairy farmers. The effectiveness of NPS mitigation was found to increase if a BMP is adopted for a longer duration. Research concludes that higher level of education of the farmer and the longer that the dairy farmer has been in operation, the longer the adoption of the BMP.

CHAPTER 1
INTRODUCTION

1.1 Introduction

The majority of milk production is Louisiana occurs in five parishes (St Helena, Tangipahoa, Washington, St Tammany, and Livingston. Approximately 90% of all dairy producers in the state are located within this five-parish area that drains into Lake Ponchartrain (See figure 1.1). We define the five-parish region as the Louisiana Dairy Production Region (LDPR). While milk production is source of income to dairy producers in this region, this production also leads to substantial environmental and possible health costs through nutrients in leaching/runoff/volatilization. Nationally, over one-quarter of U.S. surface water is contaminated from livestock production. Pollution from overall agricultural sources is estimated to contaminate three-quarters of all rivers, streams and bayous. Half of all lakes and estuaries are similarly degraded (Innes, 2000).

The Louisiana Agricultural Statistical Service (USDA-NASS) indicates that there are more than 185,000 heads of cattle in the Lake Pontchartrain Basin in 2005. While dairy cows represent only 16% of all cattle, Tangipahoa and Washington parishes account for 84% of the dairy cows in the Lake Pontchartrain watershed. As consolidation occurs and dairies expand, smaller anaerobic lagoons designed for fewer cows will probably give way to land application of manure that will increase the likelihood of the leaching of nutrients and pathogens. Therefore, the purpose of this dissertation is to find ways to improve water quality in the LDPR at the minimum cost.

1.1.1. Nonpoint Source Pollution (NPS)

The Tangipahoa River runs through the LDPR and has been subject to NPS runoff contaminated from excess nutrients and pathogens. Lake Ponchartrain, the Tchefuncte River, and the Bogue

Falaya River are also in the dairy production region and have been subject to similar pollution and to the issuance of health advisories. With an excess of 60 inches of annual rainfall, the possibility of water contamination from sediment flow, pesticides application, and leaching is likely in Louisiana. This level of rainfall is higher than experienced by the vast majority of dairy farms in the rest of the United States (Rahelizatovo, 2002). Therefore, dairy farming in Louisiana presents special challenges to the environment.

Nationally, the United States utilizes over 330 million acres to produce a low-cost and nutritious food supply of amazing variety (EPA, Point #6, 2005). While U.S. agriculture is recognized around the world for its high productivity, quality and efficiency in logistics in delivery of food products to consumers, agricultural nonpoint source pollution (NPS) is also the leading source of water impairment to surveyed streams and rivers, the third leading source to surveyed estuaries degradation and a major contributor to ground water and wetland pollution.

Agricultural NPS comes from a variety of farm productive activities. Confined animal facilities, terracing, plowing, planting, harvesting, irrigating, fertilizing, and pesticide application all impact the nearby water bodies. Sedimentation, nutrients, pathogens, salts, and pesticides all contribute to impairment of the water bodies through NPS. Therefore, a goal of the EPA and state environmental agencies is to minimize these impacts through proper management of farm activities that contribute to NPS (EPA, Point #6, 2005).

Over 40 percent of section 319 Clean Water Act grants are directed at control of agricultural NPS. U.S. Department of Agriculture (USDA) and state agencies offer cost-share programs, technical assistance, and economic incentives for farmers to apply NPS management activities to their land. These activities can be broadly classified as: (1) managing sedimentation, (2) managing nutrients, (3) managing confined animal facilities, (4) managing irrigation, (5) managing pesticides, and (6) managing livestock grazing (EPA, Point #6, 2005).

Sedimentation impairs water supplies when wind or water runoff transports soil particles from a farm field into a stream or lake. This sedimentation transfer may cloud the water and prevent sunlight from reaching aquatic plants and in turn promote the growth of low sunlight plants that pollute fish spawning grounds or food supplies. The sediment may have harmful pollutants attached to it such as phosphorus, pathogens, and heavy metals (EPA, Point #6, 2005)

Chemicals such a phosphorus, nitrogen, and potassium may be transported onto the farm as fertilizers or produced through farm activities such as manure, sludge, irrigation water, and legumes production. Application of these chemicals in excess of crop needs pollutes nearby water bodies through runoff. This chemical laden runoff encourages excessive plant growth, reduces aquatic recreational activities, creates foul orders and tastes in drinking water and kills aquatic life (EPA, Point #6, 2005).

Farmers confine animals in lots to efficiently feed and manage the livestock. Poorly managed lots can lead to runoff problems from bacteria, viruses, pathogens, and oxygen deprivation to sensitive shellfish such as oysters. Contaminated seepage can degrade groundwater (EPA, Point #6, 2005).

When natural precipitation is lacking, irrigation for the crops becomes a necessity to protect the plants from freezing or wilting. Excessive irrigation can concentrate pesticides, pathogens, nutrients, and salts which are harmful to water quality. Measuring crop needs becomes paramount in an effort to avoid this harm (EPA, Point #6, 2005).

Killing pests and controlling weeds and fungus is accomplished through pesticides, herbicides, and fungicides. Runoff, wind transport, and atmospheric deposition can move these chemical from the plants they are intended to protect into the water supplies where they can kill fish and wildlife, poison food supplies, and destroy protective plant cover. Integrated Pest

Management (IPM) is a system of procedures used to manage pests while not harming the farm environment at the same time (EPA, Point #6, 2005).

Overgrazing by livestock can expose soils and increase erosion, thereby encouraging the growth of undesirable plant species. Erosion can degrade stream banks and destroy fish habitat. Keeping livestock out of sensitive areas and prevention of overgrazing are the first steps to take in erosion prevention (EPA, Point #6, 2005)

1.1.2. NPS Mitigation Efforts

While agriculture is widely thought to have significant impacts on water quality, no comprehensive national study of agriculture and water quality has been conducted. It is important to document the links between agriculture and water quality to help policymakers provide incentives to farmers for controlling pollution that originates on their farms (Ribaudo, *et al.*, 2006). Towards this effort, this dissertation examined four mitigation techniques: (1) Best Management Practices (BMPs), (2) Point source/nonpoint source (PS/NPS) trading, (3) Mechanism design theory, and (4) Entry-and-exit factors correlated with BMP adoption.

In order to mitigate the effects of dairy runoff into nearby water bodies, the farmer is encouraged to voluntarily adopt Best Management Practices (BMPs). BMPs may be highly effective in reducing runoff. However, the runoff may still exceed water quality standards (Clausen *et al*, 1989). Realizing that controlling pollution after it occurs is often expensive and possibly impractical, the emphasis is to prevent pollution from occurring in the first place by practicing everyday farming conduct in a more environmentally sensitive manner. BMP practices are designed to protect the environment and save the taxpayer money at the same time.

Another voluntary proposal to deal with agricultural pollution is point source (PS) and nonpoint source (NPS) trading between two firms that can reduce the total amount of pollution reaching a given watershed. When the nonpoint source is significant and the cost of its control is lower than the cost of additional point source controls, trading between the two firms can achieve an overall lowering of pollutants within the watershed (Feather *et al*., 1995).

PS/NPS trading is a policy that will allow point sources to avoid reducing their pollutants by purchasing loadings reductions from nearby nonpoint sources (Malik *et al.*, 1993). This dissertation will present a policy of PS-NPS pollution trading as an alternative to the most currently employed NPS policy solution of mainly cost-share reimbursement for pollution barrier construction in the effort to keep water sources unpolluted in Louisiana.

Mechanism design theory attempts to develop a system of rules along with compatible incentives to adhere to those rules such that a desired outcome will occur. The desired outcome in economics usually includes a goal of economic efficiency. In achieving the goal of NPS mitigation, efforts must be taken to eliminate the problem of free riders of economic resources. Therefore, the third mitigation effort in this research examines a mechanism that goes towards eliminating the free-rider problem and is known as continuous Vickrey-Clarke-Groves mechanism (cVCG). A fourth mitigation technique is to identify factors that lead to long-term adoption of BMP and therefore will enhance overall mitigation effectiveness. These factors are identified through the use of the Hazard model for farmers within the LDPR.

1.2. Rationale

The Tangipahoa River is 61 miles long and runs though the Louisiana dairy production region. Historically, the river provided ample recreational activity such as swimming, fishing, boating, and tubing. The Tangipahoa River was included on the 2004 Impaired Waterbodies list from high fecal coliform levels. These high levels come from municipal and individual wastewater treatment plants and dairy farms (Lake Pontchartrain Basin Foundation, 2005)

Dairy production yields manure as by-product that may harm the aquatic environment through three main types of vectors. First, manure can escape confinement facilities and pollute nearby water sources that are used for human consumption and enjoyment in recreational activities. Secondly, direct ambient air pollution occurs through leakage from the storage facilities. The pollutants eventually may precipitate into the water bodies. Finally, nutrient runoff and leaching reach surface waters when dairy manure is used for plant nutrients. Of these three externals, nutrient runoff and leaching and air quality problems (ammonia emissions) are the most common (Vukina, 2003). Therefore, the challenge of dairy manure management is to protect nearby water quality while obtaining: (1) maximum production benefits, while (2) subject to environmental constraints

1.3. Statement of Objectives

1. Determine the impact of dairy production on water quality in LDPR watersheds.
2. Estimate LDPR PS/NPS trading through simulation and explore the feasibility of obtaining the desired level of water quality in the study region.
3. Identify factors that lead to long-term adoption of BMPs

1.4. Chapter Outlines

This dissertation includes essays concerning pollution mitigation strategies for the LDPR. The first chapter is the overall introduction to the dissertation. The second chapter uses GIS modules to determine the least cost solution for N reduction for the entire LDPR. Data also are provided for P and sediment reduction, but the goal was to focus on N. Chapter three focuses on PS and NPS pollution data for a nutrient trading scenario. An aggregate basin analysis is created that is smaller than the whole LDPR. The area includes about a third of the to production area and is generally located in the northeast portion of the LDPR. The aggregate basin contains approximately 162 dairy farmers, six point sources, and two weather stations. The goal is to create a trading scenario where the PS finances a suite of BMPs for the NPS farmers in lieu of lowering their effluents. Since the abatement costs of the PS are much greater than for the NPS, trading will achieve a greater overall reduction of N and P than mandating that the PS only lower their effluents. As BMP introduction is voluntary on the part of the NPS farmers, such introduction must not be costly or adoption will not likely occur. The fourth chapter studies factors that encourage continued adoption of BMPs. The longer that a BMP is adopted and maintained, the greater is there a chance for mitigating effluents. The identification of dairy farmer characteristics that encourage longevity of adoption is accomplished through the use of the Hazard model focusing on entry-and-exit of BMP adoption. Chapter five presents the conclusion to the dissertation.

1.5. References

Clausen, J., and D. Meals.1989. "Water Quality Achievable with Agricultural Best Management Practices." Soil Conservation Service, USDA

Environmental Protection Agency.2005. "Managing Nonpoint Source Pollution from Agriculture." Pointer No. 6 EPA841-F-96-004
http://www.epa.gov/owow/nps/facts/point6.htm

Feather, P., and J. Cooper.1995."Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution." USDA/ERS Publications
Agricultural Information Bulletin No. 716

Innes, R.. 2000."The Economics of Livestock Waste and Its Regulation." *American Journal of Agricultural Economics* 82: 97-117

Lake Pontchartrain Basin Foundation.2005."Tangipahoa River Water Quality Improvement Project." Nomination for the 2005 Targeted Watershed Grant Program

Malik A., and D. Letson.1993. "Point/Nonpoint Source Trading of Pollution Abatement: Choosing the Right Trading Ratio." *American Journal of Agricultural Economics* 75:959-967

Rahelizatovo, N. 2002."Adoption of Best Management Practices by Louisiana Dairy Producers." Ph.D. dissertation, Louisiana State University,

Ribaudo, M., and R. Johansson.2006."Water Quality: Impacts of Agriculture." USDA/ERS Publications Agricultural Resources and Environmental Indicators,

Vukina, T. 2003."The Relationship between Contracting and Livestock Waste Pollution." *Review of Agricultural Economics.* 25: 66-88

Louisiana Dairy Farmer Location

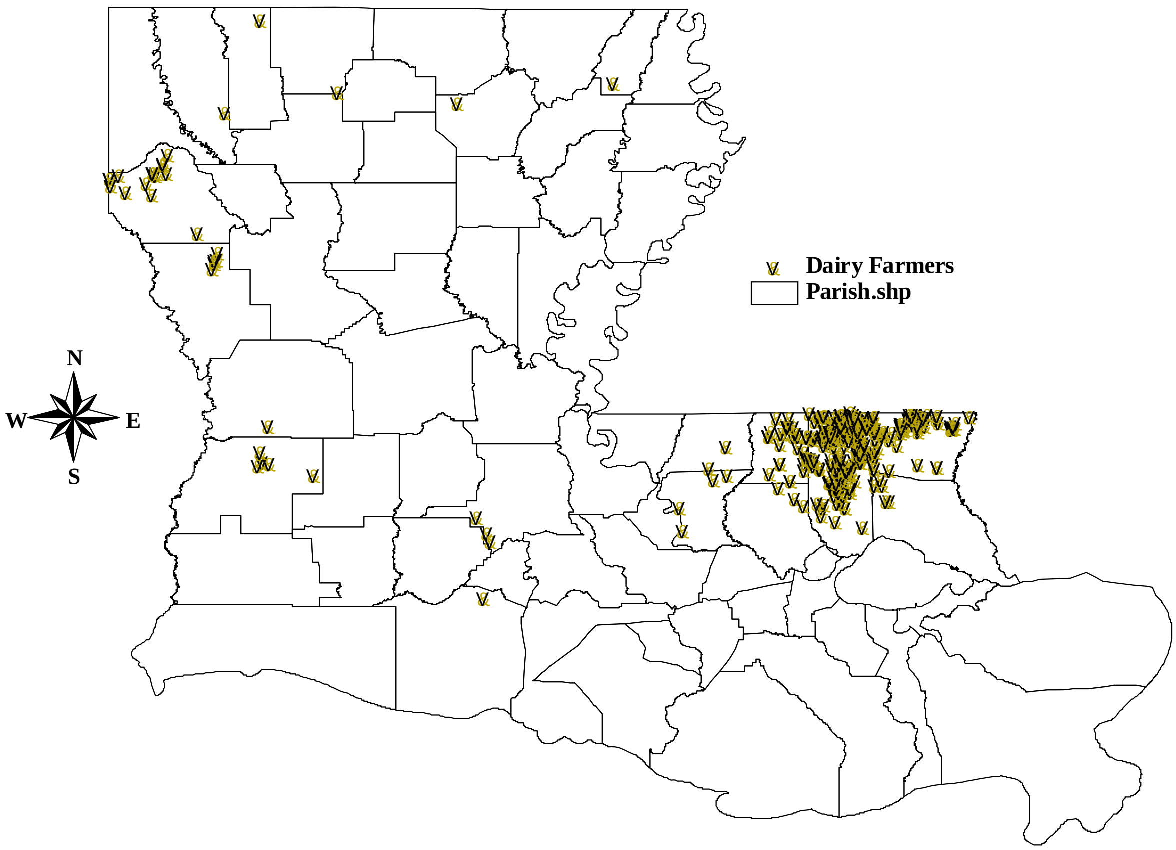


Figure 1.1. Location of Louisiana Dairy Farmers

CHAPTER 2
ESSAY 1

EFFECTIVENESS OF BEST MANAGEMENT PRACTICES (BMPs) TO REDUCE NUTRIENT POLLUTION IN THE LOUISIANA DAIRY PRODUCTION REGION

Dairy farms in Louisiana's Florida Parishes can be considered to be both point and nonpoint sources of pollution. Five southeast Louisiana parishes (Washington, St. Tammany, Tangipahoa, St. Helena, Livingston) contribute over 90% of the dairy products for the state. However, these farms also constitute a large potential threat to the water quality of the area from dairy manure. Nutrients such as nitrogen and phosphorus are necessary for plant growth but when these elements are applied improperly on cropland, they leach or runoff to nearby waterbodies While phosphorus may be required for plant growth, it also harms adjacent water quality through eutrophication if allowed to migrate into that water body. Eutrophication is recognized as the most ubiquitous water quality impairment in the United States (Sharpley et al., 2002). Nitrogen is a component of dairy manure and may also harm the local watershed if allowed to flow into nearby water bodies. Nitrogen inputs from fertilizers and manure used for crops or left as agricultural wastes are correlated with the high concentration of nitrogen found in streams near agricultural lands (Ribaudo et al., 2001).

The dairy production region contributes to the nitrogen load of nearby water bodies through manure application to land. Manure is a by-product of milk production. Excess nitrogen can pass through the soil layers and pollute the surface water as nitrate. Surface water pollution from groundwater is an important environmental problem since an estimated 30% of surface water stream flow originates from groundwater sources (Fleming et al., 1997). Once the surface waters are contaminated with elevated nutrients, eutrophication may occur. The dairy production region is mainly in five parishes in southeast Louisiana. The area's watershed contains several surface waters such as the Tangipahoa River, Ponchatoula River, and the Lower Tchefuncte River that all drain into Lake Ponchartrain and subsequently into the Gulf of Mexico. Hypoxia occurs when overnutrification (i.e., nitrogen and/or phosphorus compounds) enters a water body and is decomposed by microorganism such as bacteria and other chemical processes. The microorganisms subsequently die and the decomposition process uses oxygen. Nitrate (NO_3) is the main nitrogen based compound transported through the Mississippi river basin that is linked to hypoxia in the Gulf of Mexico (Burkart et al., 1999).

These processes use up large amounts of oxygen that kills aerobic organisms and forms a "Dead Zone." Hypoxic zones (<2.0 mg/l of dissolved oxygen) have been a dominant characteristic of the Gulf of Mexico. The hypoxic impacts are growing larger over time. The hypoxia zones that averaged 8,300 km^2 in 1985-1992 are now estimated to average 16,000 km^2 in 1993-2001 (Scavia et al., 2003). While there are numerous sources of nitrogen in the Mississippi basin such as municipal and industrial point sources, commercial fertilizer, septic systems, and atmospheric deposition, agricultural nonpoint sources (i.e., manure) are estimated to contribute 65% of the nitrogen pollution in the Gulf while point sources contribute 11%. (Ribaudo et al., 2001). Congress enacted the Harmful Algal Bloom and Hypoxia Research Control Act of 1988 to create an interagency task force to determine the causes and consequences of hypoxia in the Gulf of Mexico. The task force's goal was to develop a plan of action to reduce and control hypoxia in the Gulf. The resulting action plan determined that the primary goal was to reduce both point and nonpoint nutrient loads entering the Gulf to control hypoxia and improve overall water quality of the Mississippi basin. The types of pollutions resulting from agriculture are an important policy issue since they may cause serious environmental and health risks to society (Rejesus et al., 1999).

The objective of this chapter is to determine a suite of Best Management Practices (BMPs) that meets the goal of nitrogen reduction in waterbodies at the minimum cost. Our focus is on nitrogen, as Gulf of Mexico hypoxia problem is related to nitrogen pollution (Ribaudo et al., 2001; Scavia et al., 2003; Burkart et al., 1999). Additionally, 200,000 U.S. water supply records showed that more than two million people drank water exceeding federal nitrate standard. Over half of all U.S. community water wells are contaminated by nitrate pollution. Nitrate contamination can cause immediate health consequences such as methemoglobinemia and gastric cancer. We used a set of three interrelated Graphical Information Systems (GIS) software packages to identify the suite of best management practices that can reduce used along with local information pertaining to the Louisiana dairy production region to identify the suite of best management practices.

2.1. Literature Review

2.1.1. The Clean Water Act (CWA)

The main regulation governing water pollution within the United States is the Federal Water Pollution Act or Clean Water Act originally enacted in 1948 (Copeland, 2007). Revised and refined in 1972, The Clean Water Act (CWA) is an attempt to restore and maintain the chemical, physical, and biological composition of the nations' watersheds (EPA, 2003). The CWA had idealistic goals of "fishable and swimmable" waters by 1983 and "zero discharge" of pollutant by 1985. It provided for a national policy that required that the elimination of pollutant discharges and subsequent goals of protecting the fish, wildlife and recreational uses of those watersheds. These goals would be met by programs to control both point and nonpoint source pollutants. The states were recognized as having the primary right and responsibility for meeting these goals. The National Pollutant Discharge Elimination System (NPDES) is the primary mechanism used to achieve control of point source pollution. The Total Maximum Daily Load

(TMDL) guidelines where establish to designate a maximum concentration of a particular pollutant that would be allowed in a watershed before human health impairment was possible. An important feature of the TMDL program is that states have freedom in selecting among policy instruments to accomplish its goals (Horan et al., 2004). The CWA of 1972 mandated that each state develop and implement TMDLs by 1979, but this has not occurred in many areas of the country (King, 2005). Watersheds may or may not have TMDL levels designated depending on the state in which the watershed is located. The Clean Water Act contains two major provisions: (1) authorization of federal assistance for municipal sewage treatment plant construction, and (2) regulatory guidelines for industrial and municipal discharges. The act is considered a technology-forcing statue as those industries and municipalities regulated by the stature must achieve greater and greater abatement under deadlines specified by law. The earliest emphasis was placed on controlling conventional discharges such as solids while more recently emphasis is on toxic pollution discharges. The earliest efforts were also placed on point source discharges. Amendments to the act in 1987 broadened the scope by addressing nonpoint source pollution that now is estimated to be more than 50% of the nations water quality impairment problem. The federal jurisdiction to establish these standards is broad, particularly concerning effluent limits. The states are delegated certain responsibilities such as implementation of day-to-day enforcement activities. An overarching concept is that all pollution discharges are unlawful unless a permit has been granted for the discharge. The permit is the main enforcement tool and the law has civil, criminal and administrative aspects. The law also allows for citizen suit for enforcement.

PS emissions are largely identified and controlled in the U.S today. However, NPS continues to be a major pollution problem. NPS pollution is the number one source of pollution in our nation’s waterbodies and agriculture activities being the major contributor to the impairment of these waters (Dowd et al., 2008). NPS is also a recognized as a major pollution issue on other countries such as China (Wang et al., 2004). NPS pollution from agriculture may be of three forms: (1) excessive runoff of sediment, (2) nutrients, and (3) pesticides. When excess nutrients enter the water supply the problem of "overnutrification" occurs. "Overnutrification" of the nation's rivers, streams, lakes, and coastal areas such as the Gulf of Mexico is an increasingly serious problem (King and Kuch, 2003). PS pollution has been significantly addressed and monitored which leaves the problem of NPS to be solved. Surface waters may be polluted from the application of manures or fertilizers to cropland through: (1) direct runoff into drainage ditches or streams, (2) leaching into the groundwater that may percolate later into nearby surface water.

2.1.2.Best Management Practices (BMPs)

Best Management Practices (BMPs) are designed to minimize pollutant impacts on the nearby water bodies. Edwards et al., (1996) determined BMPs are effective in minimizing the impacts of confined animal operations and pastures treated with animal manure on such water bodies.

Extensive research has been conducted to determine what characteristics encourage BMP adoption. Greater levels of education levels have been consistently identified has having a positive relationship with adoption. In addition, other factors include having access to information (i.e., computer access), higher income levels, larger acres under farming, higher capital levels, greater diversity of farm operations, and access to labor to work on the farm all have a positive relationship with BMP adoption (Prokopy et al., 2008).

The CWA stipulates that individual states are responsible for controlling agricultural nonpoint pollution, the USDA installed both voluntary and mandatory policies to encourage farmers to adopt BMPs to address pollution issues. Voluntary policies use an incentive to encourage the farm operator to adopt less polluting technologies and have been the primary approach used to reduce nonpoint source pollution. For example, changes in timing and application rates of nitrogen and water may reduce nitrogen pollution with little profit loss (Johnson et al., 1991).

Other common voluntary methods to encourage farmers to adopt less polluting practices are cost sharing and incentive payments. Involuntary incentives force the farmer to use pollution-control methods through higher input costs or direct regulation. Taxes raise the price of an input to encourage less use and drive down pollution. Another involuntary method to reduce pollution is regulations. Direct regulation is the most common involuntary method and requires farm operators to meet minimum design standards for certain pollution technologies or minimum performance standards for emission levels.

Since sediments, nutrients, pesticides and other contaminates may be washed from agricultural land, various BMPs are designed to mitigate this threat to surface and groundwater. BMPs are practical ways to ensure that these risks to the environment are reduced without hampering economic productivity. Suggested BMPs for the dairy industry are shown in Appendix A.

BMPs are designed to reduce effluents getting into waterbodies so they are an important element of pollution prevention. The more a potentially harmful substance is used in agriculture, the more likely it is to negatively affect other parts of the environment. BMPs are tied most directly towards minimizing the loss of fertilizers, manures and pesticides from crop field.

Generic BMPs used with the GIS software package used in this research are shown in Appendix B. The BMPs used in this study is aligned with the BMPs that the Louisiana dairy farmers adopted (Table 2.1) in their farming practices according a dairy survey received from the farmers. Therefore, these BMPs were modified and more accurately address the BMPs commonly used in the dairy production region of Louisiana that are shown in Appendix C

2.1.3.Spatial Analysis and the Role of GIS in Environmental Economics

Until recently, most environmental economic applications of GIS has concerned hedonic property pricing analysis which try to explain house price variation in terms of observed differences in preferences for a particular attribute (Bateman et al., 2002). GIS also is used to automate and standardize spatial measurement such a road distance to assist in estimating travel cost assessments to nearby recreational sites. Recently, GIS is used to analyze environmental impacts such as the optimal riparian buffer used to sequester pollutant runoff into a lake. GIS is also used to analyze the targeting of conservation contracts in heterogeneous landscapes. These contracts are used to transfer payments from one party (usually the government) to another party (usually the landowner) in order to develop environment improvements such as improved water quality through conversion of agricultural land to forested land.

Computer models have been developed to estimate rainfall events and chemical transport effects on a watershed (Young et al., 1989). An example is the Agricultural Nonpoint Source (AGNPS) model developed by the Agricultural Research Service (ARS) to analyze and develop estimates of water runoff from a watershed. The model simulates water runoff, sediment, and nutrient transport within agricultural watersheds containing both point and nonpoint sources using hydrology, erosion, sediment and chemical transport coefficients.

BMP effectiveness on a watershed is not easily determined. A recent model, the Soil and Water Assessment Tool (SWAT) has been validated for flow, sediment and nutrient transport and has shown usefulness in such determination for both point and nonpoint sources in a large watershed (Santhi et al., 2001). Ancev (2003) found through use of the SWAT model that changing management practices such as preventing pasture overgrazing was effective in reducing phosphorus loading.

Future advances in computing power and enhancements to GIS software will allow more widespread study of environmental economics issues particularly concerning optimization. Srivastava et al. (2002) demonstrated a 56% reduction in pollutant load and a 109% increased net return by using a nonpoint pollution model named Annualized Agricultural Non-Point Source Pollution (AnnAGNPS) continuous watershed simulation model with an optimization algorithm.

2.2. Methods

Nonpoint source pollution is now recognized a major cause of water quality impairment. Identification of the source is often difficult to accomplish and monitoring such pollution in order to quantify levels is generally cost prohibitive. Consequently, simulation programs have been developed to estimate pollution loads at the watershed level. These watershed simulation models are now considered the essential tool used for estimating the sources and controlling sediment and nutrient loads entering surface waters.

Unfortunately, these models are difficult to utilize and require broad spatial and temporal scales encompassing tremendous amounts of data that must be identified, compiled, integrated, analyzed and interpreted. These simulation efforts have experienced significant improvements over the last several decades through the development of GIS technology. GIS software has been used extensively in state and federal applications and in hundreds of watershed applications.

The Pennsylvania Department of Environmental Protection (DEP) has recognized the used of GIS technology and has developed GIS based watershed application tools (Evan et al., 2003). One such application is the customized interface developed by Penn State is used to parameterize input data for the GWLF model.

This GIS application package is known as the ArcView Generalized Watershed Loading Function (AVGWLF) and is used to analyze the dairy production region of Louisiana. The data for AVGWLF are input in “layers” and is shown in Appendix E. AVGWLF was developed for

Total Maximum Daily Load (TMDL) project in the state of Pennsylvania and will be adapted for Louisiana watersheds. The procedure used for this initial research step will be to: (1) input environmental data (precipitation, animal density, vegetation, road types, etc.) for an "impaired" watershed using the AVGWLF module, (2) simulate the runoff effects of nutrient and sediment loads using the Generalized Watershed Loading Function (GWLF) module, (3) identify and implement pollution reduction strategies such as Best Management Practices (BMPs) to estimate an overall reduction in simulated pollution by using the Pollution Reduction Impact Comparison Tool (PRedICT), (4) make a policy recommendation for a cost effective approach for pollution reduction in the Louisiana dairy production region by using an optimization routine. A more detailed description of the AVGWLF, GWLF, and PRedICT packages is found in Appendix D.

The watershed simulation model used in lieu of cost prohibitive on-site monitoring is the GWLF module. This model simulated the runoff of sediment, nitrogen, and phosphorus loadings given the local environmental characteristics. This module also contains algorithms for calculating septic system loads and point source discharge information. GWLF in a continuous simulation module using daily time steps to analyze weather data and resulting water balance calculations. Daily water balance calculations are accumulated into monthly amounts that result in monthly sediment and nutrient load estimates.

The GWLF module uses a lumped parameter or combined distributed watershed model. The module is distributed in that it uses multiple land uses or land covering possibilities. However, each land area is assumed to be homogenous with respect to the environmental characteristics. There is no spatial routing in that the sources are not spatially distributed but are rather aggregated into a watershed total. Subsurface loadings are obtained by use of a lumped parameter approach and there are no distinct separate subsurface flow characteristics incorporated. Infiltration into the subsurface is the difference between precipitation and snowmelt minus evapotranspiration and surface runoff. Sediment and erosion movements are estimated using monthly erosion calculations based on cover crop and soil characteristics. A sediment delivery ratio is derived based on watershed size and a transport capacity determined from an average daily runoff is then applied to the erosion coefficient to arrive a sediment yield every source area. Dissolved nitrogen and phosphorus coefficients are use to determine surface nutrient losses from surface runoff. A sediment coefficient is applied to the yield portion for every agriculture source.

Discharges from point sources also contribute to dissolved losses are listed as kilograms per month. Manured areas can also be included as well as septic systems. Urban sources are listed as solid phase inputs and GWLF uses an exponential accumulation as well as a washoff function to account for these pollutants. Subsurface movements are determined by using dissolved N and P coefficients for shallow groundwater inputs to stream nutrient loadings using a lumped parameter approach.For our initial analysis, we choose a section of northern Tangipahoa Parish that included six subsection of the major watershed where a significant number of dairy farms within the parish are located. These six subsections then formed a basin aggregate (Basin Aggregate 1). Our initial efforts for the study then focused on the layers of information within Basin Aggregate 1. After developing and running a small “pilot plant” area such as Basin Aggregate 1, the entire five- parish dairy production region is analyzed.

After the layers for Basin Aggregate 1 are entered, the AVGWLF application is used to create input data files for subsequent use in the Generalized Watershed Loading Function (GWLF). This model simulates runoff, sediment, and nutrient (N and P) loadings from a watershed given the agricultural, forested, and developed land available. In addition, it contains algorithms to calculate septic system loads and point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance estimations. Daily water balance is accumulated into monthly amounts and these calculations result in sediment and nutrient loads.

These estimates are then loaded into the Pollution Reduction Impact Comparison Tool (PRedICT) to estimate BMP effectiveness. This model was developed for use in evaluating the implementation of agricultural and non-agricultural pollution reduction at the watershed level. The user can create scenarios for current versus future landscape conditions and pollution loads and predicts the reduction in pollution in the watershed on the different scenarios. BMP implementation for pollution reduction is enacted at this point. The BMPs in the PRedICT module are group into eight categories: cover crops, conservation tillage, conservation plans, agricultural to forest conversion, agricultural to wetland conversion, nutrient management, grazing land management, a user defined BMP

BMPs effectiveness is determined through the use of "reduction coefficients." BMP reduction coefficients are related to the percentage of N, P, and sediment that are prevented from reaching the nearby water bodies from the implementation and proper maintenance of a particular BMP. These coefficients where reviewed for validity by faculty at the Department of Agricultural Engineering at Louisiana State University. The BMP reduction coefficients were then incorporated into the PRedICT module in the Rural BMP Load Reduction Efficiency Editor and relevant costs associated with the relevant BMPs in the BMP cost editor. These BMP were modified in PRedICT to reflect the BMPs in actual use in the LDPR. For example, Cover and Green Manure is in use while Agricultural to Wetland Conversion is not in wide use in the LDPR.

2.3. Data and Study Area

Data were collected from a survey sent to all 344 Louisiana dairy farms using a mail survey following the tailored designed method (Dilman, 2000). The survey contained four sections:

Table 2.1. Information Related to BMP Adopters and Nonadopters Among Louisiana Dairy Producers Note: Adopted from Paudel et al., 2008

	Respondents		Adopters	
Cost-share BMPs	**Number**	**Percent**	**Number**	**Percent**
Waste Treatment Lagoon	46	94	31	67
Waste Storage Facility	38	78	14	37
Sediment Basin	40	82	14	35
Watering Facility	41	84	12	29
Field Borders and Filter Strips	41	84	10	24
Fence	43	88	9	21
Grassed Waterways	41	84	8	19
Cover and Green Manure Crop	42	86	7	17
Heavy use area protection	39	80	6	15
Critical Area Planting	38	78	4	11
Streambank and Shoreline Protection	41	84	4	10
Riparian Forest Buffer	41	84	3	7
Roof Runoff Management	40	82	1	2.5
Incentive Payment BMPs				
Residue Management or CTP	41	84	12	29
Nutrient Management	41	84	14	34
Pest Management	40	82	9	22
Prescribed Grazing	40	82	12	30
Waste Utilization	41	84	17	41

Dairy Manure Disposal, Milk Reduction Programs, Dairy Best Management Practices (BMPs) and Socio-Economic Characteristics of the Principal Operator

Surveys were mailed first on May 2004 and then follow up surveys were mailed again after three weeks. After two weeks of mailing the survey, a reminder post card was mailed to each individual whom the survey questionnaires were mailed. In addition, telephone contact attempts were made to encourage responses. Only 49 surveys were received for a response rate of 14.24%. The low response rate reflects several aspects of current dairy production. The industry is in decline in Louisiana and some farmers on the mailing list were either out of business or had retired. In conversation with the farmers, many expressed a feeling that they were being constantly survey and were tired of the process. Several farmers felt that nothing good ever came out of such surveys because the price for their milk just keeps falling.

The survey determined BMP adoption among farmers through the use of thirteen adoption questions. For example, waste treatment lagoons and cover and green manure crop participation rates were determined. If a BMP was not under current adoption, the farmer was asked to determine the level of total costs that he/she would pay to adopt.

Table 2.3 and Table 2.4 shows the effects of actual adoption rates found in Table 2.1 on estimated load reductions for both all 10 possible BMPs (Table 2.3) and using the actual rates on the low cost solution found through simulation. Table 2.4 shows the effect of using actual adoption rates in the low cost solution found through simulation in which the goal was to maximize N reduction for the minimum cost. Table 2.5 shows the effect on load reduction for the low cost solution.

Table 2.2. Estimated Load Reductions for Actual Adoption Rates

	Sediment (lbs)	Total N (lbs)	Total P (lbs)
Without Adoption	1,458,560,019	18,308,970	1,797,389
With Adoption	1,366,873,048	16,781,082	1,665,916
% Reduction	6.3	8.4	7.3
Cost of Adoption	$107,728,042.80		
Unit Cost ($) for one Pound Reduction	1.18	70.51	819.39

Table 2.2 shows that the current BMP usage that results in a 8.4% reduction in N for an estimated cost of $107,728,042.80 while the low cost solution will reduce N by 13.9% for a cost of $37,254,154.10 (Table 2.4). While the low cost solution with current BMP adoption will cost only $27,328,143.50, the N reduction will be lower also at 6.6% (Table 2.3)

Table 2.3. Estimated Load Reductions w/ Low Cost Solution with Actual Adoption Rates

	Sediment (lbs)	Total N (lbs)	Total P (lbs)
Without Adoption	1,458,560,019	18,308,970	1,797,389
With Adoption	1,372,584,646	17,094,833	1,711,515
% Reduction	5.9	6.6	4.8
Cost of Adoption	$27,328,143.50		
Unit Cost ($) for one Pound Reduction	0.32	22.51	318.24

Table 2.4. Estimated Load Reductions for Low Cost Solution

	Sediment (lbs)	Total N (lbs)	Total P (lbs)
Without Adoption	1,458,560,019	18,308,970	1,797,389
With Adoption	1,373,081,480	15,758,117	1,641,166
% Reduction	5.9	13.9	8.7
Cost of Adoption	$37,254,154.10		
Unit Cost ($) for one Pound Reduction	0.44	14.60	238.47

2.4. Results and Discussion

The PRedICT model was run 199 times in an attempt to estimate the greatest reduction of nitrogen for the least cost solution. The total study area contained 2,107,125 acres and was given the name “Big Basin.” Within this area were 109,648 acres of row crops and 517,058 acres of pastureland. Nitrogen is selected as the primary pollutant for reduction because it is considered the major chemical contributing to water pollution from dairy manure as well as to the welldocumented “dead zone” in the Gulf of Mexico. Reduction of phosphorus was also desired but secondary to nitrogen. The reduction of sediment is also a desired outcome but behind the two major chemical pollutants, nitrogen and phosphorus. Therefore, the main goal was to maximize the reduction of nitrogen at the minimum cost. The reductions of phosphorus and sediment where regarded as secondary and tertiary goals, respectively.

The process involved selecting alternative BMPs that minimized nitrogen effluents. Several different combinations of BMPs were adopted on pasture/crop land at various amounts ranging from zero to 100 percent. The percentage adopted means that a specified amount of area was adopted for that particular BMP. For example, as 109,648 acres of row crops where possible for planting in the entire basin aggregate, a 100% adoption of a BMP means that the entire 109,648 acres of row crops is impacted by the BMP adoption. The BMPs adopted were not mutually exclusive such that adopting 100 percent of one BMP does not exclude other BMPs from adoption.

The least cost solution occurred on run number 199 by keeping an eye on nitrogen and experimenting with each BMP. The total cost was $37,254,154.10 that produced a 13.9% reduction in nitrogen. Phosphorus reduction was 8.7% and sediment reduction was 5.9%. These reductions represent 2,550,853 pounds of N, and 156,223 pounds of P, and 85,478,539 pounds of sediment. The solution occurred with seven BMPs out of a possible ten. Crop BMP #1 (cover and green manure) was 10%, Crop BMP #2 (conservation tillage) was 0%, Crop BMP #3 (riparian buffer) was 10%, Crop BMP #5 (critical planting area) was 5%, Crop BMP #6 (nutrient management) was 75%, Pasture BMP #5 (critical planting area) was 0%, Pasture BMP #6 (nutrient management) was 100%, Pasture BMP #7 (prescribed grazing) was 0%. Vegetative buffer was 185 miles and the Fence buffer was 100 miles. Both Crop BMP #4 (forest to agriculture conversion) and Pasture BMP # (terraces and diversions) were not applicable. Forest to Agriculture conversion was considered too expensive at #15,000 per acre and terraces and diversion was not applicable for the LDPR geographical area. While a greater amount of nitrogen reduction was gained in run number 182 with a 14% reduction, the cost was over $40 million to achieve the reduction. Since sediment reduced by 10.5% and P by 8.9% for this cost, management may determine that the extra expenditure is worthwhile. However, staying with N as the primary chemical for reduction, run number 199 is chosen. Given the fact that multiple combination of best management practices are possible to be adopted in the whole watershed basin at several combinations, an exhaustive list is impossible to come up. However, these results show some guidelines on how to reduce nutrient pollution at the minimum cost.

The actual BMPs in use costs $107,728,042.80 for a N reduction of 8.4% versus $37,254,154.10 for a 13.9% reduction for the low cost solution of simulation. In contrast, the estimated load reduction for actual usage using the low cost solution is $27,328,143.50 with only a 6.6% N reduction. Therefore, the BMPs currently in adoption cost almost three times ($107,728,042.80 vs $37,254,154.10) as much as the low cost solution with an actual decrease in N reduction (8.4% vs 13.9%). While a usage of the current rates in the low cost solution would bring a decrease of cost ($27,328,143.50 vs $37,254,154.10) it would also bring a decrease of N reduction (6.6 vs 13.9).The low cost solution yielded a cost of $14.60 per pound of N reduced versus a cost of $70.51per pound of N reduced for the currently adopted BMP suite.

Cost figures for reducing pollutants in the LPDR are found in figure 2.1. Unit cost data for sediment, N and P are found in figures 2.2., 2.3,, and 2.4. Descriptive statistics for N, P, and sediment are found in Table 2.1.The SAS code for this chapter is available in Appendix G.

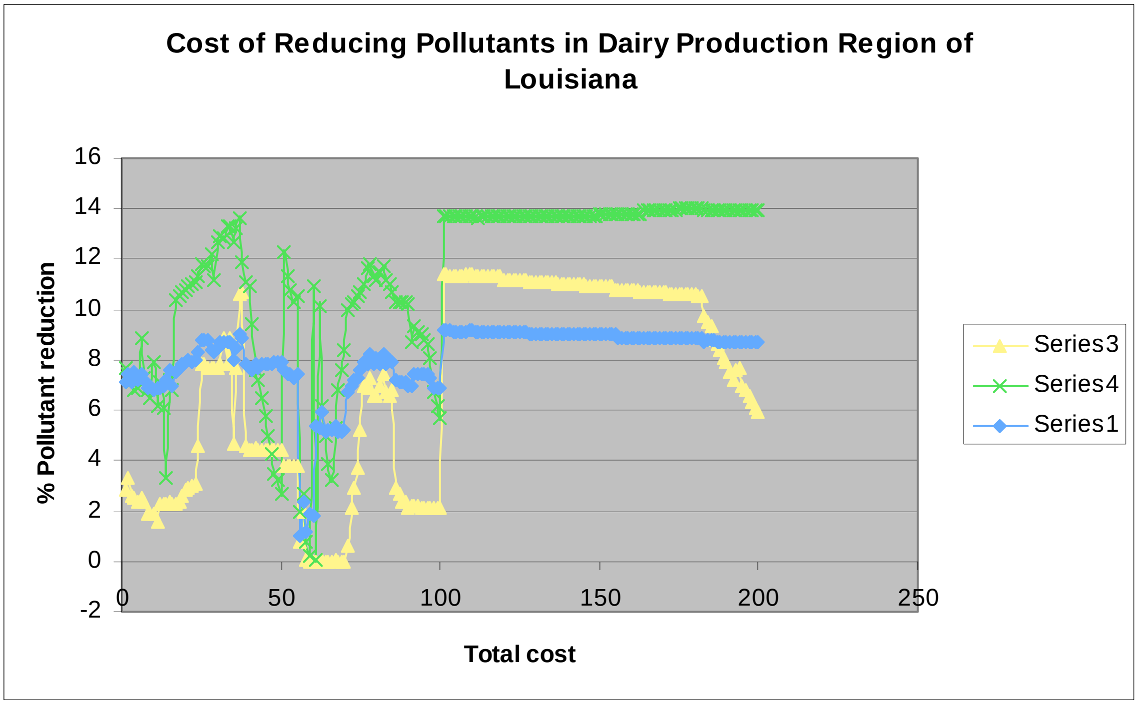


Figure 2.1. Cost of Reducing Pollutants in Dairy Production Region of Louisiana (Series 3 = Sediment; Series 4 = N; Series 1 = Phosphorus)

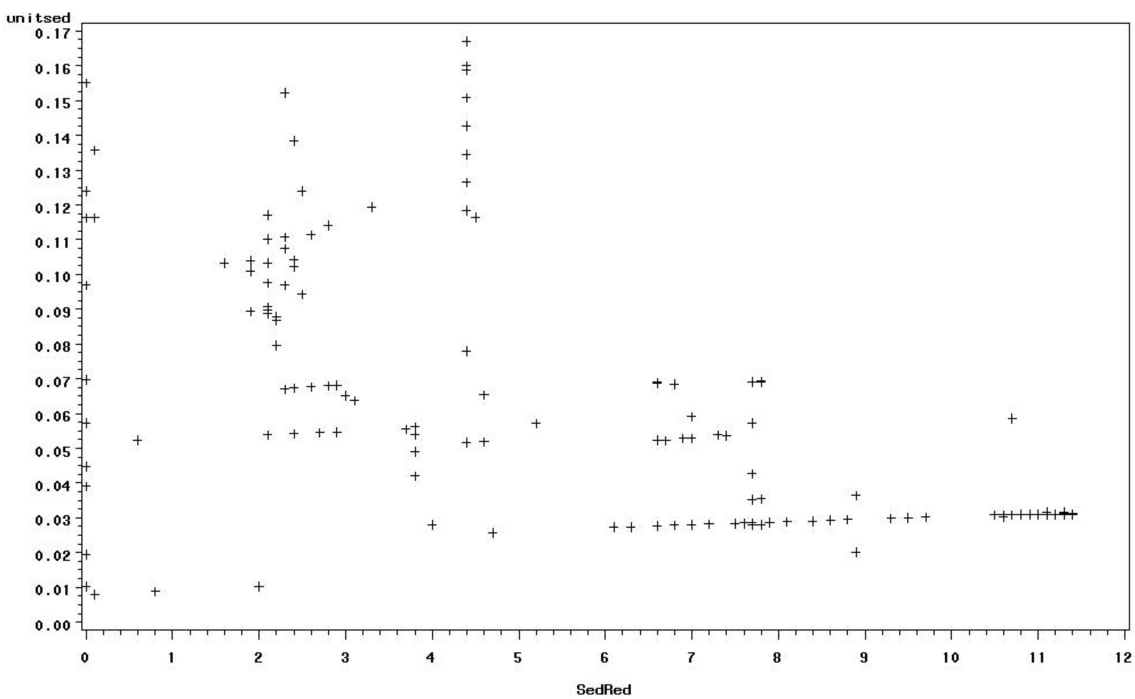


Figure 2.2. Unit Cost of Reducing Sediment in the LDPR (x-axis: percentage of sediment reduce, y-axis: unit cost to reduce one pound of sediment from the watershed)

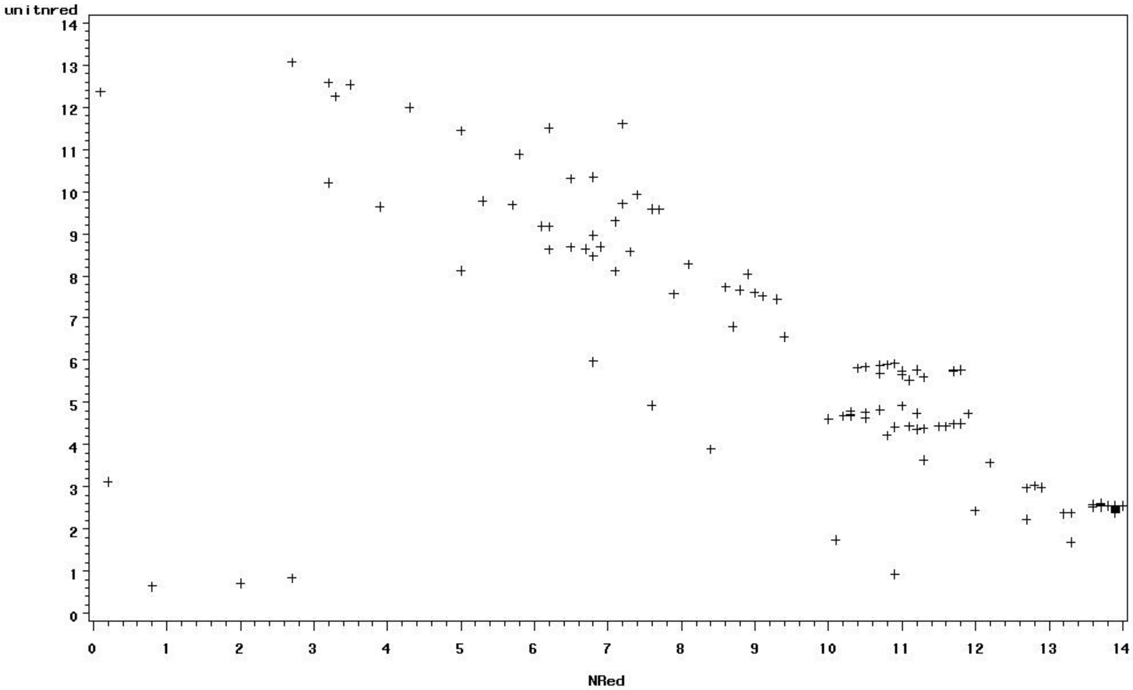


Figure 2.3. Unit Cost of Reducing N in the LDPR (x-axis: percentage of N reduction, Y-axis: cost per pound of N reduction in the watershed)

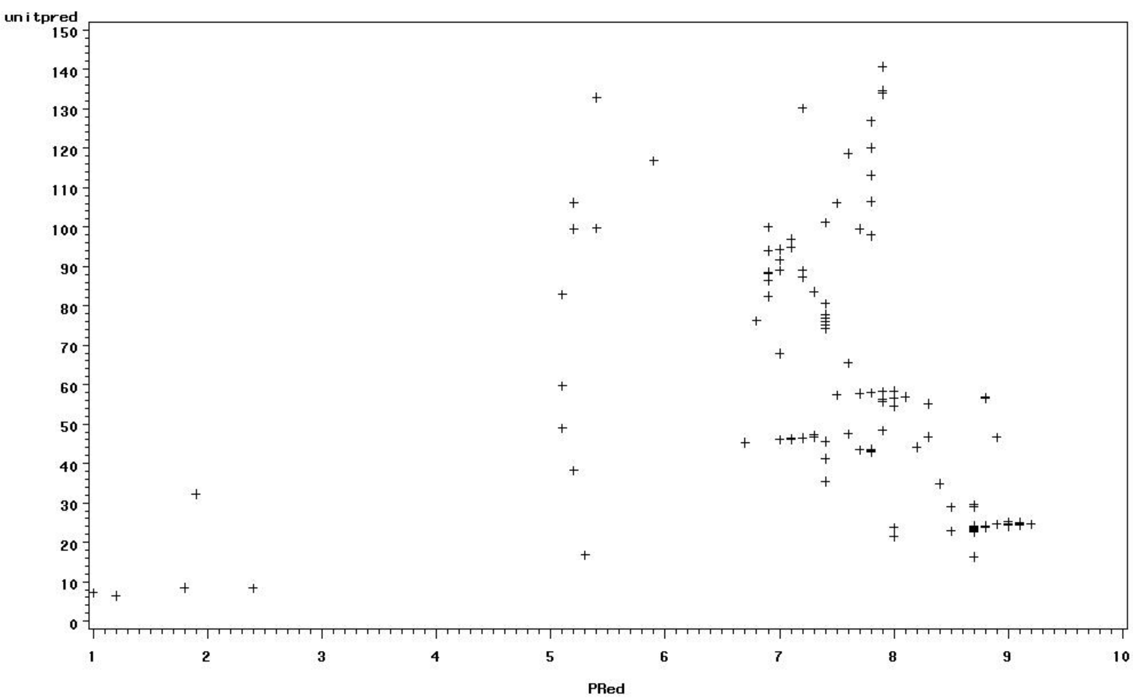


Figure 2.4. Unit Cost of Reducing P in the LDPR (x-axis: percentage of P reduction, y-axis: cost per pound of P reduction in the watershed)

Table 2.5. **Descriptive Statistics on Sediment, Phosphorus and N Reduction in the LDPR**

Variables	N	Mean	Std. Dev.	Min	Max
SedRed	199	7.041256	3.975596	0.001	11.4
NRed	199	11.25075	3.392473	0.1	14
PRed	199	8.039196	1.431031	1	9.2
Cost	199	74339830	51636063	11614358	2.33E+08
Cost in Million	199	74.33983	51.63606	11.61436	232.8718
Initial Sediment	199	1.46E+09	0	1.46E+09	1.46E+09
Initial Nitrogen	199	18308970	0	18308970	18308970
Initial Phosphorus	199	1797389	0	1797389	1797389
Area in Acres of LDPR	199	2107125	0	2107125	2107125
Unit Cost of Reducing Sediment	199	0.053847	0.035568	0.007971	0.167007
Unit Cost of Reducing N	199	4.487428	2.915506	0.639469	13.07195
Unit Cost of Reducing P	199	44.81203	30.77871	6.540278	140.6745
Cost per acre	199	35.28022	24.50546	5.511945	110.5164

2.5. Conclusions

Several biophysical simulation packages are available to assess the effect of alternative best management practices (BMPs) on reducing pollution. The use of a GIS-based simulation package is a recent development in environmental economics literature. In this study we did an analysis of the effect of BMP adoption on N, P, and sediment reduction in the Louisiana dairy production region (LDPR). This area is located in the southeast portion of the state and is located in a watershed that drains into Lake Ponchartrain, the largest lake in the state and located directly north of New Orleans. Three interrelated GIS software modules are used to determine BMP effectiveness. An area in the LPDR watershed is first designated for analysis. Basins may be analyzed individually or aggregated. Data "layers " of weather, farm animal load estimation, typographical features such as paved and unpaved roads, pasture land, forests, row crops, and point source data are entered into the AVGWLF module for load estimation. Next, the GWLF module estimates dissolved and total nitrogen and phosphorus loads in stream flow for the designated basin or basin aggregate through loading functions. Both groundwater and surface flows, point sources, and septic systems are used in the calculation. Water quality data is not needed for calibration. Annual estimate load reduction estimates are generated in report form.. The selected basin area produces total sediment, total N, and total P from upland erosion (row crops, hay or pasture land, high density urban, low density urban, and unpaved roads), and stream bank erosion. Only total N and P loads are needed for groundwater/subsurface, point source discharge, and septic systems. The aggregate load for sediment, N, and P along with the total basin area in acres or hectares is then available. The load data is then transferred to the PRedICT module for BMP effectiveness estimation. BMP effectiveness is determined through dairy specific BMPs with reduction coefficient estimates along with cost data. BMPs generally have different levels of effectiveness and different level of costs. In this study, the lowest cost suite of BMPs for the entire LDPR produced a reduction of 13.9% in N, 8.7% reduction of P, and a 5.9% reduction of sediment for a cost of $37,254,154.10 when nitrogen was the parameter of concern. Seven BMPs where adopted with the nutrient management BMP being the most heavily adopted (100% for pasture use and 75% for row crop implementation). Vegetated buffers for stream bank (185 miles) and stream bank fencing (100 miles) were both employed in the lowest cost solution. The low cost solution yielded a cost of $14.60 per pound of N reduced versus a cost of $70.51 per pound of N reduced for the currently adopted BMP suite showing a significant cost saving for adopting the low cost solution suite of BMPs.

2.6. References

Ancev, T. 2003. “Optimal Allocation of Waste Management Practices with Economic Implications for Policies to Regulate Phosphorus Pollution in the Eucha-Spavinaw Watershed.” Dissertation. Oklahoma State University

Bateman, I.J., Jones, A.P., Lovett, A.A., Lake, I.R., and B.H. Day.2002. “Applying Geographical Information Systems (GIS) to Environmental and Resource Economics.” *Environmental and Resource Economics* 22:219-269

Burkart, M.R., and D.E. James.1999. “Agricultural-Nitrogen Contributions to Hypoxia in the Gulf of Mexico.” *Journal of Environmental Quality* 28:850-859

Copeland, C.2007.“Clean Water Act: A Summary of the Law”, *CRS Report to Congress,* Congressional Research Service

Dowd, B., D. Press, and M. Los Huertos. 2008. “Agricultural Nonpoint Source Pollution Policy: The Case of California’s Central Coast.” *Agriculture, Ecosystems, and Environment.* 128:151-161

EPA point source permit web address:
http://www.epa.gov/enviro/html/pcs/pcs_query.html

Edwards, D.R., Daniel T.C., Scott, H.D., Murdoch, J.F., Habiger, M.J., and H.M. Burks. 1996. “Stream Quality Impacts of Best Management Practices in a Northwestern Arkansas Basin.” *Water Resources Bulletin* 32:499-509

Environmental Protection Agency. 2003. “Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Implementing Guidance.”

Environmental Protection Agency. 2003. “Water Quality Trading Policy” Office of Water.

Environmental Protection Agency. 2003. “Elements of a State Water Monitoring and Assessment Program.” Assessment and Watershed Protection Division, Office of Wetlands, Ocean and Watersheds. EPA-841-B-03-003

Evans, B., Lehning, D., Borisova, T., Corradini, K, Sheeder, S.,and W. Brown. 2003.
AVGWLF, GWLF, and PRedICT Manuals
Penn State Institute of the Environment
The Pennsylvania State University

Feather, P. and J. Cooper. 2006.“Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution” Accessed from the web Http://www.ers.usda.gov

Fleming, R.A. and R.M. Adams. 1997. “The Importance of Site-Specific Information in the Design of Policies to Control Pollution.” *Journal of Environmental Economics* 33:347-358

Hilliard, C and Reedyk.2006. S “Agricultural Best Management Practices”
Accessed from the web http://www.agr.gc.ca/pfra/water/agribtm_e.htm

Horan, R.D., Shortle,J.S. and D. G. Abler. 2004. “The Coordination and Design of Point-Nonpoint Trading Programs and Agri-Environmental Policies.” *Agricultural and Resource Economics Review*. 33(1):61-78
Johnson, S.L., Adams, R.M., and G.M. Perry. 1991. “The On-Farm Costs of Reducing Groundwater Pollution.” *American Agricultural Economics Association* 73:1063-1073

King, D., 2005. “Crunch Time for Water Quality Trading” Choices. 20(1):71-75

King, D., and P. Kuch. 2003. "Will Nutrient Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles." *Environmental Law Reporter*. 33(5):10352-10368

Knapp, K., and K. Schwabe. 2008. "Spatial Dynamics of Water and Nitrogen Management in Irrigated Agriculture." *American Journal of Agricultural Economics* 90:524-539

LSU AgCenter/USDA/NRCS.2002. "Dairy Production Best Management Practices (BMPs)."

The New Palgrave Dictionary of Economics Online. Palgrave Macmillan. http://www.dictionaryofeconomics.com/article?id=pde2008_G000184

Overman, H. G.2008. "GIS Data in Economics." *The New Palgrave Dictionary of Economics. Second Edition.* Eds. Steven N. Durlauf and Lawrence E. Blume. Palgrave Macmillan, 2008.

Paudel, K.P., Gauthier, W..M., Westra, J.V., and L.M. Hall. 2008. "Factors Influencing and Steps Leading to the Adoption of Best Management Practices by Louisiana Dairy Farmers. *Journal of Agricultural and Applied Economics* 40:203-222

Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., and A. Baumgart-Getz. 2008. "Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature." *Journal of Soil and Water Conservation.* 63:300-311

Rejesus, R. M., and R.H. Hornbaker. 1999. "Economic and Environmental Evaluation of Alternative Pollution—Reducing Nitrogen Management Practices in Central Illinois." *Agriculture, Ecosystems and Environment* 75:41-53

Ribaudo, M.O., Heimlich, R., Claassen, R, and M. Peters. 2001. "Least-Cost Management of Nonpoint Source Pollution: Source Reduction Versus Interception Strategies for Controlling Nitrogen Loss in the Mississippi Basin." *Ecological Economics* 37:183-197

Ribaudo, M., R. Heimlich, and M. Peters. 2005. "Nitrogen Sources and Gulf Hypoxia: Potential for Environmental Credit Trading." *Ecological Economics*. 52:159-168

Santhi, C., Arnold, J.G., Williams, J.R., Hauck, L.M., and W.A. Dugas. 2001. "Application of a Watershed Model to Evaluate Management Effects on Point and Nonpoint Source Pollution." *Transactions of the American Society of Agricultural Engineers*. 44:1559-1570

Scavia, D., Rabalais, N., Turner, R.E., Justic, D., and W. Wiseman. 2003. "Predicting the Response of Gulf of Mexico Hypoxia to Variations in Mississippi River Nitrogen Load." *Limnology and Oceanography* 48:951-957

Sharpley, A.N., Kleinman, P.J.A., McDowell, R.W., Gitau, M. and R.B. Bryant. 2002. "Modeling Phosphorus Transport in Agricultural Watersheds: Processes and Possibilities." *Journal of Soil and Water Conservation* 57:425-439

Srivastava, P., Hamlet, J.M., Robillard, P.D., and R.L. Day. 2002. "Watershed Optimization of Best Management Practices Using AnnAGNPS and a Genetic Algorithm." *Water Resources Research* 38:1-14

Young, R.A., Onstad, C.A., Bosch, D.D., and W.P. Anderson. 1989. "AGNPS: A Nonpoint-Source Pollution Model for Evaluating Agricultural Watersheds." 53:168-173

Wang, X., W. Zhang, Y. Huang, and S. Li. 2004. "Modeling and Simulation of Point-NonPoint Source Effluent Trading in Taihu Lake Areas: Perspective of Nonpoint Sources Control in China." *Science of the Total Environment.* 325:39-50

CHAPTER 3
ESSAY 2

POINT SOURCE AND NONPOINT SOURCE WATER POLLUTION TRADING PROGRAMS: A REVIEW OF RECENT RESEARCH WITH APPLICATION TO THE DAIRY PRODUCTION REGION OF LOUISIANA

Pollution from nonpoint sources continues to be the major contributor to the impairment of our nations watersheds (Dowd et al., 2008). Advances in market based approaches promises to achieve cleaner water at a lower cost when compared to traditional command-and-control attempts. Water quality trading is a market-based approach that may achieve desired water quality standards at a more economically efficient and thereby lower cost level than traditional approaches (EPA, 2007). For example, effluent trading is being considered for nearly a dozen watersheds as an alternative to meeting nutrient concentration standards since upgrading treatment at local municipal sewage facilities is viewed as prohibitively expensive (Lankoski et al., 2008). Water quality trading may occur between point source PS and PS, between PS and nonpoint source NPS, and between NPS and NPS. This chapter reviews the NPS pollution issue, successful effluent trading programs, recent research into PS/NPS trading to identify successes, and failures and associated shortcomings and the possible application of PS/NPS trading to solve the NPS pollution issue in Louisiana's dairy production region.

The EPA believes that PS/NPS trading offers greater efficiency for meeting the CWA requirements than traditional approaches by allowing a polluting source to meet its regulatory obligations by purchasing credits created by a polluting source with lower control costs. Therefore, trading utilizes economies of scale and control cost differentials between pollutant sources to reach a more economically efficient solution. The EPA Trading Policy lists the following components for a trading program to be credible and successful (EPA, 2003):

1. Legal authorities and mechanisms for trading to occur.
2. Clearly defined units of trade.
3. Creation and duration of credits.
4. Quantifying credits and addressing uncertainty.
5. Compliance and enforcement provisions.
6. Public participation and access to information
7. Periodic program evaluation.

We develop a point-nonpoint source trading model with emphasis on these seven points. It is expected that point/nonpoint source trading will be able to reduce effluents in waterbodies at a lower cost to the public than would be if alternative methods such as BMPs only is used in reducing nonpoint source pollution.

3.1. Literature Review

Since the success of SO2 trading in air pollution mitigation, increased emphasis has been placed on PS/NPS trading as a policy to mitigate water pollution. In addition, this policy hopes to create a more economically efficient solution compared to traditional command-and-control approaches. Trading has been discussed for almost a dozen watersheds (Lankoski et al., 2008). Three water quality trading programs that have been implemented over the past decade are Tar-Pamlico (NC), Cherry Creek (CO), and Fox River Basin (WI) (Horan et al., 2005) Water Quality Trading (WQT), also known as nutrient trading, has been growing in interest as a solution to NPS for three reasons: (1) the idea is catching on because of the success of SO2 trading, (2) The EPA's emphasis on TMDL programs that can be used to capture loading limits for watersheds, and (3) the changing dynamics of the U.S. water pollution problem. Where PS was considered the main pollution problem in the past, NPS now is the major contributor to the U.S. water pollution problem because of the success of the NPDES program for controlling PS pollution. (Woodward, et al., 2002).

While a conventional market may need only a buyer and a seller for a successful trade, nutrient trading has three groups of participants:(1) willing buyers, (2) willing sellers, and (3) trade regulators willing to approve the trade validity (King and Kuch, 2003). After these necessary conditions for trading are in place, PS/NPS trading can proceed in two ways: (1) Emissions for Inputs (E-I), or (2) Emissions for Loadings (E-LO) (Dowd et al., 2008). The E-I system is when polluters trade changes in PS emissions for changes in fertilizer or management practices. For example, selecting feed that produces manure with lower nitrogen content. The E-LO system trades PS emissions for reductions in NPS nutrient loadings that are estimated by a simulation model. Research in the Louisiana dairy production region will use the E-LO procedure to calculate nutrient loadings by using GIS simulation models, ArcView Generalized Watershed Loading Function (AVGWLF), Generalized Watershed Loading Function (GWLF), and the Pollution Reduction Impact Comparison Tool (PRedICT) (Evans et al., 2003). Estimates of nutrient loading from simulation are used in lieu of actual water sampling because of cost considerations.

The most significant factor influencing the demand for credits will be the cap on further emissions. If there is no cap, there will be no demand for credits. If there is a cap in place, the demand for credits from the PS depends on the difference between the cost of additional on-site waste treatment and the cost of buying enough NPS credits to offset additional discharges (King and Kuch, 2003). The purchased credits will be determined from the trading ratio and the associated transaction costs. The economic reason that a PS polluter would trade for a pollution credit from a NPS polluter is that it is cost effective to make the trade. The marginal cost of abatement for the next unit of PS abatement should be greater that the marginal cost of abatement for the next unit of NPS abatement. The cost of marginal abatement for PS control becomes increasingly expensive as the PS experiences diminishing reduction with additional abatement. For example, the cost of a PS reduction is estimated to be up to 65 times greater than a NPS reduction and substituting tertiary water treatment with agricultural NPS reduction may save the U.S. up to $15 billion (Fang, et al., 2005).

The supply of nutrient credits by the NPS polluter is determined by the baseline below which valid credits are issued (King and Kuch, 2003). Nutrient management practices for which the farmer has already been paid or required by state law (i.e., TMDLs) may already achieve a certain level or baseline of abatement. The NPS should not be paid twice for the same abatement. The costs of reducing edge-of-farm pollution will increase as more discharges are eliminated. Therefore, credits will become increasingly expensive to generate. The costs of a marketable credit will include transactions costs and on-farm treatment costs each of which will affect credit supply.

3.1.1 Basics of Nutrient Credit Trading

In conventional markets, the trading activity tends to be self-governing as willing buyers and willing sellers compete and negotiate with each other to obtain the best trade concerning price and quantity (King and Kuch, 2003). In these markets, trade negotiators rarely impose quality control measures since buyers are aware of quality standards that they are willing to accept before the purchase. However, the environmental credit market is very different. Buyers are neither knowledgeable nor particularly concerned about the underlying quality of the credit. The regulator is concerned about the quality of credit instead of the buyer. Demand is created by regulatory requirements that create “credit seekers” when caps are imposed on PS polluters. Supply is created when regulators validate that management activities or structures reduce pollutant loadings. Buyers want to minimize the cost of purchasing an offset credit and sellers want to minimize the cost of producing the credit. Quality of the credit is not important to either buyer or seller. The regulator is solely concerned with quality. Therefore, the trade concerns three parties: buyers, sellers, and regulators. This structure leads to "gaming behavior" that is almost completely absent from conventional markets as buyers and sellers may align with each other in an effort to buy and sell credits at the lowest cost possible. Only the regulator is concerned if the credit actually reduces loading for the amount corresponding to what is written on the NPDES permit and estimated in the BMP design.

3.1.2.Types of Trading

While conventional goods usually operate in recognized markets structures (i.e., food stores, auctions), the market structure for nutrient trading is still evolving (King and Kuch, 2003). The market structure for WQT may be classified according to the following: (1) exchanges, (2) clearing houses, (3) bilateral negotiations, and (4) sole-source offsets (Woodward et al., 2002). Exchanges like the New York exchange is the textbook idea for this type of structure. Open information and fluid transactions between buyers and sellers are characteristics. Prices are common knowledge and there is a unique market-clearing price. Transactions costs are small and transactions are easily accomplished. Uniformity of goods is a major characteristic.

Bilateral negotiations are characterized by substantial interaction between buyer and seller. An example is a used car market where there is not an exact substitute for any one car. No two cars have the same mileage, maintenance, or repair history. Buyers generally do not have such have such detailed information and therefore arrive at an agreed upon selling price through negotiation. Transaction cost such as information, contracting and enforcement are higher than in an exchange. However, bilateral negotiations strength is in allowing a trade of a non-uniform good that would not be possible on an exchange and is the most common structure in WQT markets.

A clearinghouse is a structure where the link between buyer and seller is severed and are linked instead through the actions of an intermediary. A meat distributor that buys product from many suppliers at different grades and prices yet sells the meat at uniform prices for particular grades. The distributor converts various price and quality into uniform standards. For WQT, an oversight agency allows the clearinghouse to pay for pollution reductions and then sell the uniform credits to buyers needing to exceed their allowances. A key feature of clearinghouses is that state law must be written to authorize a state agency or some other legal enterprise to act as the clearinghouse to allow this structure to function. An example of this structure is the Tar Pamlico Basin in North Carolina where PS and agricultural NPS trading occur through a clearinghouse. Farmers are paid a cost-share of 75% for BMP implementation to reduce runoff of nitrogen and phosphorus. PS facilities then buy fixed priced credits based on the average cost to reduce loadings. Clearinghouses are able to reduce transaction costs compared to bilateral exchanges through three methods: (1) information costs are less since both buyer and seller deal with only one party, the clearinghouse, (2) Regulators accept the price of credits which reduces uncertainty, and (3) since the credit price is known, bargaining and negotiation costs are reduced. When a degree of uniformity is achieved for the buyers of credits, the clearinghouse is particularly useful. However, operation costs such as establishing uniformity of credits and review and completion of trades may be greater than transaction costs of a bilateral trade structure.

The sole-source offset structure may not involve trading at all. In WQT, a sole-source offset in when a facility is allowed to increase pollution at one component if it lowers pollution by an equal or greater amount at another component either on site or by carrying out the pollution reduction activities off site. As only one party is involved, the responsibility to achieve the offsets rests with that party. This structure is not appropriate for the Louisiana dairy production region.

3.1.3. Capturing Uncertainty through Trading Ratios

A significant challenge to PS/NPS trading is to capture the variability of NPS nutrient loadings while PS are considered certain through monitoring (Hennessy and Feng, 2008). The nature of the pollutant (i.e., uniformly mix or not uniformly mixed) will have an impact on the design of a trading system (Hung and Shaw, 2005). A method used in attempting to estimate with accuracy NPS loadings is the use of trading ratios. Trading ratios are used to capture the uncertainty associated with NPS loadings (Farrow et al., 2005). Another consideration is permits. When the number of permits is large and exogenously determined, then larger ratios are likely to occur (Horan et al., 2005). For an economically efficient solution, the trading ratio should capture the relative expected marginal environmental damage from each source, the uncertainty created by each source from an estimate of this damage, and the relative transaction costs of a trade between sources (Horan and Shortle, 2005). Most real world PS/NPS trading will not be economically efficient with a trading ratio of 1:1 where one unit (pound) of NPS credit exactly equals one unit of PS reduction. The process is similar to trading for a particular product for a service. A pound of emission is allowed by the PS (the product) in exchange for the agreement of the NPS to adopt a practice that will generate a pound of nutrient loading reduction (the service) (King and Kuch, 2003). In addition to recognizing that a 1:1 trade will not improve the overall water quality, most pollution trading is not generated on a “one pollutant pound-to-one pollutant credit” basis (EPA, 2007). A trading ratio is used in recognition that uncertainties exist with NPS reductions. While it is easy to estimate a PS reduction by monitoring end-of-pipe emissions with monitoring, estimates of NPS reduction is subject to various uncertainties. A trading ratio of 3:1 would require the PS buy three credits (pounds) at the NPS site in lieu of one pound of reduction at the

PS site. There is not a set limit for the ratio as ratios depend on specific circumstances existing the particular watershed. PS/NPS trading ratios are influenced by environmental conditions and water quality goals. The basic categories of trading ratios that go into the overall trading ratio calculation is: (1) delivery, (2) location, (3) equivalency, (4) retirement, and (5) uncertainty. A delivery ratio accounts for the distance and unique characteristics of the watershed. This ratio demonstrates that a pound of pollutant upstream will not arrive as a pound of pollutant a mile downstream. A 4:1 delivery ratio means that the downstream polluter needs to purchase four pounds of pollutants at the upstream location for one pound released at the downstream location. Location ratios are used when both polluting sources are located the water body of concern. For example, a PS may have a location ratio of 2:1 and a NPS farther upstream may have a location ratio of 3:1. The resulting location ratio of the two sources combined would be 3:2. The Equivalency ratio is to adjust for different chemical forms of the same pollutant. For example, phosphorus may have different chemical forms when emitted from a PS versus a NPS. Nutrients may be biologically available or bound to sediment. Generally, PS pollutants will be more biologically available than NPS pollutants that may be bound to sediment as it transports from the farm through the watershed. The uncertainty ratio is used to account for various types of uncertainties. While most PS/PS trades will not involve this ratio, trades involving NPS generally will have to incorporate this ratio. The EPA Trading Policy recommends that states take into account uncertainties associated with NPS loadings reductions and recognizes three types of uncertainties;(1) measurement uncertainty that addresses the confidence level of the field testing of a NPS Best Management Practice (BMP), (2) implement uncertainty that addresses the confidence level that a NPS BMP is properly designed, installed, operated, and maintained, and (3) performance uncertainty that addresses the risk of a BMP that fails to meet design standards. Uncertainty ratios are reduced though improvements in monitoring, modeling, and estimating BMP effectiveness. The retirement ratio is used when the goal of the trading program is to accelerate the improvement of water quality standards. The ratios are used to retire a percentage of credits. The retired credits cannot be used in the future. Consequently, the overall water quality is improved and loadings reduced with each trade. This ratio is particularly useful in watersheds that do not have a TMDL established. Retirement ratios are always > 1:1 as the purpose is to quicken water quality improvement. The overall trading ratio may contain one or all of these ratios depending on the watershed characteristics and goals. The EPA recommends that the underlying ratios be specific as possible about how they are calculated. The trading program design may allow adjustment to the ratios to allow for changes in uncertainty or changes to the watershed. Transparency in ratio development will encourage program compliance.

3.1.4. Trading Credits

PN/NPS water quality trading depends on the creation of NPS pollution credits to function. Trading also depends on an emissions reduction cost differential between PS/NPS sources that is required in order to reduce their pollutants (Tisdell and Cloves, 2008). Credits are produced when the NPS pollution activity achieves a potential reduction in pollutants though the use of structural changes or management activities such as BMPs. For example, a change in land-use practices such a creation of a riparian buffer between the farming activity and a nearby waterbody can reduce the flow of sediment and nutrients into the surface water. Unfortunately, the effectiveness of BMP introduction for the purpose of containing pollutions is uncertain since reduction depends on localized land features and climate. Therefore, verifying pollutant reduction for credit generation is also uncertain. Estimating NPS reduction loads is accomplished thought hydrological models that have an error component. Large storm events such as hurricanes that frequently make landfall in Louisiana add to the uncertainty since some years have multiple landings while other years have no landings. Actual loads can only determine after the passage of time. For these reasons, NPS loads are less predictable both spatially and temporally than PS effluents. Trading ratios are used to mitigate this uncertainty. There are other factors leading to uncertainty that can be addressed such as the timing of credits.

3.1.5. Credit Timing and Duration

The timing and duration of credit generation is influenced by the credit reconciliation period (EPA, 2007). A credit reconciliation period is the time frame between when the NPS polluter generates the credit and the PS polluter buys the credit. Timing is important since credits should not be used before the time period in which they are generated. The permitting authority (usually state or local authorities) should not allow a pollution reduction credit in a NPDES permit until the verified reduction in the NPS source. A proposed or unverified BMP introduction is not a verified reduction in loadings. The regulatory authority determines at what point in time the credit is generated. The regulator might require one year of monitored data from the PS to determine total annual loading before a baseline is determined for trading. Credits produced by NPS BMPs might not be quickly available since a time lag is to be expected between BMP introduction and nutrient reductions. Another consideration is precipitation variability. A BMP introduced in a dry period will have greater reduction efficiency than a BMP introduced in an extremely wet period. Credits should also have similar time frames. A PS that has monthly reduction data should not trade with a NPS that basis its reduction on a yearly estimation. Credits should be used in the same month in which they are generated. In addition, the permitting authority should make a determination as to when the credits expire. While PS polluters may expect that effluent amounts can be consistently estimated, NPS loadings may experience greater decrease in BMP effectiveness over time without proper maintenance or replacement as required. Temperature differences may impact credit duration. For example, nitrogen removal from PS pollution is more effective in warmer months from increased biological activity. PS polluters may need to trade for more credits in the cooler months to meet the same level of nitrogen mitigation. NPS polluters may also be affected by seasonal temperature variations as temperature affects sediment and nutrient bindings. Regulators may consider annual mass-balance discharge limits for some nutrients to facilitate trading. Trading programs may seek to contract NPS and PS facilities over longer periods of time (i.e., 5 years or more) to more accurately capture actual emissions and loadings and reduce the risk associated with these uncertainties. While it is not feasible to expect that 100% of NPS loading can be controlled, an effort should be made to estimate the maximum level of reductions achievable. This level is important to prevent PS polluters from over buying credits from NPS polluters. PS should never be allowed to buy more credits than NPS can reasonably be expected to generate.

3.1.6. Equivalency of Credits

BMPs are used "end-of-farm" to curtail NPS pollutants and thus are potential credits "offsets' (King and Kuch, 2003). In order to "score" these practices, structure, or management activities, the effectiveness of the BMP must be determined first. Scoring the BMP is difficult since effectiveness is impacted by soil type, hydrology, historical land use, previous crop plantings, irrigation patterns, fertilizer use, weather, and maintenance efforts. Other factors include spatial considerations such as the distance from the BMP to the water body. Landscape characteristics impact effectiveness. For example, the slope of the land and how hilly the land is affects water movement. Therefore, a significant challenge to PS/NPS trading is the effort to determine when a pound of PS pollutant is equal to a pound of NPS reduction on order for the trade to accurately occur. This difficulty of accurately estimating NPS reduction encourages "regulator approved" bilateral negotiated trades rather than a "commodity-style" credit trading scenario. Use of a regulator to document the accuracy of these reductions on a case-by-case basis can be expected to substantially increase transaction costs.

3.1.7. Transaction Costs

PS/NPS trading does not occur in a frictionless environment. Transaction costs are the costs associated with implementation of the trade. These costs may be related to time involved in permit negotiation, searching for trading partners, administrative expenditures, and communication between parties. Other activities such a monitoring and reporting are expenditures. Estimates show that total costs increase by at 35% after transaction costs are included (Fang et al., 2005). Research suggests that there is a trade-off between lowering environmental risks by increasing trade auditing and verification with the subsequent increase in transaction costs (King and Kuch, 2003). The audit and verification steps are important components in evaluation of credit trading program potential. Proponents of trading tend who base their support on theoretical justifications support a view of “cap and trade” with many buyers and sellers exchanging standardized units of pollution. These trading systems would have low transaction costs. However, actual trading systems tend to be “regulator approved” involving contracts addressing specific issues. Point source polluters typically lack knowledge about agriculture and must rely on outside help to broker a deal with a NPS polluter that adds significantly to transaction costs. PS trades with NPS may involve risky assessments. The entire costs of gaining offsets through trade involves not only the amount that must be paid to the NPS to undertake pollution reduction activities but also the cost of developing and exercising the trade and verifying the reduction along with the risks associated with the verification process. These uncertainties are mitigated through the use of trading ratios. These ratios attempt to mitigate risk but at increased transaction costs.

3.2. Increasing BMP Adoption

Recent research documents BMP adoption by dairy farmers in Louisiana (Paudel et al., 2008). Eighteen BMPs are available for adoption. All eighteen BMPs showed adoption to some degree. However, only the waste treatment lagoon showed adoption by the majority (67%) of the farmers. Therefore, an interim goal of a WQ trading program is to increase adoption using additional mechanisms to the greatest extent possible during the preparation and introduction stages of a PS/NPS trading program. An example of a successful BMP adoption program that may be used as a model for Louisiana is found in the California Central Coast (Dowd et al., 2008). The Central Coast Regional Quality Control Board acts as the regulatory agency for the region with both quasi-executive and judicial authority.

Agriculture is the main industry in the region with small-to-medium scale growers of nutrient-intensive production constituting the majority of agriculture activity. Small-to-median farmers likewise dominate the Louisiana dairy production region without a Confined Animal Feeding Operation (CAFO) in operation in the area. The California region is concerned with runoff caused by frequent cultivation of vegetable production. The Louisiana region is concerned with runoff from livestock manure and high precipitation. Both groups of farmers are exempt from NPDES permits for NPS pollution. However, the California region faces regulation by the California Water Code. A lawsuit by the California Public Interest Research Group and the Waterkeepers of Northern California in February 2002 claimed that the state regulatory agencies had illegally neglected its regulatory duties by neglecting agricultural induced water pollution. The California legislators quickly amended the water code to end any pre-existing waiver programs and required regional boards to stem pollution by 2003. The new laws also focused on a watershed-based approach to monitoring. An advisory committee comprised of local farm bureaus and environmental groups formed to create a new waiver authority and resulted in the

Agricultural Waiver Program (AWP). The AWP adopted on July 9, 2004 a voluntary negotiated agreement using BMP design standards to meet environmental goals. Farmers are urged to attend educational classes, implement farm plans, adopt cooperative or individual monitoring, and choose BMPs to meet ambient water conditions. By September 2007, 93% of all irrigated land in the region had enrolled in the AWP. Members decided to adopt BMPs instead of command-and-control mechanisms to meet environmental targets and agreed to yearly farmer assessments ($0.87 to $1.27 per hectare) for monitoring. State voters passed two different propositions to fund water quality improvements that provide grants of $2.5 million available for monitoring and are available for a three-year period. The two sources total $4.8 million for monitoring. Farmers rely primarily on Environmental Quality Improvement Program (EQIP) funding for BMP implementation. However, other sources of funding include ballot measures, violator settlements, and section 319 of the CWA administered by the EPA. The process used in the California central coast can be used as a model to increase BMP adoption and monitor BMP effectiveness in the Louisiana dairy production region as a pre-requisite to PS/NPS trading.

3.3. Instituting a PS/NPS Trading Program for the Louisiana Dairy Production Region

The possibility exists for PS/NPS trading in the Louisiana dairy production region since both PS and NPS discharge into the watershed. The region has over 200 dairy farms in production and potential NPS dischargers and 14 PS dischargers. Only one of the PS has both phosphorus and nitrogen discharge. Consequently, the focus of a trading program would be nitrogen. The critical elements of a water quality trading program are now listed and should be identified and addressed to institute a program in Louisiana (Abdalla et al., 2007): (1) public water quality goals, (2) pollution cap for a watershed, (3) regulated baseline for PS, (4) unregulated baseline for agriculture NPS, (5) credits generated for every unit of pollution beyond a baseline, (6) sellers of credits, (7) buyers of credits, (8) trading ratio, and (9) regulator.

For this study, the focus was on a section of the LDPR that included 162 dairy farmers, six point sources, and two weather stations. Under a trading scenario, the point source will be able to offset its nitrogen discharge reduction by purchasing reductions from the dairy farmers. The farmers trade with the wastewater treatment plant by adopting BMPs the reduce nitrogen loadings on their land. The nitrogen reduction credits are purchased based on a trading ratio. A 1:1 ratio means that there is one pound of nitrogen reduced on the dairy farm land instead of a pound of nitrogen reduced by the treatment facility. The actual ratio is determined by taking into consideration any uncertainty pertaining to the BMP effectiveness on the actual land on which it will be adopted.

3.4. Model

A number of articles exist to address the point and nonpoint sources pollution trading as reflected in the literature section (Farrow et al. 2005; Wang et al., 2002). We developed our watershed optimization model based on the existing literature. If the goal is to reduce total cost of pollution from point and nonpoint sources in a watershed in Louisiana dominated by dairy production and point sources then, the model can be stated as:

$$\begin{aligned} &Min \quad C = c_q(q_p) + c_n(q_n) \\ &s.t., \\ &P\left\{[e_p(q_p) + e_n(q_n)] \le e^0\right\} \ge \alpha \end{aligned} \tag{3.1}$$

We consider pasture-based dairy as nonpoint source pollution. Additionally, point source pollution is from sewage treatment facilities. In equation 3.1,, C is total abatement cost from point and nonpoint sources, $c(q_p)$ is cost of reducing q_p pollutant from point source, $c(q_n)$ is cost of reducing q_n pollutant from nonpoint sources, e_p is an equation describing the balance of point source pollutant, and e_n is an equation describing the balance of a nonpoint source pollutant.

We defined the e^0 as a target level of pollutant with a likelihood of meeting that level by α probability.

We assumed a standard cost function for both point and nonpoint sources with $c'(q_p)>0$, $c''(q_p) > 0$, $c'(q_n)> 0$ and $c''(q_n)>0$. For the point source pollution we assumed a linear function of the form $e_p=e_{p0}-bq_p$. Here e_{p0} is the initial point source pollution. Similarly for the non-point source emissions we assumed a functional form of $e_n = e_{n0} - \gamma f(q_n)$, where e_{n0} is the initial non-point source emissions given as an average long-term value; γ is a random variable representing stochastic events such as weather impacting the effluents. We assume that γ has a normal distribution. $F(q_n)$ could be linear or nonlinear in q_n.

Using the concept of chance constraint program developed by Charnes and Coooper (1964), we can convert the stochastic equation into a deterministic equation as follow:

$$e_p + E(e_n) + k_\alpha\{\text{var}[e_n]\} \le e^0 \qquad (3.2)$$

The new variables introduced here are $E(e_n)$ which is the expected pollution from nonpoint sources and var[e_n] indicates the variance of nonpoint source pollution, and $\Phi(K_\alpha) = \alpha$

The trading ratio is the number of units of pollutants reduced (from a NPS) per units credited to a discharger. Therefore, a trading ratio of 1:1 means the point source polluter can purchase one unit of a nonpoint source's reduction to avoid lowering its own loading by one unit. If the left hand side of the constraint in equation 3.2 is represented as y, then the trading ratio t can be calculated as (Wang et al. 2004):

$$t = \frac{dy/dq_p}{dy/dq_n} = \frac{e_p^{'}}{\{-E(\gamma) + k_\alpha[\text{var}(\gamma)]^{1/2} f^{'}(q_n)\}} \qquad (3.3)$$

We calculated the value of E(γ) from using a GIS based AVGWLF/GWLF program as described in the Chapter 2. This is the mean amount of nitrogen effluents obtained from nonpoint source without any adoption of BMPs. The variance represented the fluctuation in N pollutant as rain and other factors change the effluent runoff on a day-to-day basis.

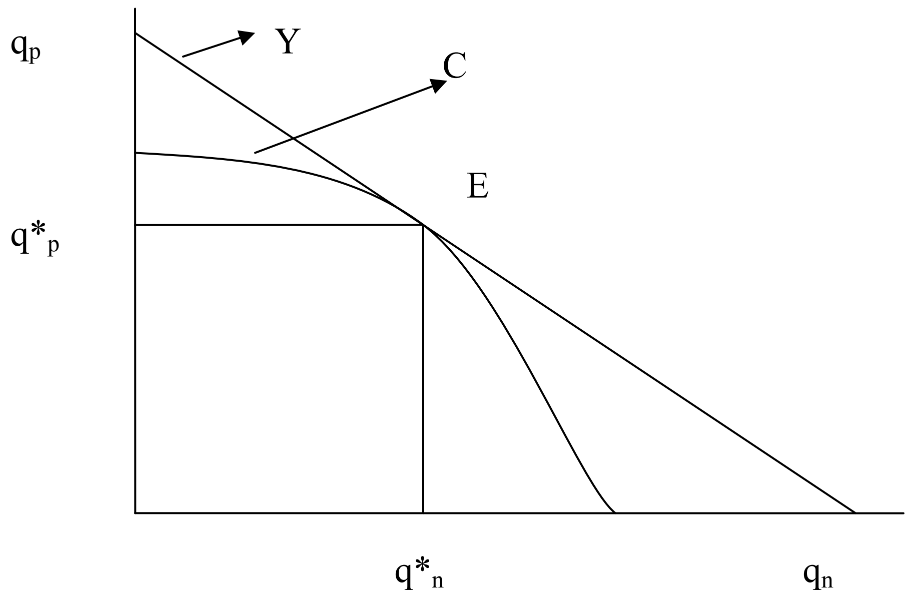


Fig. 3.1. Optimal point E for trading PS and NPS

Figure 3.1 shows the optimal amount of point and nonpoint source abatement to consider. The slope of the cost curve C is equal to the relative marginal abatement cost between point and non-point sources while holding the total cost constant. The trading equilibrium at point located at point E and is the optimal abatement allocation found at the tangency of the C curves and the Y curve which is the aggregate emissions of both point and non-point sources.

3.5. Simulation of Trading in the LDPR

Value used for actual simulation and optimization is presented in Table 3.1. We used the mean and variance of pollutants obtained from AVGWLF program. The optimization program was solved using mathematica software (Appendix F).

Table 3.1 Trading Ratio as Affected by Efficacy of Nonpoint Source Treatment and Reliability Parameters

t(Trading Ratio)	A (efficacy of nonpoint source)	k_1 (reliability parameter)
2.475108	0.1	0.1
1.254562	0.2	0.2
0.848029	0.3	0.3
0.64501	0.4	0.4
0.523404	0.5	0.5
0.442513	0.6	0.6
0.384894	0.7	0.7
0.341827	0.8	0.8
0.308466	0.9	0.9
0.281906	1	1

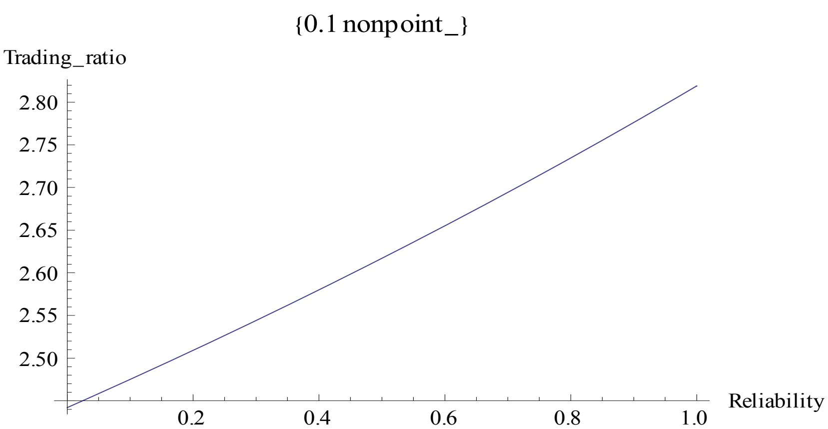


Figure 3.2. Trading Ratio with NPS Abatement at 0.1 Efficacy

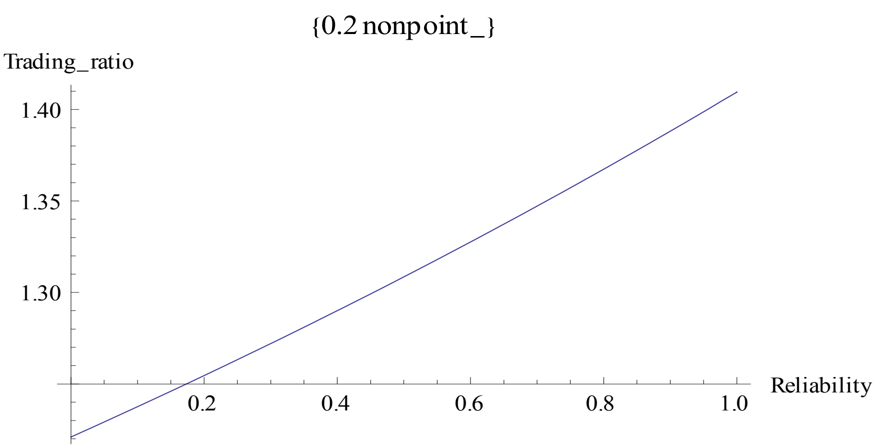


Figure 3.3. Trading Ratio with NPS Abatement at 0.2 Efficacy

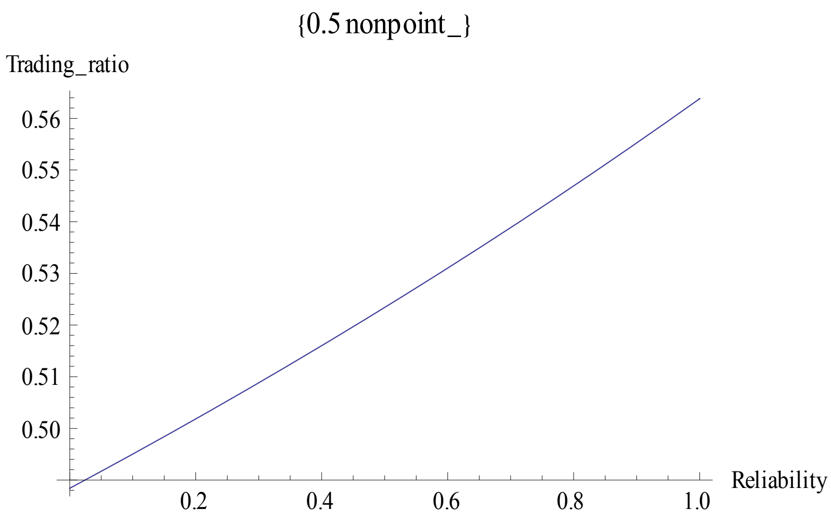


Figure 3.4. Trading Ratio with NPS Abatement at 0.5 Efficacy

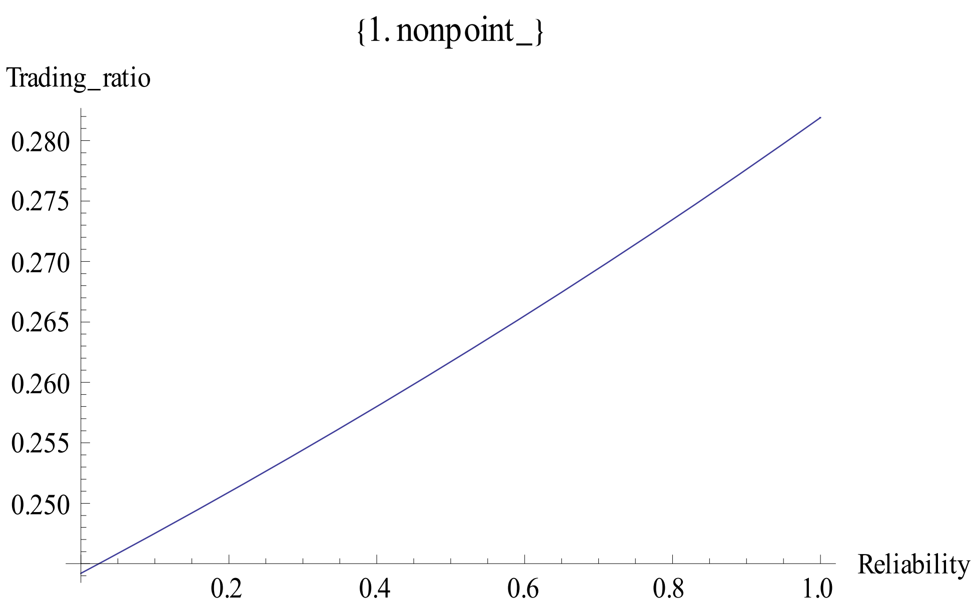


Figure 3.5. Trading Ratio with NPS Abatement at 1.0 Efficacy

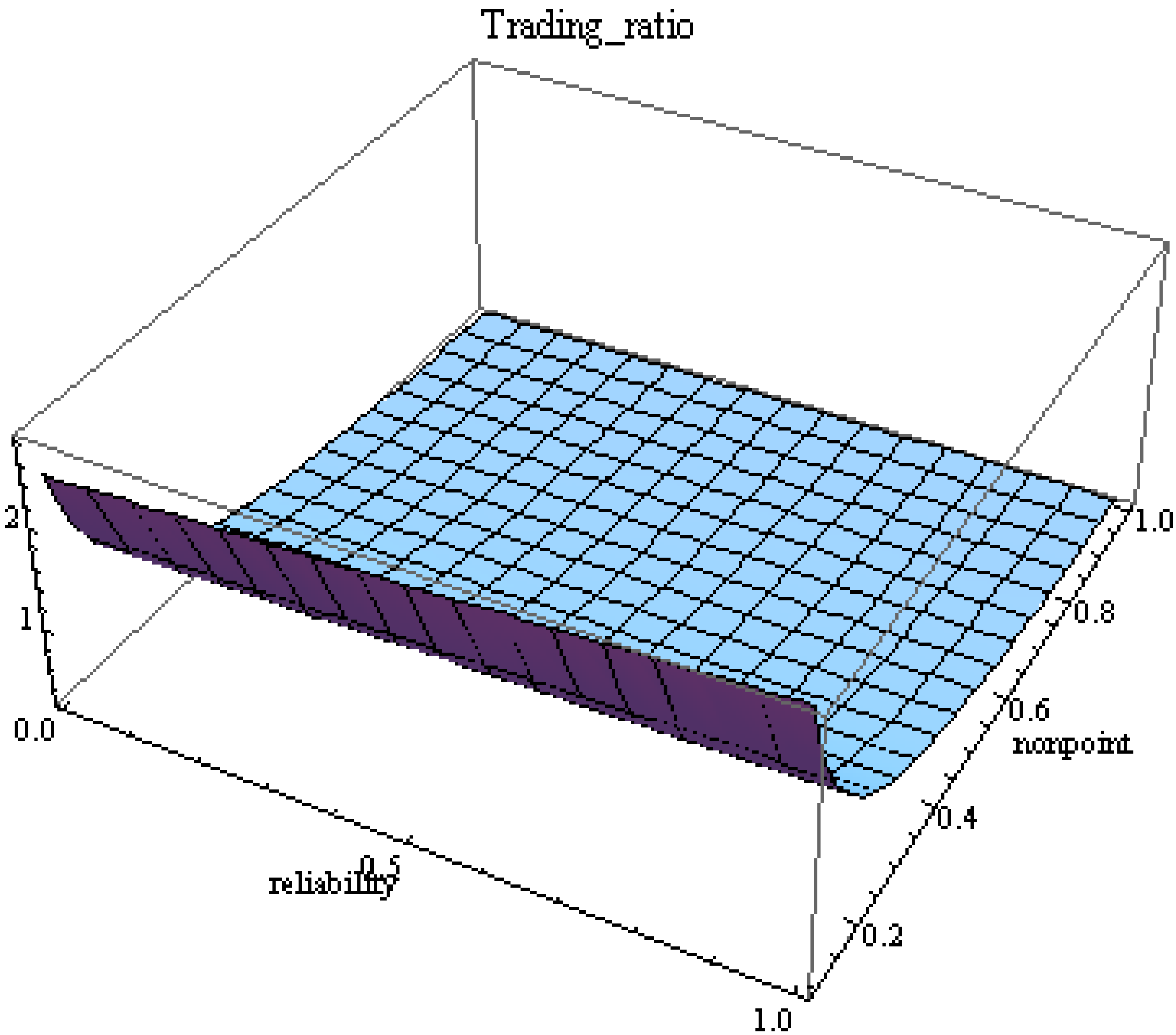


Figure 3. 6. Relationship between Reliability Parameter (k1), Efficacy of Nonpoint Source Treatment (a) and Trading Ratio (t)

Table 3.2. Optimal Amount of Effluent Treatments When Point and Nonpoint Sources are Traded and When the Overall Goal of Effluent Amount in a Watershed is Targeted to a Certain Level or Below

Emission goal in watershed (N in pounds)	k (reliability parameter)	Point source effluent reduction (pounds)	Nonpoint source effluent reduction (N in pounds)	Total cost of pollution reduction ($)
500	0.25	0	15036	2401
1000	0.25	0	14321	2291
2000	0.25	0	12892	2062
3000	0.25	0	11464	1834
4000	0.25	0	10036	1606

Table 3.3. Effect of Change in Cost of Treating Point and Nonpoint Sources on Cost and the Level of Treatment of Point and Nonpoint Source Pollutants

Emission goal in watershed (N in pounds)	k (reliability parameter)	Point source effluent reduction (pounds)	Nonpoint source effluent reduction (N in pounds)	Total cost of pollution reduction ($)
500	0.25	90.7	14906	14992
1000	0.25	90.7	14192	14278
2000	0.25	90.7	12763	12849
3000	0.25	90.7	11334	11421
4000	0.25	90.7	11334	11421

3.6. Results and Discussion

Point and nonpoint source pollution trading can be a cheap way to reduce pollution sources. A crucial concept in accomplishing this goal is the trading ratio. The trading ratio represents the units pollutant reduced per unit credited to a discharger. A ratio 1:1 means that a point source is allowed to purchase on unit of abatement reduction in lieu of abating it own facility by one unit. The point source will be willing to do this because it is more expensive to reduce it own effluent (higher marginal cost of abatement) than the source at the site of purchase (lower marginal cost of abatement). In dealing with nonpoint source pollution, a great deal of uncertainty exits in estimating the efficacy of abatement because of naturally occurring stochastic events such as rainfall. Therefore, the trading ration will usually be greater than 1:1.

In this study, simulation based in mean and variance of effluents estimated for a section of the LDPR was produced through GIS software. These values were then used in the trading ratio. An efficacy parameter of the nonpoint abatement effort (a) and a reliability parameter of the variance of the effluents (k) are used to estimate the trading ratio (Table 3.1). A high trading ratio (2.475) is found when efficacy of the abatement is low (0.1) and the reliability of the variance estimate is also low (0.1). The point source would need to purchase 2.475 pounds of nonpoint source effluent (N) in lieu of abating one pound of its own effluent. In other words, it the PS would need to purchase a BMP that would abate 2.475 pounds of nonpoint source to achieve the same overall watershed improvement as abating one pound at its own facility. This relatively high amount is because of a combination of low NPS efficacy and low reliability of the variance estimate of NPS effluents. On the other end of the scale, if the efficacy of NPS abatement is high at 1 (100%) and the reliability of the variance estimate of NPS is also high at 1 (100%) then the trading ratio is low at 0.281. This extreme means that the point source would abate 0.281 pounds of NPS to achieve the same overall watershed improvement at abating one pound at its own facility. In between this extremes are various combinations of abatement (Figures 3.2,3.3,3.4, and 3.5). For example, figure 3.2 shows the estimates when the abatement efficacy is maintained at 0.1 and the reliability parameter is allowed to vary from 0 to 1. The trading ratio varies between approximately 2.4 and 2.8. In essence, this scenario means that reliability of the effluent variance estimate has little impact compared to the abatement efficacy. The point source will have to purchase a high amount of credits in all cases. In figure 3.4, the abatement efficacy is as high as possible at 1 (100%) while the reliability of the variance estimate is allowed to vary and all trading ratios are small (0.25 to 0.28). While both the efficacy and reliability parameter affect the trading ratio, the efficacy of the NPS abatement has a much more pronounced impact on the ratio than the reliability of the NPS effluent variance estimate. Figure 3.5 shows a 3 dimensional view of the interaction of all three variables, the reliability of NPS effluent variance estimate, the efficacy of abatement, and the resulting trading ratio. Table 3.2 shows the effect on cost of abatement with a change of the emission target. The lower the target required (greater the abatement) the greater the cost of abatement. Finally, Table 3.3 demonstrates that taking into account point source emissions substantially adds to the total cost of abatement for a particular emission goal.

3.7. Conclusions

Uncertainty is inherent in nonpoint source pollution estimation. Trading ratios are designed to make the estimation of NPS effluents less uncertain. The trading ratio represents the units pollutant reduced by a NPS emitter per unit credited to a discharger of PS effluent. A ratio 1:1 means that a point source is allowed to purchase one unit of abatement reduction in lieu of abating it own facility by one unit. The point source will be willing to do this because it is more expensive to reduce it own effluent (higher marginal cost of abatement) than the source at the site of purchase (lower marginal cost of abatement). While the focus of this discussion has been on determining particular value for a trading ratio, a range of ratio values for a particular situation is more in keeping with reality A trading ratio is rarely less than 1:1. Another consideration is permits. When the number of permits is large and exogenously determined, then larger ratios are likely to occur.

The trading ratios for this research were found through GIS-based simulation derived from mean and variance estimates of effluents for a section of the LDPR. An efficacy parameter of the nonpoint abatement effort (a) and a reliability parameter of the variance of the effluents (k) are used to estimate the trading ratio. The trading ratio found from simulation varied from .28 to 2.48. This study achieved the goal of determining a trading ratio to be used in the LDPR through the use of efficacy estimates of the NPS abatement and use of reliability estimates of the effluent's variance. If both of these parameters are low, then the trading ratio will be high. For example, if both parameters are 0.1, then the trading ratio will be 2.48. The closer value both of these parameters are to 1.0, the lower value the trading ratio will be as a result. If both parameters are 1.0, the trading ratio is .0.28**.** Finally, all basins are different. While a spatial approach such as this GIS-based model captures the most relevant transport, nutrient,, and weather parameters, each basin will have a unique solution and may need a unique approach to more accurately estimate the basin-specific trading ratio**.**

3.8. References

Abdalla, C., T. Borisova, D. Parker, and K. Saacke Blunk. 2007. "Water Quality Credit Trading and Agriculture: Recognizing the Challenges and Policy Issues Ahead." *Choices*. 22:117-123

Breetz, H.L., K. Fisher-Vanden, H. Jacobs, and C. Schary. 2005. "Trust and Communication: Mechanisms for Increasing Farmer's Participation in Water Quality Trading." *Land Economics.* 81:170-190

Dowd, B., D. Press, and M. Los Huertos. 2008. "Agricultural Nonpoint Source Pollution Policy: The Case of California's Central Coast." *Agriculture, Ecosystems, and Environment*. 128:151-161

Environmental Protection Agency. 1996. “ U.S. EPA NPDES Permit Writers’ Manual”. . Office of Water EPA -833-B-96-003.

Environmental Protection Agency. 2003. “Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Implementing Guidance.”

Environmental Protection Agency. 2003. “Water Quality Trading Policy” Office of Water.

Environmental Protection Agency. 2003. “Elements of a State Water Monitoring and Assessment Program.” Assessment and Watershed Protection Division, Office of Wetlands, Ocean and Watersheds. EPA-841-B-03-003.

Environmental Protection Agency. 2007. “Water Quality Trading Toolkit for Permit Writers.” Office of the Wastewater Management Water Permits Division. EPA 833-R-07-004

Environmental Protection Agency. 2008. “Title 40: Protection of the Environment” *Code of Federal Regulations*. http://www.access.gpo.gov/nara/cfr/waisidx_03/40cfr124_03.html

Evans. B., D. Lehning, T. Borisova, K. Corradini, S. Sheeder, and W. Brown. 2003.“AVGWLF, GWLF, and PRedICT” manuals. Pennsylvania State Institute of the Environment. The Pennsylvania State University.

Fang, F., K.W. Easter, and P.L. Brezonik. 2005. “Point-Nonpoint Source Water Quality Trading: A Case Study in the Minnesota River Basin.” *Journal of the American Water Resources Association*. June. 645-657.

Farrow, R.S., M.T. Schultz, P. Celikkol, and G. L. Van Houtven. 2005. “Pollution Trading in Water Quality Limited Areas: Use of Benefits Assessment and Cost-Effective Trading Ratios.” *Land Economics*. 81:191-205

Hennessy, D., and H. Feng. 2008. “When Should Uncertain Nonpoint Emissions be Penalized in a Trading Progams.” *American Journal of Agricultural Economics*, 90:249-255

Horan, R., and J. Shortle. 2005. “When Two Wrongs Make a Right: Second-Best Point-Nonpoint Trading Ratios.” *American Journal of Agricultural Economics*. 87:340-352

Horan, R.D., Shortle, J.S., and D. G. Abler. 2004. “The Coordination and Design of Point-Nonpoint Trading Programs and Agri-Environmental Policies.” *Agricultural and Resource Economics Review*. 33:61-78

Hung, M.F., and D. Shaw. 2005. “A Trading-Ratio System for Trading Water Pollution Discharge Permits.” *Journal of Environmental Economics and Management*. 49:83-102

King, D., 2005. “Crunch Time for Water Quality Trading” Choices. 20:71-75

King, D., and P. Kuch. 2003. “Will Nutrient Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles.” *Environmental Law Reporter*. 33:10352-10368

Lankoski, J., E. Lichtenberg, and M. Ollikaninen. 2008. "Point/Nonpoint Effluent Trading with Spatial Heterogeneity." *American Journal of Agricultural Economics*, 90:1044-1058

Paudel, K.P., W.M. Gauthier, J.V. Westra, and L.M. Hall. 2008. "Factors Influencing and Steps Leading to the Adoption of Best Management Practices by Louisiana Dairy Farmers." *Journal of Agricultural and Applied Economics.* 40:203-222

Raymond, L., and G. Shively. 2008. "Market-Based Approaches to CO2 Emissions Reductions." *Choice*s. 23: 38-40.

Ribaudo, M., R. Heimlich, and M. Peters. 2005. "Nitrogen Sources and Gulf Hypoxia: Potential for Environmental Credit Trading." *Ecological Economics* 52:159-168

Tietenberg, T., 2006. "Emissions Trading: Principles and Practices." *Resources for the Future Press.*

Tisdell, J., and D. Clowes. 2008. "The Problem of Uncertain Nonpoint Pollution Credit Production in Point and Nonpoint Emissions Trading Markets." *Environmental Economics and Policy Studies*. 9:25-42

Wang, X., W. Zhang, Y. Huang, and S. Li. 2004. "Modeling and Simulation of Point-NonPoint Source Effluent Trading in Taihu Lake Areas: Perspective of Nonpoint Sources Control in China." *Science of the Total Environment.* 325:39-50

Woodward, R.T. 2003. "Lessons about Effluent Trading from a Single Trade." *Review of Agricultural Economics.* 25: 235-245

Woodward, R.T., R. Kaiser, and A. M. B. Wicks. 2002. "The Structure of Water Quality Trading Markets." *American Water Resources Association*. 38:967-979

CHAPTER 4
ESSAY 3

DECISION TO ADOPT AND EXIT BEST MANAGEMENT PRACTICES (BMPs) BY LOUISIANA DAIRY FARMERS

Best management practices (BMPs) are voluntary practices recommended by the USDA under the Environmental Quality Incentive Program (EQIP) to overcome nonpoint source pollution. Government supports up to 95% of the total cost to implement these practices but still the adoption rate of the BMPs are not at the rate that the policy makers like to see. The main contention regarding the adoption has been its cost that is private in nature and benefit that is public in nature. Therefore, the adoption and thereafter continuation of these practices have been of a serious concern. Most of the past studies on adoption uses probit/logit model to explain the probability of a firm adopting a new technology at a time. There is a lack of study explicitly addressing the time path of adoption which is an important aspect for adoption of environmental practices like BMPs which generally have contract obligation for as long as ten years.

Dairy Production in Louisiana is an important agricultural enterprise contributing significantly to the income of farmers in the three-parish-area of Washington, St. Helena and Tangipahoa. Dairy farmers in the region are also blamed for environmental pollution due to which there has been a closure of popular recreational area. Additionally, nitrogen leaching and volatilization and phosphorus runoff from dairy operation and land application of manure have compromised the integrity of ecosystem health in the watersheds encompassing these parishes. Having situated on the North of a very productive Lake Ponchartrain Basin, dairy production in these parishes is also blamed for the elevated level of N in waterbodies in the basin. To overcome these pollution concerns, dairy farmers in the region are adopting best management practices with the assistance from the USDA/NRCS program and cleaning their manure lagoon more responsibly with the help of Lake Pontchartrain Basin Foundation financial support.

USDA/NRCS in collaboration with the Louisiana State University Agricultural Center have recommended eighteen different best management practices for the farmers to adopt to address environmental concerns in the region. Out of these eighteen best management practices, Paudel *et al.* report that farmers have adopted waste management lagoon and waste management practices extensively. However, the other best management practices have not been adopted and efforts need to be put to increase the adoption of these BMPs in the dairy farming operation. In addition to the low adoption of BMPs, there is also concern that farmers once adopted may not continue these practices because some of the practices are costly and BMPs adoption is done voluntary. Additionally, the cost share contractual agreement obligates them to adopt these practices for maximum of 10 years. Our objective in this paper is to find the characteristics of the farmers who have adopted best management practices and stayed adopting those practices. We also identify the characteristics of farmers who have adopted these practices in the past but had since exited from adopting the BMPs. We used survey data collected from Louisiana dairy producers to identify the variables determining the entry and exit from adopting best management practices.

4.1. Literature Review

Adoption of BMPs may be influenced by market structure. Research into adoption of innovative technology showed those firms not participating in a concentrated market will adopt the technology sooner than firms who do not fit that description (Levin *et al.*). The Louisiana dairy industry may be classified as low concentration since the industry is composed mainly of many small farms. Therefore, these producers should adopt best management practices early if there is profit to be made from adopting the practices.

Theoretical literature has recognized that incentive based policies can achieve a higher adoption rate compared to conventional regulations such as technological or performance standards. BMP adoption is an incentive based approach as a cost-share percentage paid by the Federal government provides the incentive for adoption. Kerr and Newell showed that adoption of technology increased as cost to the firm falls. They further added that firms with lower benefits and higher costs will adopt more slowly. BMP adoption by the dairy farmers should increase if more cost share is provided to the dairy producers to adopt these environmentally friendly practices.

Socioeconomic characteristics of the dairy farm operator may have an impact on BMP adoption. Gould and Saupe researched these factors and determined that investments in human capital yielded positive and measurable results. The level of education of the dairy farm's principal operator may have an impact on entry or exit of adoption. The use of a personal computer may increase informational awareness concerning environment benefits of adoption and thus increasing human capital. On-the job experience is another way to increase human capital concerning dairy farm operation

A barrier to entry may be the cost of capital to implement the BMP. MacDonald found that capital commitment deters both entry and exit of firms into and from the U.S. food manufacturing industry and sunk physical capital costs acts as a general barrier to mobility of resources. Even with a substantial governmental cost-share, the dairy producer may refuse BMP implementation.

Size of the dairy farm may play a role in entry and exit of BMP adoption. Dunne and Roberts determined in firm entry and exit patterns in U.S. manufacturing industries that there was significant variation in the entry patterns and subsequent size and exit patterns for different categories of those entrants. Larger firms that enter are less likely to exit than smaller firms.

Baldwin and Gorecki showed that exit is not solely a small-firm phenomenon. Larger size firms did not experience exit (close down) rates of zero. This study used estimated net farm income as a proxy for size (capitalization) to determine the relationship between farm size and BMP entry and exit.

Hopenhayn developed and analyzed a dynamic stochastic model for a competitive industry that endogenously determined entry and exit and introduced the term "stationary equilibrium." This concept implies that in the steady state as many firms were entering as exiting as well as job creation and destruction.

4.2. Method

To address BMPs adoption decision at first and then ultimately decide to terminate BMPs in a farm, we employ a proportional hazard model. A proportion hazard model helps to analyze the effect of economic and regulatory variables on adoption and exit decision by dairy producers with respect to adopting new environmental friendly technology. The hazard model is appropriate because our focus is on the timing of new technology.

We followed Wooldridge (2002) to develop our theoretical model. Indicate an initiate state as an adoption of a BMP by a dairy farmer. T is the time measured in years until the dairy farmer discontinues the BMP in his farm. The cumulative distribution function of T is defined as F(t) = P(T $\leq$t), here t denotes a particular value of T. The survival function, defined as the probability of a farmer adopting BMP past time t, is s(t) = 1-F(t) = P(T>t).

We assume a random draw i from dairy producers in Louisiana. Let a_i Є [0,b] denote the time at which dairy farmer i adopts BMP, let t_i^* denote the length of time which s/he adopts a given BMP and let x_i denote the vector of observed explanatory variables. Assume that t_i^* has a continuous conditional density function $f(t \mid x_i ;\theta); t \geq 0$ where θ is the vector of unknown parameters. To account for the right sensoring, we assume that the observed duration t_i is obtained as $t_i = \min(t_i^*, c_i)$. We assume that conditional on the covariates, the true duration is independent of the starting point a_i and the censoring time c_i. The conditional distribution D(.) can be written as $D(t_i^* \mid x_i, a_i, c_i) = D(t_i^* \mid x_i)$. Letting d_i be a censoring indicator (1/0 variable), the conditional likelihood for observation i can be written as:

$$f(t_i \mid x_i, \theta)^{d_i}[1 - F(t_i \mid x_i; \theta]^{1-d_i}.$$

If we have data on (t_i,d_i,x_i) for a random sample of size N, the maximum likelihood estimator of θ is obtained by maximizing:

$$\sum_{i=1}^{N}\{d_i \log[f(t_i \mid x_i;\theta)] + (1-d_i)\log[1 - F(t_i \mid x_i;\theta)]\}$$

where the coefficients are then estimated using a maximum likelihood approach.

We estimated the parameterized baseline hazard approach for adoption and exit decisions. For robustness of the model, we conducted sensitivity analyses assuming that a hazard function possesses exponential, lognormal, log logistic, and Weibull density functions. These assumptions allow for the possibility that the baseline hazard increases or decreases over time.

4.3. Data

Data were collected using survey of dairy farmers. The survey was conducted using the tailored design method (Dillman). A focus group, consisting of dairy farmers and county agents from the three parishes in the principal milk production area of Louisiana, was used to help design and pre-test the survey instrument. The survey was mailed to all 325 Louisiana dairy farmers with an option to complete the survey online. Two weeks after the initial mailing, non-respondents were contacted with a postcard reminder request to complete the survey. A second round of surveys was mailed to dairy farmers three weeks after the first round. To further encourage participation, payments of $10 per survey for the first fifty fully completed surveys were promised along with an opportunity for all respondents to qualify for a $250 lottery cash prize drawing. The size and number of payments offered were limited by the availability of funds. A graduate student repeatedly contacted dairy farmers by phone requesting survey completion.

The twelve-page survey had four distinct sections including dairy manure disposal, milk reduction programs, dairy best management practices (BMP) adoption, and socio-economic characteristics of the principal operator. One section of the survey asked questions related to the adoption of best management practices (BMP) in terms of: 1) cost shares and EQIP incentive payments; 2) sources of information most important in making the adopt/non-adopt decision; and 3) the role of USDA-NRCS in the responder's adoption or non-adoption decision. Eighteen BMPs identified by USDA-NRCS as most appropriate for Louisiana dairy farms were identified in terms of cost-share or EQIP incentive payment per practice. A common format used in presenting each of the eighteen BMP practices and in eliciting responses is as follows:

Residue Management or Conservation Tillage Practices (NRCS code 329A, B, C): *A system designed to manage the amount, orientation and distribution of crop and other plant residues on the soil surface year round (such as No-till, Strip-till, Ridge-till and Mulch-till systems). Incentive payment =$10 -15 per acre, 100 acre limit, 2-3 years.*

Have you adopted this BMP on your farm?

[ ] YES. **If YES, in which year? If stopped, in what year_______?**

Total Incentive Payment received for this BMP $______ per acre

[ ] NO **If NO, would you adopt this BMP on your farm?**

[ ] YES

[ ] NO

[ ] Not suitable for my farm

The BMP was described in the survey and identified with its USDA-NRCS code number and an estimated reference cost. The BMP reference cost was an average cost based on adoption information of the BMP in Louisiana between 1997 and 2001.

4.4. Results and Discussion

The model specified in the method section is estimated using the SAS software. We estimated the right sensored model assuming the hazard density function as Weibull, log logistic, logistic, log normal and gamma functions. Descriptive statistics of the results indicated that there were 133 observations. Only four of these eighteen BMPs were adopted and then later on discontinued by operators. Some of the BMPs were adopted as early as 1952. Observing closely, we found that nearly half of the BMPs had been adopted by the farmers before the beginning of the EQIP program that started in 1997. The average retention time (Table 5.1) for the BMPs was close to 15 years.

Table 4.1. Descriptive Statistics

Variable	N	Mean	Std Dev	Minimum	Maximum
Entry	133	1989.14	10.3241273	1952	2004
Exit	133	45.0225564	297.4965868	0	2002
EQIP	133	0.2180451	0.4144793	0	1
retention1	133	14.6842105	10.3684899	0	52
Age	133	26.4875188	9.8431759	7	46
age2	133	797.7482827	546.0011771	49	2116
Education	133	0.6240602	0.4861959	0	1
Computer	133	0.5488722	0.4994871	0	1
Male	133	0.887218	0.317522	0	1
Offtime	133	0.481203	0.5015356	0	1
subdivision	133	0.2406015	0.4290648	0	1
netincome	61	2	0	2	2
incomeshare	133	73.1352632	32.3806615	0	100
Censor	133	0.0225564	0.1490457	0	1
Ols	133	0.0827068	0.7390116	0	8

We have also found that more than half of the farmers own computers. Almost all of the operators are male and one of the spouses worked off-farm. This is perhaps to supplement income from dairy farming. Additionally, twenty five percent farmers said their farm is close to a subdivision. This indicates continuous development of subdivisions in these parishes probably because people from New Orleans have been moving up to these parishes.

Results from survival analysis were not encouraging as almost all of the parameters estimated came out to be insignificant. Therefore, we are not going to discuss these results. However, the results are presented in Table 5.2.

Table 4.2. Parameter Estimates

Variables	**OLS**	**PHREG**	**PHREG (Hazard)**	**Weibull**	**Log-logistic**	**Log-Normal**	**Gamma**
Intercept	12.49633*			43.5153	43.1695	24.7616	15.196
Age	0.09764	-0.03763	0.963	0.0455	0.0463	0.054	0.0457
Education	4.33339^{8}	16.98261	23738601	-37.151	-36.935	-17.566	-8.598
EQIP	-13.0486^{8}	1.51848	4.565	34.8445	34.72	16.2945	6.6247
Income-share	-0.00352	0.00583	1.006	0.0073	0.0074	0.0081	0.0064
Scale				1.4479	1.4274	3.2967	2.5588
Weibull/Gamma				0.6906			0.0945

Because of the insignificance of the parameters estimated, we resorted to an OLS method to describe whether the time duration a BMP has been adopted has any relationship with farm and operator characteristics. We have series of BMPs with each adopted at different length of time by the dairy farmers. We regressed this duration (or length of time a BMP is adopted in the farm) to four explanatory variables. Most of these variables are also the variables that Paudel *et al.* have selected in their study. The first variable used is the number of years the operator has worked in the farm. If an operator has been familiar with the dairy farming, s/he would know the practices that would help to reduce pollution and also help to abide by the existing environmental regulations. Education is the second variable we have chosen as an explanatory variable. It is likely that higher educated individual would be more conscious about environment and would therefore adopt BMPs for a longer period. Therefore, we expect this variable to have a positive sign. EQIP is a binary variable with adoption done before 1997 getting 0 value or 1 otherwise. This is the year that the government has started the EQIP program. Income share is a continuous variable indicating the share of income from a dairy operation. The more dependent is a farmer in a dairy operation, the less likely is that he would have extra money to adopt BMPs or to that matter able to cost share the needed expenses to adopt BMPs. Therefore, we hypothesized a negative coefficient associated with this variable.

Our results provided signs of the parameters consistent with our *a priori* belief. However, we did not find age and income-share to be significant. EQIP and education variables had positive signs. EQIP indicated that if a BMP has been adopted after 1997, it is less likely to be adopted for a long time. This may be because our observations are right sensored after 2004. Or it could be that farmers would implement the practice and terminate the practice after they are no longer obligated to continue it. Education increases the longevity of BMP adoption. A farmer who has a college education would like to increase the adoption duration by four years.

4.5. Conclusions

We examined the behavior of dairy farmers to adopt or exit BMP practices. We estimated right sensored hazard model but the parameters of the model were found to be insignificant. When the duration of BMP adoption is regressed on age that operator has been in a dairy farming practice, education of the operator, a binary EQIP variable and income share, we found consistent sign across these parameters. We also found education to have a positive significant effect in the longevity of adopting a given BMP practice. Therefore, this study indicates a need to target educated farmers to promote best management practices to get the most benefit. Additionally, longer the individual has been in a dairy business, he is more receptive to adopting these environmental practices

4.6. References

Baldwin, J. R., and P. K. Gorecki. 1991. "Firm Entry and Exit in the Canadian Manufacturing Sector, 1970-1982" *The Canadian Journal of Economics* 24:300-323.

Dunne, T., M. J. Roberts, and L. Samuelson.1988. "Patterns of Firm Entry and Exit in U.S. Manufacturing Industries" *The RAND Journal of Economics* 19:495-515.

Gould, B. W., and W. E. Saupe. 1989."Off-Farm Labor Market Entry and Exit" *American Journal of Agricultural Economics* 71:960-969.

Hopenhayn, H. A. 1992. "Entry, Exit and Firm Dynamics in Long Run Equilibrium" *Econometrica* 60:1127-1150.

Kerr, S., and R. Newell. 2003. "Policy-Induced Technology Adoption: Evidence from The U.S. Lead Phasedown" *Journal of Industrial Economics* 51:317-343.

Levin, S.G., S. L. Levin, and J. B. Meisel.1987. "A Dynamic Analysis of the Adoption of a New Technology: The Case of Optical Scanners" *The Review of Economics and Statistics* 69:12-17.

MacDonald, J. 1986. "Entry and Exit on the Competitive Fringe" *Southern Economic Journal* 52:640-652.

Paudel, K.P., W. Gauthier, J. Westra, and L. Hall. 2008. "Factors Influencing and Steps Leading to the Adoption of Best Management Practices by Louisiana Dairy Farmers". *Journal of Agricultural and Applied Economics* 40:203-222

Wooldridge, J.M. 2002. "Econometric Analysis of Cross Section and Panel Data." The MIT Press, Cambridge, MA, 2002

CHAPTER 5
CONCLUSIONS

The Louisiana dairy production region (LDPR) is located in the southeast portion of Louisiana and includes five parishes (Tangipahoa, Washington, Livingston, St. Helena, and St. Tammany) is impacting the local watershed through nitrogen, phosphorus, and sediment effluents. An attempt is made to mitigate this impact through three strategies. The first strategy uses three interrelated geographical information system (GIS) based modules to model various dairy specific BMPs for adoption to in order to reduce the effluent reductions. There are ten BMPs available for adoption. The existing effluent loads are estimated at 1,458,560,019 pounds of sediment, 18,308,970 pounds of N, and 1,797,389 pounds of P. Nitrogen is chosen at the primary nutrient for reduction since it has the largest current impact and therefore has the greatest impact on hypoxia. The strategy is to maximize the reduction of one effluent (N) by adopting BMPs that have the greatest impact on reduction with the minimum cost. The Max reduction at min cost solution is determined by adopting seven BMPs. Adoption of the Nutrient management BMP in both row crops (75%) and pasture land (100%) is found to have the greatest impact of all BMPs. The cost for the LPDR basin of 2,107,125 acres is determined to be $37,254,154.10. This expenditure results in a reduction of 13.9% (2,550,853 pounds) of N along with 8.7% (156,223 pounds) of P, and 5.9% (85,478,539 pounds) of sediment.

The second mitigation strategy is the use of point source (PS) and nonpoint source (NPS) trading. Trading occurs because the cost of lowering a point source effluent is more expensive than the cost to lower the same amount of NPS effluent. Nitrogen is the targeted effluent since it is found in the PS (waste water treatment plants) as well as in the NPS (dairy farms) effluents. P is not found large amounts in PS effluents the LDPR. A trading ratio is employed to capture the uncertainly related from NPS abatement effectiveness since NPS by nature involves a large degree of uncertainty. A section of the LDPR that is about a third of the total basin and having approximately 162 dairy farms, six point sources, and two weather stations is aggregated using GIS software to obtain preliminary trading data.

In this study, simulation based in mean and variance of effluents estimated for a section of the LDPR was produced through GIS software. These values were then used in the trading ratio. An efficacy parameter of the nonpoint abatement effort (a) and a reliability parameter of the variance of the effluents (k) are used to estimate the trading ratio (Table 3.1.). A high trading ratio (2.475) is found when efficacy of the abatement is low (0.1) and the reliability of the variance estimate is also low (0.1). The point source would need to purchase 2.475 pounds of nonpoint source effluent (N) in lieu of abating one pound of its own effluent. In other words, it the PS would need to purchase a BMP that would abate 2.475 pounds of nonpoint source to achieve the same overall watershed improvement as abating one pound at its own facility. This relatively high amount is because of a combination of low NPS efficacy and low reliability of the variance estimate of NPS effluents. On the other end of the scale, if the efficacy of NPS abatement is high at 1 (100%) and the reliability of the variance estimate of NPS is also high at 1 (100%) then the trading ratio is low at 0.281. This extreme means that the point source would abate 0.281 pounds of NPS to achieve the same overall watershed improvement at abating one pound at its own facility.

Point source pollution is easily quantified since the location of the effluents is known and monitoring is required by federal regulation. In contrast, uncertainty is inherent in nonpoint source pollution estimation. Trading ratios are designed to make the estimation of NPS effluents less uncertain. This study achieved that goal through the use of efficacy estimates of the NPS abatement and use of reliability estimates of the effluent's variance. If both of these parameters are low, then the trading ration will be high. For example, if both parameters are 0.1, then the trading ratio will be 2.48. The closer value both of these parameters are to 1.0, the lower value the trading ratio will be as a result. If both parameters are 1.0, the trading ratio is .0.28.

Finally, the third mitigation strategy uses the Hazard model to determine characteristics of dairy farmers that encourage long-term adoption of dairy BMPs. The longer a BMP is adopted, the greater the effluent mitigation. Research results show that the longer a farmer has been in operating the dairy farm and the greater degree of his or her education, the longer that the farmer maintains dairy BMP adoption and thus mitigation.

A promising area of research that may be applicable in solving NPS pollution in the near future is the theory of mechanism design. Mechanism design uses incentive compatible features to encourage participates towards a desired (economically efficient) result. For the LDPR, the participants (PS and NPS) are induced towards a trading scenario that results in an economically efficient trade of nitrogen effluents. This research into incentive compatible cooperation protocols focused on simulating a mechanism design, the continuous Vickrey-Clarke-Groves (cVCG) model. Importantly, the cVCG model focuses on elimination free-riding i.e., one farmer may not participate in mitigation but still receives environmental benefit. Another issue is that it is necessary to design an incentive that encourages all dairy farmers to declare their private information concerning their environmental benefit coefficient. A common traditional voluntary tool for nonpoint source pollution control is adoption of best management practices. However, It is well known that farmers do not adopt best management practices sufficiently in a voluntarily scenario as they perceive the benefit as public in nature. Therefore, they express a need for fair compensation to adopt these practices. Additionally, farmers may understate their benefit coefficient from clean water as they think some one else should bear the cost of abatement. A new approach to the issue is known as mechanism design theory.

Noble laureate Leonid Hurwicz began the theory of economic mechanism design concerning optimal usage of economic resources and informational efficiency. He continued his formal treatment of mechanism design as the problem of selecting one mechanism from a group of possible mechanisms. In this context, a mechanism is a mathematical structure modeling economic activity that is guided and coordinated by institutional forces.

Five commonly used mechanisms designs in public good reviewed are: (1) Voluntary Contribution, (2) Proportional Tax, (3) Groves-Ledyard, (4) Walker, and (5) Continuous Vickery-Clarke-Groves. A dairy producers' preference for clean water and his/her endowment (wealth) are private information and the marginal cost of effluent reduction (nitrogen, phosphorus and sediment) is assumed to be a constant.

While still in its policy infancy, mechanism design theory can address the environmental benefit coefficient revelation issue. Individuals may not tell the truth if they perceive an economic advantage by not freely admitting their preferences. Truth telling is a necessary requirement for optimal policy effectiveness and mechanism design theory is on the leading edge of capturing that parameter. Another important concern is free riding. Since the cVCG mechanism is particularly designed to eliminate free riding, policy should encourage attempts at this mechanism design construction to proceed toward a more economically efficient solution. A major goal in designing the mechanism is to induce informational efficiency through systematic design procedures. These procedures are usually algorithms that result in informational efficient mechanisms that result in a goal function in correlated equilibrium. The goal of this review is to design an efficient economic allocation mechanism to maximize water pollution abatement in the Louisiana Dairy Production Region (LDPR).

The main policy implication of this research is that dairy specific BMP adoption should be encouraged and efforts to maintain the adoption should focus on education and financial assistance for the adoption and maintenance. The dairy industry is decreasing in the LDPR and any increase of the cost of doing business such as BMP adoption will have a detrimental effect on farm profits. The longer that a farm stays in business, the longer the BMP will potentially stay adopted and the longer NPS will be mitigated. Therefore, a policy implication should be to encourage long-term operations of those dairy farms that adopt and continue adopting dairy specific BMPs. For example, tax credits might be offered for adoption.

A low cost suite of BMPs was identified has having the greatest mitigation efficacy. The low cost suite of BMPs was found to be significantly less expensive ($37 million versus $107 million) and more effective at reducing N (13.9% versus 8.4%) in the LDPR watershed than the currently adopted BMPs. In addition, targeting not only a suite of BMPs but also the most effective BMP may be of particular use as a mitigation strategy. The nutrient management BMP was identified as particularly crucial for N mitigation. Therefore, the policy should target that individual BMP for adoption perhaps through cost share incentives.

PS/NPS trading is a feasible mitigation strategy for the LDPR since several PS and multiple NPS emitters of N are in the region. A trading scenario with purchase of NPS credits by the PS is more likely if both BMP efficacy and reliability of variance estimates are known with relative certainty. The PS/NPS policy needs to address capturing this information in order to present a lowest cost solution for the PS and an incentive to participate in trading.

APPENDIX A: DAIRY (LSU AGCENTER/UDSA/NRCS)

APPENDIX A
DAIRY BMPs (LSU AGCENTER/UDSA/NRCS)

BMP CATEGORY	NAME	NRCS CODE	DESCRIPTION
Soil & Water Management	Field Borders	368	Vegetation to Prevent Runoff
Soil & Water Management	Filter Strips	393	Vegetation to Prevent Runoff
	Grass Waterways	412	Vegetation to Channel Runoff
	Fence	382	Wood & Metal Structures to Prevent Erosion
	Heavy Use Area Protection	561	Structures to Prevent Erosion
	Prescribed Grazing	528A	Conservation Management System
	Roof Runoff Management	558	Runoff Control
	Sediment Basin	350	Sediment Storage
	Trough or Tank	614	Drinking Water for Animals to Prevent Erosion
	Waste Management System	312	Concentrated Animal Waste Areas
	Waste Storage Facility	313	Temporary Waste Storage Facility
	Waste Treatment Lagoon	359	Temporary Waste Storage and Biological Treatment
	Cover & Green Manure Crop	340	Seasonal Crop for Erosion Protection
	Critical Area Planting	342	Vegetation for Soil Stabilization
	Conservation Tillage Practices	329	Crop Residue Management
	Riparian Forest Buffer	391	Conservation Management System
	Stream bank & Shoreline Protection	580	Vegetation/Structures to Stabilize Stream bank
	Waste Utilization	633	Waste for Fertilization
Nutrient Management	Nutrient Management Plan for N or P	590	Obtain Optimum Crop Yield & Minimize Nutrient Movement

APPENDIX B: TYPES OF GENERIC BMPS FOR USE IN THE PREDICT SYSTEM

APPENDIX B
TYPES OF GENERIC BMPS FOR USE IN THE PREDICT SYSTEM

1) Crop Residue Management
2) Vegetated Buffers
3) Crop Rotation
4) Cover Crops
5) Contour Farming/Stripcropping
6) Terraces and Diversions
7) Grazing Land Management
8) Stream bank Protection
9) Nutrient Diversion

APPENDIX C: BMP MODIFIED IN PREDICT TO REFLECT DAIRY FARMER USAGE WITH REDUCTION AND COSTCOEFFICIENTS

APPENDIX C
BMP MODIFIED IN PREDICT TO REFLECT DAIRY FARMER USAGE WITH REDUCTION AND COSTCOEFFICIENTS

BMP #	Survey #	BMP Name	N	P	Sediment	BMP Costs
1	2	Cover & Green Manure	0.36	0.16	0.27	$12/acre
2	14	Conservation Tillage	0.50	0.38	0.64	$30/acre
3	8	Riparian Buffer	0.13	0.19	0.03	$1/acre
4	N/A	Forest to Ag Conversion	N/A	N/A	N/A	$5,000/acre
5	3	Critical Area Planting	0	30.6	0	$415/acre
6	18	Nutrient Management	0.70	0.28	0	$33/acre
7	17	Prescribed Grazing	0.43	0.34	0.13	$360/acre
8	N/A	Terraces & Diversions	N/A	N/A	N/A	$500/acre
9	5	Vegetative Buffer	0.64	0.52	0.58	$1,500/mile
10	4	Stream bank Fencing	0.56	0.78	0.76	$15,000/mile

Note: Critical area planting and Nutrient Management BMPs may be used in both row crop and pasture land use

Note: Stream length is equal to half of the total steam bank length with specified BMP

APPENDIX D: METHODS (AVGWLF, GWLF AND PREDICT)

APPENDIX D
METHODS (AVGWLF, GWLF AND PREDICT)

AVGWLF

Data are input as "layers" into AVGWLF. Sediment flow is a major consideration. As stream bank erosion is a component to overall sediment flows, a stream bank erosion algorithm is included based on an approach used in the field of geomorphology. Monthly stream bank erosion is estimated by calculating a watershed-specific lateral erosion rate using the formula

$$LER = aq^{0.6}$$

Where LER = the estimated lateral erosion rate

a = the empirically-derived constant related to the mass of soil eroded from the stream bank that depends on various watershed conditions, and

q = the monthly stream flow in cubic meter per second

The total stream bank erosion sediment flow or load is then calculated by multiplying the LER times the total length of streams (in meters) in the watershed, the average stream bank height (in meters) and the average bulk density (in kg/m^3).

The AVGWLF module requires three separate input files: weather.dat transport.dat, and nutrient.dat, and. A customized interface developed by Penn State for the ArcView GIS package is used to parameterize these input files for used in the GWLF simulation module. In order to used this interface the user is required to identify other "nonspatial" model parameters such as the beginning and end of growing seasons and the months that manure is spread on the ground. The weather.dat file contains the weather data such as temperature highs and lows and precipitation for specific dates.

TRANSPORT.DAT File

The transport.dat file identifies the required for each source area (area size and sediment delivery ratio). In order to estimate hydrology and nutrient loads over a particular watershed, AVGWLF uses a digital land use or land cover in use for the particular area. This is raster data that was originally created by the U.S. federal government as part of the Multi-Resolution Land Characteristic database project.

Another parameter used in the transport.dat file is the curve numbers. Curve numbers are used in watershed hydrology simulation studies and reflect the relative amounts of surface runoff and infiltration at a particular point in time. These numbers are derived based on combinations of land use and soil type characteristics (hydrologic soil group type). Soil type information is gathered from a generalized statewide data layer termed "STATSGO." This data layer refers to the state-level soil mapping products developed for each state by NRCS. AVWGLF uses this information along with the land use or land cover data to estimate the curve number for each source area contributing to a particular watershed.

An important equation containing several factors is known as the USLE equation. This equation is used in the GWLF simulation that is integral to production of the transport.dat file. One factor is the soil erodibility (k) that measures the inherent soil erosion potential and is an estimate based on soil texture and composition. The k factor has been determined for every soil type in the United States and is used in the STASGO soil map. AVGWLF uses as "area weighted" k factor parameter for each land use or cover type for a particular watershed.

The slope-length (LS) factor is used by the USLE equation and is a function of overland runoff and slope of the land. NRCS developed this factor based on slope length and the slope gradient for a particular area of land. The slope gradient is estimated though use of a statewide digital elevation layer for spatial resolution of 100 meters. The slope length (L) is found by the equation

$$L = \frac{SD}{0.5A}$$

where: SD = stream density, and

A = area of the watershed

The stream density is determined by using a digital lay that depicts all "blue line" streams appearing on a 1:24,000-scale USGS topographical map. The watershed area is then determined from polygon attribute information. LS factor calculation are then calculated using a "scaling factor" during the model calibration procedure.

The USLE equation uses two additional factors through the cropping management (C) and erosion control practice (P) factors. The crop management factor is also known as the vegetation cover factor and is used to show the consequence of ground cover attributes, soil conditions, and general farm management practices effects on soil erosion. The erosion control practice is used to show the effectiveness of both structural and nonstructural farm erosion control efforts such as terracing and residue management on cultivated land. Local cropping practices and conditions cause variations of this value throughout the state. AVGWLF uses estimates of both C and P compiled on a county (parish for Louisiana) basis and added to a digital "county boundary." In the GWLF simulation, parish estimates are used for both C and P for the particular affected watershed.

The coefficient that estimates the relative amount of evapotranspiration occurring within a particular watershed is the ET cover coefficient. This parameter is based on the existing cover of vegetation. AVGWLF uses these measures based on the land use or cover type and are area-weighted to determine the average values for each month of the year. These values range between 1.0 for wooded cover during the growing season to 0.3 for annual crops during the dormant time of the year. A smoothing algorithm is used to estimate the gradual rise and fall of ET that occurs at vegetation grows and withers throughout the year. The effects of daylight hours are calculated by use of latitude and longitude parameters of the centriod for a particular watershed within AVGWLF. The time frame of the growing season is input directly by the user. GWLF then uses a simple algorithm to estimate the effects of daylight and growing season on evapotranspiration.

AVGWLF uses two different erosivity values for eastern and western zones within a state through the use of a digital physiographic region map. GWLF then incorporates these values to estimate rainfall erosivity coefficients to estimate the rainfall intensity factor for use in the USLE algorithm. This factor varies by season and geographic location. The GWLF User's Manual contains a generalized map of rainfall erosivity zones.

GWLF allows specification of rainfall and snowmelt for up to five days prior to model start date. The GWLF manual recommends that a "0" be used when lacking such information. These values are reset after input of climate and soils data for the first year simulation.

Subsurface water is divided into unsaturated, shallow saturated, and deep saturated zones within GWLF. Daily water balances are estimated using weather and subsurface soil conditions. A value of 10 cm is recommended by the User's Manual when the initial amount of unsaturated water in unknown. A default value of 0 cm is used when the initial saturated storage in unknown. These values are also used as default values within AVGWLF.

There is no currently accepted technique for estimating the rate constant for deep seepage loss. Therefore, the conservative approach is to assume the parameter is zero. This is the value input in AVGWLF. The recession coefficient is based on historical stream flow records by use of standard hydrograph separation techniques. The typical values nationwide range from around 0.01 to 0.2. AVWGLF uses a default value of 0.1 for the northeast United States.

AVWGLF requires a value for unsaturated available water capacity. This parameter is calculated though use of soils data layer (STATAGO) as described earlier. An average value for available water holding capability (in cm) has been estimated and placed in one of the attribute fields for each soil-mapping unit. An area-weighted value of all the soil-mapping units in a watershed is calculated and placed in the transport.dat input file for used in GWLF.

A sediment delivery ratio is the percentage of material eroded from the land surface and deposited prior to reaching close by water bodies. The heavier soil particles are most likely to be deposited before reaching those waters. The amount of soil that does not reach the waters has been empirically related to the watershed size. This soil amount is called the sediment yield. The sediment delivery ratios determined though AVGWLF is based on the following factors:

$$SDR = 0.45\ (b^{0.298})$$

where: SDR = sediment delivery ration, and

b = size of the watershed in square kilometers

The lateral erosion rate is based on an approach used by researchers in the field of geomorphology. The monthly stream bank erosion is estimated by initially calculating a watershed-specific lateral erosion rate by using a form of this equation:

$$LER = aq^{0.6}$$

where: LER = an estimated lateral erosion rate

a = an empirically-derived constant related to the mass of soil eroding from the stream bank depending upon various watershed conditions, and

q = monthly stream flow in cubic meters per second

Bases on a study performed at Penn State’s Environmental Resources Research Institute, the value estimate for the “a” constant ranged from around 0.0004 to 0.00005 for Pennsylvania watersheds. This constant is statistically related to five important watershed parameters: animal density, curve number, soil erodibility (k factor), mean annual precipitation, and the percentage of land developed within the particular watershed. AVGWLF derives this constant according to the following equation:

$$a = (0.00500 * PD) + (0.000048 * AD) + (0.00005 * CN) + (0.000628 * KF) - (0.000003 * SP) - 0.000567$$

where: PD = Percent;; developed land in the watershed

AD = Animal density of the watershed in animal equivalent units (AEUs)

CN = Average curve number value of the watershed

KF = Average soil “k” factor value for the watershed, and

SP = Average Slope for the watershed

The total sediment load via stream bank erosion for the entire watershed is determined by multiplying the LER value times the total stream bank length (in meters), the average stream bank height (in meters), and the average bulk density of the soil (in kg/m^3. Default values of 1.5 are used for average stream bank height and 15000 for soil bulk density within AVGWLF. A digital stream layer integral to AVGWLF computes the stream bank length.

NUTRIENT.DAT FILE

The nutrient.dat file identifies pollution sources such as septic systems and manure concentrations. The nutrient flows into the streams contain dissolved and solid phases. The dissolved phase contributions come from runoff, point sources, and subsurface groundwater discharges that flow into streams. The solid-phase nutrients come from point sources, soil erosion, and washoff deposits from urban areas. Nutrient loads from non-urban flows and eroded soil from various source areas are considered homogenous in terms of soil and cover types within GWLF. The dissolved loads for each type of flow are obtained by multiplying runoff volume times average dissolved concentrations for both nitrogen and phosphorus. AVGWLF uses default dissolved nutrient concentrations that are a combination of those values recommended in the GWLF User’s Manual.

GWLF also allows for input of dissolved nutrient concentrations from agricultural sources runoff such as when manure is land applied as fertilizer. For use in AVGWLF, default values for nitrogen and phosphorus are used and may be adjusted upward based on the density of farm animals in production within a particular watershed. Within this context, animal density is expressed in animal equivalent units (AEUs). One AEU is equal to 1000 pounds of animal weight. Animal density is attributed to the particular postal zone zip code where the animals are located for use in a GIS layer.

For urban runoff, GWLF uses the concepts of nutrient "build up" and "wash off" to estimate these nutrient loads. Nutrients accumulate overtime in urban areas from different sources such as atmospheric deposition, animal litter, and street refuse. These pollutants are subsequently washed off from intermittent precipitation occurrences. Once again, AVGWLF uses default values found in the GWLF manual.

Point source discharges are indicated by the user and added to the nonpoint source loads that are calculated by the model. The point source layer contains information of monthly loads (Kg/month) of total nitrogen and total phosphorus discharged at the point source location. However, point source data may be difficult to obtain from all point sources in the watershed. While the total number of point sources captured may be less than a third of the total number of sources, the reported loads is estimated to be around 80% of the total discharged. Data for these point sources where obtained from the EPA Envirofacts website. At this site, the Water Discharge Permits Query Form allows you to retrieve selected data from the Permit Compliance System (PCS) database with regard to specific facilities holding National Pollutant Discharge Elimination System (NPDES) permits. The user can specify the facilities by using any combination of facility name, geographic location, standard industrial classification, and chemicals. Total nitrogen and total phosphorus point source data used for this analysis was obtained through the PCS Query form for the five parish dairy production region. The user must specify the nitrogen and phosphorus compounds of interest by using a parameter code. For example, the code for nitrogen, ammonia total (as N) was 00610. This search produced results for both total nitrogen, as ammonia and total phosphorus (as P). However, only one point source site produced results for both pollutants. A search for any phosphorus related pollutant produced little or no data. Most wastewater treatment facilities produced results. Most industrial sites produced no data. Water discharge permit information can be found at the EPA permit web site (EPA, 2008).

In order to estimate the amount of nitrogen loads entering streams, GWLF requires an estimate of the nitrogen concentration in groundwater. This estimate is accomplished by using a statewide map that uses a spatial relationship between nitrogen concentration and rock type and land use/cover type. An area-weighted value is calculated for a particular watershed and the scaled by a constant to reflect subsurface concentrations.

The phosphorus in groundwater is set to a default value of 0.008 mg/l in AVGWLF where agricultural impacts are viewed as minimal. The high rates of phosphorus in groundwater are found to correlate with high levels of nitrogen from agricultural impacts in Pennsylvania. For this situation, AVGWLF sets phosphorus concentrations at 0.008 mg/l when nitrogen concentrations are less than or equal to 0.7 mg/l. When nitrogen concentrations are greater than 0.7 mg/l, groundwater P is found by the following equation

$$GWP\ (0.0097 * GWN) + 0.0089$$

where: GWP = groundwater phosphorus concentrations in mg/l, and

GWN = groundwater nitrogen concentrations in mg/l

Both nitrogen concentration in sediment and phosphorus concentration in sediment are important parameters as soil erosion is the main mechanism for transport to surface waters. Both of these parameters where obtained from the agronomy department at Louisiana State University for the dairy production region in Louisiana**.**

The septic systems within the area of interest are a source of pollution. GWLF uses the number of persons served by septic systems to calculate nutrient loads. This data is calculated through a statewide census tract layer in AVGWLF. The GWLF simulation then uses the per capita values for nutrient loads in the septic tank effluent and the values for nutrient uptake by plants found in the GWLF users manual to estimate pollution loads.

GWLF

After data files are input through the AVGWLF module, the GWLF module performs a simulation of sediment, nitrogen and phosphorus flows into the surrounding water bodies. The mathematical models used to estimate nonpoint sources of phosphorus and nitrogen in water bodies are export coefficients, loading functions, and chemical simulation models. Export coefficients are estimates of average annual unit nutrient loads reaching watersheds from land uses. These coefficients are gross estimates of nutrient loads. However, they are limited in value for estimating seasonal patterns or water pollution control efforts. Chemical simulation models provide mass balance estimates by considering nutrient availability, transport, wash off and losses. While chemical simulation models may provide the most complete estimates of nutrient loads reaching the watershed, they are typically too data intensive for many water pollution studies.

Loading functions allow for the estimation of nutrient loads when chemical simulation models prove impractical. These functions represent compromises between the complexity of chemical simulation models and empirically derived export coefficients. Mechanistic modeling is limited to sediment and/or water movement. The chemical behavior of nutrients are either ignored or represented by simple empirical relationships.

The GWLF model requires daily temperature and precipitation data, runoff sources, and chemical and transport parameters. Transport parameters include area and runoff curve numbers. Watershed transport parameters include average daylight hours, growing season indicators, and evapotranspiration cover factors. The model estimates both dissolved and total monthly amounts of phosphorus and nitrogen loads in water flows from watersheds. Surface runoff and groundwater sources are both used in the estimation. Nutrient loads from point sources as well as septic systems are also included. The model produces monthly stream flow, soil erosion and sediment yield totals and does not require water quality data for calibration. Water runoff and groundwater discharge constitutes stream flow. Groundwater discharge is determined from a lumped parameter watershed water balance.

The model structure includes dissolved and solid phase nitrogen and phosphorus. Dissolved loads come from point sources, nonpoint sources, and rural runoff. Solid phase loads come from rural and urban runoff. Rural sources are transported in water runoff and soil erosion from many source areas, each of which is considered uniform in cover and soil type. Runoff is multiplied by dissolved concentration percentage to obtain the dissolved loads for each source area. The runoff is obtained by use of the Soil Conservation Service Curve Number Equation. The product of monthly sediment yields and average sediment nutrient concentration determines the solid-phase rural nutrient loads. The Universal Soil Loss Equation is used to determine soil erosion. The product of erosion and sediment delivery ratio determines the sediment yield. The sediment yield for any month is proportional to the total transport capacity of daily runoff for that month. Urban nutrient loads are considered to be entirely solid phase and are modeled using exponential accumulation and a washoff function. Septic systems nutrient loads are calculated by estimating the per capita daily load and the number of people in the watershed. Daily evapotranspiration is estimated from potential evapotranspiration and a cover factor. Potential evaptranspiration is estimated as a function of saturated water vapor pressure, daily temperature, and daylight hours.

Nutrient input data from rural source areas are dissolved nitrogen and dissolved phosphorus concentrations in runoff and sediment solid-phase nutrient concentrations. Septic systems require estimates of the per capita nutrient load in the septic system effluent and per capita nutrient losses from plant uptake and the total number of people served. Point sources for nitrogen and phosphorus are assumed to be in a dissolved state and specified on a monthly basis. The GWLF model simulation outputs the following: monthly stream flow, monthly watershed erosion and sediment yield, monthly total nitrogen and phosphorus loads in stream flow, annual erosion from each land use, annual nitrogen and phosphorus loads from each use, monthly precipitation and evapotranspiration, monthly groundwater discharge to stream flow, monthly watershed runoff, monthly dissolved nitrogen and phosphorus loads to stream flow, annual dissolved nitrogen and phosphorus loads from each land use, and annual dissolved nitrogen and phosphorus loads from each septic system.

PRedICT

The model used to estimate the impact of agricultural and urban Best Management Practices (BMP) implementation upon water pollution control is the Pollution Reduction Impact Comparison Tool (PRedICT). This tool was developed to monitor both agricultural and non-agricultural watershed pollution reduction strategies. A number of agricultural BMPs, urban BMPs and wastewater reduction options are available within PRedICT. The model allows the user to create and compare various pollution reduction efforts. The tool introduces current landscape conditions with respect to both point source and nonpoint source pollution loads and then compares those results with future conditions occurring after BMP implementations. PRedICT includes pollution reduction coefficients for nitrogen, phosphorus and sediment. Built in cost information is contained for various pollution reduction strategies or techniques. Load reduction costs are estimated through simple cost accounting. The user identifies the number of septic systems converted through centralized wastewater treatment, the number of acres of agricultural BMPs to be implemented, the types of sewage treatment plants upgrades to occur, and the percentage of urban areas to be treated by wetland and detention basins. Using this information, built-in reduction coefficients and unit costs are incorporated to calculate the sediment and nutrient load reductions and the cost to perform those reductions. An optimization routine is available for the user to identify the most economically efficient scenario concerning pollution reduction and cost tradeoff. The basis for the load reduction coefficients, unit reduction costs, the load and cost calculations, and a description of the optimization routines are examined in the next sections.

BMPs are structural, non-structural, and managerial efforts to mitigate pollution loads in watershed draining from both rural and urban areas. The Soil and Water Conservation defines a BMP as "a practice or combination of practices that are determined by a state or designated area-wide planning agency to be the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point and non-point pollutants at levels compatible with environmental quality goals." These efforts in rural areas are often referred to as conservation practices or agricultural and silvicultural BMPs.

An important goal of BMP implementation is to estimate it's a priori effectiveness in reducing the pollutants of interest. The PRedICT model is used to estimate BMPs effectiveness in nitrogen, phosphorus, and sediment reduction and there are a wide range of BMPs with resulting costs and effectiveness from which to select. It is critical for farm-level economic efficiency to select the most cost-effective BMP targeting the pollutants of concern for that specific geographic location. For assessing general water quality issues within a watershed, it may not be as crucial to identify specific BMPs at specific locations in the initial planning stages. However, if nonpoint pollution is the primary concern within a watershed then it useful to initially identify the potential effectiveness of general types of BMPs for nonpoint mitigation.

PRedICT organizes BMPs into nine categories: (1) Crop residue management which refers to the use of crop residue to protect soil surface, (2) Vegetated buffer strips which are areas of land maintained with some type of permanent vegetation such as grasses or shrubs, (3) Cover crops which are annual or perennial crops to prevent soil erosion. These crops and also improve soil health and provide additional income, (4) Crop rotations which are conservation practices that require the use of different crops in a specified sequence on the same farm field. These practices are employed to prevent soil erosion, (5) Contour farming which refers to of conducting tillage, planting and harvesting operations perpendicular to the gradient of the slope to reduce erosion, (6) Terraces and Diversions which refer to earthen channels that intercept runoff on sloping land areas thereby reducing runoff, (7) Grazing land management which refers to conservation practices to ensure adequate vegetation cover reduce soil erosion resulting from overgrazing, (8) Stream bank protection which collectively refers to practices employed to mitigate the polluting effect that nearby grazing stock has on streams, and (9) Nutrient management which is the planned use of organic and inorganic nutrients employed to optimize crop production while also protecting the nearby water bodies. The successful implementation of this practice usually requires the introduction of a farm-wide nutrient management plan with an objective of optimizing forage and crop yields while at the same time minimizing nutrient loss to the nearby surface and ground waters.

BMPs are generally used in concert rather than singularly to tackle farm pollution problems. PRedICT takes a system approach to mitigate on-farm soil and nutrient transport issues. The BMPs used by PRedICT estimate BMP reduction efficiencies by percentage by pollution type. Values for stream bank fencing and vegetated buffer are per mile of stream bank . For each stream mile in which each particular BMP is implemented, the “strerambank” or “surface load” is respectively reduced by the percentage displayed. The other values are on a “per acre” basis.

Costs associated with BMP implementation are included. Long term maintenance or operation costs are not considered within PRedICT. The individual costs are considered for a BMP and then summed for the relevant parameter (acre or mile).

Two types of urban BMPs are used by PRedICT; (1) Detention basin which are designed to temporarily capture and store surface runoff from storm episodes, and (2) Constructed wetlands which refers to artificial shallow water-filled basins planted with emergency plant vegetation. These structures are designed to achieve a specific water quality objective by removing suspended solids, nutrients, heavy metals, toxic organic pollutants, and organic compounds. Constructed wetlands are also capable of reducing peak runoff events and are useful in stabilizing water flow into nearby natural wetlands.

PRedICT uses default values for sediment, nitrogen, and phosphorus mitigation for detention basins and constructed wetlands. These default values may be modified by the user. The costs for implementing these structures are included. These estimates are construction costs only and does not include maintenance or operational expenses.

Septic systems are estimated based in the number of people on centralized sewage systems that are input by the user. The default reduction efficiencies for wastewater treatments are derived from wastewater technology textbooks and can be modified by the user if necessary. The costs for these treatments are included and may also be revised by the user if required.

APPENDIX E: GIS LAYERS REQUIRED AND LOCATION OF DATA TO RUN THE AVGWLF MODEL

APPENDIX E
GIS LAYERS REQUIRED AND LOCATION OF DATA TO RUN THE AVGWLF MODEL

1. Weather (a point layer): that includes all the weather stations in the area and a table of data (TMax, TMin. and Precipitation) associated with each weather station. Web address is: http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html

2. Point Source (a point layer): contains monthly loads of data found at the EPA's Toxic Release Inventory (TRI) web site :http://www.epa.gov/enviro/html/tris/tris_query.html and EPA point source (N & P) permit web address:http://www.epa.gov/enviro/html/pcs/pcs_query.html

5. Streams: Louisiana GIS CD

6. Unpaved Roads: digitized this layer on site.

7. Road: Louisiana GIS CD

3. Basin (Sub watershed Layer): Digital Elevation Models (DEM) used to generate this layer. Download DEM data from Louisiana Statewide GIS Web site at: http://www.atlas.lsu.edu

8. Counties (parishes): from Louisiana GIS CD

9. Septic System: from census population (2000) by census tract level data.

10. Animal-Density (a zip code polygon layer): from ESRI using the farm number by zip code from AG and use parish level data (number of animals in each farm) to estimate how many animals in each zip code area.
NASS web site at: http://www.nass.usda.gov/census/index1997.htm

11. Soils: From Louisiana GIS CD

12. Physiographic Provinces (a polygon layer): digitized layer in ArcMap from physiographic features of the United States found at :http://tapestry.usgs.gov/physiogr/physio.html
.
13. Land use: from Louisiana GIS CD

14: Elevation: Digital Elevation Models (DEM) used to generate this layer. Download DEM data from Louisianan Statewide GIS Web site at: http://www.atlas.lsu.edu

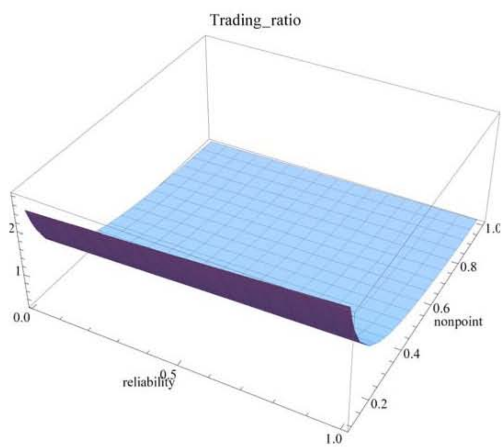
15. Groundwater-N (a grid image layer): groundwater sample data at found ate the LDEQ web site: http://www.deq.state.la.us/surveillance/wqdata/wqdata.aspx

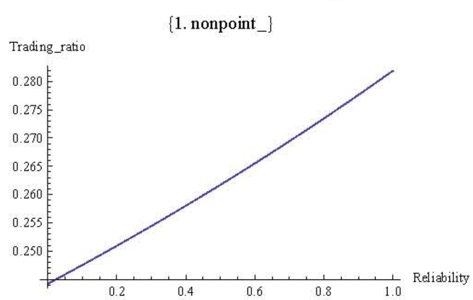
16. Soil-P (a grid image layer): found soil sample data in the Soil Testing Lab in the Department of Agronomy at Louisiana State University

APPENDIX F: MATHEMATICA PROGRAM FOR PS/NPS TRADING

APPENDIX F
MATHEMATICA PROGRAM FOR PS/NPS TRADING

```
(*  Point/nonpoint trading LARRY HALL DISSERTATION *)
Clear[e, qp, c, cn, qn, mean1, variance1, f, k1, qp, qn, t, a, nonpoint];
e[qp_] = -qp; (* qp is point source abatement.  e[qp] is abatement cost *)
c[qp_] = 0.14 * qp^1.5; (* abatement cost of point source, defined in terms of q_p *)
cn[qn_] = 1.16 * qn;
(* abatement cost agricultural nonpoint source from nonpoint source pollution *)
mean1 = 4.095; (* value mean in thousand ton of nonpoint source nitrogen emission *)
variance1 = .300; (* variance of nonpoint source pollution in thousands *)
f[qn_] = a * qn;
(* k1=0.3  (*  reliability parameter -- this parameter can vary from 0.6 to .95*) *)
t = {e'[qp]} / {(-mean1 + k1 * (variance1) ^ .5) * f'[qn]} (* Trading Ratio *);
plot1 = Plot3D [t, {k1, 0.01, 1}, {a, 0.1, 1},
  AxesLabel → {reliability, nonpoint}, PlotLabel → Trading_ratio]
(* Column[Table[t,{a,0.1,1,0.1},{k1,0,1,0.1}],a,k1] *)
plot2 = Plot[t /. a → 1.0, {k1, 0, 1},
  AxesLabel → {Reliability, Trading_ratio}, PlotLabel → {nonpoint_1.0}]
```





APPENDIX G: SAS PROGRAM FOR BMP EFFECTIVENESS

APPENDIX G
SAS PROGRAM FOR BMP EFFECTIVENESS

```
dm "log;clear;output;clear";
title 'dissertation chapter 2';
data new;
input SedRed NRed PRed Cost costinmillion;
initialsed=1458560019;  /* lbs */
initialn=18308970;  /* lbs */
initialp=1797389; /* lbs */
acresofland=2107125;
actualsed=initialsed-sedred*initialsed/100;
actualn=initialn-nred*initialn/100;
actualp=initialp-pred*initialp/100;
if sedred=0 then sedred=0.001;
unitsed=cost/actualsed;
unitnred=cost/actualn;
unitpred=cost/actualp;
/* if unitsed >100 then delete; */
costperacre=cost/acresofland;
cards;
2.8 7.7 7.1 161785626.80 161.7856268
3.3 7.4 7.4 168353543.00 168.353543
2.6 7.1 7.1 158187061.00 158.187061
2.5 6.8 7.5 176454417.80 176.4544178
2.4 6.9 7.2 148326462.60 148.3264626
2.5 8.9 7.4 134107367.60 134.1073676
2.4 7.3 7.2 145482643.60 145.4826436
1.9 6.8 6.9 144528706.00 144.528706
1.9 6.5 7 148717259.60 148.7172596
1.9 7.9 6.8 127774491.60 127.7744916
1.6 6.2 6.9 148278667.60 148.2786676
2.3 7.1 6.9 138026579.00 138.026579
2.3 6.1 7 157778195.20 157.7781952
2.3 3.3 7.2 217033042.00 217.033042
2.4 7.2 7.6 197126309.00 197.126309
2.3 6.8 7 153015536.20 153.0155362
2.3 10.4 7.5 95466980.80 95.4669808
2.4 10.5 7.7 95763030.00 95.76303
2.6 10.7 7.8 96081009.60 96.0810096
2.8 10.8 7.9 96338682.40 96.3386824
2.9 10.9 8 96596355.20 96.5963552
3 11 7.9 92117234.40 92.1172344
3.1 11.1 8 89990063.20 89.9900632
4.6 11.3 8.3 90980063.80 90.9800638
```

7.8 11.8 8.8 93125065.10 93.1250651
7.8 11.7 8.8 93064758.70 93.0647587
7.7 11.7 8.8 92966075.50 92.9660755
7.7 12.2 8.4 57444190.90 57.4441909
7.7 11.2 8.3 77195806.50 77.1958065
7.7 12.7 8.5 47568383.10 47.5683831
7.8 12.9 8.7 47643383.60 47.6433836
8.9 12.8 8.7 48393383.60 48.3933836
7.8 13.3 8.7 37767575.80 37.7675758
8.9 13.3 8.7 26849451.98 26.84945198
4.7 12.7 8 35712574.10 35.7125741
7.7 13.2 8.5 37692575.30 37.6925753
10.6 13.6 9 39672576.50 39.6725765
10.7 11.9 8.9 76397777.50 76.3977775
4.6 11.1 7.8 72272775.00 72.272775
4.4 10.9 7.7 72015102.20 72.0151022
4.4 9.4 7.6 108674514.40 108.6745144
4.5 7.6 7.8 162241723.20 162.2417232
4.4 7.2 7.7 165085542.20 165.0855422
4.4 6.5 7.8 176383259.50 176.3832595
4.4 5.8 7.8 187680976.80 187.6809768
4.4 5 7.8 198978694.10 198.9786941
4.4 4.3 7.8 210276411.40 210.2764114
4.4 3.5 7.9 221574128.70 221.5741287
4.4 3.2 7.9 222996038.20 222.9960382
4.4 2.7 7.9 232871846.00 232.871846
4 12 8 39187887.60 39.1878876
3.8 11.3 7.4 58939503.20 58.9395032
3.8 10.8 7.4 68815311.00 68.815311
3.8 10.3 7.3 78691118.80 78.6911188
3.8 10.5 7.4 75847299.80 75.8472998
0.8 2 1 12820486.00 12.820486
2 2.7 2.4 14794150.00 14.79415
0.1 0.8 1.2 11614358.00 11.614358
0.0 0.2 1.9 57008630.00 57.00863
0.0 10.9 1.8 15123094.00 15.123094\
0.0 0.1 5.4 226083780.00 226.08378
0.0 10.1 5.3 28567624.00 28.567624
0.1 6.2 5.9 197645590.00 197.64559
0.0 5.0 5.1 141389679.60 141.3896796
0.0 3.9 5.2 169595193.50 169.5951935
0.0 3.2 5.2 180892910.87 180.8929109
0.1 5.3 5.4 169517634.80 169.5176348
0.0 6.8 5.1 101886448.40 101.8864484
0.0 7.6 5.1 83556742.30 83.5567423
0.0 8.4 5.2 65227036.20 65.2270362
0.6 10.0 6.7 75994469.80 75.9944698
2.1 10.2 7.0 76984470.40 76.9844704

2.9	10.3	7.2	77479470.70	77.4794707
3.7	10.5	7.3	77974471.00	77.974471
5.2	10.7	7.6	78964471.60	78.9644716
7.0	11.0	7.9	80119472.30	80.1194723
6.9	11.6	7.8	71819118.70	71.8191187
7.3	11.8	8.2	72805950.70	72.8059507
6.6	11.3	7.8	71216054.70	71.2160547
6.6	11.2	8.1	93913190.70	93.9131907
7.0	11.5	7.8	71786224.30	71.7862243
7.4	11.7	8.2	72575689.90	72.5756899
6.7	11.2	7.8	70985793.90	70.9857939
6.6	11.0	8.0	93682929.90	93.6829299
6.8	10.7	7.9	92992147.50	92.9921475
2.9	10.3	7.2	77479470.70	77.4794707
2.7	10.3	7.1	77314470.60	77.3144706
2.4	10.3	7.1	77149470.50	77.1494705
2.4	10.3	7.1	77149470.50	77.1494705
2.1	10.2	7.0	76984470.40	76.9844704
2.2	8.7	7.0	113643882.60	113.6438826
2.2	9.3	7.4	123804072.30	123.8040723
2.2	9.1	7.4	125225981.80	125.2259818
2.1	9.0	7.4	126647891.30	126.6478913
2.1	8.8	7.4	128069800.80	128.0698008
2.1	8.6	7.4	129491710.30	129.4917103
2.1	8.1	7.3	139367518.10	139.3675181
2.1	6.7	6.9	147537034.50	147.5370345
2.1	6.2	6.9	157412842.30	157.4128423
2.1	5.7	6.9	167288650.10	167.2886501
11.4	13.7	9.2	40147840.16	40.14784016
11.4	13.7	9.2	40128103.52	40.12810352
11.3	13.7	9.2	40108366.88	40.10836688
11.3	13.7	9.1	40088630.24	40.08863024
11.3	13.7	9.1	40068893.60	40.0688936
11.3	13.7	9.1	40049156.96	40.04915696
11.3	13.7	9.1	40100691.52	40.10069152
11.4	13.7	9.1	40132489.44	40.13248944
11.4	13.7	9.2	40164287.36	40.16428736
11.4	13.7	9.2	40196085.28	40.19608528
11.3	13.7	9.1	40491038.40	40.4910384
11.3	13.6	9.1	40913183.20	40.9131832
11.3	13.7	9.1	40072183.04	40.07218304
11.3	13.7	9.1	40075472.48	40.07547248
11.3	13.7	9.1	40078761.92	40.07876192
11.3	13.7	9.1	40082051.36	40.08205136
11.3	13.7	9.1	40085340.80	40.0853408
11.3	13.7	9.1	40088630.24	40.08863024
11.3	13.7	9.1	40091919.68	40.09191968
11.2	13.7	9.1	40095209.12	40.09520912

11.2	13.7	9.1	40089498.56	40.08949856
11.2	13.7	9.1	40101788.00	40.101788
11.2	13.7	9.1	40105077.44	40.10507744
11.2	13.7	9.1	40108366.88	40.10836688
11.2	13.7	9.1	40111656.32	40.11165632
11.2	13.7	9.1	40114945.76	40.11494576
11.2	13.7	9.1	40118235.20	40.1182352
11.1	13.7	9	40121524.64	40.12152464
11.1	13.7	9	40124814.08	40.12481408
11.1	13.7	9	40128103.52	40.12810352
11.1	13.7	9	40131392.96	40.13139296
11.1	13.7	9	40134682.40	40.1346824
11.1	13.7	9	41137971.84	41.13797184
11.1	13.7	9	40141261.28	40.14126128
11.1	13.7	9	40144550.72	40.14455072
11.1	13.7	9	40147840.16	40.14784016
11	13.7	9	40151129.60	40.1511296
11	13.7	9	40154419.04	40.15441904
11	13.7	9	40157708.48	40.15770848
11	13.7	9	40160997.92	40.16099792
11	13.7	9	40164287.36	40.16428736
11	13.7	9	40167576.80	40.1675768
11	13.7	9	40170866.24	40.17086624
11	13.7	9	40174155.68	40.17415568
11	13.7	9	40177445.12	40.17744512
10.9	13.7	9	40180734.56	40.18073456
10.9	13.7	9	40184024.00	40.184024
10.9	13.7	9	40187313.44	40.18731344
10.9	13.7	9	40190602.88	40.19060288
10.9	13.8	9	40193892.32	40.19389232
10.9	13.8	9	40197181.76	40.19718176
10.9	13.8	9	40200471.20	40.2004712
10.9	13.8	9	40203760.64	40.20376064
10.9	13.8	9	40207050.08	40.20705008
10.8	13.8	9	40210339.52	40.21033952
10.8	13.8	8.9	40213628.96	40.21362896
10.8	13.8	8.9	40216918.40	40.2169184
10.8	13.8	8.9	40220207.84	40.22020784
10.8	13.8	8.9	40223497.28	40.22349728
10.8	13.8	8.9	40226786.72	40.22678672
10.8	13.8	8.9	40230076.16	40.23007616
10.8	13.8	8.9	40233365.60	40.2333656
10.7	13.8	8.9	40236655.04	40.23665504
10.7	13.9	8.9	40239944.48	40.23994448
10.7	13.9	8.9	40243233.92	40.24323392
10.7	13.9	8.9	40246523.36	40.24652336
10.7	13.9	8.9	40249812.80	40.2498128
10.7	13.9	8.9	40253102.24	40.25310224

```
10.7 13.9 8.9 40256391.68 40.25639168
10.7 13.9 8.9 40259681.12 40.25968112
10.7 13.9 8.9 40262970.56 40.26297056
10.6 13.9 8.9 40266260.00 40.26626
10.6 13.9 8.9 40269549.44 40.26954944
10.6 13.9 8.9 40272838.88 40.27283888
10.6 14 8.9 40276128.32 40.27612832
10.6 14 8.9 40279417.76 40.27941776
10.6 14 8.9 40282707.20 40.2827072
10.6 14 8.9 40285996.64 40.28599664
10.6 14 8.9 40289286.08 40.28928608
10.6 14 8.9 40292575.52 40.29257552
10.5 14 8.9 40295864.96 40.29586496
10.5 14 8.9 40299154.40 40.2991544
9.7 13.9 8.7 39789154.00 39.789154
9.5 13.9 8.8 39543154.10 39.5431541
9.3 13.9 8.8 39504154.10 39.5041541
8.8 13.9 8.8 39204154.10 39.2041541
8.6 13.9 8.7 39054154.10 39.0541541
8.4 13.9 8.7 38904154.10 38.9041541
8.1 13.9 8.7 38754154.10 38.7541541
7.9 13.9 8.7 38604154.10 38.6041541
7.5 13.9 8.7 38304154.10 38.3041541
7.2 13.9 8.7 38154154.10 38.1541541
7.6 13.9 8.7 38367154.12 38.36715412
7.7 13.9 8.7 38427154.12 38.42715412
7 13.9 8.7 38004154.10 38.0041541
6.8 13.9 8.7 37854154.10 37.8541541
6.6 13.9 8.7 37704154.10 37.7041541
6.3 13.9 8.7 37554154.10 37.5541541
6.1 13.9 8.7 37404154.10 37.4041541
;
proc means;
run;
  proc gplot;   plot unitnred*nred;
  proc gplot;   plot unitpred*pred;
  proc gplot;   plot unitsed*sedred;
run;
proc print;
run;
```

APPENDIX H: DAIRY SURVEY

APPENDIX H
DAIRY SURVEY

DAIRY MANURE DISPOSAL, DAIRY PROGRAM, AND BMP ADOPTION SURVEY

We appreciate that this is a necessarily lengthy questionnaire. For that reason, we will pay $15.00 to the first fifty respondents of completed questionnaires who also provide their Social Security Numbers. Know that any information you provide will be appreciated and that the quality of any analysis is no better than its input. Thanks in advance for your support.

MILKING PARLOR LOCATION Physical Address: ________________________
City or Town / Zip: ________________ / ______
If Known: Longitude ________ Latitude ____

SECTION I. SOCIO-ECONOMIC CHARACTERISTICS OF THE PRINCIPAL OPERATOR

1. How many years since age 18 has the principal operator worked on a dairy farm? ________ years

2. What is the age of the principal operator of this dairy farm? ______ years

3. How many years has this dairy farm been in the family? _____ years

4. What is the principal farm operator's educational level?

[ ] Less Than High School [ ] High School [ ] Some College
[ ] Bachelor's Degree [ ] Graduate Degree [ ] Vocational Training

5. Do you use a personal computer to get information on dairy related matters? [ ] YES [ ] NO

6. Gender of Principal Operator [ ] Male [ ] Female

7. What is the ownership arrangement of your dairy farm operation?

[ ]Individual owner[ ] Other partnership [ ] Other ____________ (specify)
[ ] Father-son partnership [ ] Family Corporation

8. Does the principal operator have off-farm employment? [ ] YES [ ] NO.
If YES, approximately how many hours per week? _____

9. Does your spouse have off-farm employment? [ ] YES [ ] NO.
If YES, approximately how many hours per week? ________

10. When you retire, will someone in your family continue your dairy operation? [ ] YES [ ] NO

11. Are any residential subdivisions adjacent to or near the dairy farm? [ ] YES [ ] NO
If YES, please estimate the distance: _____ miles

12. Do you think your dairy farm would be worth more if developed for nonagricultural uses, like a subdivision?
[ ] YES [ ] NO

13. Are you a member of a dairy marketing cooperative? [ ] YES [ ] NO.

14. Do you have other sources of income (stocks, bonds, pensions, etc.) besides your dairy?
[ ] YES [ ] NO

15. What percentage of total family income comes from off-farm and other income sources? _____ %

16. What was the estimated net income from the dairy in 2003?

[ ] $100,000 or more
[ ] $50,000- 99,999
[ ] 0- $49,999
[ ] Lost up to $25,000
[ ] Lost between $25,000-50,000
[ ] Lost more than $50,000

17. What percentage of your annual household net income comes from the dairy operation?

[ ] 0 - 20%
[ ] 21- 40%
[ ] 41- 60%
[ ] 61- 80%
[ ] 81- 100%

18. Liability is an obligation or debt owed to someone else. Assets include the monetary values of all the properties and tangible assets you have in the farm. Which of the following best describes your liability and asset situation?

[ ] I do not have any liability or debt.
[ ] My liability is anywhere between 1- 20% of my total assets.
[ ] My liability is anywhere between 21- 40% of my total assets.
[ ] My liability is anywhere between 41- 60% of my total assets.
[ ] My liability is more than 60% of my total assets

SECTION II. Dairy Manure Disposal

1. How many cows are in your dairy herd?

___________ Number of milking cows
___________ Number of dry cows
___________ Number of heifers over one year old not freshened
___________ Number of heifers and calves under one year old

2. What was your herd's annual average milk production per cow last year (Jan 1, 2003- Dec 31, 2003)?

___________ Lbs of milk per cow last year

3. How many acres of land do you own and rent for your dairy operation?
OWN RENT PRIMARY CROPS GROWN

Permanent pasture for hay, grazing & winter ryegrass ______ _____
Permanent pasture only ______ _____
Hay crop only ______ _____
Row cropland ______ _____ _______________
Woodlands used for shade & loafing ______ _____
Acres tied up by milking parlor and farmstead ______ _____

4. How many additional acres do you own and rent (not devoted to the dairy operation) such as woodland or pasture for beef? _______ acres

Of these acres, how many could manure be spread on? ______ acres

How many of these are rented acres? ___________ acres

5. How do you currently dispose of the dairy manure produced in and around your milking parlor, barns, and other dairy facilities? Please mark [X] all that apply.

[ ] Scrape manure and load into a spreader for dispersal.
[ ] Pile it up and spread it every _____ months.
[ ] Flush manure into the lagoon and pump it out later.
[ ] Apply to crops and pasture that I own or rent.
  Number of years I've been applying manure to my land: _____ Years.
[ ] Sell it to other farmers.
[ ] Give manure to others and
  [ ] They haul it away.
  [ ] I haul it away.
[ ] Pay someone to pump it out of the lagoon and apply it to my land.
[ ] Apply it to neighbor's land at:
  [ ] No Charge.
  [ ] Neighbor pays $_____ per ton.
  [ ] I pay $_____ per ton to spread.
[ ] Wash it off the slab.
[ ] No need for formal manure management. Manure remains on land.
[ ] Other; please specify ____________________________

6. What is the main reason for not selling your dairy manure?

[ ] No good method for moving it off my farm.
[ ] Market is not available to sell manure in my area (no one will buy it).
[ ] I use all the manure on my own crops.
[ ] I use all the manure on my pastures.
[ ] Absence of custom removal services.

7. Do you store manure? [ ] YES [ ] NO

If YES, which of the following describe your storage facility and its storage capacity?

Type of Storage Facility	**Approximate Capacity**
[ ] Pile	____________ *(tons)*
[ ] Lagoon	____________ *(designed for how many cows)*
[ ] Other (Specify) ____________	____________ *(______)*

8. Do you have a waste lagoon? [ ] YES [ ] NO

If YES, what year was it built? _______. How many cows were you milking at that time?______ Cows

9. Do you have a sand trap in your milking or feeding sheds? [ ] YES [ ] NO

If YES, is it functional? [ ] YES [ ] NO

10. How often do you pump out (remove waste water only) your manure lagoon?

[ ] Weekly [ ] Every _______ weeks [ ] Never [ ] Other (Specify) ______

11. How often do you clean out (remove waste water, dig out & remove solids) your lagoon?

[ ] Annually [ ] Every _______ years [ ] Never [ ] Other (Specify) ______

12. When you clean out your lagoon, what is the estimated total cost of cleaning? $______________

13. If you apply manure on your land (owned, rented or leased), what determines the time of application?

[ ] Manure lagoon is full.
[ ] Application optimum for planting or plant growth.
[ ] My turn on the "clean out" circuit.

14. What form of manure do you primarily apply on crop and pasture?

A. Cropland	[ ] Solid	[ ] Liquid/slurry	[ ] Combinations
B. Pastureland	[ ] Solid	[ ] Liquid/slurry	[ ] Combinations

15. If you apply as slurry, indicate how many acres and how many inches of manure slurry you applied to pasture and cropland when you last emptied your lagoon.

Numbers of acres	Inches of manure slurry applied	
A. Apply on pasture	___________	_____
B. Apply on cropland	___________	_____

16. If you apply as solid, indicate how many acres and how many tons of manure solids you applied to pasture and cropland when you last emptied your lagoon.

Numbers of acres	Tons of manure solids applied	
A. Apply on pasture	___________	_____
B. Apply on cropland	___________	_____

17. Have you bought any specialized equipment to handle manure in the last five years? [ ]YES [ ]NO

18. What kind of specialized equipment is used for manure handling and application on your farm?

	Size	Purchase Price
[ ] Honey Wagon	_______	__________
[ ] Spreader	_______	___________
[ ] Reel Applicator	_______	___________
[ ] Others (Specify) ___________	_______	___________

19. What are the minimum and maximum distances your dairy manure needs to be transported from the manure lagoon or assembly pile for application to crop or pasture lands?

Minimum: _________ Miles Maximum: __________ Miles

20. Have you ever cost shared with the Lake Pontchartrain Basin Foundation for dairy waste disposal?

[ ] YES [ ] NO

21. As you know, disposing of manure is a regular and necessary activity in any dairy operation. Do you find it profitable or at least cost-effective to apply dairy manure (slurry and solid) to your land, given the cost of commercial fertilizer and given the fact that manure handling and disposal are necessary milk production activities?

[ ] YES [ ] NO

If you responded NO, please answer the questions on the following page.

At present, USDA/NRCS (with funds from the Lake Pontchartrain Basin Foundation) offers a 75% cost share up to a maximum of $3,750 to clean out a lagoon every four years. This assumes it takes $5,000 to clean out an average-sized lagoon. Suppose the price of cleaning out the lagoon increases, but the cost-share and NRCS support does not increase beyond $3,750. At what cost would it be too expensive for you to clean out the lagoon? Mark [X] in the one that best applies to you.

[ ] I would not clean out the lagoon if the total cost for cleaning increases to $5,500 (or 10%).
[ ] I would not clean out the lagoon if the total cost for cleaning increases to $6,000 (or 20%).
[ ] I would not clean out the lagoon if the total cost for cleaning increases to $6,500 (or 30%).
[ ] I would not clean out the lagoon if the total cost for cleaning increases to $7,000 (or 40%).
[ ] I would not clean out the lagoon if the total cost for cleaning increases to $7,500 (or 50%).

22. **Have you heard of a Comprehensive Nutrient Management Plan?** [ ]YES [ ] NO
If YES, have you developed one for your dairy farm? [ ]YES [ ] NO

SECTION III. MILK REDUCTION PROGRAMS

Please read the following paragraphs before you answer the questions in this section.

Some consider dairy farms in Louisiana's Florida Parishes to be both point and nonpoint sources of pollution. This means there are two possible alternatives for minimizing pollution problems attributable to dairy farms. The first alternative is to reduce the number of dairy cows in the area. The second alternative is for dairy farmers to adopt the maximum number of applicable best management practices (BMPs) to minimize the negative environmental problems attributable to dairy farms.

The dairy termination program (DTP) of 1986 and the milk diversion program (MDP) of 1984-1985 were implemented to reduce the amount of milk produced by reducing the number of dairy cows. The purpose of these programs was to reduce milk production so as to raise milk prices and reduce the costs of the dairy price support program to the government. Similarly, the amount of manure being produced can be reduced by decreasing the number of cows. In the DTP, the producer submitted a bid price per hundredweight of milk for which the producer agreed to slaughter or export all female dairy animals and to exit milk production for at least five years. All bids of $22.50 or less per hundredweight of milk were accepted. In the MDP, the producer entered into a contract with the government to reduce milk production 5 - 30% from some base period level of production in exchange for a payment of $10.00 per hundredweight for an 18-month period. Since the rational producer would cull the lowest producing cows first, a participating producer would cull a percentage of cows that was higher than the contracted percentage of production. Both programs had the effect of reducing cow numbers, which reduced the total milk supply, put upward pressures on milk prices and reduced surplus stock levels. It follows that any reductions in cow numbers will reduce the volume of cow manure and its contributions to water pollution and phosphorous buildup in the soil.

The second alternative is to promote best management practices (BMPs) that minimize water quality deterioration from dairy production. Since 1996, USDA has used the Environmental Quality Incentive Program (EQIP) to assist farmers in adopting BMPs. Adopting BMPs allows dairy producers to simultaneously produce milk and be more environmentally responsible because BMPs reduce both point and nonpoint sources of pollution in water bodies. Dairy farmers have many BMPs available under EQIP, and the BMPs vary in their suitability by farm. Generally, the USDA helps share the cost of implementing various BMPs with the dairy producer. The cost share from the USDA under EQIP could be up to 75%, depending upon land quality, proximity to water bodies, and other unique attributes of the dairy farm. Limited resource farmers or first-time farmers potentially qualify for up to a 90% cost share. The contracts for BMPs under EQIP last for 1-10 years.

When requesting hypothetical values for participating in a milk reduction program or cost sharing in a BMP, previous research indicates that respondents over-estimate the amount they are willing to accept to participate in a supply control program and underestimate the amounts they are willing to pay to cost share in a BMP. If your responses are not well thought out, policy makers would most likely ignore the responses and look at industry cost levels or benefit data in establishing cost share values for the various BMPs. Therefore, it is imperative that you respond with values you believe to be true for you today, not historical values from other programs.

Now, we would like to ask you a series of questions regarding your participation in supply control programs and in cost sharing BMP initiatives.

1. Did you participate in the Milk Diversion Program or the Dairy Termination Program in the past?

Milk Diversion Program (MDP) (1984-85) [ ] YES [ ] NO
Dairy Termination Program (DTP) (1986) [ ] YES [ ] NO

If YES, what was the minimum amount you bid to participate in the DTP (that is, to stop producing milk for at least five years, and to slaughter or export all of your female dairy animals)?
$ ________ **per cwt milk**. **What was the maximum contraction in milk production you agreed to under the MDP for the $10 per hundredweight payment ?** ______ %.

2. Would you consider participating in a Milk Diversion Program (MDP) if it were offered today?

[ ] YES [ ] NO

If YES, what is the minimum payment you would be willing to accept to reduce your milk production? $ _____ per cwt milk.
For that payment, what is the maximum percent you would be willing to reduce your milk production? _______ %. **What percentage of your cow herd would be culled to achieve this rate of reduction?** _______ %.
What would you bid to participate in a Dairy Termination Program today? $______ per cwt milk.

3. What reasons contributed to your willingness to participate in a DTP or MDP today? Check all that apply.

[ ] Dairy operation is not profitable.
[ ] Dairy operation is reasonably profitable, but the future for dairying in Louisiana does not appear bright.
[ ] I am of retirement age.
[ ] Other (Specify) ________________________

4. Did you submit a bid to participate in the August 2003 CWT program? [ ] YES [ ] NO

If YES, how much did you bid? $ _____ per cwt milk.
Was your bid accepted? [ ] YES [ ] NO

5. What would have you done if your August 2003 CWT bid had been accepted and you had to exit the dairy industry?

[ ] Retire from full-time farming
[ ] Continue to farm full-time, but not dairy
[ ] Continue to farm part-time, but not dairy
[ ] Seek nonfarm employment
[ ] Other (specify) ________________________

SECTION IV. DAIRY BEST MANAGEMENT PRACTICES (BMP) ADOPTION

Regardless of your responses to both MDP and DTP questions, suppose that to continue producing milk you were required to incorporate BMPs into your dairy herd and dairy manure management programs. For the following BMPs, please indicate if a given dairy BMP is suitable for your particular dairy farm. The average cost cited after the definition of a BMP is the estimated average cost of adopting it in Louisiana during 1997-2001. This cost is for ~~the~~ reference purposes only. It is designed to enhance ~~help you~~ ~~make~~ your awareness ~~on~~ of the estimated cost incurred by others in ~~to~~ adopting a particular BMP. Your cost for these practices may be different

1. **Waste Treatment Lagoon (NRCS code 359):** *An impoundment made by excavation or earth fill for the temporary storage and biological treatment of animal or other agricultural waste.*
Estimated cost=$11,750 each

Has this BMP been adopted on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year?_______ Total cost from all sources to install BMP** $ ______ ***Your* cost-share ____%**
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

2. **Cover and Green Manure Crop (NRCS code 340):** *A crop of close growing grasses, legumes or small grains primarily for seasonal protection and soil improvement. Estimated Cost = $12.39 per acre*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share ____%**
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

3. **Critical Area Planting (NRCS code 342):** *A planting of vegetation such as trees, shrubs, vines, grasses or legumes on highly erodible areas. Estimated Cost = $416.64 per acre*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share ____%**
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

4. Fence (NRCS code 382): *A constructed barrier to livestock, wildlife or people to facilitate the application of conservation practices. Estimated Cost = $1.35 per foot*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your*** **cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

5. Field Borders and Filter Strips (NRCS code 386 and 393): *Strips of grasses or other close growing vegetation planted around fields and along drainage ways, streams and other bodies of water to reduce sediment, organic material, nutrients and chemicals carried in runoff. Estimated Cost = $0.10 per foot for Field Borders and $210.40 per acre for Filter Strips.*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ **Y*our*** **cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

6. Grassed Waterways (NRCS code 422): *A channel that is shaped or graded to required dimensions and established in suitable vegetation to convey runoff from terraces, diversion or other water concentration. Estimated Cost = $0.85 per foot*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your*** **cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

7. Heavy Use Area Protection (NRCS code 561): *Protecting areas by establishing vegetative cover. Estimated Cost =$0.95 per acre*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your*** **cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

8. **Riparian Forest Buffer (NRCS code 391):** *An area of trees, shrubs and other vegetation located adjacent to watercourses or water bodies. Estimated Cost = $1.08 per acre*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

9. **Roof Runoff Management (NRCS code 558):** *A facility for collecting, controlling and disposing of roof runoff water. Estimated Cost =$72.69 each*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

10. **Sediment Basin (NRCS code 350):** *A basin to collect and store debris or sediment (sand trap). Estimated Cost = $4,092 for each basin*

Have you adopted this BMP on your farm?

[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%

[ ] NO → **If NO, would you adopt this BMP on your farm?**

[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?

[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

11. Streambank and Shoreline Protection (NRCS code 580): *Use of vegetation or structures to stabilize and protect banks or streams and lakes against scouring and erosion. Estimated Cost =$4,140 per acre*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

12. Watering Facility (NRCS code 614): *A trough or tank with needed devices for water control and waste disposal installed to provide drinking water for livestock. Estimated Cost = $779.91 for each*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

13. Waste Storage Facility (NRCS code 313): *An impoundment to temporarily store manure, wastewater and contaminated runoff. Estimated Cost = $89,499.47 for each facility*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______? Total cost from all sources to install BMP** $ ______ ***Your* cost-share** ____%
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm
If YES, what is the maximum percentage of total cost you would pay to adopt this BMP?
[ ] 0 - 9.9% [ ] 10 - 19.9% [ ] 20 - 29.9% [ ] 30 - 40% [ ] more than 40%

The following BMPs qualify for incentive payments under EQIP. Practices with Incentive Payments, that are part of an EQIP contract that involves structural BMPs, receive a set fee per acre for a limited period (1-3 years). There is no cost share associated with these practices.

14. **Conservation Tillage Practices (NRCS code 329A,B,C) :** *A system designed to manage the amount, orientation and distribution of crop and other plant residues on the soil surface year around (such as Reduced Till, Ridge Till, No Till, Strip Till, Mulch Till and Residue Management Systems). Incentive payment =$10 -15 per acre, 2 year max, 100 acre upper limit on contract acreage*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______?**
Total Incentive Payment received for this BMP $______ per acre
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the minimum additional incentive payment do you need to receive to adopt this BMP?
[ ] 20% [ ] 40% [ ] 60% [ ] 80% [ ] 100%

15. **Nutrient Management:** *Management of the amount, form, placement and timing of application of plant nutrients (fertilizers) for optimum forage and crop yields. Also includes soil samples and comprehensive nutrient management plans. Incentive payment =$5/acre, max100 acre limit*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______?**
Total Incentive Payment received for this BMP $______ per acre
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the minimum additional incentive payment do you need to receive to adopt this BMP?
[ ] 20% [ ] 40% [ ] 60% [ ] 80% [ ] 100%

16. **Pest Management (NRCS code 595):** *A pest control program consistent with crop production goals and environmental standards. Incentive payment = $5/acre, maximum of 100 acre limit*

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______?**
Total Incentive Payment received for this BMP $______ per acre
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the minimum additional incentive payment do you need to receive to adopt this BMP?
[ ] 20% [ ] 40% [ ] 60% [ ] 80% [ ] 100%

17. Proscribed Grazing (NRCS code 528A): *Controlled harvest of vegetation with grazing animals.*
Incentive payment =$5/acre, for two years, max limit 100 acres per contract

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______?**
Total Incentive Payment received for this BMP $______ per acre
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the minimum additional incentive payment do you need to receive to adopt this BMP?
[ ] 20% [ ] 40% [ ] 60% [ ] 80% [ ] 100%

18. Waste Utilization: *Use of agricultural wastes on land in an environmentally acceptable manner to provide fertility for crop foliage and to improve or maintain soil structures.*
Incentive payment =$10/acre, for two years, max limit 100 acres

Have you adopted this BMP on your farm?
[ ] YES → **If YES, in which year? ______ If stopped, in what year_______?**
Total Incentive Payment received for this BMP $______ per acre
[ ] NO → **If NO, would you adopt this BMP on your farm?**
[ ] YES
[ ] NO
[ ] Not suitable for my farm

If YES, what is the minimum additional incentive payment do you need to receive to adopt this BMP?
[ ] 20% [ ] 40% [ ] 60% [ ] 80% [ ] 100%

19. If you answered NO to any of the BMP adoption questions, please check [x] all that apply and identify the BMP by question number.
[ ] I am planning to retire from farming in a few years.
[ ] It is not cost-effective on my farm, regardless of the cost-share. #____, # ____, # ____, # ___, #___
[ ] I talked to USDA about this BMP and decided not to use it on my farm. #____, # ____, # ____, # ___

20. Please rate each of the following sources ~~in~~ on a 1 to 5 scale (5=very important, 4=some what important, 3=important, 2 = not important, 1= not important at all) to their relative value as sources of information ~~were~~ for you in learning about BMPs ~~or~~ and EQIP.

BMPs	EQIP	Sources
_____	_____	Hoard's Dairyman or other dairy publication
_____	_____	Delta Farm Press or other farm publication
_____	_____	Article in newspaper
_____	_____	TV or radio
_____	_____	USDA-NRCS
_____	_____	LSU Ag Center
_____	_____	Southern University Ag Center
_____	_____	Master Farmer Program
_____	_____	DHIA or other dairy association
_____	_____	Dairy producers
_____	_____	Non-dairy producers

21. Have you ever visited or talked with USDA-NRCS District Conservationists about any BMPs or EQIP?
[ ] NO, I have never visited or talked with USDA-NRCS about BMPs or EQIP..
[ ] YES, I visited the USDA Service Center or talked with NRCS staff about BMPs or EQIP.

22. Have you ever submitted an application for EQIP to USDA-NRCS?

[ ] NO, I have never submitted an application for EQIP.
[ ] YES, I submitted an application for EQIP.
[ ] YES, I submitted an application for EQIP, BUT I withdrew it before it was ranked for environmental (practice) benefits.

23. Have you ever had an EQIP application ranked for environmental (practice) benefits by USDA-NRCS?
[ ] NO, my EQIP application was never ranked. I withdrew the application before this step was completed.
[ ] YES, my EQIP application was ranked for environmental (practice) benefits by USDA-NRCS.
[ ] YES, my EQIP application was ranked for environmental (practice) benefits, BUT I withdrew it before it was sorted with all the other applications.

24. Have you ever had an EQIP application accepted by USDA-NRCS?
[ ] NO, my EQIP application was not accepted by USDA-NRCS.
[ ] YES, my EQIP application was accepted by USDA-NRCS.
[ ] YES, my EQIP application was accepted by USDA-NRCS, BUT I withdrew it before USDA-NRCS visited my farm.
[ ] YES, my EQIP application was accepted by USDA-NRCS, BUT it was declared ineligible by USDA-NRCS after they visited my farm.

25. After an EQIP application was accepted by USDA-NRCS, did you draw up a plan?
[ ] NO, USDA-NRCS staff visited my farm but we never drew up a plan.
[ ] YES, USDA-NRCS staff helped me develop plans to implement the BMPs in the EQIP application.

26. After a plan was developed for your EQIP application, did you sign a contract for the plan?
[ ] NO, I decided not to sign the EQIP contract because of the costs required to implement it.
[ ] NO, I decided not to sign the EQIP contract for some reason other than the costs required to implement it.
[ ] YES, I signed the EQIP contract with USDA-NRCS.

27. For each statement, please place an X in the column that most nearly represents your views.

Statements	**Strongly agree**	**Somewhat agree**	**Undecided**	**Somewhat disagree**	**Strongly disagree**
Laws regulating water pollution are needed.					
Given the economic realities, soil and water conservation programs are often carried too far.					
Government should pay farmers to promote practices that enhance soil and water conservation.					
The government should not be involved in agriculture at all.					
Government involvement in dairy has helped farmers.					

28. Please write your SSN so that we can send you a $15 check in the mail. ______________________

Thanks for your help. It is only with the help of people like you that we can do an effective study.

VITA

Larry M. Hall was born in Natchitoches, Louisiana, while his parents attended Northwestern State College of Louisiana. He was raised in Baton Rouge and as a boy spent a great amount of time in the Boy Scouts and on camping trips where he grew to love nature. He returned to Natchitoches for college and graduated from Northwestern State University of Louisiana (NSU). While at NSU, received a commission in the United States Army through the Reserve Officers Training Corps (ROTC) program and served on active duty for two years as a Vulcan platoon leader. After release from active duty, he earned a Master of Business Administration (MBA) from Northeast Louisiana University (NLU) and a bachelor of science in chemical engineering from Louisiana State University (LSU). Desiring a career in technical sales, he sold computers for The Computer Place, the first personal computer store in Baton Rouge. He returned to active duty in the Army and was awarded the Legion of Merit upon retirement from the military. A new career began with a desire to learn more about economics and in particular, environmental economics. He hopes that through his new career he will have a positive impact on protecting the environment.