To the Graduate Council:

I am submitting herewith a thesis written by David Garland Sawyer entitled "An Evaluation of Targeting as a Strategy for Attaining Objectives of Conservation and Water Quality in the North Fork Forked Deer Watershed." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

William M. Park

William M. Park, Major Professor

We have read this thesis
and recommend its acceptance:

Luther H. Keller

Thomas H. Klindt

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

Thesis
83
.S299
Cop.2

AN EVALUATION OF TARGETING AS A STRATEGY FOR ATTAINING OBJECTIVES OF CONSERVATION AND WATER QUALITY IN THE NORTH FORK FORKED DEER WATERSHED

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

David Garland Sawyer

June 1983

1483020

ACKNOWLEDGMENTS

Without the love and guidance provided by the Lord Jesus Christ as my Savior through this research process the effort would not be complete.

I am eternally grateful to my mother, Mrs. Claude T. Sawyer (Peggy), for her continual support and encouragement through this long and ardurous process. I thank, too, my brothers, Mark and Stephen, for providing real understanding as well.

The contributions of my advisor, William Park, without question served to greatly improve the final product of this study. His guidance and patience during the entire course of graduate study was a great encouragement to me. I thank him for the time and effort he invested in developing my research capabilities.

I thank Luther Keller and Thomas Klindt for serving as the author's graduate committee. Their positive attitude and constructive criticism in reviewing this manuscript and participating in my oral examination were greatly appreciated.

A number of other individuals made significant contributions in terms of providing data and guidance for this research project. I must thank Sandra Batie and Alyson Grumbach of the Agricultural Economics Department, Virginia Polytechnic Institute for assistance in gathering, compiling, and analyzing much of the data base. I also thank Johnny Sandefur, Craig Ellis, Curtis Haynes, Shirley Elliott, Clarence Conner, and James Mize of the Soil Conservation

Service and Jim Nance and his staff of the Agricultural Stabilization and Conservation Service for providing technical assistance for this research effort. I thank Morgan Gray for invaluable assistance with computer programming. I also would like to thank Pearl Geddings, Melitta Stout, Pat Hickman, and Gail Pitt for compiling data and typing the manuscript.

Finally, the support for this project was provided by a grant from the Economics and Statistics Service of the USDA which is gratefully acknowledged.

ABSTRACT

Renewed concern regarding the problem of soil erosion from agricultural land has led to a serious re-evaluation of federal soil erosion control policy in the United States. The objective of reducing off-site water quality impacts of soil erosion has gained in prominence relative to that of maintaining on-site productivity. Recognition that most federal cost sharing supports implementation of best management practices (BMPs) on land with only slight to moderate erosion problems has led to proposals for targeting efforts to more highly erosive land. Cost effectiveness of soil erosion control efforts can be defined in terms of maximizing erosion reduction per dollar of federal expenditure when off-site water quality impact is considered the dominant objective. The purpose of this study was to evaluate (a) the extent to which the cost effectiveness of soil erosion control efforts was or could be increased by targeting to and within a critically eroding area, the North Fork Forked Deer (NFFD) Watershed of West Tennessee. The NFFD Watershed was an excellent case study area due to the severity of its erosion problem and an extensive base of collected data.

A special Agricultural Conservation Program (ACP) water quality project on the NFFD provided 75% cost sharing for application of BMPs sufficient to bring every field's erosion rate down to soil loss tolerance. In Chapter III summarization of the

set of BMPs planned under this project was developed so as to be as comparable as possible with the findings of the National Summary Evaluation of the Agricultural Conservation Program, Phase I (NSE-ACP-I). BMPs included were establishment of permanent vegetative cover, improvement of permanent vegetative cover, terraces, diversions, winter cover, critical area treatment and conservation tillage. Comparison on the basis of the distribution of BMPs by pre-practice erosion rate class and cost per ton of erosion reduction indicated that targeting funds to a critical watershed increased cost effectiveness. This was apparently due primarily to the more highly erosive land base in the NFFD Watershed, rather than any targeting accomplished within the context of the project itself. This set of BMPs was viewed too in light of the pre-project situation in terms of acreage in various pre-practice erosion rate classes and compared to the recommended treatment goals in the project application. The conclusion was drawn that significant potential exists for targeting to highly erosive land within a watershed and more cost-effective BMPs in order to increase cost effectiveness.

Based on the development of the equi-marginal principle of cost efficiency for application to the soil erosion control problem at hand in Chapter II, an LP model of the NFFD Watershed was constructed and employed as reported in Chapter IV. The basic LP model had as its objective maximization of erosion reduction subject to a constraint on available cost sharing funds. The activities in the LP model were BMPs applicable to fields on eight farms

synthesized to represent the land and owner-operator characteristics in the NFFD Watershed. Deviation of an "optimal" BMP set from the LP model served to emphasize the conclusion regarding potential for targeting to land within watershed and particular BMPs to increase cost effectiveness.

Policy implications outlined in Chapter V included support for further shifting of funds to critical watershed or areas but also the need to re-evaluate particular aspects of the current approach to include BMP implementation within a project or regular county program. The whole-farm requirement may limit cost effectiveness to the extent that treatment of slight erosive fields is mandated in addition to treatment of highly erosive fields. Possible modifications of the voluntary, first come-first served soil loss tolerance, and uniform cost-sharing aspects of the current approach merit consideration to allow for increased cost effectiveness. Of course, concern for the on-site productivity objective of soil erosion control may influence the advisability of some of these possible changes.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
	Objectives	9
	Outline of the Report	10
II.	THEORETICAL CONSIDERATIONS	11
	Soil Erosion as an Externality	11
	Soil Erosion Control Policy	12
	Economic Efficiency and Soil Erosion Control Policy	14
III.	ANALYSIS AND EVALUATION OF A SPECIAL ACP WATER QUALITY PROJECT	20
	Introduction	20
	Development of the Information Base for the NFFD Watershed Project	21
	The Impact of Targeting to the NFFD Watershed	28
	The Potential for Targeting Within the NFFD Watershed	44
	Summary Comments	50
IV.	A MODEL FOR ANALYSIS OF SOIL EROSION CONTROL IN THE NFFD WATERSHED	53
	Introduction	53
	Development of Representative Farm Units and BMPs for the NFFD Watershed	56
	Development of Coefficients for the NFFD LP Model	63
	Application of the LP Model	69
	Summary Comments	85
V.	CONCLUSIONS	87
	Summary of Findings	87
	Policy Implications	91
	Research Implications	97
REFERENCES		99
VITA		103

LIST OF TABLES

TABLE		PAGE
1.	Conservation Practice Adopted by Severity of Sheet and Rill Erosion, ACP, 171 Sample Counties, 1975-78.	6
2.	Percentage Distribution of Acreage and Practices Across Prepractice Erosion Rate Classes.	30
3.	Percentage Distribution of Practices Across Prepractice Erosion Rate Classes	33
4.	Average Cost Per Ton of Erosion Reduction. . . .	37
5.	Average Cost Per Ton of Erosion Reduction by Prepractice Erosion Rate--North Fork Forked Deer Special Water Quality Project	41
6.	Comparison of NFFD Watershed Preproject Situation with Project Accomplishments	46
7.	Conservation Treatment Goals of NFFD Watershed Acreage by Land Capability Subclass	48
8.	Elements Used to Characterize the Representative Farm Units of the NFFD Watershed	58
9.	Net Cost of Implementing Selected NFFD Watershed Best Management Practices	64
10.	Optimal Solutions of Whole Farm and Single Field NFFD LP Models with Budget of $0.6 Million.	72
11.	Average and Marginal Cost Per Ton of Erosion Reduction: $0.2 to $2.4 Million Funding Levels	79
12.	Optimal Solutions: NFFD LP, Single Field Model, with Budgets $0.2 to $2.0 Million	83

CHAPTER I

INTRODUCTION

Soil erosion again has emerged as a growing public concern in the United States. During the 1930's, United States citizens witnessed devastating floods and dustbowls that scoured the land leaving great quantities of soil virtually useless for agricultural production. Today, with expectations of high prices for their commodities and very few acreage restrictions on crops, farmers are planting their row crops on marginal land without regard to the damage inflicted upon the soil and water resources from soil erosion. Many farmers recognize that the problem exists; but with constraints imposed by high debt-equity positions, short planning horizons and other factors, the incentives for private action to reduce soil erosion are weak.

An excessive rate of soil erosion has two distinct effects upon the environment and society. First, soil erosion reduces the productive potential and the economic viability of the soil base. Soil erosion erodes topsoil from the soil profile which reduces the available water holding capacity of the soil, deteriorates the soil structure, and reduces the available rooting zone for plant growth. As a result, yield potentials for agricultural crops may be significantly reduced on some soil types. If the loss of excessive amounts of soil eroding from cropland continues at rates

presently experienced in the United States, the productivity of much of the nation's farmland will be diminished. In 1977 an estimated 168 million hectares of the United States land area was row cropped. Placing the loss of crop production from soil erosion on the 168 million hectares of cropland at 0.1 percent per year's yields an equivalent of 4.2, 8.4, and 16.8 million hectares of productive cropland will be excluded from crop production in the next 25, 50, and 100 years, respectively (13). The magnitude of the loss of productivity from United States farmland is increased even further when the costs of replacement inputs and removal of erosion damaged land from production are considered.

Second, eroded soil sediments are deposited in streambeds which clog and alter the flow of the water causing flooding in low lying areas. Eroded sediments carry nutrients to receiving water bodies which may promote excessive flora and fauna growth thus, reducing available oxygen and endangering the aquatic life. Sediment also transports chemical residues from pecticide application which may be toxic to fish and wildlife, and even man. The magnitude of the problem faced with regard to sediment and related discharges from agricultural land is great. On a national basis soil sediments are the major pollutants to United States streams by volume. The majority of soil sediments that are deposited in United States streams are derived from agricultural cropland runoff. Nelson estimated that in 1968 damages from soil sediments exceeded that from all other forms of water pollutants discharged

into the country's water sources. A study published by the Senate Agriculture and Forestry Committee in 1974 estimated that approximately 2 billion tons of sediment enter the nation's water supply from 400 million acres of cropland on an annual basis (24). The cost of removing the soil sediments from United States waterways and the devaluation of cropable bottom land is ever increasing. Nelson estimated losses from sediment damage in upstream water areas in the United States amounted to $1.25 billion annually as of 1968. In 1977 a national authority estimated that total damages from all forms of nonpoint pollution well exceeded $2 billion annually (15).

West Tennessee is one of the most critical regions in the nation with long-term average annual gross erosion rates, as predicted by the Universal Soil Loss Equation (USLE), being almost 10 times the national average and ranging up to 200 tons, per acre, annually. The extent to which soil productivity declines due to excessive soil erosion varies with soil type. For example, loess (wind blown) soils with fragipans exhibit a significant decline in crop yields when subjected to severe erosion. However, the deep loess soils without fragipans exhibit no significant decline in yields when they are severely eroded (7).

In West Tennessee excessive rates of soil erosion not only affect soil productivity but also alter the quality of the area's water. The review draft of the 208 Water Quality Management Plan, Obion-Forked Deer River Basin, which encompasses a large portion

of Northwest Tennessee's acreage states, "The most serious problems in the basin are related to nonpoint sources of pollution. Soil erosion, runoff of agricultural chemicals, siltation, flooding, and channel modification have combined to produce severe water quality problems." Sediment carried in runoff water is deposited in stream channels which impairs drainage and destroys aquatic habitat. Further, runoff from cropland contains chemical pesticides attached to soil particles or in solution in sufficient quantities that the threat of toxicity to many animals and man is ever present (21).

In an effort to combat the problem of soil erosion in the past, the United States Department of Agriculture (USDA) has developed 34 conservation programs. Three major programs are the Conservation Operations Program (COP), the Great Plains Conservation Program (GPCP), and the Agricultural Conservation Program (ACP). These programs all operate under a voluntary framework whereby technical assistance, cost-share payments and both short- and long-term agreements are used to encourage farmers to implement conservation practices. The Soil and Water Resources Conservation Act of 1977 (RCA), which was a report developed for the purpose of assessing the efficiency of the USDA's traditional soil conservation programs, has shown that the programs presently in use are having limited effectiveness in preventing soil erosion from cropland. In fact, the report indicated that levels of soil erosion were on the increase and that the long held goals of

conservation and improvement of farm incomes were often in conflict (22). Also in 1977, the Comptroller General of the United States reported to Congress that the USDA through its controlling agencies had not placed proper emphasis upon the problem of soil erosion (26). One of the major conclusions of this report was that ACP cost-share payments were not utilized in an efficient manner. It was noted that the Agricultural Stabilization and Conservation Service (ASCS) tended to approve cost-share payments for short-term, output-enchancing practices such as liming, drainage, land leveling, and irrigation as opposed to bona fide soil conservation practices. In most cases these output-enhancing practices were profitable enough that farmers would undertake these practices on their own without subsidization. The Comptroller General also cited these programs for not placing proper emphasis upon the areas with the most critical land erosion problems, i.e., land capability classes, IV, VI, and VII.

Accusations made by the Comptroller General concerning noneffective use of ACP funds were verified in several investigations into the use of cost-share payments. The National Summary Evaluation of ACP, Phase I, revealed that over one-half of the practices cost shared from 1975-78 were applied to land eroding at a rate of less than 5 tons, per acre, per year with no serious problems (see Table 1) (23). The 5 tons, per acre, per year threshold is often used as an approximation of soil loss tolerance which is defined as the estimated average annual soil loss expressed

TABLE 1. Conservation Practice Adopted by Severity of Sheet and Rill Erosion, ACP, 171 Sample Counties, 1975-78

Soil Loss (tons/acres	Distribtuion of Practice (percent)
0-4.9	52
5-9.9	19
10-14.9	11
15-29.9	11
30 and over	7
Total	100

in tons, per acre that can be tolerated while substaining the existing level of agricultural production potential indefinitely. Soil loss tolerance actually ranges from 2 to 5 tons, per acre, per year depending upon the soil type and degree of previous erosion. In contrast, only 18 percent of the conservation practices were applied to land eroding at greater than or equal to 15 tons, per acre. This land accounted for 84 percent of land eroding at a rate in excess of 5 tons, per acre, annually.

The Federal Water Pollution Control Act Amendments (FWPCAA) of 1972, as amended in 1977, resulted from the growing national concern over the deterioration of water quality of the United States streams. Section 101 of the Act states that the objective of the Act is to restore and maintain the chemical, physical, and

biological integrity of the nation's waters. In order to achieve this objective, the national goal was to eliminate discharge of pollutants into the navigable waters by 1985. Unlike previous legislation, this Act recognized and distinguished between the sources of water pollution. The point sources of water pollution are defined as those predominantly discharged from industrial and municipal facilities. Nonpoint sources of pollution refer to discharges of sediments and other material in storm-induced runoff from land. Agricultural activities mainly contribute wastes that are classified as nonpoint sources of pollution, but can involve point sources of pollution.

Section 208 of the FWPCAA of 1972 has been a public law for nearly 10 years but appears to have done little except to emphasize the off-farm water quality improvement purpose of soil erosion control relative to the historical on-farm productivity maintenance purpose of soil conservation. Section 208 of the Act most directly influences efforts toward soil erosion control and was included "for the purpose of encouraging and facilitating the development and implementation of area-wide waste treatment plans, which shall contain alternatives for waste treatment management and be applicable to all wastes generated in the area involved." The water quality management plans will in part include: "identification of water quality problems, identification of pollution sources, recommendations of guidelines for locally developed best management practices (BMPs) to curb pollution for identified sources,

and recommendations of state and local agencies needed to implement long-term water quality programs" (25).

In the current period of evaluation and redirection for federal conservation programs, strategies for improving cost effectiveness of cost-sharing and technical assistance, and targeting cost-sharing funds to critically eroding areas in particular, are receiving increased attention. Critically eroding areas (watersheds) have recently been defined with increasing emphasis on the problem of the deterioration of water quality downstream, but the program approach remains much the same as the traditional on-farm oriented soil conservation programs. From an economic viewpoint targeting funds to critical watersheds is justifiable because benefits in terms of both soil productivity maintenance and water quality improvement and costs of reducing soil erosion differ widely across the country (23). In recent years a portion of the federal ACP funds has been diverted from general county allocations to special water quality projects on critically eroding watersheds in the hope that the impact per dollar of ACP funds expended would be increased. The Rural Clean Water Program (RCWP) also appropriates funds separately for similar uses on other critically eroding watersheds.

In this study, the overall goal of soil erosion control policy was generally considered to be maximization of erosion reduction per dollar of subsidy payment, reflecting predominance of the off-site water quality objective of the special projects.

However to give some weight the on-site productivity objective, pursuit of this overall goal was assumed to be constrained by the requirement that if a BMP were to be applied to a field it must be sufficient to bring the erosion rate down to soil loss tolerance. As alternative objective which would reflect primary concern for the on-site productivity objective would be maximization of the number of acres on which the erosion rate was brought down to tolerance per dollar of subsidy payment.

I. OBJECTIVES

The overall objective of this study was to evaluate the potential of alternative targeting strategies for increasing cost effectiveness of soil erosion control efforts in a case study of a critical watershed, the North Fork Forked Deer Watershed (NFFD) in West Tennessee. Specific objectives of the study were as follows:

1. To identify the set of BMPs to be implemented as part of the special ACP water quality project on the NFFD Watershed for comparison with the set outlined in the project application.
2. To estimate the cost effectiveness of the set of BMPs to be implemented for comparison with similar estimates in the National Summary Evaluation of the ACP, Phase I.
3. To develop and employ a mathematical model to identify the sets of BMPs which would maximize the reduction in

gross erosion of the NFFD Watershed given various program budgets.

4. To suggest, on the basis of comparison of the actual (objective 1) and "optimal" (objective 3) sets of BMPs, targeting strategies which might improve cost effectiveness of soil erosion control efforts.

II. OUTLINE OF THE REPORT

The remainder of this report is structured in the following manner. Economic theory related to subsidy policies for inducing soil erosion control is presented in Chapter II. A detailed analysis and evaluation of the special ACP water quality project of the North Fork Forked Deer Watershed (NFFD) is provided in Chapter III. This evaluation includes a comparison of the effectiveness of best management practices (BMPs) implemented in the watershed to those installed on a national basis. A description of the linear programming (LP) model and its use in identifying BMPs which would maximize the reduction in gross erosion for the watershed given various program budgets is summarized in Chapter IV. Finally, conclusions and recommendations regarding present and future targeting strategies are discussed in Chapter V.

CHAPTER II

THEORETICAL CONSIDERATIONS

Analysis of nonpoint pollution control policy for an agriculture watershed like the North Fork Forked Deer Watershed requires attention to both physical properties of soil erosion control and economic principles which can properly guide the development of policy strategies. A strategy which utilizes targeting as the tool for a proposed solution must be theoretically sound and address relevant aspects of the problem.

I. SOIL EROSION AS AN EXTERNALITY

Nonpoint pollution in the NFFD Watershed has many adverse impacts upon the environment. This analysis focuses upon the downstream effects of sediment eroded from upland cropland. Erosion of soil particles and the related water quality problems can be characterized as follows. First, the production of row crops yields primary agricultural products from which the farmer earns returns. Secondly, the activity of row crop production yields sediment deposition downstream, affecting other land owners and society as a whole.

From an economic perspective agricultural production discharges residuals into stream channels generating externalities in terms of diminished on-site agricultural production potential,

water quality, and recreational use values. To the extent that individuals farmers' interest in the future of maintaining the productivity of farmland differs from that of society allowing diminishing agricultural productivity to be viewed as an externality. The existence of such residuals can be viewed as a potential market failure where the costs of the by-products are not internalized by upstream landowners, and downstream users of property are not compensated for their economic losses. Under a perfectly competitive market, with no externalities of this type, the free market system can be expected to allocate resources so as to maximize social welfare, given the initial distribution of property rights (3). When external effects exist, a free market system can no longer be expected to allocate resources in society's best interest. Externalities in this care directly alter the output of producers and consumers downstream other than through market exchange. This divergence between private and social costs is not accounted for in the marketplace.

II. SOIL EROSION CONTROL POLICY

In response to the ever increasing level of residuals that continue to enter the nation's waterway in runoff from agricultural land, the government has decided that nonpoint pollution should be decreased by placing emphasis on soil erosion control at the source of the problem, i.e., field or farm level. The alternative institutional arrangements for addressing the problem include

educational and technical assistance, subsidies, cross compliance with other agricultural programs, and taxation (8).

In the past cost-sharing has been a large component of traditional programs designed to induce voluntary adoption of soil erosion control practices. Participation in the program apparently occurred in cases where farmers, acting in their private interest, perceived the sum of the on-site productivity benefit and the cost-share payment to exceed the cost of the practice. Research and program experience indicate that subsidies are required to induce the farmer to voluntarily implement BMPs to reduce agricultural nonpoint pollution. Sharp and Bromley suggest, "Subsidies are a reality in nonpoint source abatement programs and one of the most pressing issues facing local and state units of government is the allocation of scarce federal, state and local funds in a manner conducive to the attainment of the goals of PL 92-500" (20). Subsidy payments aid the farmer in recouping net costs associated with adoption of BMPs, i.e., "to compensate farmers for costs net of the on-farm productivity benefits of soil erosion control" (17).

However, according to a recent study of cost-sharing for soil erosion control across the entire United States (National Summary Evaluation of the ACP, Phase I), great sums of the Agricultural Conservation Program (ACP) funds were being distributed in an inefficient manner from the standpoint of the public interest in reducing total gross soil erosion. In the past all cost-sharing programs to induce soil erosion control have been conducted on a

voluntary, first come-first serve basis, which has allowed practices to be applied to low priority or nonexistent problems. Data from the Natural Resources Inventory undertaken by the Soil Conservation Service indicate that a much greater reduction in soil erosion could be obtained through sharply focusing conservation program expenditures to land with the highest rates of erosion. This concept has been labeled "targeting" by its advocates.

Targeting may be undertaken at two different levels. First, targeting may involve transfer of available funding from less erosive regions of the country to those regions where more severe erosion problems exist. Second, targeting within a particular county or watershed would offer incentives in such a way as to induce appropriate treatment of the most erosive land. Targeting of program funds may mean that not all those willing to participate in the program will necessarily be able to participate.

III. ECONOMIC EFFICIENCY AND SOIL EROSION CONTROL POLICY

An economically efficient method of controlling nonpoint pollution through implementation of a targeting strategy is conceptualized as it applies to the NFFD Watershed in the following discussion. Economic efficiency can be defined as the maximization of net social benefits from reducing total gross erosion. Under current conditions, however, subsidy programs are limited in supply of inputs (ACP funds) which are used to produce a variety

of outputs (BMPs); and benefits are difficult to measure in dollar terms. With these conditions constraining the implementation of BMPs, the economic efficiency objective with water quality as the dominant concern is more appropriately defined in terms of maximizing the reduction of total gross erosion given a fixed budget, i.e., cost efficiency in use of public subsidy funds.

The economic principle for the cost efficient use of a limited budget can be illustrated in Figure 1 which shows the marginal cost (MC) curves for reducing gross erosion (E) by application of BMPs on two different fields. Given a fixed budget, the cost efficient levels of erosion reduction are E_1 and E_2 where the marginal cost for the last unit of erosion reduction is equated across the two fields. However, soil erosion of control programs have apparently led to a higher level of treatment of some fields, say, up to E_1' on field 1, and a lower level on others, say, up to E_2' on field 2. Because of the difference in MC, $E_1' - E_1$ would necessarily be less than $E_2 - E_2'$, i.e., less total reduction in soil erosion could be gained. The "cost saving" of $E_2'CDE_2$ from lower treatment of field 2 would allow for only a smaller increase in treatment on field 1, since E_1ABE_1' must be equal to E_2DCE_2' to stay within the fixed budget constraint. To look at it in reverse, from the situation of treatment levels E_1' and E_2' funds could be shifted from field 1 to field 2 in order to increase the total erosion reduction from $E_1' + E_2'$ to $E_1 + E_2$.

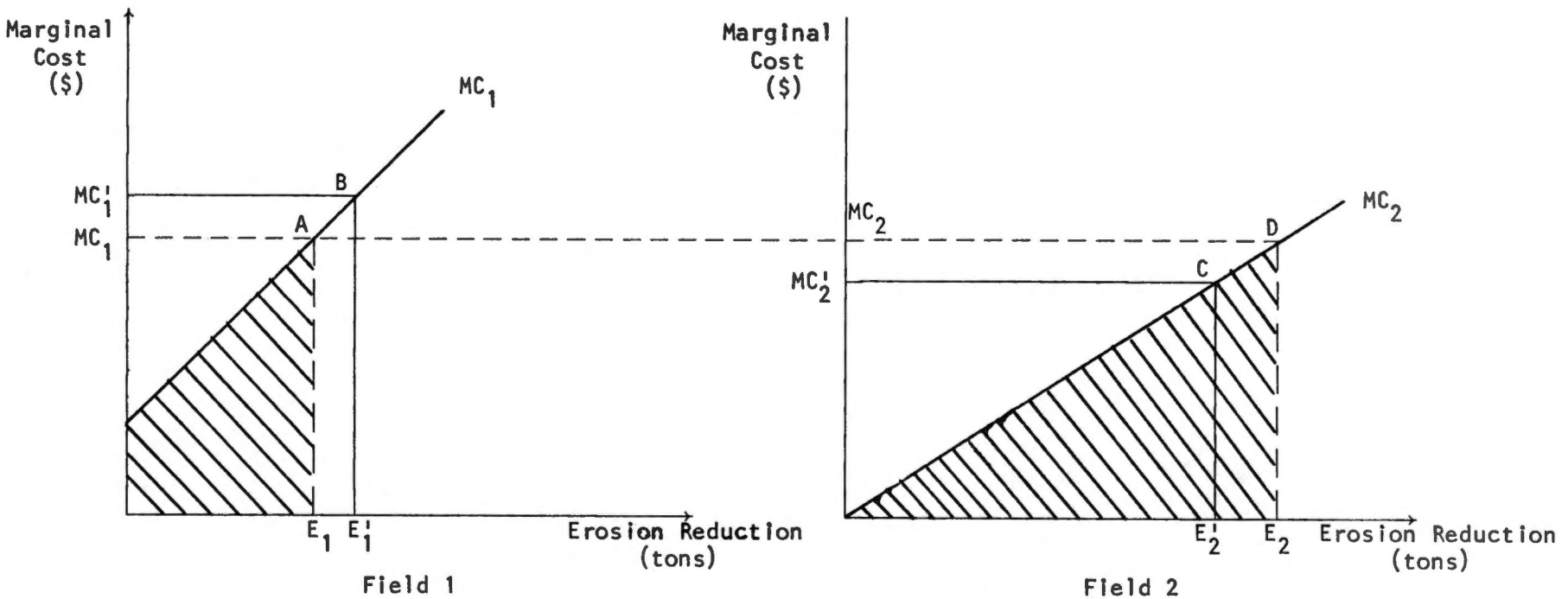

FIGURE 1. Marginal Cost Per Ton of Erosion Reduction.

To tie more closely back to the concerns expressed earlier, slightly erosive fields with MC well above MC_1 (= Mc_2) for the first unit of E have been treated, while highly erosive fields with MC well below MC_1 (= MC_2) for the first unit of E have not been treated. Or, if treatment of a field is viewed as an all-or-none decision (i.e., to bring the erosion rate down to tolerance), cost efficiency can be conceived as using available funds in a particular order, treating fields with the lowest average cost per ton of erosion reduction first. The voluntary first come-first served cost-sharing approach cannot be expected to generate this result.

Public subsidy costs for a given erosion reduction level are not minimized for at least two major reasons in addition to the equi-marginal principle not being applied. First, rents are assocated with uniform cost-share subsidies because net cost as a percentage of gross cost differs with variation in the characteristics of the land, BMP and operator. For example, net cost as a percentage of gross cost may differ widely for a BMP such as terracing depending upon the slope or soil type and whether the operator is an owner or a renter. The uniform payment amount for a particular BMP in many cases is formulated from the cost of implementation of that BMP on a so-called typical field of soil type and slope under controlled conditions. In many cases the landowner's cost of adoption of a BMP is less than the cost-share payment received; therefore, he receives a rent associated with the cost-share payment, the amount above the minimum which would

be necessary to induce adoption of the BMP. In many situations the 50 or 75 percent cost-share subsidy payments may not have been necessary to induce adoption of a BMP, i.e., a lower percentage subsidy would have sufficed.

Second, public subsidy costs may be greater than the minimum for a given erosion reduction level due to underestimation of the true on-site benefits that accrued from adoption of a BMP. Farmers may underestimate the value of the on-site productivity benefits, therefore, a greater cost-share subsidy than the real net cost (hatched areas, Figure 1) is necessary to induce participation in ACP. The primary reason farmers underestimate on-site benefits is that the benefits come in the form of long-term soil productivity maintenance. As a result they may perceive the net cost of implementation of a BMP to be significantly higher than the real net cost. Reducing the gap between perceived and real net costs through information and education regarding the actual physical and economic gains by the farmer from adoption of a BMP may reduce cost-sharing levels necessary to induce adoption of BMPs.

To help minimize public subsidy cost a variety of policy changes have been made in recent years. First, emphasis was shifted from short-term, production oriented, single field practices to long-term, conservation oriented, whole farm plans which employ the soil loss tolerance requirement. Second, extra funds have been targeted to highly erosive regions or watersheds like the NFFD Watershed. Third, a new pilot program called the variable cost

sharing (VCS) ACP program has been iniated to provide a redirection toward greater cost effectiveness of public fund use. The program is currently being implemented within the context of regular county ACP programs in which variable cost-share rates are offered depending upon the magnitude of erosion reduction associated with a particular practice on a particular type of field (17). This strategy provides a relatively greater incentive for adoption of conservation practices for a farmer's most erosive land. The VCS strategy works on the premise that farmers with the highly erosive land have not participated in ACP programs because their perceived net cost of adoption of a practice has been greater than the traditional percentage ACP cost-share payment of the gross cost (50 to 75 percent).

One of the objectives of this study is to consider the effectiveness of emphasizing long-term, conservation oriented, whole farm plans, and targeting to highly erosive regions in improving cost efficiency in the context of the NFFD Watershed case study area. On the basis of an analysis of the accomplishments of the special water quality project and a linear programming model of the erosive control options of the NFFD Watershed, other strategies designed to target efforts for improved cost efficiency may be suggested, e.g., offering a subsidy payment per ton of erosion reduction (which would be consistent with the equi-marginal cost principle) or establishing a priority system for availability of cost-sharing funds.

CHAPTER III

ANALYSIS AND EVALUATION OF A SPECIAL ACP WATER QUALITY PROJECT

I. INTRODUCTION

In order to meet the objectives presented in Chaper I, it was necessary to develop a framework for analyzing the cost effectiveness of best management practices (BMPs) implemented in the special ACP water quality project on the North Fork Forked Deer (NFFD) Watershed. The first section of this chapter reports on how information on costs and erosion reductions for the NFFD Watershed project were derived from long-term agreements (LTAs) developed for farms in the NFFD Watershed. In the second section this information is summarized to allow for the cost and erosion reductions experienced in the NFFD Watershed project to be compared with the findings from the National Summary Evaluation of the ACP Phase I (23) with a view to assessing the impact of shifting funds from nation-wide use to a critical watershed. In the third section the information from the NFFD Watershed project is analyzed within the context of the preproject situation and goals outlined in the project application with a view to assessing the potential impact of targeting within a critical watershed.

II. DEVELOPMENT OF THE INFORMATION BASE FOR THE NFFD WATERSHED PROJECT

Because of severe soil erosion and related water quality impacts, West Tennessee is considered to be one of the highest priority areas for soil conservation activities in the United States. The North Fork Forked Deer (NFFD) Watershed in Gibson County, Tennessee, is an excellent case study area for which to evaluate the potential of targeting because of the severity of soil erosion in this area. The upland acreage used for row crop production eroding at a rate above soil loss tolerance in the Watershed has an average erosion rate of approximately 40 tons of soil sediment per acre, annually, and at this rate of erosion an average one inch of topsoil is lost every four years during periods of crop production (16).

The NFFD Watershed consists of 80,190-acres within the central portion of Gibson County and is located in the Mississippi Hatchie subregion of the Lower Mississippi Resources Area; it is also part of the plateau slope of West Tennessee (16). The North Fork of the Forked Deer River, the principle stream in the Watershed, flows northeasterly through Gibson County to its confluence with the Forked Deer River about five miles downstream from Trenton, Gibson County's county seat. This area is characterized by loess parent material that covers marine deposits of the Coastal Plain with undulating to rolling topography in the uplands which are nearly level to moderately steep in slope. The floodplains are

broad nearly level areas with varying degrees of soil wetness depending upon their position relative to the streambed.

Agriculture is the dominant industry in the area with cash crop enterprises providing the greatest revenue. Soybeans, corn, wheat, and cotton are the predominant crops grown with vegetables and hay of secondary importance. Soil erosion and related water quality problems have been magnified in recent years due to the fact that price incentives for soybean production have led operators to grow soybeans continuously using conventional tillage methods and few conservation practices on land capability classes III, IV, VI, and VII, with little regard for the long-term impacts on soil productivity or current impacts on water quality.

Because of the existence of an extensive data base the NFFD Watershed is an ideal case study area for analysis of the potential cost effectiveness of targeting strategies. A special Agricultural Conservation Program (ACP) authorized by the Agricultural Stabilization and Conservation Service (ASCS) has been operational in the NFFD Watershed since 1979. This project is an integral part of the planned comprehensive land treatment program for the Watershed considered to be necessary to decrease downstream water quality problems. In conjunction with the special ACP water quality project, the agencies of the USDA compiled a Watershed Plan which contains an inventory of the NFFD Watershed's land resources and overall objectives of the special project which served as a basis for various assumptions made in the study of the NFFD Watershed. Also available for informational purposes were individual conservation plans from

the Gibson County Soil Conservation District which were developed under the traditional ACP program.

Long-Term Agreement Summarization

The analysis of objectives 1, 2, and 4 relied most importantly upon a detailed compilation of the data contained in the LTAs developed from the special ACP water quality project. A LTA is defined as a contract agreed upon between the USDA-ASCS and the individual landowner which requires the cooperator to implement soil erosion control practices such that erosion rates on each field of the farming operation are estimated to meet soil loss tolerance for a period of 3 to 10 years (16). To ease the financial burden of installing required BMPs, cost-share subsidy payments of 75 percent of the gross cost of implementing the practice specified in the LTA is available up to a maximum of $3,500 per year for 10 years.

As of 1982, approximately 70 LTAs had been developed, signed and were either completed or currently being implemented in the Watershed. The following information was derived and compiled from the LTAs:

1. Farm cooperator's name, address, ASCS farm number and total farm acreage within the Watershed.
2. Present farming enterprises and future plans and objectives of the cooperator.
3. Field layouts, total acres per field and farming practices prior to the LTA.

4. Soil mapping unit(s) for each field of all LTAs.
5. Required set of postassistance BMPs to be implemented per field, per year.
6. Projected amount of cost-share payments for implementation of each individual BMP.

A list of conservation practices approved by the Gibson County Soil Conservation District includes these BMPs: permanent vegetative cover establishment, permanent vegetative cover improvement, gradient and parallel terraces, diversions, interim cover (cropland protective cover), conservation tillage and permanent vegetative cover on critically eroding areas. Water impoundment reservoirs, sediment retention, water control structures, and sod waterways are the cost-shared practices approved for controlling excessive gully erosion in the NFFD Watershed.

Estimation of Erosion Reductions

The NFFD Watershed LTA data were used to estimate erosion reductions in the following manner. The first items of information derived were gross rates of soil erosion per field, per farm, measure in tons, per acre, annually with and without best management practices in place. Gross erosion rates were estimated with the use of the Universal Soil Loss Equation (USLE). This equation is of the form A = RKLSCP where:

A = average annual soil loss in tons per acre

R = erosion index, which indicates the effect of amount and intensity of rainfall on soil erosion for specific locations

K = soil erodability factor, reflects the rate at which differing soil types erode, expressed in soil loss in tons per acre per unit of rainfall erosion index (R) from clean-tilled continuous fallow on a 9 percent slope, 72.6 feet long

L = slope length factor, expressed as soil loss on a given length of slope of that from a slope 72.6 feet long, considering all other conditions are constant.

S = slope steepness factor, expressed as soil loss on a given percent slope compared to soil loss on a 9 percent slope with all other conditions constant

C = cropping-management factor, reflecting the expected ratio of soil loss from land cropped under specified conditions to soil loss from continuous fallow with all other conditions constant

P = conservation practice factor, indicating the ratio of soil loss with a particular practice in comparison to soil loss with straight row tillage.

Information for the values used as factors in the USLE were obtained from several sources. The rainfall index (R), which is constant for Gibson County, and the soil erodability factor (K)

were obtained from Jent, et al. (11). The cropping management factor (C) values were obtained from an unpublished article from the Tennessee State Office of the Soil Conservation Service. The slope steepness factors (S) values were obtained directly from soil mapping units on soil maps contained in each individual LTA. The slope length factor (L) and the conservation practice factor (P) could not readily be obtained from the Gibson County soil maps or LTAs. After consultation with SCS soil scientist and conservationists in West Tennessee and personnel from the Plant and Soil Science Department, University of Tennessee, average values for these factors were derived for common field situations encountered in West Tennessee. It was determined that fields which were to be terraced could be assumed to have had a prepractice slope length of 150 feet. The remaining fields were assumed to have a slope length of 100 feet. The conservation practice factor used as a "rule of thumb" value by SCS personnel was 1.0; therefore, the NFFD Watershed analysis of targeting strategies used this value when the value of P could not be determined from an individual LTA file.

To derive an estimate of the total erosion reduction for each field treated under an LTA in the NFFD Watershed, it was necessary to determine for each BMP the length of time for which that practice would effectively reduce sheet and rill erosion. The National Summary Evaluation of ACP Phase I was consulted as a guide for determining the "expected life" of BMPs implemented in the Watershed. Establishment of permanent vegetative cover and

improving permanent vegetative cover were assumed to be effective for five years. Terraces, diversions, and establishment of vegetative cover on critically eroding areas were assumed to be effective for a 10-year period. The BMPs interim cover and conservation tillage are designed as single year conservation practices, but generally LTAs utilizing these practices provide for cost-share payments for more than one year depending upon the landowner's farming objectives. All benefits in the form of erosion reductions per field, derived from the adoption of BMPs were figured over a 10-year period to make all comparisions between individual BMPs relevant.

Estimation of Costs of Implementing Best Management Practices

Cost estimates of two types were made for the installation of BMPs. Current cost was defined as the amount of the ACP cost-share payment paid to the landowner for the adoption of a BMP valued in 1982 dollars, i.e., 75 percent of the gross cost of placing a conservation measure or structure upon the land. An adjusted cost was also developed for the BMPs where costs and benefits did not occur in the same time period. For example, terraces are placed upon the land and paid for during the first year, but the benefits from reducing soil erosion would accrue over a period of several years. Adjusted cost was derived by amortization of current cost at 8 percent over the period for which reduced soil erosion occurred. Adjusted cost estimates for

NFFD BMPs were amortized at 8 percent, the rate utilized in the NSE-ACP-I, to provide for comparability of the national and NFFD Watershed findings.

III. THE IMPACT OF TARGETING TO THE NFFD WATERSHED

In order to address objective 2 of Chapter I, an estimate of the cost effectiveness of the best managment practices implemented in the Watershed was compared to the National Summary Evaluation of the Agricultural Conservation Program Phase I (NSE-ACP-I). The information reported in the NSE-ACP-I was collected from 171 counties all across the United States which included almost 61,000 cost-shared practices for which assistance was provided from 1975 through half of 1978. These practices were implemented on a single-field basis without the requirements that postpractice erosion rates meet soil loss tolerance. The NSE-ACP-I and the summarization of NFFD Watershed LTAs both analyze the impact of cost-shared practices upon sheet and rill erosion caused by water but at differing application levels, i.e., national and watershed. The purpose of this comparison will be to test the hypothesis that (1) targeting cost-share funds to a critical watershed rather than using them nation-wide, and (2) employing the whole farm, soil loss tolerance requirement improves the cost effectiveness of public funds directed to soil erosion control.

Distribution of BMPs by Prepractice Erosion Class

The percentage distribution of the United States and the NFFD Watershed acreage and ACP practices installed across pre-practices erosion rate classes is displayed in Table 2. The rows of the table contain the prepractice erosion rate classes, and the columns represent the percent of acreage and percent of ACP practices per erosion rate class. For example, row 3 and columns 2 and 3 of the NSE-ACP-I signify that 2.3 percent of the nation's farmland eroded at a rate of between 10 and 15 tons, per acre, per year (T/A/Y),[1] and that of the ACP cost-shared practices installed from 1975 to 1978, an estimated 10.6 percent were installed on land eroding at this rate

At the national level 86.7 percent of the farmland erodes at a rate of or below 5 T/A/Y. Land eroding at a rate of 5 to 15 T/A/Y accounted for 11.5 percent of the land area; land eroding at a rate of 15 and 30 T/A/Y 2.2 percent; and land eroding at a rate in excess of 30 tons, less than 2 percent. The NSE-ACP-I reveals that over one-half (52.4 percent) of all ACP practices were installed on land eroding at a rate near or below soil loss tolerance, while only 6.4 percent of all practices were implemented on cropland eroding at a rate in excess of 30 T/A/Y.

---

[1]From this point on throughout the body of the text T/A/Y represents tons, per acre, per year.

TABLE 2. Percentage Distribution of Acreage and Practices Across Prepractice Erosion Rate Classes

National Summary Evaluation of the Agricultural Conservation Program, Phase I					North Fork Forked Deer Special Water Quality Project				
Prepractice Erosion Rate Class (tons/acre/year)	Percent[a] of Acreage	Percent of ACP Practice	Cumulative Percent of Acreage	Cumulative Percentage of Practices	Prepractice Erosion Rate Class (tons/acres/year)	Percent[a] of Acreage	Percent of ACP Practice	Cumulative Percent of Acreage	Cumulative Percent of Practices
0-5	86.7	52.4	86.7	52.4	0-5	63.2	29.2	63.2	29.2
5-10	7.0	19.5	93.7	71.9	5-10	6.3	12.6	69.5	41.8
10-15	2.3	10.6	96.0	82.5	10-15	6.9	12.2	76.4	54.0
15-30	2.2	10.9	98.2	93.4	15-30	14.0	24.3	90.4	78.3
30-100	1.5	5.7	99.7	99.1	30-90	6.0	20.7	96.4	99.0
100+	0.3	0.9	100.0	100.0	90+	3.7	1.0	100.1	100.0
Total percent	100.0	100.0	100.0	100.0	Total percent	100.1	100.0	100.1	100.0

[a]Source: National Resource Inventory, USDA-SCS.

In comparison, in the NFFD Watershed 63.2 percent of the farmland is eroding at a rate near or below soil loss tolerance, 13.2 percent at a rate of 5 to 15 T/A/Y, 14 percent at a rate of 15 to 30 T/A/Y, and 10.7 percent at a rate in excess of 30 T/A/Y. In the NFFD Watershed row cropped land eroding at or below 5 T/A/Y received 29.2 percent of all ACP practices, while land eroding at a rate in excess of 30 T/A/Y received 21.7 percent of ACP cost-shared practices.

The question may be raised as to why a relatively greater percentage of practices were allocated to more highly erosive land in the NFFD Watershed as compared to nation-wide. As ACP funds are distributed on a voluntary, first come-first served basis, one would expect the distribution of practices to have some relationship to the distribution of cropland acres. Given the NFFD Watersheds' generally more highly erosive land, one would naturally expect, even with a voluntary first come-first served approach, a higher percentage of practices to be implemented on more erosive land as compared to nation-wide. A further question remains, though, as to whether this factor alone accounts for the relatively greater treatment of more highly erosive land. Examination of the relatively uniform distribution of practices according to the distribution of acreage across prepractice erosion rate classes, as displayed in columns 4, 5, 9, and 10 of Table 2, provide little evidence that the whole farm requirement of the LTA approach (or any other aspect of targeting implicit in the NFFD project) actually increased

treatment of more highly erosive land beyond what would have been expected given the factor above.

Further insights as to the extent of increased treatment of highly erosive land from targeting ACP funds to critical watersheds can be gained from comparing information on the distribution of individual best management practices across prepractice erosion rate classes. Information relevant to this comparison is presented in Table 3 for the seven practices that were common to both the NSE-ACP-I and the NFFD special water quality project. The cost-shared practices analyzed in Table 3 apply only to sheet and rill erosion reduction and include the following BMPs: SL-1, establishment of permanent vegetative cover; SL-2, improving permanent vegetative cover; SL-4, terraces; SL-5, diversions; SL-8, interim cover; SL-15, conservation tillage; and SL-11, establishment of vegetative cover on critically eroding areas. Cost-share payments designated for SL-15, conservation tillage in the Watershed, were appropriated only for no-till crop production systems, although in many of the NFFD LTAs minimum tillage practices such as disk-drilled soybeans were included as noncost-share items. The rows of Table 3 contain the prepractice erosion rate classes, and the columns represent the percentage distribution of individual BMPs across the prepractice erosion rate classes. For example, row 3 column 4 of the NSE-ACP-I signifies that nation-wide an estimated 22 percent of all SL-4 BMPs, terraces, were implemented on land eroding at a rate of between 10 and 15 tons per acre per year.

TABLE 3. Percentage Distribution of Practices Across Prepractice Erosion Rate Classes

National Summary Evaluation of the Agricultural Conservation Program, Phase I									North Fork Forked Deer Special Water Quality Project								
Prepractice Erosion Rate Class (tons/acre/year)	Type of Practice[a]								Prepractice Erosion Rate Class (tons/acre/year)	Type of Practice[a]							
	SL-1	SL-2	SL-4	SL-5	SL-8	SL-15	SL-11	Total		SL-1	SL-2	SL-4	SL-5	SL-8	SL-15	SL-11	Total
0-5	53	69	15	37	28	38	9	51	0-5	7	78	9	35	14	21	18	28
5-10	18	13	27	23	38	26	5	20	5-10	7	2	21	15	25	19	0	12
10-15	9	7	22	10	22	19	17	11	10-15	11	2	17	8	14	24	6	12
15-30	11	7	26	15	6	14	52	6	15-30	23	4	43	28	34	32	12	24
30-100	8	3	10	10	4	3	11	7	30-90	52	13	10	15	4	4	60	24
100+	1	1	0	5	2	0	6	1	90+	1	0	0	0	0	0	6	1
Total percent	100	100	100	100	100	100	100	101	Total percent	101	99	100	101	101	100	102	101
Total number[b]	10,315	6,978	1,754	429	2,916	119	217	22,728	Total number	178	139	132	52	36	72	17	626

[a]Practices are defined as follows: SL-1, permanent vegetative cover establishment; SL-2, permanent vegetative cover improvement; SL-4, terraces; SL-5, diversion; SL-8, cropland protective cover (winter); SL-11, critical area treatment; SL-15, conservation tillage.

[b]Number of incidences of each practice, whether alone or in combination with one or more practices on a single field.

Comparison of column 9, Table 2, percentage distribution of all ACP practices adopted in the NFFD Watershed, and columns 10 through 18 of Table 3, the percentage distributions of individual BMPs adopted in the NFFD Watershed revealed some significant differences. The BMPs SL-5, SL-8, and SL-15 were installed across prepractice erosion rate classes in a manner which closely corresponded to the overall distribution of all NFFD practices. In the prepractice erosion rate class, 0-5 T/A/Y, nearly 80 percent of the acreage of SL-2 was installed in this class because improvement of permanent vegetative cover was designed to upgrade existing stands of pasture or hayland which initially eroded at a level near or below soil loss tolerance. The percentage distribution of SL-4, terraces, implemented in the Watershed was slightly concentrated in the prepractice erosion rate class 15-30 T/A/Y because the BMP is in most instances used as an erosion control device for land with slope gradients ranging from 2 to 8 percent which generally corresponds to cropland eroding at this rate. The percentage of the BMPs SL-1 and SL-11 implemented in the Watershed were concentrated in the prepractice erosion rate class 30-90 T/A/Y. The data in table 2 reveals that overall, 20.7 percent of all cost-shared practices were implemented in this class; but SL-1 and SL-11 exhibited much higher percentages at 52 and 60 percent, respectively. SL-1 and SL-11 were utilized by the program managers in the Watershed to convert eroding cropland and gullied land to grassland or trees. Of the seven possible BMPs

available for use in the Watershed, only SL-1 and SL-11 consistently had a C value low enough to reduce soil loss down to tolerance on highly erosive fields; thus, to meet the tolerance requirement of NFFD LTAs the use of those two practices was mandatory for many NFFD fields.

Comparing the values of Tables 2 and 3 disclosed in the BMPs implemented at the national level displayed a percentage distribution pattern across erosion rate classes similar to the distribution exhibited in the NFFD Watershed except for the BMP SL-1. Nationally, 53 percent of the acres treated with the BMP SL-1 were contained in the erosion rate class 0-5 T/A/Y, contrasted to only 7 percent in the Watershed. The large difference in the percentage distribution of SL-1 across erosion rate classes probably is due to variations in the characteristics of the land base and conditions that program managers operated under at the different program levels. The soils as a whole in the NFFD Watershed are more erosive than the average erodability of soils nation-wide; thus, it would be expected that implementation of this BMP to be weighted upward in prepractice erosion rate classes in the NFFD Watershed compared to the national level. Also, farmland eroding in the lower erosion rate classes in the NFFD Watershed generally contain highly productive soils. Thus, farmers are unwilling to forego present income streams from row crop production to convert to grassland uses which yield significantly smaller revenues.

Analysis of Average Cost Per Ton of Erosion Reduction

Comparison of the average cost per ton of erosion reduction for various BMPs provides a further basis for assessing the impact of targeting funds to the NFFD Watershed. Data in table 4 is arrayed by the average cost per ton of erosion reduction for the five BMPs common to both the NSE-ACP-I and the NFFD Watershed for which erosion reduction estimates could be made within the USLE. Those practices include: SL-1, establishment permanent vegetative cover; SL-2, improvement permanent vegetative cover; SL-4, terraces; SL-8, cropland protective cover; and SL-15, conservation tillage. BMPs analyzed in the NSE-ACP-I were not required to reduce soil loss to tolerance, while in the NFFD Watershed all implemented BMPs met the tolerance requirement. The cost figures found in the NSE-ACP-I were adjusted to make them comparable to those estimated for the NFFD Watershed. The cost estimates for the NSE-ACP-I were computed for the year 1978 and in the Watershed for the year 1981, so an adjustment factor of 1.39 was used for all the NSE-ACP-I BMPs to account for inflation over a period 1978 to 1981 as measured by the Producer Price Index. An adjustment factor of 0.75 was also used for all BMPs since figures from the NSE-ACP-I were for total cost, while those from the NFFD project were for 75 percent ASCS cost-share. Cost estimates for the BMPs SL-1 and SL-2 were multiplied by an adjustment factor of 1.39 to make estimates comparable from the NSE-ACP-I and the NFFD Watershed. Cost estimates in the NSE-ACP-I were amortized over an eight-year period while in the analysis of

TABLE 4. Average Cost Per Ton of Erosion Reduction

Best Management Practice	National Summary Evaluation of the Agricultural Conservation Program, Phase I		North Fork Forked Deer Special Water Quality Project	
	Incidence	Average Cost Per Ton of Erosion Reduction[a] (1981 dollars)	Incidence[e]	Average Cost Per Ton of Erosion Reduction[f] (1981 dollars)
SL-1 - Permanent vegetative cover establishment	10,315	2.77[b]	136	0.81
SL-2 - Permanent vegetative cover improvement	6,978	4.20[b]	109	11.21
SL-4 - Terraces	1,754	1.56[c]	69	2.05
SL-8 - Cropland protective cover (winter)	2,916	8.39	8	0.70
SL-15 - Conservation tillage	119	1.02	39	0.84[g]
Average for all practices[d]	19,166	2.95	353	1.65

[a]An adjustment factor of 1.39 was used for all practices to account for inflation as measured by the producer price index for the period 1978 to 1981. An adjustment factor of 0.75 was also used for all practices since figures from the NSE-ACP-I were for total cost, while those from the NFFD project were for the 75 percent ASCS cost-share.

[b]An adjustment factor 1.39 was used for SL-1 and SL-2 to account for differences in assumed length of practice life. In amortizing cost at 8 percent, the NSE-ACP-I used eight years while the analysis of the NFFD project used the minimum required maintenance period of five years.

[c]An adjustment factor 1.28 was used for SL-4 to account for the difference in assumed length of practice life. In amortizing at 8 percent, the NSE-ACP-I used 15 years while the analysis of the NFFD project used the minimum required maintenance period of 10 years.

[d]Weighting is by percentage of total erosion reduction. Since acreage data were not available, it was assumed that average field size was the same for each practice in the NSE-ACP-I. SL-8 is not included because of noncomparability.

[e]The number of incidences or fields for each practice represent cases where only one cost-shared practice was applied. The numbers in Table 1 include cases where two or more cost-shared practices were applied in combination.

[f]These cost figures are for the (generally) 75 percent ASCS cost-share only.

[g]Cost-sharing for SL-15 in the NFFD project was strictly for no-tillage.

the NFFD project it was assumed that the life of these practices was the minimum required maintenance period of five years. For the BMP SL-4 the NSE-ACP-I amortized the initial cost for 15 years, while in the analysis of the NFFD project it was assumed that the life of these practices was the minimum required maintenance period of 10 years. To account for this difference, an adjustment factor of 1.28 was used on the NSE-ACP-I cost figures for SL-4.

As indicated in the bottom row of Table 4, the average cost per ton of erosion reduction for all the BMPs (SL-8 was excluded since the cost estimates were not comparable for reasons discussed later) was lower for the NFFD Watershed, $1.65 per ton of erosion reduction compared to $2.95, or approximately 44 percent lower. This difference in average cost for all practices was in a large part due to the BMP SL-1 with an average cost of $.81 in the NFFD Watershed compared to $2.77 nationally. This is due, of course, to the fact that in the NFFD Watershed SL-1 was installed on more highly erosive land than in the NSE-ACP-I. Thus, a comparable total cost per acre was spread over larger erosion reductions.

For SL-2, the average cost per ton of erosion reduction in the NFFD Watershed was more than $7 higher than cost figures exhibited in the NSE-ACP-I. The higher cost resulted from the fact that for the NFFD Watershed in virtually every case the prepractice erosion rate was estimated to be in the 0-5 T/A/Y class. Nationally, 31 percent of the grassland treated with SL-2 was installed on fields

with prepractice erosion rates in excess of 5 T/A/Y. It is unclear from procedures employed in the NSE-ACP-I how it was possible that such a high percentage of SL-2 practices were installed on land eroding at a rate in excess of 5 T/A/Y since such a high percentage of cropland in the nation erodes at less than 5 T/A/Y annually, and even poor sod has a very low C-factor in the USLE.

It is interesting to note that terraces (SL-4) were less cost efficient in the NFFD project than the NSE-ACP-I in view of the fact that they were installed on slightly more highly erosive land in the Watershed. The primary explanation for this is that terrace costs apparently rise faster than erosion reduction in that range of increasing slope where more of the terraces in the NFFD Watershed project were concentrated. This point is discussed in more detail a bit later.

The average cost per ton of erosion reduction figures for SL-8 (cropland protective cover) were not comparable to those for the other BMPs for the following reason. Acceptance of a cost-share payment for the winter cover crop (usually a small grain) in the Watershed required commitment to a conservation cropping system, with no cost-share payment for the reduced tillage operation, where necessary to insure that the soil loss tolerance requirement was met. The much lower cost per ton of erosion reduction for the NFFD Watershed project is a function more of the reduced tillage change than the impact of the winter cover crop.

The cost per ton of erosion reduction was slightly lower for SL-15 in the NFFD Watershed (where cost-share payments were made only for no-till operation) than in the NSE-ACP-I. This difference was due primarily to the relatively greater application of SL-15 to more highly erosive land in the Watershed.

Some caution should be taken in comparing the average cost per ton of erosion reduction figures from the NFFD special ACP water quality project and the NSE-ACP-I. The cost figures published in the NSE-ACP-I were for the full cost of implementing the BMPs. To provide comparability with the NFFD project cost estimates, which were based on the 75 percent ASCS cost-share alone, the NSE-ACP-I cost figures were adjusted by a factor of 0.75. However, ASCS cost-sharing for the NSE-ACP-I BMPs implemented nationally was often less than 75 percent, typically 50 percent (23). By adjusting the NSE-ACP-I cost figures by a more conservative factor of 0.50 the overall average cost of NFFD BMPs would be only 16 percent lower compared to BMPs installed nationally.

The information in Table 5 provides additional perspective on the basis for the lower overall cost per ton of erosion reduction in the NFFD Watershed by highlighting the large variation in the average cost per ton of erosion reduction across prepractice erosion rate classes. The five BMPs analyzed were: SL-1, establishment of permanent vegetative cover; SL-2, improvement of permanent vegetative cover; SL-4, terraces; SL-8, cropland protective cover; and SL-15, conservation tillage. The rows of Table 5 contain the

TABLE 5. Average Cost Per Ton of Erosion Reduction by Prepractice Erosion Rate--North Fork Forked Deer Special Water Quality Project

Initial Erosion Rate[a]	Type of Practice[b]					Average for all Practices
	SL-1	SL-2	SL-4	SL-8	SL-15	
	1981 dollars					
0-5	9.66	27.48	9.07	3.91	3.74	19.55
5-10	3.00	3.99	3.02	1.13	0.94	2.99
10-15	1.38	3.07	1.56		0.62	1.42
15-20	1.42		1.84	0.24	0.98	1.64
20-30	0.85	1.23	2.05		0.57	0.90
30-40	0.66	0.55		0.07	0.49	0.64
40-50	0.57		0.79			0.59
50-70	0.44					0.44
70-90	0.27					0.27
90+	0.21					0.21
All classes	0.81	11.21	2.05	0.70	0.84	1.65

[a]Tons per acre per year based on application of the Universal Soil Loss Equation.

[b]See Table 4 for definitions.

prepractice erosion rate classes and the columns the type of best management practice. Thus, the figure in row 4, column 1, indicates that on average it cost $1.42 per ton of erosion reduction by implementing the BMP SL-1 on land initially eroding at a rate of 15-20 T/A/Y.

Inspection of the percentage variation in the average cost per ton of erosion reduction indicated that as the erosion rate decreased, the average cost increased. This is basically because a nearly constant cost was spread over fewer tons of erosion reduction. For the BMP SL-1, sharp increases in average cost did not occur until erosion rates declined to a level of 5-10 and 0-5 T/A/Y. The BMPs SL-2, SL-8, and SL-15 exhibited similar variation in the average cost per ton of erosion reduction. The BMP SL-4 exhibited less variation in average cost per ton of erosion reduction as perpractice erosion rate decreased.

The BMP SL-4, terraces, did not exhibit a uniform increasing average cost across decreasing prepractice erosion rate levels in the NFFD Watershed. The average cost declined when terraces were applied to land eroding at a rate of 0-15 T/A/Y. Land eroding at a level of 15-40 T/A/Y exhibited an average cost that increased slightly as erosion rates increased. The explanation for this lies in the fact that the cost of terraces increases as slope and prepractice erosion rates increase, because the quantity of soil materials needed to construct the earthen structure increases with

slope. From class 0-5 T/A/Y to 10-15 T/A/Y erosion reduction increased more quickly than cost, but from class 10-15 T/A/Y to 20-30 T/A/Y erosion reduction increased more slowly than cost. Thus, the variation in average cost across prepractice erosion rates is due to the fact that terrace costs increase rather rapidly as a function of increasing slope gradient.

Analysis of the variation in average cost per ton of erosion reduction for the BMPs SL-1, SL-4, and SL-15 was insightful in comparing the cost effectiveness of implemented practices on NFFD farmland experiencing differing soil erosion problems. On NFFD land eroding at 0-5 T/A/Y, SL-15 was the most efficient BMP of the set with an available cost of $3.74 per ton of erosion reduction. On farmland eroding at this rate SL-1 and SL-4 had much higher average costs at $9.66 and $9.07, respectively. Land eroding at a rate of 5-15 T/A/Y was most efficiently brought to soil loss tolerance by implementing the BMP SL-15 at an average cost of $.78 per ton of erosion reduction. The BMPs SL-1 and SL-4 displayed nearly identical average costs of approximately $2.25 per ton of erosion reduction at the erosion rate level of 5-15 T/A/Y. The practices SL-15 and SL-1 were cost effective in erosion reduction on land eroding at a rate of 15-40 T/A/Y with SL-4 displaying an average cost figure which was significantly higher. The respective average cost values for that range were $.68, $.98, and $1.94 per ton of erosion reduction. For NFFD farmland eroding at a rate in excess of 40 T/A/Y the BMP SL-1 was generally the only applicable practice with an average cost of $.37 per ton of erosion reduction.

An overall average cost per ton of erosion reduction for each of the prepractice erosion rate classes is displayed in Table 5. The overall average cost was derived by calculating a weighted mean for the summation of the average cost values for each of the five BMPs within an erosion class interval. Each BMP in a particular prepractice erosion rate class was weighted according to its average annual erosion reduction per acre and total acres treated.

In the NFFD Watershed the overall average cost per ton of erosion reduction calculated from all practices taken together within each prepractice erosion rate class decreased as the erosion rate increased, except for the class 15-20 T/A/Y which increased just slightly. Inspection of the average cost per ton of erosion reduction values from the NSE-ACP-I for those practices common to both the national and watershed levels of analysis revealed close consistency in the average costs for each BMP across prepractice erosion rate classes. This is consistent with the earlier conclusion that the increased cost efficiency in the NFFD Watershed project as compared to the national level was primarily due to relatively greater application of the same BMPs to more highly erosive land.

IV. THE POTENTIAL FOR TARGETING WITHIN THE NFFD WATERSHED

Recognizing that average cost per ton of erosion reduction differs widely across erosion rate classes, it is revealing to view

the percentage of land in the NFFD Watershed in various prepractice erosion rate classes which were treated with BMPs, as presented in Table 6. Information in the last column, reveals that 15-20 percent of the land in each prepractice erosion rate class between 5 and 90 T/A/Y was adequately treated (brought to soil loss tolerance) with BMP application. Less than 5 percent of land eroding at a rate of less than 5 T/A/Y was treated by conservation practices, but this reflects a large number of acres given that 63.2 percent of the land in the Watershed occurs in this prepractice erosion rate class. Only slightly greater than 2 percent of the Watershed's land eroding at a rate in excess of 90 T/A/Y was treated with conservation practices. This indicates that possible further use of the BMP SL-11, establishment of vegetative cover on critically eroding areas, should be directed toward land in the Watershed eroding at this excessive level. Inspection of the distribution of practices across prepractice erosion rate classes reveals that thousands of acres of land with erosion rates in excess of 15 T/A/Y could conceivably have been treated rather than some of the land with relatively low erosion rates. The distribution of implemented practices in the NFFD Watershed across the various initial erosion rate levels shows a great potential for targeting funds to critical areas within the Watershed itself, as does the fact that only slightly over 30 percent of the Watershed's land area received application of BMPs with an average cost of less than $3.00 per ton of erosion reduction.

TABLE 6. Comparison of NFFD Watershed Preproject Situation with Project Accomplishments

Erosion Class[a]	Preproject[b]		Project Practices		Percent of Acreage with Practices
	Acres	Percent	Acres	Percent	
0-5	50,672	63.2	2,366	34.1	4.7
5-10	5,010	6.3	936	13.5	18.7
10-15	5,527	6.9	964	13.9	17.4
15-30	11,199	14.0	1,707	24.6	15.2
30-90	4,813	6.0	957	13.8	19.9
90+	2,967	3.7	69	1.0	2.3
Total	80,190	100.0	6,939	100.0	8.7

[a]Tons per acre per year based on application of the Universal Soil Loss Equation.

[b]NFFD Watershed Plan (1980).

In the original application for the special water quality project in the NFFD Watershed a rough summary plan of objectives was outlined for the targeting of best management practices. Further perspective on the potential for targeting within the NFFD can be obtained from a comparison of the summary of planned obtives regarding the distribution of ACP funds across land capability subclasses and the actual set of practices incorporated in the long-term agreements of the Watershed.[2]

Viewing the "Percent of Acreage with Practices" column of Table 7 revealed that 80 percent of the excessively eroding row crop land in land capability subclass IIe was reduced to soil loss tolerance. This subclass contains some of the more level, highly productive upland soils of the Watershed where crop yield potential is at a maximum related to land in the higher land capability classes. BMPs such as terraces and no-till crop production systems are the

---

[2]For comparative purposes it was necessary to correlate prepractice erosion rate classes developed from the LTAs with the land capability subclass classification outlined in the Watershed plan. This was accomplished through the use of the USLE, which was used to determine gross erosion rates for the relevant soil mapping units of the NFFD Watershed. An individual soil mapping unit is entirely included within one capability subclass, and a lower and upper soil loss level was computed for each soil mapping unit; therefore, it was possible to categorize a land capability subclass into one or more erosion classes. As a result of the correlation process, it was possible to calculate which prepractice erosion rate classes corresponded to a particular land capability subclass.

TABLE 7. Conservation Treatment Goals of NFFD Watershed Acreage by Land Capability Subclass

Land Capability Subclass	Acres Requiring Conservation Assistance[a]	Acres Receiving Conservation Assistance	Percent of Acreage with Practices	Recommended BMPs for Conservation Assistance
Class IIe	5,488	4,414	80.4	no-till terraces contour residue management
Class IIIe	5,835	1,570	26.9	no-till terraces short rotations contour residue management
Class IVe	3,130	813	26.0	no-till terraces residue management
Classes VIe and VIIe	4,408	142	3.2	grass trees
Total	18,861	6,939	36.8	

[a]Source: North Fork Forked Deer River (NFFD) Watershed Plan.

practices most commonly employed to control erosion of this type of land. Land capability subclasses IIIe and IVe received conservation assistance on slightly over 25 percent of the acreage in these subclasses requiring treatment. Soils in these land capability subclasses are undulating in slope and often contain fragipans in the subsoil which increase their susceptibility to the detrimental effects of excessive erosion. In addition to terraces and no-till production systems, short rotations based with meadows were recommended to control erosion on land eroding in these subclasses. Only 3.2 percent of the acreage requiring treatment in the land capability subclasses VIe and VIIe was adequately treated with conservation practices. In almost every case it was necessary to convert this highly erosive cropland to grass or trees to fulfill the soil loss tolerance requirement of LTAs. Thus, most of the soil erosion control effort was directed toward the most productive upland agricultural acreage, i.e., land in the lower prepractice erosion rate classes. Directing a greater quantity of cost-share funds to land capability subclasses VIe and VIIe would reduce the overall average cost per ton of erosion reduction for all BMPs utilized in the Watershed, emphasizing the significant potential for targeting within this critical watershed.

Finally, in analyzing the extent to which the objectives of targeting ACP cost-shared funds to the NFFD Watershed were met, it was useful to consider the extent to which the treatment goals

in terms of acreages of specific practices were actually accomplished. Acreage goals for SL-4 (terraces), SL-15 (no-till), rotations, SL-1 (establishment of permanent vegetative cover), and SL-2 (improvement of permanent vegetative cover) were set which would have provided nearly complete treatment for the NFFD Watershed's excessively eroding cropland more than could be expected to be accomplished within the financial and time constraints of the NFFD project. However, acreage treated as a percentage of the acreage goal across practices can be considered. These percentages were 71.6 percent for terraces, 36.6 percent for no-till (SL-15 plus conservation tillage), something near zero percent for rotations (no cost-share payments were available for rotations), 42.8 percent for establishment of permanent vegetative cover, and 171.5 percent for improvement of permanent vegetative cover. Interestingly, the percentage accomplishment of goals was lowest for the most cost efficient practices and highest for the least cost efficient practices. Thus, the potential for targeting to particular practices appears great as well.

V. SUMMARY COMMENTS

Inspection of the distribution pattern of best management practices across prepractice erosion rate classes revealed that at both the national and NFFD Watershed levels the percent of practices implemented per erosion class was closely related to the percentage of total farmland acres within the prepractice erosion

rate class. At both the national and NFFD Watershed levels of application of the Agricultural Conservation Program, program managers apparently lacked the proper information, priorities and mechanisms for directing assistance to the more serious erosion areas of problems. Therefore, soil erosion control assistance tended to be distributed across prepractice erosion rate classes without very much regard for the severity of the soil erosion problem. However, because of the more highly erosive land in general in the NFFD Watershed and the lower cost per ton of erosion reduction in treating more highly erosive land, the targeting of cost-share funds to the NFFD Watershed resulted in a significant increase in overall cost effectiveness. At the same time, analysis of additional information indicated that the potential for targeting of ACP funds within such a critically eroding watershed is great. Following a brief discussion of a specific factor which may have limited targeting within the NFFD Watershed, presentation is made in the next chapter of a simplified model of the NFFD Watershed which sheds further light on how the distribution of cost-share funds might be modified to increase the cost efficiency of BMPs implemented in the NFFD Watershed or other critical watersheds.

In the NFFD Watershed the distribution of BMPs was restricted by the whole farm requirement of long-term agreements. This requirement forced the NFFD program managers to treat every field of a farm cooperator's acreage eroding at a rate greater than soil

loss tolerance, regardless of the farmer's objectives in acquiring conservation assistance or program priorities. That is to say, if the farmer's main priority was to treat classes IIe and IIIe land, he was also forced to meet soil loss tolerance on his highly eroding class VIe and VIIe land. But treatment is also required on class IIe and IIIe land though the farmer's or program's primary interest may have been in taking critically eroding land out of crop production. In contrast at the national level cost-shared practices were implemented on a single field basis without requirement that post practice erosion rates meet soil loss tolerance. Constrained by this requirement, NFFD program managers were limited in their ability to make use of a particular cost effective practice on or treatment of a particular prepractice erosion rate class a priority to reduce the overall average cost per ton of erosion reduction of BMPs installed in the Watershed.

CHAPTER IV

A MODEL FOR ANALYSIS OF SOIL EROSION CONTROL IN THE NFFD WATERSHED

I. INTRODUCTION

Operations research methodology provides an analytical framework for the estimation of the potential for targeting the cost effectiveness of nonpoint pollution reductions in the North Fork Forked Deer Watershed. Operations research methods specify a set of variables which represent the decision quantities for attainment of objectives under a particular environment represented by technology, prices, and resource limitations (9). Linear programming a particular operations research technique, provides the researcher with tools which allow analysis of and optimization for particular decisions within their own setting, where the planning and decision method can be highly systematic. The objective of the typical business application of an LP, which includes farm management analysis, is to maximize profit subject to constraints imposed by the nature of the activities in terms of input-output coefficients, and availability of fixed inputs or prices of variable inputs.

Linear programming has been used for evaluating the impact of soil erosion control practices at the national, regional, state, watershed, and farm levels. Wade, Nicol, and Heady developed a

large scale linear programming model for the nation which modeled the effects of reducing nonpoint pollution on gross farm income (27). At the regional level Seitz developed a linear programming model of the midwestern states to determine the effect of reducing soil loss and consequently nitrogen from agricultural land (19). At the watershed level of analysis studies by Alt and Heady, Kasal. Narayanan and Swanson, and Lee all conclude that most farmers can adopt conservation practices without greatly reducing net on-farm income (1, 12, 14). Farm level studies utilizing linear programming have analyzed the effects of soil erosion on a representative farm basis as Boggess and Hunter have done (5, 10).

Evaluation of alternative targeting strategies for improving cost effectiveness of BMP implementation in the NFFD Watershed required the development and use of a linear programming (LP) model. The most relevant objective from a viewpoint of improving water quality would appear to be maximization of total gross erosion reduction for the entire NFFD Watershed. An algebraic method of expressing the NFFD Watershed maximization problem in a matrix form is: Maximization of $Z = C_1X_1 + C_2X_2 + \ldots + C_nX_n$ subject to:

$$A_{11}X_1 + A_{12}X_2 + \ldots A_{1n}X_n \leq B_1$$

$$A_{21}X_2 + A_{22}X_2 + \ldots A_{2n}X_n \leq B_2$$

$$X_1, X_2, \ldots, X_n \geq 0$$

The activities X_1 to X_n represent the best management practices under consideration in the model. The term C represents the reduction

in soil erosion and A is the matrix of technical coefficients. For example C_1 is the tons of reduced soil erosion per acre, per designated period, derived from the implementation of BMP_1, while A_{11} is the cost per acre of adoption of BMP_1, and A_{21} is the acres per acre of a BMP. Constraining the reduction in soil erosion is the availability of ACP funds and acres per field, per farm, represented by B_1 and B_2, respectively, in the matrix equations.

The linear programming model typifying the physical and structural characteristics of NFFD Watershed farms was constructed to evaluate objectives 3 and 4 as outlined in Chapter I. The mathematical model operates in a manner such that the most cost efficient BMPs were adopted for reducing soil loss to tolerance for a specified period of time (either 5 or 10 years). The LP model was constrained by a fixed cost share budget based on the availability of ACP funds targeted to the Watershed making it possible to compare the actual sets of BMPs implemented as part of the special ACP water quality project in the watershed (objective 1) and the "optimal" sets of BMPs derived from the LP model analysis. The set of BMPs derived from the LP model will only be optimal in an economic sense, that is, in abstraction from legal, political, and administrative constraints which may influence what is optimal in practice. From this comparison of actual and optimal sets of BMPs it was possible to outline policy alternatives that would target implementation of existing and future BMPs toward the optimal set.

II. DEVELOPMENT OF REPRESENTATIVE FARM UNITS AND BMPs FOR THE NFFD WATERSHED

The procedure followed in developing the NFFD LP model began by constructing representative farm units (RFUs) which represented the upland cropland and farm operator characteristics of the watershed. The data utilized in constructing the RFUs were derived from a random survey of operators of farms within the boundary of the NFFD Watershed. Approximately 85 farms were randomly selected to be surveyed from the Gibson County ASCS files on NFFD Watershed farms. The ASCS files contained such information as the farmers production operations for the past five years on crops with production quotas or price supports, maps with field boundaries, acreage per field, crop(s) grown on each field, and the person(s) owning and operating the farm property in the watershed.

The person most directly responsible for making the majority of the management decisions of operating the selected farm was surveyed in person. This person was first questioned concerning the ownership characteristics of the farm, i.e., owned and operated by same person or was the acreage leased or rented. Secondly, the person was asked to indicate their farm production practices on an individual field by field basis. Information was collected on the number of acres per field, crop(s) produced per field (which included pasture and hay), crop production practices employed, soil conservation practices utilized, and soil type and slope. Thirdly,

the surveyed person was asked to inventory the types of farming equipment he owned. This question was asked to determine the extent to which some NFFD farmers had greater capability, or flexibility for implementing production or conservation practices other than those currently employed. To determine the number of farms utilizing livestock as a revenue producing enterprise the surveyed person was asked to approximate the number of livestock falling into two categories, i.e., beef and swine.

The relevant data from the surveys were summarized and compiled into categories and was added to the information on the watershed collected by the USDA in the special ACP water quality project application. The total collection of data was used to represent all the characteristics of farms and farmers in the NFFD Watershed on a representative farm basis.

Eight representative farm units (RFUs) were constructed representing a total of 33,100 acres of NFFD upland cropland. As Table 8 illustrates the RFUs were differentiated upon the basis of the following factors: total number of acres per representative farm unit, number of individual fields per RFU, cropland acreage per field, soil series, slope gradient, crop(s) grown on an individual field basis, crop production practice(s) employed, ownership characteristics, livestock enterprises, and ownership of sod planting equipment and/or earth moving equipment by operator of the RFU.

The representative farm units were analyzed in total farm acreage sizes of 150 acres (large farms) and 40 acres (small farms)

TABLE 8. Elements Used to Characterize the Representative Farm Units of the NFFD Watershed

	Representative Farm Units							
	RFU 1	RFU 2	RFU 3	RFU 4	RFU 5	RFU 6	RFU 7	RFU 8
Watershed acreage represented by RFU	3750	3750	3200	3200	4800	4800	4800	4800
Cropland acres/RFU	150	150	40	40	40	40	40	40
Farm Ownership	Rented	Owner-Operator	Rented	Owner-Operator	Rented	Owner-Operator	Rented	Owner-Operator
Cropland acreage/field/RFU	F1[c] 70 F2 60 F3 20	F1 70 F2 40 F3 40	F1 40	F1 25 F2 15	F1 20 F2 20	F1 20 F2 20	F1 15 F2 25	F1 20 F2 20
Crop(s) grown/field/RFU[a]	F1 W/SB F2 W/SB F3 SB	F1 W/SB F2 Corn F3 Sb	F1 SB	F1 SB F2 SB	F1 SB F2 Corn	F1 W/SB F2 W/SB	F1 SB F2 SB	F1 Corn F2 SB
Corn production practice/field/RFU[b]	F1 CT F2 NT F3 CT	F1 MT F2 CT F3 CT	F1 CT	F1 CT F2 CT	F1 CT F2 CT	F1 MT F2 CT	F1 CT F2 CT	F1 CT F2 CT
Slope gradient class/field/RFU	F1 0-2 F2 2-5 F3 5-8	F1 2-5 F2 5-8 F3 8-12	F1 2-5	F1 5-8 F2 8-12	F1 0-2 F2 2-5	F1 0-2 F2 2-5	F1 2-5 F2 5-8	F1 5-8 F2 8-12
Soil series	Grenada-Loring	Grenada Loring	Memphis	Lexington-Ruston	Grenada-Loring	Grenada-Loring	Grenada-Loring	Grenada-Loring
Livestock enterprise	No	Yes	No	Yes	Yes	No	No	Yes
Ownership of sod planter	Yes	No	No	No	No	No	No	No
Ownership of earth moving equipment	Yes	Yes	No	No	No	No	No	No

[a]SB = soybeans; W/SB = double cropped wheat and soybeans.

[b]CT = conventional tillage; NT = no-till; MT = minimum tillage.

[c]FX represents field X.

with each RFU representing 3,200 to 4,800 watershed cropland acres. Cropped fields of the RFUs range in occurrence from one to three and in acreage from 15 to 70 acres. Three soil series based on five soil types were included in the composition of the RFUs those being Grenada-Loring, Memphis, and Lexington-Ruston soils. Slope gradient classes included in the RFUs were 0 to 2, 2 to 5, 5 to 8, and 8 to 12 percent slopes. Five crop production enterprises were included as being representative of those most commonly used in the watershed. The representative enterprises were soybeans conventionally tilled, corn conventionally tilled, double crop wheat/soybean conventionally tilled, double crop wheat/soybeans disk drilled, and double crop wheat/soybeans no till. The RFUs were characterized by being either owner-operated or rented. The commercial beef and swine livestock enterprises were included in one classification of livestock, thus the distinction was livestock versus nonlivestock. Ownership of sod planting equipment and earth moving equipment by the farm operator was also considered.

The combinations of the physical and structural characteristics utilized in deriving the eight representative farm units were not the only possible arrangement of factors that applied to the NFFD Watershed. Actual farms in the watershed vary widely in their total composition of farm related factors. In the composition of the RFUs the factors expected to most directly effect soil erosion control options and costs were included, but each factors as noncropland acres and uses were excluded. It was an objective of the LP model

composition process to develop representative RFUs in a manner which accurately portrayed actual NFFD farming conditions yet maintaining a simple LP model format. NFFD farms with operational characteristics that are different from any RFU derived from the ASCS survey of watershed farms may be thought of as being represented by the most similar RFU. The RFUs together represent every acre of upland cropland in the watershed, but do not fully model all farm operations that occur on this cropland. Recognizing the limitations encountered in developing the RFUs of the model, the BMP activities are now discussed.

BMPs for the LP model consisted of practices which were incorporated in the long term agreements of the Gibson County Soil Conservation Districts conservation plans. A total of 43 alternative BMPs were developed which had the potential of reducing soil erosion to a level at or below soil loss tolerance. The BMPs of the LP model were derived from the following ACP practices for which soil loss estimates could be calculated utilizing the USLE: SL1, establishment of permanent vegetative cover; SL4, terraces; SL8, interim cover; and SL15, conservation tillage; and RFU characteristics regarding crops produced (soybeans, corn, and wheat), ownership, livestock, sod planter, and earth moving equipment. Cost per ton of erosion reduction also differed depending on the soil series and slope gradient of the field.

The objective function row contains coefficients that were determined by the number of tons of erosion reduction per 10-year

period by the implementation of a BMP. The coefficients were derived by calculating an initial annual rate of soil loss prior to adoption of the BMP. The annual rate of soil loss after implementation of the BMP was subtracted from this figure to arrive at the amount of erosion reduction per acre, annually due to the adoption of a BMP. All coefficients were calculated on the assumption that all BMPs yield an erosion reduction for a 10-year period in soil loss, although some BMPs only actively reduced soil loss for five years.

The net cost row containing coefficients were developed to represent the actual cost of implementing a BMP over a 10-year period on an acre of NFFD cropland. The net cost coefficients were calculated in present value terms according to the yearly schedule of costs of implementing the BMP. As an example the greatest percentage of the net cost of implementing a terrace is incurred in the year of installation, whereas the cost of implementing no-till soybeans is uniformally spread over a 10-year period. Net cost was estimated by subtracting on-site benefits returns from gross cost for each BMP of the NFFD LP model.

The gross cost reflected the cost incurred by a farmer in implementing a BMP, either in terms of out-of-pocket costs or foregone income and were based on budgets developed from The University of Tennessee Farm Planning Manual (18). The gross cost figure included such items as the establishment cost of grass, the construction cost of terrace, and the difference in net returns for conventional and conservation production systems. All cost and revenues were calculated in terms of 1981 dollars.

The on-site benefit was calculated to reflect, in monetary value, the yield savings over time from reducing gross soil erosion. The estimation of on-site benefits proceeded as follows. The annual rate of soil loss measured in tons, divided by 150 tons/inch (assumed weight for silt loam topsoil) gives the inches of topsoil lost per acre, per year, from erosion of cropland. Using the procedure for determining the decline in crop productivity developed by Hunter (10), it was possible to estimate the decline in yield (bushels) from the loss of an inch of topsoil excluding Memphis soils. Multiplication of the inches of soil lost per acre, annually and the reduction in bushels of crop yield per inch of soil lost annually produced the total number of bushels of crop yield lost per acre, annually. It was then possible to figure the total decline in soil productivity for the 10 year period of this analysis. This procedure for estimating soil productivity declines was applied both with and without each BMP, with the difference in the calculated values representing the savings in potential yield (in bushels) from BMP implementation. This value was multiplied by the price per bushel of the crop under consideration to derive an annual dollar savings due to the implementation of a soil conserving BMP.[3] The present value on-site benefit was calculated for the appropriate length

---

[3]Linear regression was used to derive a "normal" 1981 price for the crops wheat, soybeans, and corn. A 10 year period of average commodity prices for Tennessee from 1971 to 1981 were analyzed to derive the long-term trend prices (wheat $3.98, soybeans $7.64, and corn $3.30).

of time a BMP must be maintained (either five or ten years) as outlined by the ACP guidelines. On-site benefits were not calculated for Memphis soils because they apparently do not experience a significant yield reduction when eroded at levels most commonly experienced in the NFFD Watershed (7).

Net cost was then calculated by subtracting the value of the on-site benefit from the gross cost for a particular BMP on a soil mapping unit. Net cost then represents the minimum present value amount of a subsidy needed to induce BMP implementation under the assumption that farmers fully recognize the value of the on-site productivity benefit. Illustration of the way in which net cost figures for the basic BMPs differed on the basis of various factors is provided in Table 9.

III. DEVELOPMENT OF COEFFICIENTS FOR THE NFFD LP MODEL

The LP model was constrained by the availability of funds and also by the number of acres per field, per representative farm unit. To simulate the funding limitations experienced in the NFFD Watershed special water quality project, an upper limit on operating funds was placed at 0.6 million dollars the approximate amount of funding directed to practices in the LP model, i.e., SL-1, SL-2, SL-4, SL-8, and SL-15. A total of 1.3 million dollars was appropriated to the NFFD project, but 0.7 million dollars was spent on the implementation of other BMPs which control gully erosion for which

TABLE 9. Net Cost of Implementing Selected NFFD Watershed Best Management Practices

Best Management Practices[a]	Elements of Best Management Practices[b]											
	OO W/L	R W/L	OO WO/L	R WO/L	OO W/EME WO/WCC	R W/EME WO/WCC	OO WO/EME W/WCC	R WO/EME W/WCC	OO W/SP W/WCC	R W/SP W/WCC	OO WO/SP WO/WCC	R WO/SP WO/WCC
	Net Cost (Dollars)											
SL-1[c]	167.81	213.35	269.14	314.68								
SL-4[d]					128.85	176.30	377.78	425.23				
SL-15[e]									160.74	213.38	17.57	65.02

[a]All net costs represent the present value (dollars) of implementing BMPs for a 10 year period. The net costs were calculated for reducing soil loss to tolerance on Grenada-Loring soils, 5 to 8 percent slopes, producing soybeans.

[b]OO = owner operator; R = renter; W/L = with ownership of livestock enterprise; WO/L = without ownership of livestock enterprise; W/EME = with ownership of earth moving equipment; WO/EME = without ownership of earth moving equipment; W/SP = with ownership of sod planter; WO/SP = without ownership of sod planter; W/WCC = with winter cover crop; WO/WCC = without winter cover crop.

[c]SL-1 = establishment of permanent vegetative cover.

[d]SL-4 = terraces.

[e]SL-15 = no till.

no accurate method for deriving the efficiency of reducing soil loss is available. The acreage limitations per field were derived from the individual representative farm units.

Some important assumptions were made in the development of the BMPs for the NFFD LP model. Budgeting analysis was employed to derive the basic cost and return figures for both the prepractice crop situation and the practices employed in the LP BMPs. The 1982 Farm Planning Manual developed by the Agricultural Extension Service at The University of Tennessee was the major source of information required for developing the cost and return figures (18). Although the Farm Planning Manual contained crop budgets for the majority of West Tennessee crop production systems, it was necessary to modify the budgets to make them more specific to the characteristics of the RFUs. A brief discussion of some of the assumptions underlying costs is as follows.

Establishment of permanent vegetative cover (SL-1) was distinguished on the basis of whether the operator of the RFU raised livestock commercially or not. It was necessary to distinguish between the type of operator, because those farmers previously raising livestock maintained the potential for converting cropland to grassland uses in a much different manner than a nonlivestock operator. When an operator with no livestock operations converts cropland to grassland, he could not sell the grass without investing in haying equipment such as a mowing machine, conditioner, hay rake, and hay baler. If this farm operator, not previously involved in

livestock production, decides to include livestock as a farm enterprise he probably would be required to invest in capital improvements like livestock buildings, fences, etc. Thus, when the operator of a farm is required through a LTA to convert only a very small percentage of his total farm acreage to grassland uses it is often not economicllly feasible for him to make the necessary investment to initiate a haying or livestock system. After consultation with University of Tennessee extension personnel and analysis of hay and livestock budgets it was determined that those farmers not previously raising livestock commercially would be better off simply by establishing grass, and leaving it idle. Thus, no return or revenue from this BMP is expected.

For those farm operators who had previously raised livestock on a commercial basis, the most profitable use of their cropland to be converted to grassland would be to incorporate the additional grassland acreage into the existing livestock enterprise. Pasture rental rates for West Tennessee were utilized as a proxy for net returns expected from such a livestock enterprise.[4] The net cost figure for SL-1 with a livestock enterprise therefore reflected

---

[4]Linear regression was used to derive a "normal" 1981 average pasture rental rate for the major soil series of the NFFD Watershed. A 10 year period of average pasture rental rates for Tennessee from 1971 to 1981 were analyzed to derive the long-term trend rates. On 5 to 8 percent slopes the average pasture rental rates for Grenada-Loring, Memphis, and Lexington-Ruston soils were $25.38, $29.01, and $26.94, respectively.

the cost of establishing grass upon the land minus the expected net returns from a typical livestock enterprise for a five year period.

Terraces (SL-4) were differentiated on the basis of whether the operator of the RFU owned earth moving equipment or not. Earth moving equipment in this context is defined as items such as a tractor of 100 horsepower or greater, tractor grader blade, and/or a five to fifteen cubic yard capacity earth moving pan. This distinction was made in response to the possibility that a farm operator owning this type of equipment might in periods of farm inactivity be able to construct his own terraces. In this case the labor cost incurred in building the terraces could be subtracted from the total cost of the terraces because the farm operator could be assumed to be utilizing labor with an opportunity cost of zero. This distinction relies on the assumption that most farmers owning this type of equipment would possess the management capabilities necessary to efficiently undertake a task of this complexity.

For operators of representative farm units not owning earth moving equipment it was assumed that the total cost of a terrace would correspond to the rate charged by a typical contractor for constructing a terrace. Blissard's (4) work on estimating terrace costs in West Tennessee was consulted for the various gross cost estimates of the terrace BMPs in the NFFD LP model. The total construction cost of a terrace varied with the soil type and slope gradient of the fields they were to be placed upon. In general,

those soils which contained fragipans in their subsoils were the most expensive to terrace, because of the physical properties that are exhibited by fragipans. Fragipans are brittle in consistency and require greater power and fuel consumption to break the pan and transport the fine earth materials to fill positions. Also affecting the total cost of construction a terrace is the slope gradient which as it increases the total cost of constructing a terrace increases. Increasing gross costs and net costs as slope gradients increased occurred on all soil series analyzed in the NFFD Watershed.

The crop production practice no-till for soybeans and corn was differentiated by distinguishing between ownership or nonownership of a sod planter by the operator of the representative farm unit. A farm operator owning a sod planter was assumed to be able to plant an acre of soybeans or corn for a slightly less total cost than a farmer who relied on leasing a sod planter or custom hired his no-till planting operation. It was not possible to obtain an accurate estimate of costs of leasing or custom hired planting of no-till soybeans in West Tennessee. Therefore, the basic no-till budget developed by The University of Tennessee extension personnel was modified to differentiate between ownership or non-ownership of a sod planter. For the owner of a sod planter, who is assumed to be committed to some amount of no-till production on a consistent basis, the fixed costs in the basic budget was reduced slightly because of the reduced need to maintain conventional row-crow

production equipment. Thus, the farm operator owning a sod planter was assumed to be able to plant soybeans at a savings of approximately five to ten dollars, per acre compared to the non-owner.

The net cost figure used for all of the BMPs was differentiated upon the basis of whether the operator of the RFU owned or rented the acreage he farmed. This difference was incorporated because of the extended length of time (five to ten years) that BMPs installed under the ACP are required to be maintained as outlined by the rules of ACP. A farm operator renting crop acreage on a yearly basis has no guarantee that the same rented acreage will be available to him in the following years. Thus, the farm operator installing a BMP on rented or leased farmland will not be guaranteed that he will realize future benefits accruing from implementation of the BMP beyond the current year he is renting the farmland. In cases where the farm owner rents the RFU, the gross cost of implementing the BMP more closely represents the net cost from adoption of the BMP. Farmers owning the farmland on which they install a BMP upon can with greater certainty be assured that the total on-site benefits will accrue to them, thus gross cost less such benefits represents the net cost for them.

IV. APPLICATION OF THE LP MODEL

Initially the NFFD Watershed LP model was programmed in a manner such that analysis of objective 3, as outlined in the Introduction could be performed. This objective was to identify

the set of BMPs which would maximize the reduction in gross erosion for the watershed given a fixed cost share budget of $0.6 million, the approximate amount available for the ACP project directed toward practices which control sheet and rill erosion.

The procedure for programming the NFFD LP model was conducted in the following manner. It was necessary to determine the exact set of BMPs which were applicable per field, per representative farm unit. Each BMP included in the LP matrix for an excessively eroding upland field was required to reduce soil loss to or below tolerance. The tolerance restriction was imposed upon the analysis, because the actual conditions encountered by NFFD program managers in implementing BMPs under long term agreements required them to treat each field of a farm to the extent that soil loss tolerance was attained over the entire farm acreage. On some fields of the RFUs the possible number of acceptable BMPs was reduced by this restriction. For example, those fields which contained Grenada and Loring soils, 8 to 12 percent slopes were limited to one possible BMP which contained the capacity to reduce soil loss to tolerance, i.e., SL-1, establishment of permanent vegetable cover. The eight representative farm units contained a total of 17 cropland fields of which 12 required conservation measures to meet the soil loss tolerance requirement through inducement of adoption of BMPs. For the 12 fields requiring conservation a possible 43 BMPs were analyzed to determine if they contained the potential for reducing soil loss to tolerance.

The NFFD LP was modified to model two differing methods so BMPs could be allocated to fields on the RFUs. The whole farm (WF) analysis of the LP model required all or none of the fields of a representative farm unit eroding at a rate in excess of soil loss tolerance to be adequately treated with conservation practices. The whole farm restriction corresponds to the LTA requirement of the actual ACP project. The single field (SF) analysis did not restrict the sequence by which individual fields of the representative farm units were treated, thus the solution could contain a field from a RFU which was treated by a BMP, but excluded other fields of that same RFU eroding at a rate in excess of soil loss tolerance. The whole farm model in essence allows targeting to farms within the watershed, the single field model to fields within the farms as well.

LP Results for Whole Farm Model with Fixed Budget Constraints

The best management practices of the optimal solution for the NFFD LP whole farm model constrained by a fixed budget of $0.6 million are displayed in Table 10. To simplify the results, the solution was analyzed by slope class gradient.

Representative farm unit 3 contained a field with a slope gradient of 2 to 5 percent in the optimal solution which was most cost-efficiently brought to soil loss tolerance through inducing the adoption of a minimum-till production system. This field represented 3,200 acres of the highly productive Memphis soils of

TABLE 10. Optimal Solutions of Whole Farm and Single Field NFFD LP Models with Budget of $0.6 Million

Representative Farm Unit	Field Number	Best Management Practice[a]	Whole Farm Acres Treated	Single Farm Acres Treated
1	3	SL-15, no-till soybeans, with winter cover crop, ownership of sod planter	243	1,000
2	2	SL-1, establishment of permanent vegetative cover, with livestock enterprise	1,000	1,000
2	3	SL-1, establishment of permanent vegetative cover, with livestock enterprise	1,000	1,000
3	1	- minimum till soybeans, without winter cover crop	3,200	3,200
4	1	SL-1, establishment of permanent vegetative cover, with livestock enterprise	2,000	1,672
4	2	SL-1, establishment of permanent vegetative cover, with livestock enterprise	1,200	1,200
7	1	SL-15, no-till soybeans, without winter cover crop, nonownership of sod planter		1,800
8	1	SL-1, establishment of permanent vegetative cover, with livestock enterprise	2,400	2,400
8	2	SL-1, establishment of permanent vegetative cover, with livestock enterprise	2,400	2,400
			13,443	14,672

[a]All best management practices included reduced soil loss to or below tolerance.

the NFFD Watershed. The use of SL-1, establishment of permanent vegetative cover, as a BMP did not occur in the solution on fields with 2 to 5 percent slopes, because the gently sloping soils of the watershed are highly productive and the opportunity cost of converting these soils to grassland uses is too great to warrant the use of SL-1 as a BMP. BMPs utilizing SL-4, terraces, also were not found in the solution on fields with 2 to 5 percent slopes. This occurred because the construction cost of a terrace is quite high in relation to the implementation costs of other BMPs on gently sloping land, and therefore terraces are not cost-effective relative to minimum-till or no-till production operation.

Representative farm units containing fields with a slope gradient of 5 to 8 percent were most cost-effectively brought to soil loss tolerance by inducing the adoption of the BMPs, SL-1, establishment of permanent vegetative cover, with a livestock enterprise, and SL-15, no-till soybeans, without a winter cover crop. The BMP SL-1 most efficiently reduced soil loss to tolerance with slope gradients of 5 to 8 percent of representative farm units 2, 4, and 8, representing 1,000, 2,000, and 2,400 acres of NFFD cropland, respectively. The BMP SL-15 most cost-effectively treated RFU 1, field 1, representing 500 acres of NFFD cropland. On fields with a slope gradient of 5 to 8 percent the factor "operation of a livestock enterprise" dictated whether the BMP SL-1 entered the solution. In every case, SL-1 was the most cost-efficient treatment

of a RFU which possessed a field with the combination of a slope gradient of 5 to 8 percent and a livestock enterprise.

Representative farm units containing fields with a slope gradient of 8 to 12 percent were brought to soil loss tolerance by inducing adoption of the BMP SL-1, with a livestock enterprise. This BMP was the cost-effective practice on RFUs 2, 4, and 8 representing 1,000, 2,000, and 2,400 acres of NFFD cropland, respectively. Soils possessing this slope gradient could not be reduced to soil loss tolerance except through the adoption of SL-1 as a BMP. Terraces are not generally built on fields with a slope gradient greater than 8 percent and minimum and no-till production systems alone are not sufficient in reducing soil loss to 5 tons or less.

Results of the NFFD Watershed LP model constrained by a fixed budget of $0.6 million indicated that conceivably more than 4 million tons of erosion could be avoided over a 10-year period by the expenditure of funds in the manner as outlined in the LP solution. An estimated 23,300 acres of cropland in the model were eroding at a level above soil loss tolerance prior to BMP implementation.

By expending $0.6 million 13,443 acres of excessively eroding cropland could be brought to soil loss tolerance or below, representing 58 percent of the RFU cropland acreage.

Additional insight was gained by reducing the fixed ACP budget to $0.2 million while still employing the whole farm (WF) restriction. Comparing the optimal solutions with the WF restriction at the differing levels of funding revealed that the reduction in funds

resulted in the BMP SL-15 being completely removed from the solution at $0.2 million. As a result representative farm unit 1 was not provided with any conservation assistance and the use of the BMP SL-1 was significantly reduced by a reduction in funding. A total of 2,668 acres of the practice SL-1 was not implemented on RFU 4 fields 1 and 2. A $0.4 million reduction in funding would result in 2,911 fewer acres of the NFFD Watershed being treated by conservation practices and nearly one million fewer tons of soil erosion reduction over a 10-year period.

It was interesting to compare the average cost per ton of erosion reduction estimates derived for BMPs implemented as part of the actual ACP special water quality project and those for the "optimal" BMP set of the NFFD LP model. The average cost values from the actual and optimal sets of BMPs are not strictly comparable for several reasons. First, the practices included in the optimal set abstract from legal, political, and administrative constraints placed upon actual implementation of BMPs in the watershed. Second, net cost figures employed in the analysis of the optimal set of BMPs were derived by calculating the minimum subsidy payment needed to induce a farm co-operator into adopting the BMP. With such a straight dollar subsidy payment as the implicit program approach embodies, no rents were paid. Rents are associated with actual BMPs implemented in the watershed because uniform cost-share payments will generally provide more than this minimum. Third, the representative farm units used in the analysis to estimate the average costs of the

optimal set of BMPs are simplified models of actual physical and structural characteristics displayed by the NFFD farms, therefore some of the elements which could limit the cost-effectiveness of actual BMPs were not included in the composition of the RFUs.

Recognizing these differences inherent in the calculation of the average cost estimates for the actual and optimal sets of BMPs, the values are compared. The average cost per ton of erosion reduction associated with the actual ACP project was $1.65 while for the optimal set of BMPs of the LP model this cost was $0.26. It is clear from this comparison that much potential for improvement in the cost-efficiency of BMPs exists even in critical area projects. It should be noted that the increased cost-efficiency of the "optimal" BMP set derived from the NFFD LP model as compared to the actual BMPs installed in the watershed was due in part to the removal from the potential list of BMPs for the LP model of the least cost-effective BMP, SL-2, improvement of permanent vegetative cover.

LP Results for Single Field Model with Fixed Budget Constraint

Some insights regarding the effect that the whole farm (WF) restriction has on the cost-efficiency of BMP implementation in the NFFD Watershed can be gained from comparing the set of BMPs in the solutions of the WF and single field (SF) models. At the funding level of $0.6 million, the SF model allowed greater treatment of acreage across the watershed, 9.1 percent more than the WF model. Comparing the set of BMPs implemented by the WF and SF models

revealed that the SF model placed an additional 1,800 acres treatment of the BMP SL-15, no-till soybeans, on representative farm unit (RFU) 7, field 1 at the $0.6 million funding level. To install the additional acreage of SL-15, the SF model reduced the acreage of the practice SL-1 on RFU 4, field 1 by 328 acres, and removed the treatment of RFU 1, field 3 completely from the solution. Thus, in the SF model not all the cropland acreage of RFU 7 was adequately treated with conservation practices, with field 2 left untreated. Other than this exception of RFU 7, field 2, the treatment of NFFD cropland acreage yielded by the SF model did meet the whole farm requirement of long term agreements. Thus, the WF requirement made only a small difference in the composition of the sets of BMPs in the solution at $0.6 million funding. The SF option as compared to the WF requirement resulted in 3.4 percent reduction in the average cost per ton of erosion reduction. However, this small difference is likely a function of the limited number and variability of fields on the RFUs. The difference could be expected to be larger if the actual farms in the NFFD Watershed were modelled.

The BMP set derived from the single field model was more cost-effective, and represented treatment of a greater percentage of the NFFD Watershed's cropland acreage eroding at a rate in excess of soil loss tolerance, because there was no restriction to treat all or none of the fields of a RFU. The SF model was constructed such that, at least conceptually funds could be expended to selectively treat eroding cropland in a stepwise manner across the

NFFD Watershed's cropland acreage according to the cost efficiency displayed by BMPs in reducing soil erosion on a particular field. Replacing the whole farm restriction with the single field option in the requirements of NFFD LTAs would create the potential for increased cost-efficiency of BMPs implemented in the NFFD Watershed, but would of course be contrary to the whole-farm planning philosophy. In addition, farmers interested primarily in treatment of slightly erosive fields might not participate if they could receive financial assistance only for treatment at highly erosive fields.

Average and Marginal Cost Per Ton of Erosion Reduction: for Single Field Model

The NFFD Watershed LP BMPs were analyzed for their cost-efficiency at various expenditure levels by programming the model to yield an optimal solution at $0.2 million incremental units up to the point where 100 percent of the acres were treated. Table 11 illustrates the calculated values for average and marginal cost per ton of erosion reduction for the stepwise progression of ACP funds expended up to the $2.4 million level where 100 percent conservation treatment was obtained. The LP model was programmed with the single field (SF) option, i.e., any field from a representative farm unit (RFU) could enter the solution. Average cost per ton of erosion reduction was calculated by dividing the amount of funds expended by the tons of soil erosion reduced. Marginal cost per ton of erosion reduction was calculated as the change in cost

TABLE 11. Average and Marginal Cost Per Ton of Erosion Reduction: $0.2 to $2.4 Million Funding Levels

ACP Funding Level (million dollars)	Erosion Reduction (tons)	Acres Treated with BMPs	Percent of Watershed Treated with BMPs	Average Cost per Ton of Erosion Reduction (dollars)	Marginal Cost Per Ton of Erosion Reduction (dollars)
0.0	0	0	0	0	
					0.06
0.2	3,529,855	11,965	51.3	0.06	
					0.65
0.4	3,839,483	13,667	58.6	0.10	
					0.72
0.6	4,118,965	14,672	63.0	0.15	
					0.77
0.8	4,377,167	15,792	67.8	0.18	
					0.86
1.0	4,609,147	17,863	76.7	0.22	
					1.00
1.2	4,809,029	18,628	79.9	0.25	
					1.00
1.4	5,008,325	19,368	83.1	0.28	
					1.00
1.6	5,207,621	20,109	86.3	0.31	
					1.00
1.8	5,406,917	20,850	89.5	0.33	
					1.45
2.0	5,544,712	21,260	91.2	0.36	
					1.86
2.2	5,651,969	22,617	97.1	0.39	
					2.11
2.4	5,746,597	23,300	100.0	0.42	

(in $0.2 million increments) divided by the change in erosion reduction.

Analysis of the average cost per ton of erosion reduction column of Table 11 reveals that average cost increased uniformally from $0.2 to $2.4 million of funds expended. For each additional $0.2 million spent for conservation measures, average cost increased by approximately $.03 to $.05. Average cost ranged from a low value of $.06 per ton of soil saved at $0.2 million expended, to a high of $.42 at the $2.4 million expenditure level.

The marginal cost (MC) curve as illustrated in Figure 2 rose with each additional increment of funds expended for implementation of BMPs in the LP model. (Alternatively, the marginal cost information could have been presented in the more conventional fashion with erosion reduction on the horizontal axis.) The MC jumped sharply after the first $0.2 million expenditure and then rose more slowly between $0.2 and $1.2 million expended. Between the expenditure levels of $1.2 and $1.8 million, marginal cost remained constant at $1.00 per ton of erosion reduction. For spending levels above $1.8 million the MC curve again rose until the LP model adequately treated all NFFD cropland acres requiring conservation assistance. Marginal cost per ton of erosion reduction increased from a low value of $.06 to a high of $2.11 from the expenditure ranges of 0 to $0.2 and $2.2 to $2.4 million, respectively.

It was insightful to compare the sets of BMPs implemented on the fields of the eight representative farm units at selected

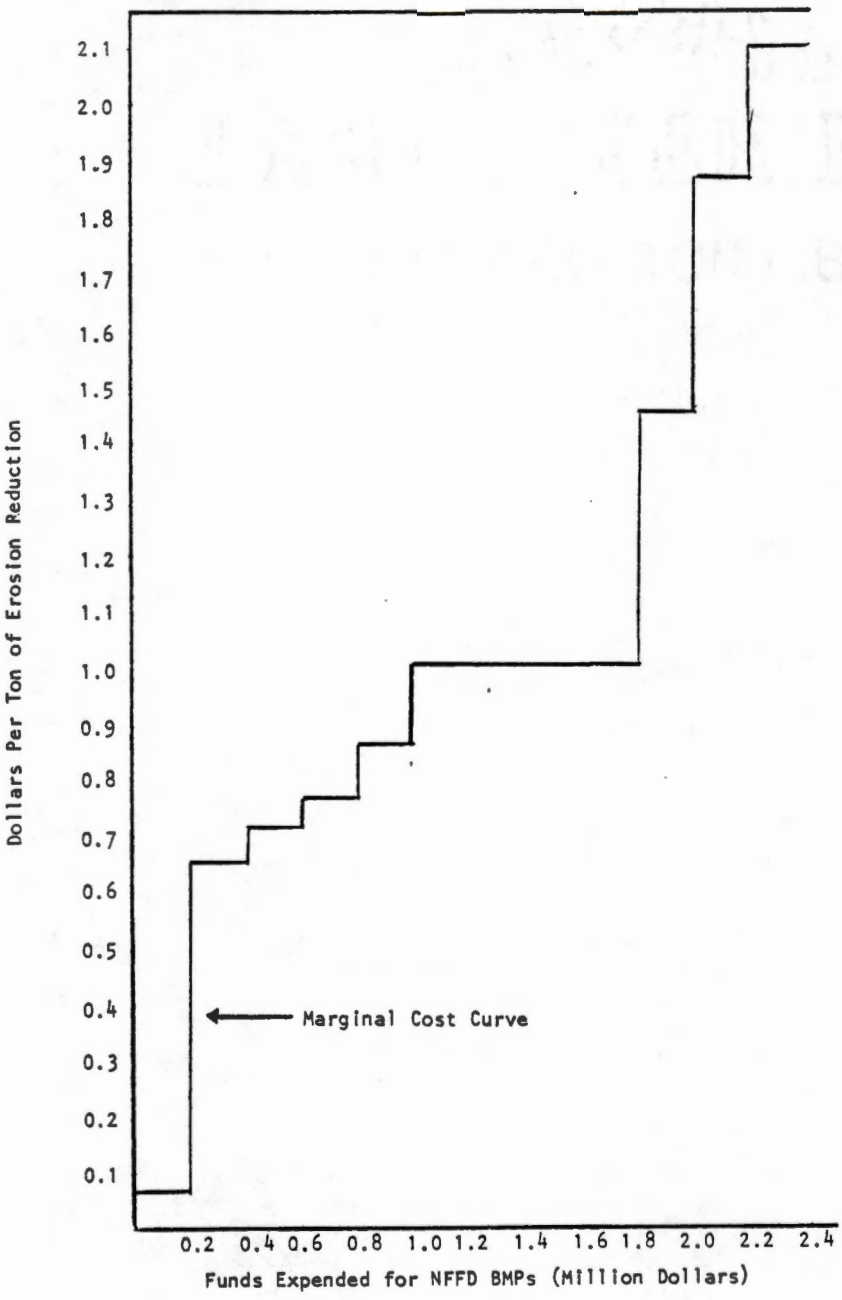

FIGURE 2. Marginal Cost Per Ton of Erosion Reduction: Single Field Model.

funding levels where marginal cost displayed a significant variation, as illustrated in Table 12. Between $0.0-$0.2 to $0.2-$0.4 million of funds expended marginal cost rose by $.60 or by over 10 times which was the largest increase experienced over the entire range of fundings ($0 to $2.4 million). Inspection of Table 12 reveals that the large increase in marginal cost was mainly due to an additional acreage of the BMP SL-15, no-till soybeans, without winter cover crop, without ownership of a sod planter being added to the solution. At the $0.2 million funding level, 94 percent of BMPs were implemented on land with a slope gradient of 5 percent or greater. The BMPs SL-1, establishment of permanent vegetative cover, with a livestock enterprise and SL-15, no-till soybeans, composed the entire percentage at 67 and 27 percent, respectively. At the $0.4 million funding level as compared to the $0.2 level BMPs were increasingly placed on the less sloping and erosive land. Of the 1,702 acres of additional conservation coverage provided at the $0.4 million funding level compared to the $0.2 million level, 61 percent of the practices were placed on land in the slope class gradient 2 to 5 percent, thus the cost-efficiency of installed BMPs declined significantly. From $0.4 to $1.0 million of ACP funding marginal cost rose quite uniformally because the optional solutions continued to contain increased percentages of SL-15, no-till production operations on gently sloping land and SL-1 on land in the slope gradient class, 5 to 8 percent.

TABLE 12. Optimal Solutions: NFFD LP, Single Field Model, with Budgets $0.2 to $2.0 Million

Best Management Practice[a]	ACP Funding Level (million dollars)									
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
	Acres									
SL-1; W/L; G5-8, 8-12	8,000	8,667	9,672	10,000	10,000	10,000	10,000	10,000	10,000	10,000
SL-1; WO/L; G5-8										3,000
SL-15; SB; W/WCC; WO/SP; G5-8						728	1,468	2,209	2,950	
SL-15; SB; W/WCC; W/SP; G5-8					500	500	500	500	500	500
SL-15; SB; WO/WCC; WO/SP; G2-5	765	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
SL-15; Corn; WO/WCC; WO/SP; G2-5				292	2,363	2,400	2,400	2,400	2,400	2,400
- ; MTSB; WO/WCC; G2-5	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200
SL-4; W/MTSB; WO/EME; G2-5										360
Total	11,965	13,667	14,672	15,292	17,863	18,628	19,368	20,109	20,850	21,260

[a]BMP characteristics are represented by SL-1 = establishment of vegetative cover, SL-15 = no-till, SL-4 = terraces, SB = soybeans; MTSB = minimum-till soybeans; W/MTSB = double cropped wheat and minimum-till soybeans; W/L = with livestock enterprise; WO/L = without livestock enterprise; W/WCC = with winter cover crop; WO/WCC = without winter cover crop; W/SP = with sod planter; WO/SP = without sod planter; WO/EME = without earth moving equipment; G = slope gradient expressed in percent.

As ACP funds were expended between a range of $1.2 and $1.8 million, marginal cost remained constant at $1.0 per ton of erosion reduction, and the overall percentage of the NFFD Watershed's cropland acreage treated with BMPs ranged from 79.9 to 89.5 percent. Viewing the acreage values for the individual BMPs across the expenditure levels of $1.2 to $1.8 million revealed that each additional increment of funding was spent to implement a greater acreage quantity of the BMP SL-15, no-till soybeans, with a winter cover crop, and without ownership of a sod planter. Over this range of spending, each dollar spent for conservation practices reduced soil erosion by exactly the same quantity (tons) per acre over a 10 year period, thus marginal cost remained constant. At the ACP funding level of $2.0 million marginal cost began to increase at an increasing rate. The reason for the significant increase in marginal cost at this expenditure level was due to the LP model bringing into the solution less cost-effective practices relative to BMPs implemented at lower spending levels. In this case these practices were SL-1 and SL-4, terraces, wheat and minimum-till soybeans, without ownership of earth moving equipment. From $2.0 to $2.4 million of ACP funds expended marginal cost per ton of erosion reduction continued to increase due to the increased use of BMPs utilizing SL-4 as their main soil conserving component.

V. SUMMARY COMMENTS

Linear programming was used to simulate the soil erosion control options in the NFFD Watershed. The LP model was constructed to provide some comparability between the actual sets of BMPs implemented as part of the special ACP water quality project and the "optimal" set of BMPs derived from the LP model analysis. This required the development of representative farm units to represent actual NFFD farm conditions and cost effectiveness information for various BMPs. A whole farm model was constructed to represent the rules embodied in long term agreements of the NFFD Watershed ACP project requiring treatment of every field of a cooperator's farm to meet soil loss tolerance. The whole farm model results reinforced conclusions from the previous chapter regarding the potential for targeting within the NFFD Watershed to improve cost effectiveness.

In addition, a single field model was developed that allowed treatment of only selected fields from NFFD farms, i.e., not every field of a cooperator's farm was necessarily treated to the point where soil loss tolerance is met. The single field model displayed greater cost-efficiency because selectively targeting to the more cost-effective practices and to the more highly erosive NFFD cropland could be accomplished. Thus, with equal funding the flexibility of the SF option allowed treatment of a greater percentage of NFFD cropland and a greater reduction in erosion, consistent with the logic of the equi-marginal cost principle developed earlier.

Both the whole farm and single field model implicitly embodied a particular subsidy approach. The subsidy cost required to induce BMP implementation was a straight dollar per acre payment equal to the net cost of implementing the practice, thus yielding no rents. With modifications the NFFD LP model could be used to simulate various program approaches designed to target for improved cost-effectiveness in reducing gross soil erosion in critically eroding areas, for example, specifying priorities with regard to BMPs or erosion rate classes on variable cost-sharing.

CHAPTER V

CONCLUSIONS

I. SUMMARY OF FINDINGS

The focus of this study has been on analysis of the cost effectiveness of targeting of Agricultural Conservation Program (ACP) cost-share funds to and within the NFFD Watershed. To complete the analysis, information was collected on the actual set of BMPs implemented in the special water quality project on the NFFD Watershed, including acreage treated per BMP, implementation cost and prepractice and postpractice erosion rates. Doing so allowed comparison of the distribution of practices across prepractice erosion rates and cost per ton of erosion reduction with similar findings from a national survey reported in the National Summary Evaluation of the Agricultural Conservation Program, Phase I. This comparison indicated the impact of targeting to a critical watershed. In addition, information was developed from a random survey of farms in the NFFD Watershed and incorporated in a linear programming (LP) model of representative farm units. The model results indicated the set of BMPs which would maximize gross erosion reduction in the NFFD Watershed. Information from both the analysis of the special ACP project and the LP model applications served to indicate the potential for targeting within the NFFD Watershed. Time and data limitations did not permit

development of as complete or detailed information base on some of these areas as would be desired, and specific limitations were discussed in previous chapters.

Based on the above analysis, there were several findings which warrant discussion and further consideration. Estimation of the cost effectiveness of the set of best management practices implemented in the NFFD Watershed compared with similar estimates in the National Summary Evaluation of the Agricultural Conservation Program Phase I (NSE-ACP-I) revealed that practices installed in the Watershed as a whole were more cost effective than practices implemented nation-wide. An average cost per ton of erosion reduction value was calculated for all BMPs across prepractice erosion rate classes and across practices for a basis of comparison. The average cost per ton of erosion reduction for all BMPs considered together was $2.95 at the NSE-ACP-I and $1.65 in the NFFD Watershed.

The explanation for this considerable difference in average cost at these two levels appears to lie primarily in the fact that in the NFFD Watershed BMPs were installed on more highly eroding fields. Comparing acreage distribution patterns across prepractice erosion rate classes showed that only 13 percent of the nation's farmland erodes at a rate in excess of soil loss tolerance compared to 37 percent in the NFFD Watershed. Nation-wide, then, 17 percent of practices were applied to land eroding at a rate greater than 15 T/A/Y, while in the NFFD Watershed 46

percent of BMPs were applied to this highly erosive land. This comparison provides evidence that in the NFFD Watershed the cost of implementing a practice was generally spread over a greater quantity of tons of erosion reduction, thus reducing average cost for the NFFD Watershed project.

Additionally, the improved cost effectiveness of BMPs installed in the Watershed may be partly due to the whole farm (WF) requirement of long-term agreements implemented as part of the NFFD special project as opposed to the single field approach of implementing BMPs in the NSE-ACP-I. The whole farm requirement in many cases may have forced treatment of highly erosive fields in addition to more moderately erosive ones, thus improving the overall cost efficiency of NFFD BMPs. On the other hand, this whole farm requirement may have reduced overall cost efficiency to the extent that treatment of slightly erosive fields was forced.

From the standpoint of the potential for targeting within the NFFD Watershed, it was also interesting to identify the set of BMPs to be implemented as part of the special ACP water quality project in the NFFD Watershed for comparison with the set outlined in the project application. The extent to which the treatment goals outlined in the NFFD project were met revealed that percentage attainment of goals was highest for the least cost effective practices and lowest for the most cost effective BMPs. The least cost effective practice analyzed was SL-2, improving permanent vegetative cover, which received nearly twice the recommended

percentage of use. In contrast, the most cost effective BMP across erosion classes was SL-15, conservation tillage, which received implementation on only one-third of the acreage that program managers had recommended in the project application. Further, accomplishment of prepractice goals by land capability subclass revealed that the slightly eroding land in the Watershed received a greater percentage of conservation treatment than highly eroding land. NFFD farmland in land capability subclass IIe received 84 percent treatment by BMPs designated as in need of conservation assistance compared to 3 percent coverage of the most highly erosive land in subclasses VIe and VIIe. These findings suggest that the potential value from development of policy measures for targeting to particular soil erosion control practices and more highly erosive fields appears great.

The findings from the LP model analysis served to re-emphasize these conclusions. The LP model derived an "optimal" set of BMPs that maximized the reduction in gross soil erosion in the NFFD Watershed when constrained by various subsidy payments budgets. Two basic LP models were constructed for analysis of the cost effectiveness of BMPs applicable to the NFFD Watershed. The whole farm (WF) model was developed to represent the requirement of the LTA approach to maximizing erosion reduction, i.e., long-term, whole farm planning with treatment of every field of a cooperator's farm to the point where soil loss tolerance is attained. The single field (SF) model simulated targeting conservation funds to specific

fields within the Watershed, regardless of whether all fields on a representative farm were treated.

Comparison of the WF and SF model results revealed that with equal budgets the SF option provided for adequate treatment of a greater quantity of excessively eroding acres across the NFFD Watershed and a lower average cost per ton of erosion reduction. The greater flexibility afforded with the SF option in selectively choosing the more erosive fields to implement BMPs upon increased the overall cost effectiveness of this model relative to the WF model.

Though not strictly comparable, the overall cost effectiveness of the optimal set of BMPs employed in either the WF model is much lower than the average cost of erosion reductions in the NFFD Watershed project. The LP model simulation allowed derivation of a marginal cost function for the NFFD Watershed which indicated that for cost effectiveness, funds would be expended first to induce implementation of permanent vegetative cover establishment on highly erosive land and conservation tillage on moderately erosive land. Terraces and treatment of slightly erosive land were well up along this marginal cost curve. This stands in contrast with the experience from the NFFD Watershed special water quality project analysis.

II. POLICY IMPLICATIONS

Targeting funds to critical areas with more highly erosive land than the nation as a whole appears to improve cost effectiveness,

and further shifts in the allocation of funds in this direction should be considered on the basis that greater erosion reduction can be obtained per dollar expended in critically eroding areas. However, there are a number of aspects of the current policy approach which deserve re-evaluation in the interest of targeting to improve the cost effectiveness of soil erosion control expenditures within critical watersheds. Alternative approaches or modifications warrant serious consideration. This section seeks to provide some degree of such re-evaluation and consideration from the perspective of the findings of this study.

The whole farm requirement of long-term agreements (LTAs) under the ACP embodies traditional principles important to the conservationist philosophy, but cost effectiveness may be limited under this approach. The WF requirement of LTAs inhibits the operational efficiency of program managers by denying them the flexibility to set priorities according to average cost per ton of erosion reduction, initial erosion rate of land capability class, particular type of practices, etc. With limited funding and the recognition of the potential cost effectiveness of targeting on such bases, priority allocation of funds with water quality as the dominant objective may dictate consideration of modifications of the WF requirement.

Analysis of the average cost per ton of erosion reduction of BMPs implemented in the NFFD Watershed across all practices revealed that the variation in the cost efficiency between individual

BMPs is significant in many cases. Thus, even within the WF requirement the potential for improving the overall cost efficiency by targeting funds to particular BMPs appears to be great. One method by which this could be accomplished with some degree of certainty is by limiting availability of cost-share payments to the most cost efficient BMPs appropriate to the field in question. Individual practices could be ranked according to the average cost per ton of erosion reduction of implementing BMPs on land eroding at various intervals.

The soil loss tolerance requirement is based on the logic that if a field is to be treated at all, it should be treated to the point where the soil can sustain its present level of productivity by having the average amount of eroded topsoil lost through erosion annually replaced with organic matter accululated during the growing season. The tolerance requirement assures that severely eroding cropland will be converted to grassland uses or trees. However, tolerance values are low enough that even on moderately sloping land the only practice that will reduce soil loss to tolerance is SL-1, establishment of permanent vegetative cover, which may be a very costly practice. This is because net returns from grassland uses do not nearly equal those of row crops, and with the debt-equity positions of present day farmers conversion of row cropland to grass may not be considered a viable option. However, BMPs possessing some type of reduced tillage production operations often will reduce soil loss to levels near tolerance but not to

tolerance on moderately sloping land. If erosion rates up to 5 T/A/Y above tolerance were allowed on moderately sloping land, the potential for utilization of more cost effective no-till and minimum till practices would be increased significantly.

The first come-first served nature of the current approach could be modified in an effort to target for increased cost effectiveness. Some percentage of regular county allocations of ACP funds are currently restricted for use on LTAs. Working from this precedent, with knowledge of the distribution of acreage by prepractice erosion rate or capability class, some percentage of funds could be restricted for use on the most highly erosive land in a critical watershed or county. If these funds could not be used within some period of time, they might revert back to the state or federal level of reallocation.

All federal soil erosion control programs in the past have been implemented on a voluntary basis. However, the possibility of pressure for more cost effective soil erosion control suggests consideration of mandatory practices in some cases. For example, it has been suggested that row crop operations be excluded on land capability classes VIe and VIIe. This would require a substantial effort in retiring cropland and converting this land to grassland uses and a reallocation of program expenditures to the extent that financial assistance was provided for this type of conversion. Cost effectiveness in terms of total gross erosion reduction would

be markedly increased. However, the political and administrative ramifications of this strategy for reducing soil erosion would appear to make its use unlikely in the near future.

One element of the current approach which has strong equity foundations is uniform percentage cost-sharing, regardless of the field of practice involved. Differential subsidies, to give greater incentives for application of the most cost effective practices on the most highly erosive land and to reduce rents, could encourage targeting even within the whole farm, soil loss tolerance, voluntary, first come-first served approach. Ideally, differential subsidies would be offered on an individual field basis in amounts just sufficient to induce farmer participation, as implicitly assumed in the LP model analysis. The subsidies would be offered in order of highest to lowest erosion reduction per subsidy dollar until available ACP funds were exhausted. Though the administrative costs of implementing such a strategy are prohibitive, more practical strategies which function similarly appear to have potential.

From the standpoint of applying the equimarginal cost principle of economic efficiency as discussed earlier, a subsidy payment per ton of erosion reduction (STP) is an attractive targeting strategy. The STP approach does not eliminate rents but assures that BMPs will only be applied where the cost per ton of erosion reduction is less than or equal to the subsidy rate. The STP strategy in comparison to the uniform cost sharing would discourage use of less cost effective BMPs and treatment of slightly eroding

land and encourage use of more cost effective BMPs and treatment of highly erosive land. Serious consideration of an STP strategy is perhaps constrained by its pure or straight subsidy nature in contrast to the traditional cost-sharing approach; however, variable cost-sharing has some degree of the same efficiency characteristics.

A variable cost-sharing (VCS) pilot program is presently being implemented with the context of the ACP with cost-share rates dependent upon the magnitude of erosion reduction resulting from the installation of a particular BMP on a particular type of field (6). The VCS strategy was introduced because the historical conservation programs have apparently not provided sufficient incentives to induce adoption of practices on highly erosive land with the typical uniform 50 percent rate of cost-sharing. The basic notion behind VCS is that lack of participation by farmers who possess the most erosive land is due to the net cost of implementing BMPs on this type land being in their estimation much higher than the 50 percent offered by ACP programs to date. Experience with this pilot program should prove valuable in consideration of targeting strategies for the future.

It should be noted that any targeting efforts which maintain a voluntary nature may be constrained by the level of information and education on the part of farmers and their attitudes. If farmers do not recognize significant on-site benefits in terms of productivity maintenance and have no concern for off-site impacts on their land use, priority allocation of funds or greater

financial incentives (short of 100 percent cost-sharing) may have little effect. Thus, the role of information/education and technical assistance may be an important factor in the success of targeting strategies.

III. RESEARCH IMPLICATIONS

The primary implication for future research priorities is the need for analysis and evaluation of various targeting strategies such as those outlined in this chapter. This can be done in part by extending the LP model analysis of this study so as to simulate the impact of various strategies but will also require analysis of political feasibility and administrative cost. In addition, consideration of alternative or multiple objectives to reflect the interest in on-site soil productivity benefits as well as off-site benefits would be appropriate, e.g., maximization of the number of acres of classes IIe, IIIe and IVe land brought to soil loss tolerance.

One particular technical need can be noted as well. The estimation of annual soil loss rates is presently dependent upon the Universal Soil Loss Equation (USLE) or the Wind Erosion Evaluation (WEE) which are applicable only for the long-term effects of sheet, rill and wind erosion (2). In the NFFD Watershed and various other critically eroding areas of the United States, gully erosion comprises a significant proportion of total gross soil erosion. The USLE and WEE are not capable of estimating annual soil loss rates

from gully erosion; thus, no reliable tool is available for determining the effectiveness of such practices as SL-11 (establishment of vegative cover on critically eroding areas), WP-1 (debris basins), and WP-3 (grassed waterways in reducing soil erosion). Yet, these practices accounted for approximately half the cost-sharing payments in the NFFD Watershed project. Research in developing an acceptable and reliable method for estimating annual rates of erosion caused by gully erosion would greatly enhance research capabilities for assessment of comparable cost effectiveness of practices designed to control all types of erosion and would aid in the development of present and future targeting strategies to improve cost effectiveness of soil erosion control efforts.

REFERENCES

REFERENCES

1. Alt, Klaus, F. and Earl O. Heady. 1977. "Economics and the Environment: Impacts of Erosion Restraints on Crop Production in the Iowa River Basin." Card report 75, Center for Agricultural and Rural Development. Iowa State University. Ames, Iowa.

2. Batie, Sandra S. 1983. Soil Erosion, Crisis in America's Croplands? The Conservation Foundation. Washington, D. C.

3. Baumol, William J. and Wallace E. Oates. 1975. The Theory of Environmental Policy. Prentice-Hall. Englewood Cliffs, New Jersey.

4. Blisard, William N. 1981. "An Economic Analysis of Terraces as an Erosion Control Alternative at the Farm Level." Master's Thesis. The University of Tennessee, Knoxville. Knoxville Tennessee.

5. Boggess, William, James McGrann, Michael Boehlej, and Earl O. Heady. 1979. "Farm-Level Impacts of Alternative Soil Loss Control Policies." Journal of Soil and Water Conservation 34(4):177-184.

6. Cook, Kenneth. 1982. "Ah for the Simple Life." Journal of Soil and Water Conservation 37(3):154-157.

7. Denton, Harry P. 1978. "The Effects of Degree of Erosion and Slope Characteristics on Soybean Yields on Memphis, Grenada, Lexington and Loring Soils." Master's Thesis. The University of Tennessee, Knoxville. Knoxville, Tennessee.

8. Halcrow, Harold G., Earl O. Heady, and Melvin L. Cotner. 1982. Soil Conservation Policies, Institutions, and Incentives. Soil Conservation Society of America. Ankeny, Iowa, pp.25-39.

9. Hillier, Frederick S. and Gerald J. Lieberman. 1980. Introduction to Operations Research. Holden-Day. San Francisco, California.

10. Hunter, David L. 1981. "Economic Evaluation of Alternative Crop and Soil Management Systems for Reducing Soil Erosion Losses on West Tennessee Farms." Ph.D. Dissertation. The University of Tennessee, Knoxville. Knoxville, Tennessee.

11. Jent, C. H., Frank F. Bell, and M. E. Springer. 1967. "Predicting Soil Losses in Tennessee Under Different Management Systems." The University of Tennessee Agricultural Experiment Station. Bulletin 418.

12. Kasal, James. 1976. "Trade-offs Between Farm Income and Selected Environmental Indicators: A Case Study of Soil Loss, Fertilizers, and Land Use Constraints." Technical Bulletin No. 1550. United States Department of Agriculture, Economic Research Service.

13. Larson, W. E., F. J. Pierce, and R. H. Dowdy. 1983. "The Threat of Soil Erosion to Long-Term Crop Production." Science 219(4582):458-464.

14. Narayanan, A. S., M. T. Lee, and E. R. Swanson. 1974. "Economic Analysis of Erosion and Sedimentation: Crab Orchard Lake Watershed." Department of Agricultural Economics, Agricultural Experiment Station. University of Illinois, Irbana-Champaign and State of Illinois, Institute of Environmental Quality. IIEQ Document No. 74-29.

15. Nelson, L. R., R. N. Gallaher, R. R. Bruce, and M. R. Holmes. 1977. "Water Quality in the United States." Agronomy Journal 69(1):41:45.

16. North Fork Forked Deer River Watershed Plan. 1980. Prepared by North Fork Forked Deer River Watershed District, Gibson County Soil Conservation District, Gibson County Body of Commissioners, assisted by Soil Conservation Service and U.S. Forest Service.

17. Park, William M. 1982. "The What's, Why, and How's of Targeting." Unpublished Draft. The University of Tennessee, Knoxville. Knoxville, Tennessee.

18. Ray, Robert M. and Herbert N. Walsh. 1981. Farm Planning Manual. Agricultural Extension Service, The University of Tennessee, Knoxville.

19. Seitz, W. D., C. Osteen, and M. C. Nelson. 1978. "Economic Impacts of Policies to Control Erosion and Sedimentation in Illinois and other Corn-Belt States." Department of Agricultural Economics, University of Illinois at Urbana-Champaign.

20. Sharp, Basil M. H. 1978. "The Economics of Managing Water Quality: A Multiobjective Analysis of Alternative Policies." Ph.D. Dissertation. University of Wisconsin-Madison, Madison, Wisconsin.

21. Tennessee Department of Public Health, Division of Water Quality Control. 1972. "Obion-Forked Deer River Basin, 208 Water Quality Management Plan." Nashville, Tennessee.

22. United States Department of Agriculture. 1980. Soil and Water Resources Conservation Acts: Program Report and Environmental Impact Statement. Review Draft. U.S. Government Printing Office. Washington, D. C.

23. United States Department of Agriculture, Agricultural Stabilization and Conservation Service. 1980. National Summary Evaluation of the Agricultural Conservation Program, Phase I. U. S. Government Printing Office. Washington, D. C.

24. United States Department of Agriculture, Senate Agricultural and Forestry Committee. 1974. Program Report and Environmental Impact Statement. Review Draft. U. S. Government Printing Office. Washington, D. C.

25. United States Environmental Protection Agency, Water Planning Division. 1978. Setting the Course, Clean Water. U.S. Government printing Office. Washington, D. C.

26. United States Government Accounting Office. 1977A. Report to the Congress of the United States: To Protect Tomorrow's Food Supply, Soil Conservation Needs Priority Attention, CED-77-30. U. S. Government Printing Office, Washington, D. C.

27. Wade, James C., Kenneth J. Nicol, and Earl O. Heady. 1976. "Income Effects of Reducing Agricultural Pollution." Southern Journal of Agricultural Economics 8(1):71-79.

VITA

David Garland Sawyer was born in Morristown, Tennessee, on April 20, 1956. He attended Morristown Hamblen High School East and was graduated in June 1974. Following four years of study at The University of Tennessee, Knoxville, he received a B.S. degree in Agriculture majoring in Plant and Soil Science in 1978. Following graduation he accepted a Soil Scientist position with the United States Department of Agriculture, Soil Conservation Service in Norris, Tennessee. In January of 1981, he accepted a Graduate Research Associate position and began a M.S. program in Agricultural Economics at The University of Tennessee, Knoxville, Knoxville, Tennessee. Immediately following completion of the requirement for the Masters degree in Agricultural Economics at The University of Tennessee, Knoxville in June 1983, he returned to duty with the Soil Conservation Service.