AN ECONOMIC ANALYSIS OF ROAD REHABILITATION ON A PORTION OF CLAYTON LAKE WATERSHED

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PREFACE

An economic analysis of road rehabilitation work through best management practices was undertaken for a portion of the Clayton Lake watershed in southeastern Oklahoma. Impacts of the best management practice plan were identified and estimated, a distribution of the impacts was given, and procedures were outlined that could be used in future studies.

I wish to express my thanks to those who have helped me during this study. First, I would like to thank my committee members: Dr. David K. Lewis, my major adviser, for his help in editing and organizing of my project and thesis; Dr. Parker J. Wigington, for his patience, understanding, and technical expertise in watershed science; and Dr. Kent Olson, for his support and encouragement. Second, I would like to thank the Forestry Division of the Oklahoma Department of Agriculture for the availability of the study area and for their invaluable data. Third, I also want to extend my thanks to Mr. Floyd Brown, for his invaluable help with the Hewlett Packard microcomputer. If it were not for him, I may still be punching calculator buttons.

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CHAPTER I

INTRODUCTION

A. Problem

October 18, 1972, the 92nd United States Congress passed an act to amend the Federal Water Pollution Control Act. Known as Public Law 92-500 (PL92-500) its goal is to eliminate pollution from the nation's navigable waters and to upgrade water quality. Section 208 of PL92-500 concerns areawide waste treatment management and generates interest among natural resource managers. In part, it calls for:

> A process to identify if appropriate, agriculturally and silviculturally related non-point sources of pollution, . . . and to set forth procedures and methods (including land use requirements) to control to the extent feasible such sources. . . (PL92-500, Sec. 208 b(2)(F)).

Section 208 led the Environmental Protection Agency to develop the "best management practices" concept. Environmental Protection Agency policy states:

> Feasible best management practices (BMPs) which reduce non-point source pollution and achieve the water quality goals must be developed and implemented for all categories of nonpoint sources (Oklahoma State Department of Agriculture, 1982,p. 52).

This combination of law and policy resulted in each state assessing their own water quality problems, and developing guidelines for protecting and managing water quality.

Oklahoma's guidelines for forestry water quality practices originated in 1976. Then governor David Boren appointed the "Blue

Ribbon Committee on Forestry" to develop the guidelines. These guidelines were revised in 1982 by the Oklahoma State Department of Agriculture, Forestry Division, to assure current, "state-of-the-art" practices in forest water quality protection and management (Oklahoma State Department of Agriculture, 1982). Thus far, Oklahoma's forest water quality practices are part of a non-regulatory, voluntary program to improve Oklahoma water quality.

Inherent problems exist in a voluntary program. Participants desire benefits from their actions; they expect some incentive to comply with the program. Many private landowners do not possess the technical knowledge needed for water quality control. Technical assistance needs to be provided to the landowners. However, if landowners do not comply with a voluntary program, there may be a need to enact a regulatory program to achieve water quality goals; to many landowners that would be a less desireable course of action.

The Forestry Division is looking at Clayton Lake watershed in southeastern Oklahoma for implementing road best management practices. The watershed covers 2234 hectares and is largely forested. State, industrial forest, and non-industrial forest owners share land ownership. The two industrial forest owners manage on a short rotation basis; one owner has no plans to cut immediately, the other owner manages the timber with intermediate partial cuts, a final clearcut harvest, and subsequent planting. Non-industrially, there has been only one timber cutting operation since 1975. The area experiences relatively high recreation use; it is close to Pushmataha Game Management Area, it is near recreational facilities at Clayton Lake, and it is easily accessed by U.S. Highway 271. There exists some light grazing use in the area. In addition, both Oklahoma State University and the Oklahoma State Department of Agriculture Forestry Division have established hydrological research stations in the Clayton Lake watershed. The combination of forest production and past and current research on the watershed makes it a prime area for a study of Best Management Practice implementation and erosion (non-point pollution) control.

The Oklahoma State Department of Agriculture Forestry Division's Initial Output Report for 208 Task 710 (1981) investigated stream characteristics and potential erosion problems in the Clayton Lake watershed area, and suggested best management practices that are needed in the area. Intermittent streams are subject to natural erosion from side-cutting and surface scour in flood plain areas during high flow. Ephemereal streams experience erosion from down-cutting and shifting of finer sediment deposits. Soils exposed by silvicultural activities, roads, and grazing present a potential for accelerated surface erosion. The task force has decided that roads present the principle need for best management practices. The Division of Forestry has looked closely at the Clayton Lake Watershed, and sees a need for Best Management Practice implementation to control non-point pollution.

Of importance to the Division for future demonstration purposes on best management practices for roads, is a non-industrially owned tract of land. As stated earlier, private landowners who manage for timber production are sometimes ignorant of practices for preserving water quality and for constructing roads. Thus, they may unknowingly contribute to nonpoint sources of pollution. This study will focus on this tract of land because of concerns regarding private landowners and their role in forest industry. For these reasons, it is judicious to focus on a privately owned tract of land for the ensuing study.

B. Objectives

The approximately 120 hectare, non-industrially owned, area on Clayton Lake watershed is under consideration for a demonstration of Best Management Practice implementation. This tract of land is on Section 22, Township 1 North, Range 19 East, Pushmataha County, Oklahoma. The objective of this study is to analyze the area from a costs and benefits perspective of implementing water quality management controls. Specifically:

1. Estimate the physical and economic impacts of choosing to implement best management practices on the study area through:
   (a) examining the costs associated with implementing best management practices,
   (b) identifying the physical and economic effects (potential benefits) of implementing best management practices on: associated water quality, recreational use, local employment, fishery resources and site productivity.
2. Analyze the distribution of both the physical and economic impacts.
3. Develop basic procedures for future studies of the same type.

The area chosen for study has been thoroughly researched by the Oklahoma State Department of Agriculture Forestry Division, and provides an excellent basis for investigation and evaluation.

CHAPTER II

LITERATURE REVIEW

A. Physical Aspects of Water Quality

1. General Considerations

This review of the literature will first examine the physical impact of roads and sediment runoff on water quality. Increased sediment and turbidity levels adversely affect water quality. Forested watersheds can contribute to the problem. Logging roads are often a significant source of sediment. Knowledge of the physical aspects of water quality and forested watersheds provides the groundwork for an economic analysis of limiting sediment transport from forest roads.

One of the biggest detriments to water quality is sediment accumulation. Sediment accumulation not only detracts from water quality, but also from another resource: soil. Soil is one of our main resources. The International Soil Society defined soil as follows (Holy, 1980):

> The soil is a limited and irreplaceable resource and the growing degradation and loss of soil means that the expanding population in many parts of the world is pressing this resouce to its limits. In its absence the biospheric environments of man will collapse with devastating results for humanity (p.4).

It is through man's actions that soil erosion occurs at an accelerated rate; faster than the wind and rain can do it alone. Careful and considerate land management will help preserve the soil as a resource for all of society.

According to Satterlund (1972), sediment is the major water polluting agent in this country. The best way to stop sediment transport from wildlands is to stop erosion. Nature causes some erosion, while some erosion man causes through timber harvesting, road construction, improper grazing practices, and the like. These causes of accelerated erosion must be stopped. If these causes are not stopped, the site deteriorates increasingly unless the process is reversed (Satterlund, 1972). As more surface runoff occurs, more soil is removed, and less topsoil and nutrients remain for plant growth. This affects the microclimate of the area; the less vegetation, the more the soil is exposed to rain and wind impact (Satterlund, 1972). Satterlund, in explaining this process, described the "critical point of deterioration," which is caused by surface runoff and erosion. When an area deteriorates past the critical point, natural forces are unable to overcome the erosive process. If erosion can be controlled, the level of water quality from wildlands can be successfully preserved.

Sediment levels in waterways affect infrastructures and aquatic ecosystems. Sedimentation can begin to fill up reservoirs, clog transmission systems, damage hydroelectric plants, and adversely affect navigation (Copeland, 1963, Patric and Kidd, 1982). Increasing stream sediment levels adversely affect fish habitat (Brown and Krygier, 1971, Striffler, 1963). As turbidity levels increase, the density of fish food decreases (Packer and Haupt, 1965). When concentrations of suspended sediment climb above 20,000 ppm, gill injury or alteration of the fish's behavior patterns can result (Brown and Krygier, 1971). Sediment concentrations also indirectly affect fish. Sediment has the ability to adsorb fine organic matter. The combination of oxygen demanding substances with inorganic sediments may set into motion anaerobic decomposition that can be lethal to bottom organisms and fish eggs (Brown and Krygier, 1971, Packer and Haupt, 1965). Fish are often insensitive to pollutants, but in other situations can be extremely sensitive (Lackey, 1976). Whereas a drastic change in temperature may result in large fishkills, a slow build-up of sediment may not seem to have any effect at all. However, if sediment build-up continues, and nutrients are slowly added to the water, the water may become better inhabitable for one species over another (Lackey, 1976). Increases in stream sediment levels caused by man's activities can be detrimental to transportation and communication systems, and aquatic ecosystems.

Not only does the rise in stream sediment levels harm aquatic ecosystems, but it also harms esthetic and recreation values for society. Sedimentation may cause problems in maintenance of boat harbors and swimming areas, and the maintenance needed may be too expensive to accomplish (Ord, 1963). In addition, muddy waters and eroded roads are esthetically displeasing. Gardner (1978) recognized that there is a need to construct forest roads that allow resource utilization with minimal societal and environmental impacts, and that it is difficult to evaluate those impacts because the necessary inputs are not always well defined, or are non-existent (Gardner, 1979). Impacts on recreation and esthetic values are important considerations facing water quality management.

2. Forested Watersheds

Many researchers have singled out logging roads as a primary cause of sediment production in forested areas. Logging roads, skid trails, and landings are highly compact soils. Rainwater runs off the roads, carrying away sediments, gaining velocity, and displacing larger quantities of road material. Also, logging roads are subject to mass failure of road cuts and fills (Gardner, 1979, Tilley and Rice, 1977). A substantial part of road sediment eventually ends up in stream channels and other waterways, increasing stream turbidity levels. Generally, sediment is more likely to reach a stream channel if the logging road lies close to or crosses the stream (Haupt and Kidd, 1965, Trimble and Sartz, 1957). Many studies establish that forest road construction is a definite contributor to stream sediment, and as a contributor to non-point pollution, it has evoked controversy and additional study.

Several watershed studies have examined the increase in stream sediment levels after road construction. The greatest impact appears in the first year after construction. Copeland (1963) found streamflow sediment content to be 81 times greater than normal the first year following road construction. Fredricksen (1963) found the sediment runoff from a watershed after road construction to be 250 times greater than an undisturbed watershed. Sediment levels decrease after the first year, but do not return to normal for some time.

Research on forested watersheds tends to be highly site specific. Leaf (1974) developed a model for predicting on-site erosion and downstream sediment yield on a relatively small forested watershed in Colorado. However, Leaf asserted in his study that his work should only be applied towards similar areas of steep terrain and geology. Forest watershed studies are often site specific.

3. Modelling of Gully Development

At present, no physical formula or model is available that describes gully advancement, but several statistical models have been devised (Heede, 1976). Thompson (1964) developed a series of regression equations to calculate the rate of gully head advancement; however, these equations are not applicable to the situation to be studied, as it includes gully, sheet, and rill erosion. Seginer (1966) came up with the general prediction equation:

$$\bar{E} = CA^{0.5}$$

Where:

$\bar{E}$ = average annual advancement rate of gully head

A = watershed area draining into gully head

C = constant that varies between watersheds

If the product of the advancement of the gully head and the cross-sectional area of the junction between a lower order and higher order gully is calculated, this is nearly equal to the soil volume lost during the period of advancement (Seginer, 1966). Because of variabilities between topography, vegetation, climate, geology and use, it is difficult to come up with a universal equation for modelling gully erosion. Thus, the equation is non-existent.

B. Water Quality and Recreation

1. Means of Assessment

Recreation is a non-market good. There is no set market value for camping, hiking and the right of enjoying beautiful scenery. The primary benefits of recreation are intangible and not easily measured

(Wilder, no date). Several different methods have been devised to attempt to measure recreational benefits. These measures, or models, have been described by Wilder and others. Many of the measures have shortcomings.

One of the first measures described by Wilder (no date) is capitalization of recreation values. This measure reflects the marginal increase in private land values that results from the desire to be near a recreational area. This is assumed to be a reflection of the economic valuation of an area. David (1968) used a similar method. He claimed that substantial private property on the lake shore of his study area was positively correlated with good water quality conditions and higher property values. The problem with this method is that where resources are used both privately and publicly, benefits associated with public use will not be reflected in waterside property values (Turner, 1977). Another difficulty lies in the large number of variables that influence land values (Turner, 1977). Capitalization of recreation values can be a difficult model to use.

Market value estimates the amount recreational users would be willing to pay if payment were required to use the recreational area or facilities (Wilder, no date). This most often requires the use of interview techniques. The drawbacks of using interview techniques include how to get unbiased answers from respondents, and how to structure questions such that respondents could easily visualize the effects changes in water quality would have on the area (Turner, 1977). The limitations of the market value technique are quickly understood.

The market value of a product puts a price on products rather than usage. This measure indicates the monetary value of a product produced or collected as calculated in a commercial market (for example, fish taken by a recreationist) (Wilder, no date). Unfortunately, this method eliminates such recreation as picnicing and swimming.

Other methods also exist. Wilder (no date) presents a measure called the Economic Equivalency Index, which consists of a formula that quantifies the value of leisure time to recreationists. This method is somewhat obscure. Turner (1977) cites studies that attempt to quantify recreational resources through municipality parks and recreation budgets.

One method of measurement is suitable for assessing the impact recreation use has on local economy. This is the gross expenditure method. It is an attempt to measure the value of recreation to the user in terms of the total amount spent on recreation (Wilder, no date). In turn, this then shows what benefits the area receives from recreational use. This method takes into account all types of recreation: swimming, picnicing, boating and fishing. It is valuable in that it demonstrates the economic impact of recreation on the surrounding area.

Although not all of the methods available, these are just some of the attempts to put a monetary measure on recreation. Granted, some benefits experienced by recreationists are so intangible as to defy measurement: peace of mind, esthetic values, etc. Each method must be weighed individually as to its merit before being used in a given situation.

C. Policies Directed Towards Water Quality Management

1. General Considerations

The physical aspects of water quality have not gone unnoticed in the United States. Section 208 of PL92-500 has been a touch stone for development of various water quality policies across the United States. Policies and programs regarding water quality tend to be voluntary in nature. This holds true in the southeastern United States and in Oklahoma. It is essential to know the policy regarding water quality to adequately describe the effects and results of implementing erosion controls on forest roads; and given the benefits of implementing erosion control, how likely landowners are to practice water quality management.

Controlling non-point pollution, of which forestry roads are a contributor, concerns the entire nation. Section 208 of PL92-500 has been the subject of much debate and controversy. Section 208 has met with technical, administrative and political difficulties (Carruthers, 1979). It has been accused of overburdening the Environmental Protection Agency to devise guidelines and strategies in an unrealistically short time frame (Howe and White, 1973). A regulatory program to enforce the law would take a huge bureaucracy; at the same time there is no clear incentive structure for compliance (Carruthers, 1979). There is natural variability in water quality from area to area; it is difficult to assess and set a water quality standard (Holtje and Harper, 1975, Pisano, 1976). Water quality management is both an object of concern and of debate.

Much more work has been done with non-point pollution from agricultural lands than from forested lands. North Carolina has formed an Agricultural 208 Planning Group to identify pollutants, develop best management practices for control, and develop alternative strategies for best management practice implementation (Brown, 1979). Financial incentives in the form of cost sharing, tax relief, and low interest loans exist for agriculture (Moore et al., 1979), yet none exist for forestry. There is a concern for the quality of water draining from the vast United States agricultural lands.

Forestry is not being totally ignored. There is a desire of the Environmental Protection Agency to work with foresters in preserving water quality (Krivak, 1979). The Environmental Protection Agency also recognizes that before best management practices can be implemented, there are site specific conditions, and social, economic and political factors to consider (Krivak, 1979). Water quality control encompasses many facets of society, including forestry.

2. The Southern United States

States in the southern United States with forestry holdings are interested in maintaining water quality. Florida identified forest roads as one of the largest contributors of sediment to waterways (Greis, 1979a). Florida is promoting a voluntary water quality program and believes it can work. It consists of workshops, test watersheds, research and aggressive training and education (Greis, 1979a, 1979b). Virginia is also a proponent of voluntary programs, education and research for forestry concerns (Pennock, 1977). Virginia is opposed to a regulatory program, as are most forestry interests in the southeastern United States (Dornbusch and Herndon, 1978, Goetzl and Siegel, 1980).

The Environmental Protection Agency has stated that it desires to work with foresters in preserving water quality in a voluntary program, and would institute a regulatory program only when considered most practiceable (Krivak, 1979). Most states in the southeastern United States believe a voluntary program with emphasis on education, technical assistance and cost sharing incentives would be adequate. A regulatory program would only be needed as a back up system if the voluntary program failed (Dornbusch and Herndon, 1978). Federal land managers also work to implement practices to achieve water quality goals while abiding by state rules (Coston, 1979). With cooperation between private individuals, state agencies and federal agencies, a workable, viable water quality control program can exist in the southern United States.

3. Policy in Oklahoma

The Oklahoma Water Resources Board has stated that it will work with other state agencies and the Environmental Protection Agency to reduce non-point pollution and comply with Section 208 legislation (Oklahoma Water Resources Board, 1979). At the present time there are no specific rules and regulations associated with non-point source pollution, but as the Oklahoma Water Resources Board develops familiarity and experience with best management practices being used, they may find it necessary to develop additional rules and regulations (Oklahoma Water Resources Board, 1979). As the law in Oklahoma now stands, the definition of pollution is broad, and includes substances potentially injurious to esthetic sensibilities. The laws do not apply to waters entirely in one ownership unless it affects another's property or water (Goetzl and Siegel, 1980). Oklahoma, like many other states, is concerned with water quality, and presently has a voluntary program for compliance.

D. Economic Aspects of Water Quality Management

1. Introduction

A look at basic economic principles will provide a basis for the reasoning behind assessing impacts of best management practice implementation. Controlling water quality involves more than physical aspects and governmental policies; it is an extension of welfare economics, optimality and social welfare. Cost-benefit analysis is a useful tool that analyzes alteratives, attempting to arrive at an optimal condition. These ideas provide a basic structure for discussing the available alternatives for erosion control and forest water quality management.

2. Welfare Economics

A normative branch of economics, welfare economics concerns itself with value judgement; what is good and what is bad, rather than what is. This seperates it from the branch of positive economics (Feldman, 1980). "Welfare" has been defined as "the state of well-being of the persons comprising an economic system" (Leftwich and Eckert, 1982). With this basis in mind, it is possible to look at some of the concepts of welfare economics.

First, there is the concept of consumer behavior; all consumers make rational decisions. Consumers have what is called a set of indifference curves. Each curve shows the differing combinations of goods that give the same level of satisfaction, or utility. Higher indifference curves, or those that lay to the right, give a higher level of satisfaction than those curves to the left. Consumers attempt to achieve the maximum utility from their income. The private forest landowner will also desire to achieve maximum utility from his resources. He is only going to invest in his land should he receive satisfaction from the investment. In a highly competitive market where producers and consumers rationally attempt to achieve the greatest possible benefit for themselves, available resources will be allocated in a way that maximizes welfare for the given distribution of income (Kneese, 1964). Thus, consumer behavior and competitive markets work together in welfare economics.

The interplay of consumer behavior and competitive markets to maximize welfare breaks down when considering externalities and public goods. An externality occurs if the consumption of a good by one person decreases or increases the satisfaction level of another (Leftwich and Eckert, 1982). Suppose a firm was to use water in its production process, and afterwards released the water into a nearby river. If the water were clear, clean and cool, and improved the water quality of the river, other water users would have increased utility from the firm's consumption. But, should the firm release the water and it is contaminated with chemicals and wastes, this would decrease the utility of subsequent water users. If negative externalities occur in a production process, maximum efficiency cannot be achieved. When maximum efficiency is not being achieved, it is reflected in market prices and others' levels of utility (Feldman, 1980). Should public goods be provided by a competitive market, optimality (discussed next) may decrease. Externalities and public goods produce shortcomings in the concept of consumer behavior and competitive markets maximizing welfare.

The belief of a "Pareto Optimum" has arisen. Conceptualized by the early twentieth century Italian economist, Vilfredo Pareto, the Pareto optimum exists when no one person can be made better off without making someone else worse off (Leftwich and Eckert, 1982). There is no unique Pareto optimum to an economy. Should an economy experience a redistribution of income, the Pareto optimal situation will also shift. However, there is no objective criteria to say whether the new optimum is better or worse than the last; it is a value judgement (Leftwich and Eckert, 1982). This brings us back to the idea of welfare economics, where there is a concern for "good" and "bad", rather than describing what is. Welfare economics is concerned with the well being of society rather than individual welfare. This is demonstrated in the Pareto optimum, and can be expanded.

3. Social Welfare

From the theory of a Pareto optimum, one can move to the problems of social welfare and social choice. The idea of social choice is deciding between alternatives so as to place society in a better social or economic state. Economists have developed criteria to try to answer this question; there is the Pareto criterion, Kaldor criterion, Scitovsky criterion, and Samuelson criterion, all parts of what is known as compensation criteria (Feldman, 1980). Other approaches have been the fairness criterion, the Rawls criterion, and majority voting (Feldman, 1980). Each of these methods have shortcomings of one manner or another, and none of the methods solves the problem of social preferences and deciding what is best for society (Feldman, 1980).

Going back to the idea of consumer behavior, an individual is the best judge of his own welfare. If a group of people do something they believe to be good, they are in essence determining what is good for society on what they consider to be good for themselves (Feldman, 1980). But, because of shifts in income distribution, consumers' tastes and preferences, shifts in optimality occur. Judging alternatives at this point so as to maximize society's welfare becomes increasingly difficult.

4. Cost Benefit Analysis

Cost benefit analysis is defined as "an estimation and evaluation of net benefits associated with alternatives for achieving defined public goals" (Sassone and Schaffer, 1978). The decision between alternative choices evaluated under cost benefit analysis is a value judgement: deciding what is best for society. This leads directly back to social welfare and welfare economics. Cost benefit analysis is basically applied welfare economics. Jules Dupuit in the mid-1800's formulated the idea of a consumer surplus, which led to the concept of net social benefit, now basic to cost benefit analysis (Sassone and Schaffer, 1978). Water related programs and defense planning systems have utilized and expanded the knowledge of cost benefit analysis greatly. Over the years, cost benefit analysis has developed into a practicable art.

Sassone and Schaffer (1978) listed guiding rules for decisions between alternatives, the most applicable being the Potential Pareto Superiority criterion. This criterion labels a project as superior "if those who gain from the project could compensate those who lose so that none would be worse off with the project." Under this criterion, decisions are based upon net benefits, but other forms of decision criteria exist. According to Sassone and Schaffer (1978), net present value is the generally accepted form. It is clearer than annual value, and tends to be more applicable than a benefit/cost ratio. This is a general guideline for typical cost benefit analysis.

Problems arise when externalities and public goods exist. These things without a market price are not easily incorporated into a cost benefit analysis. Externality costs can be computed with a willingness to pay method. This involves conducting a survey among those affected by the externality, or estimating the costs of compensating for the externality (Sassone and Schaffer, 1978). When these methods are not applicable, one must resort to qualitative methods of describing externalities, thus leaving the decision to the decision maker rather than the analyst. Non-priced market goods present unique problems to cost benefit analysis.

E. Economics of Water Quality Management on Forested Watersheds

1. General Considerations

Very little has been done on the economics of water quality management of forested watersheds. Previous forest watershed studies concentrate on costs associated with different harvesting methods that produce differing levels of non-point pollution. Dykstra and Froehlich (1976) developed a procedure for appraising the costs of protection alternatives designed for steep headwater streams in the Pacific Northwest. They presented alternatives, costs and affects of each alternative, but no recommendation that any one alternative was better. Miller and Everett (1975) placed constraints on soil loss through different harvesting methods. As constraints were lessened, they observed the changes in returns, regional income, opportunity costs and other factors. Results showed that as soil loss constraints increase, management plans shift from clearcutting to group selection harvest, but incomes decreased. Miller and Everett (1975) stated that there is a substantial need for a better measure of benefits because externalities associated with pollution activity are diffuse, difficult to measure, and often entail determining values of public goods. This is just a small piece of the potential for research of the economics of water quality management of forested watersheds.

F. Water Quality Management and Watershed Rehabilitation

1. Physical Aspects

To preserve infrastructures and aquatic ecosystems, and to maintain society's welfare, there must be some way to control sedimentation from logging roads. Many studies have suggested improvements and methods to decrease sediment levels from logging roads. Researchers stress most the need for proper and careful planning <u>before</u> the road is constructed and proper maintenance after construction (Megahan and Kidd, 1972). Specific construction practices recommended for logging road construction to reduce sedimentation and stream water quality degradation include fitting the road to the surrounding topography and contours, using filter strips and cross ditches, building on gentle slopes, locating roads well away from stream channels, installing water bars, outsloping roads and building broad based dips. Addditional research has also been suggested as a means of learning how to control sediment from logging road construction (Brown, 1978). The consequences of not attempting to control erosion and sedimentation may include reduced utility of the road, making it unfit for use and the threat of regulation of forest road building and harvesting activities by public law (Cook and Hewlett, 1979). The possible benefits of control include enhancement of roadside esthetics (good for large firm public relations), reduction of road maintenance needed over the life span of the road, and the benefits to society (Sage and Tierson, 1975). A number of studies have looked at methods to control the quantity of sediment coming from forest logging roads.

2. Economic Aspects

Little work has been done on the economic aspects of rehabilitating and controlling soil erosion on forested watersheds. Most forest economic studies have looked at the costs of implementation and construction of different harvesting methods associated with producing different levels of non-point pollution. There is a need to look at the economic impacts of control and rehabilitation of logging roads on forested watersheds. This area has received little attention. In addition, most studies are concerned with large industrial forest landowners rather than the small, private forest landowner. Often, the importance of private landowners to the forest industry is noted, but rarely are the effects of the private landowner on the environment defined.

CHAPTER III

STUDY AREA AND PROCEDURES

A. Study Area

1. Physical Description

The study area for this project includes a road system on the southern half of Section 22, Township 1 North, Range 19 East, Pushmataha County, Oklahoma, and the nearby Clayton Lake. This area lies in the heavily folded Ouachita Mountains which were formed 250 million years ago during the Pennsylvanian period. The soils in this area are of the Carnasaw-Pirum-Clebit association. These soils are deep, moderately deep to shallow, strongly sloping to steep, and well drained. They have a loamy surface layer and clayey or loamy subsoil (Bain and Watterson, 1979). Clayton Lake itself was constructed in 1938 by the Work Project Administration. A relatively small reservoir, it covers just over 30 hectares (Oklahoma State Department of Agriculture, 1983).

2. History

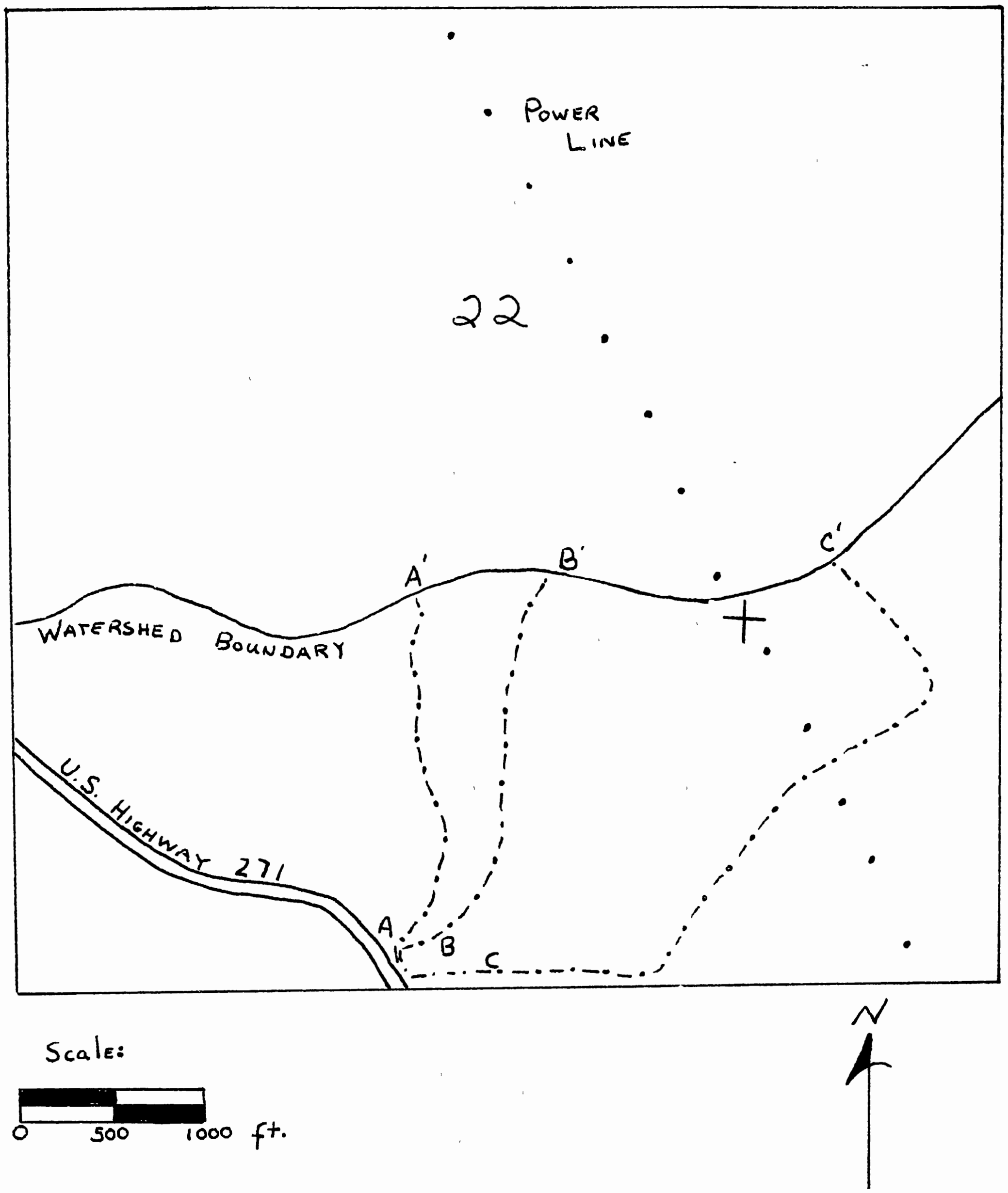
The Choctaws and Chickasaws initially settled the study area from 1835-1850 when they were moved into Indian Territory. The land was first held in common tribal ownership and later sold to individual fee owners. The Oklahoma State Department of Agriculture, Forestry Division researched the Pushmataha County Index of Records which revealed that the land deed for Section 22 has been transferred seven times, the last transaction occurring in 1975. Two timber deeds have been transacted for the section, the first in 1922, the last in 1977 by the present landowner (Oklahoma State Department of Agriculture, 1983). The road system constructed from this latest logging operation is the object of the study.

3. Road System

The road system on section 22 was constructed in 1977 for a harvesting operation. The harvest was completed in 1979 (Oklahoma State Department of Agriculture, 1983). Figure 1 on the following page shows the layout of the road system. There are also roads in the northern half of section 22; however, since these roads are not on the Clayton Lake watershed, they are not included in this study. Only the roads outlined in Figure 1 are to be studied. When first constructed, these roads were placed running uphill on the steep slopes. After the harvesting operation was completed, no water bars or any type of erosion controls were constructed or placed on the roads in question. Consequently, the road system eroded and developed gullies, a process which still continues (Oklahoma State Department of Agriculture, 1983). Appendix A gives a synopsis of the physical characteristics of each road section. The Forestry Division has proposed a management plan to rehabilitate the road system. The best management practice plan is presented in the following section.

4. Proposed Best Management Practice Plan

The Forestry Division hosted a workshop in October, 1982 on the



Source: Oklahoma State Department of Agriculture, 1983.

Figure 1. Section 22, T1N R19E, Pushmataha County, Oklahoma, with Existing Road System

study area. A working management plan was developed for the study area to control road erosion with the following conditions in mind:

1. How often the road is to be used;
2. the desired useful life of the road;
3. the type of traffic the road will experience;
4. the amount of money the landowner is willing to spend; and,
5. the possiblity of closing the road to outside traffic.

With these guidelines, the Division then developed a management plan with a number of treatments. The treatments being considered for the road system, or more specifically, the suggested best management practices, are each given below with a brief description and illustration where appropriate.

<u>Water Bars</u> (see Figure 2)

Use: Water bars dissipiate surface runoff and minimize erosion of the roadbed. They may be constructed when the road is first built, or installed at a later time (Oklahoma State Department of Agriculture, 1982).

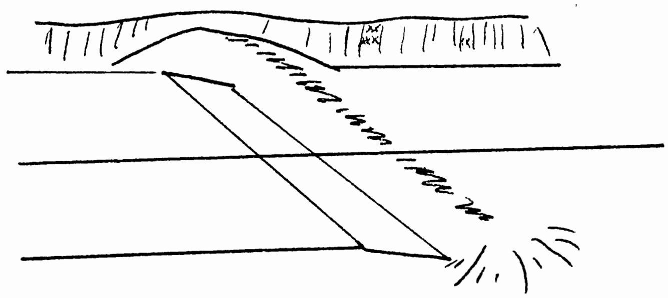
<u>Check (Rock) Dams</u> (see Figure 3)

Use: Check dams are energy dissipiators. When constructed in a gullied ditch or road, they block down slope sediment travel. As the sediment accumulates behind the rock dam, it fills in the gully and helps to stabilize the area (Oklahoma State Department of Agriculture, 1982).

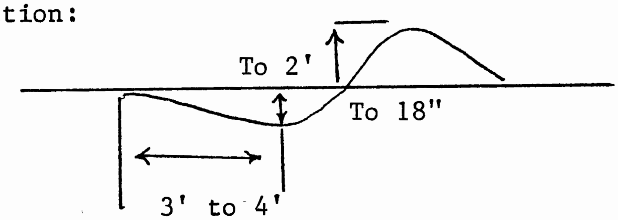
<u>Broad Based Dips</u> (see Figure 4)

Use: This is a road construction designed for drainage purposes. It is designed for low volume use and low speeds on

Top View:

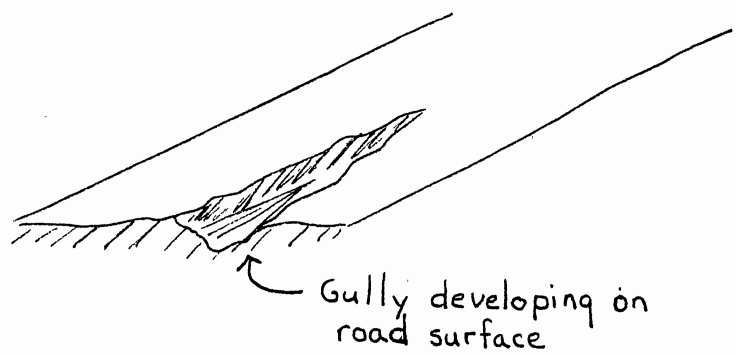


Cross Section:



Source: Oklahoma State Department of Agriculture, 1983.

Figure 2. Water Bars



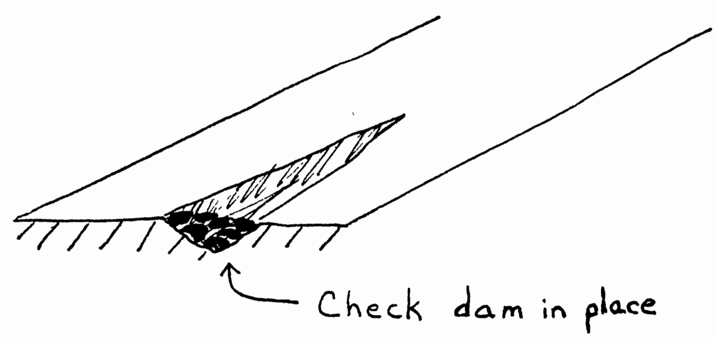


Figure 3. Check (Rock) Dam

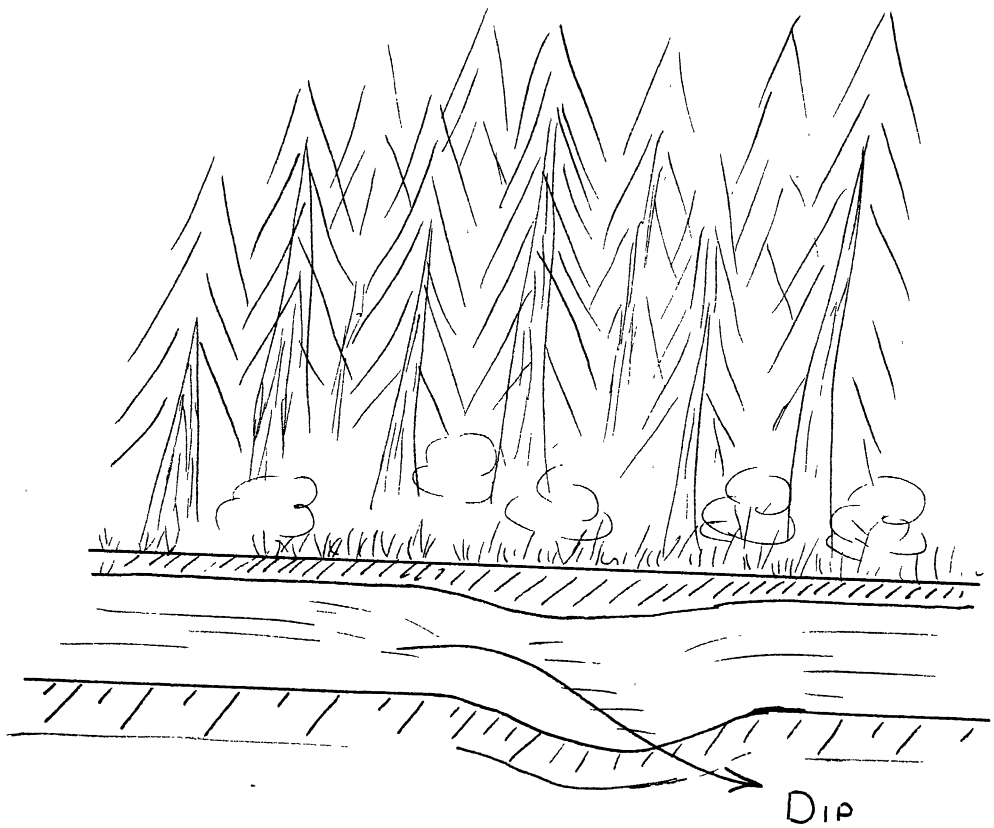


Figure 4. Broad Based Dip

slopes less than 10% (Oklahoma State Department of Agriculture, 1982).

Rock Surfacing and Gully Filling

Use: These two methods help to dissipiate energy and stabilize the immediate area. Quite similar to check dams, this construction consists of filling in gullies and surfacing roads with rock where needed (Oklahoma State Department of Agriculture, 1982).

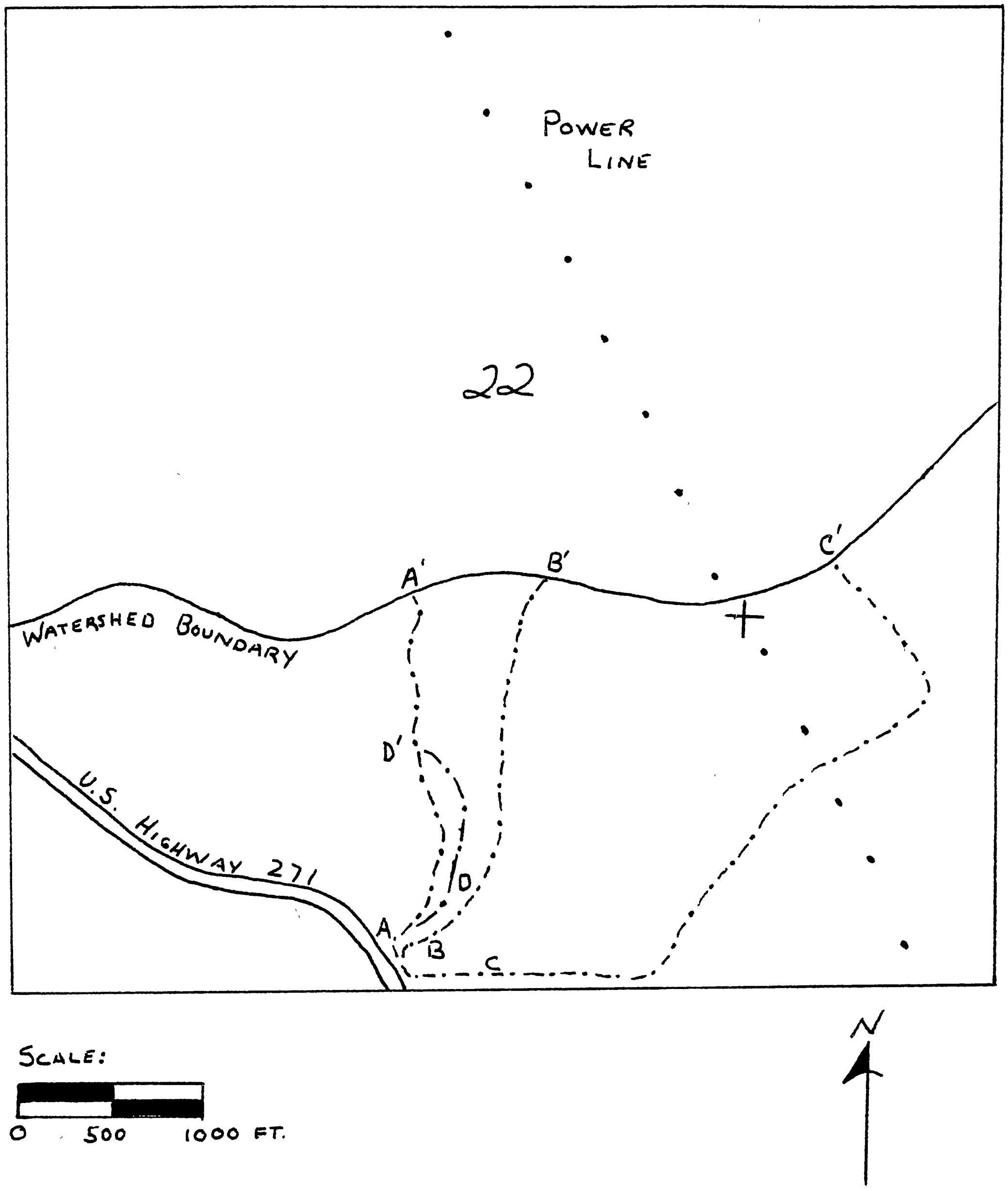
Rip-Rapping

Use: This is a method of using rock fill for a stream crossing. It prevents further erosion of the stream channel by traffic (Oklahoma State Department of Agriculture, 1982).

Seeding and Planting

Use: Seeding and planting is useful for reclaiming sections of road or stabilizing road banks. Seeding and planting involves both tree and grass species (Oklahoma State Department of Agriculture, 1982).

In addition, the Final Output Report for 208 Task 710 (Oklahoma State Department of Agriculture, 1983), recommended the following: referring to Figure 5 on the following page, segment B-B' of the road system is to be permanently retired, as will the southern parts of roads A-A' and C-C'. Retiring the roads will necessitate constructing water bars and check dams, filling gullies, and seeding and planting. Also, the northern part of road segment A-A' will be rehabilitated with two broad based dips. The northern part of road segment C-C' will be rehabilitated through rock surfacing and rip-rapping of two stream crossings. In addition, at the time of next harvest (approximately



Source: Oklahoma State Department of Agriculture, 1983.

Figure 5. Position of Road D for Management Plan

1998), a new road will be constructed, road D-D'. This then is the Forestry Division's recommendation for erosion control on the study area.

B. Procedures

1. Introduction

Procedures are divided into three main areas: costs, areas to be affected, and analysis. Each of these areas will be discussed in turn as to how they will be handled in the study.

2. Costs

There are two types of costs to be considered for this project: costs of construction, and the opportunity costs of implementing the best management practices to the landowner. Construction costs are borne by the landowner (some monetary assistance may eventually be made available to this landowner, due to the Forestry Division's interest in using the area for demonstration purposes; however, this study will treat all construction costs as if the landowner had sole responsibility). Construction costs will be based on local prices for labor, equipment rental and materials. No maintenance should be needed between the time of installing best management practices and the next harvest. No other type of costs, other than construction costs are immediately borne by the landowner.

It was initially thought that there would also be public costs associated with the implementation of best management practices, i.e., assistance from the Forestry Division. However, this type of assistance (water quality planning) normally is not provided by the Division.

Also, because there are no evident cost-sharing programs available to the private forest landowner for this type of rehabilitative work, there will be no direct public costs.

The landowner's opportunity costs of implementing best management practices also deserves mention. These opportunity costs represent the cost to the landowner of choosing to invest monetary resources in best management practices rather than consuming or investing these monetary resources elsewhere. Should the landowner decide not to invest his monetary resources in best management practices, but rather invest elsewhere, these opportunity costs present potential benefits to the landowner for not investing in best management practices. Should the landowner choose to consume his resources for present satisfaction rather than future satisfaction, there will be no future monetary return.

Construction costs are reflective of the local Pushmataha County area. Labor and equipment costs have been gathered together by the Forestry Division. The Division has also estimated preliminary costs for the rehabilitative work. This estimate is essential to this part of the study.

Opportunity costs of investing monetary resources in an alternative investment, rather than in best management practices or through consumption, are estimated, and are not to be misconstrued as absolutes. An easily understood, simple way to present the concept of these opportunity costs is through using compound interest rates and tables. This helps to clarify the concept of potential opportunity costs of investing resources in best management practices rather than elsewhere. In this manner, costs are evaluated for the study area.

3. Areas to be Affected by Implementing Best Management Practices

3.1. Water Quality. To determine how water quality will be affected by implementing the treatments, there must first be some measurement of the erosion from the existing road system, and how it affects waterways. A simple method was devised to roughly estimate the total sediment volume removed from the study roads since construction. Due to its nature, this method estimates gully, rill, and some sheet erosion. This method consisted of breaking the road down into homogenous units according to slope and general road surface characteristics (a stabilized surface, an armored surface, a bedrock surface, a excessively gullied surface, etc.). Within each homogenous unit, profiles of the road surface were taken at beginning, end, and in the middle as needed. These profiles were taken by extending a metric tape across the road and recording depths of depressions and gullies from the original road surface to the existing road surface. The original road surface was visually estimated from existing vegetation and evidence of original road cuts. Figure 6 further illustrates this process. Distances between profiles were measured along the road surface with a 30 meter tape.

Once the measurements were taken and recorded, road area, profile cross-sectional area and volume calculations were calculated in the manner shown in Figure 7. To prevent repetitive hand calculations, these calculations were carried out by a Hewlett Packard 9816 (program given in Appendix B).

No measurements have ever been made on the road before. Thus, the

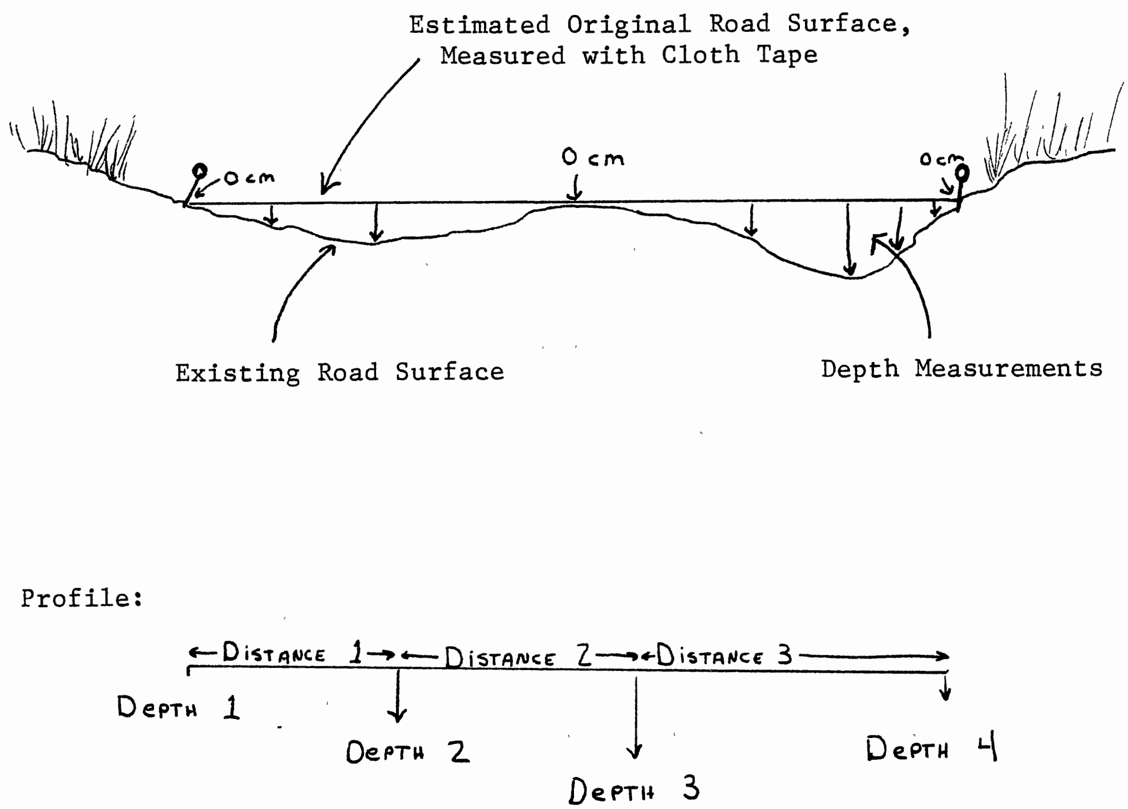
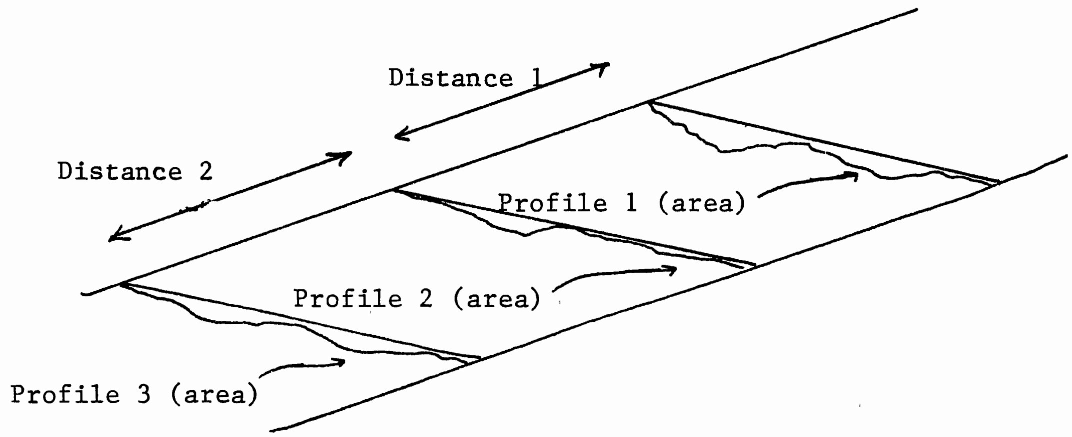


Figure 6. Measurement of Road Profiles



$$\text{Profile Area} = \sum_{i=1}^{n} \left[\left(\frac{\text{Depth}_i + \text{Depth}_{i+1}{}^*}{2} \right) \right] \text{Dist}_i{}^*$$

*Depth and Distance as shown in Figure 6.

$$\text{Volume} = \sum_{i=1}^{n} \left[\left(\frac{\text{Profile Area}_i + \text{Profile Area}_{i+1}}{2} \right) \right] \text{Dist}_i{}^{**}$$

**Distance as shown in Figure 7.

Figure 7. Calculation of Area and Volume

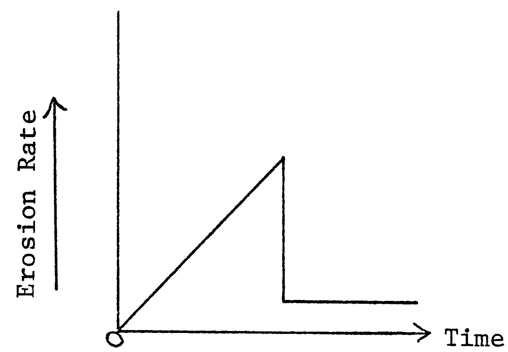
soil loss from the roads, and the measurements of this soil loss represent an estimate for a six-year period. This six year estimate is broken down into a yearly estimate of erosion rates. In addition, an attempt is made to assess how much sediment removed from the roads has been delivered to Clayton Lake. This is a visual estimate only. Under the constraints of time, money, and no previous sampling, these estimates are the best assessment of the impacts best management practice implementation will have on water quality.

Since no universal equation exists for modelling gully erosion, with sheet and rill erosion included, several assumptions need to be made to arrive at an estimated annual rate of erosion. First, erosion would have started and halted fairly quickly on sections of the road area where silt and clay lie over shallow bedrock. Second, due to armoring of the road surface, other road sections may continue to erode very slowly. Third, some road sections are deep clay and silt, and may continue to erode at a greater rate as time progresses. These three situations are illustrated in Figure 8. A large variability exists between sections of road. Because of these reasons, the way chosen to estimate annual erosion is by assuming linearity for the entire period of erosion; that is, a constant rate of erosion over the time period since construction began is assumed. The equation is as follows:

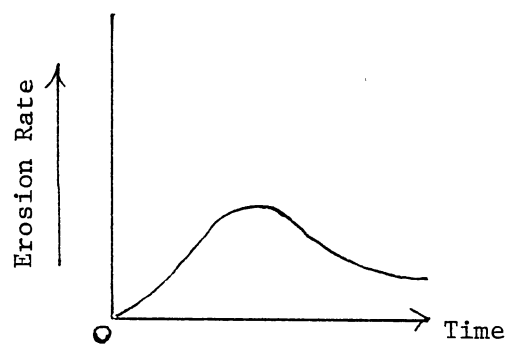
Annual Erosion = Total Erosion/Time

This equation is used to estimate annual erosion from the road area since construction.

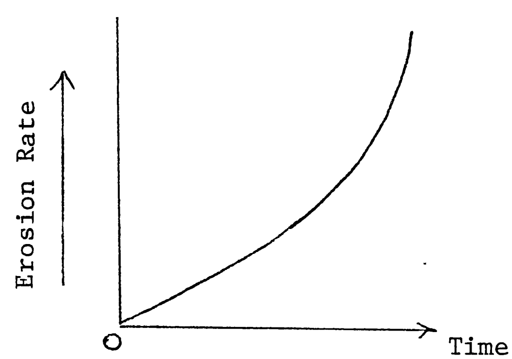
3.2. Recreation. Two areas of benefits could be assessed for the situation at Clayton Lake. The first area is the benefits that recreationists feel personally. The scope of this aspect is so broad as



A. Erosion increases rapidly in silt and clay, halts when bedrock is reached.



B. Erosion rate initially rises, stabilizes at lower rate as surface becomes armored.



C. Erosion rate continues to increase in deep clay and silt subsoil.

Figure 8. Hypothetical Differences in Rates of Erosion on Different Road Sites

to defy any type of measurement. Difficulties arise when asking people to quantify esthetic pleasures. If asked how much they would be willing to pay for clean water, esthetic pleasures, or good fishing, many people may have difficulty answering. If an answer was forthcoming, it most likely would be 1) low, for fear that entrance charges to an area were to be raised, or 2) unreasonably high, because such things are deemed by many as priceless. Some arbitrary measure may be possible through survey and interview techniques, but they may not be an accurate assessment of the situation.

The second possible area of benefits is more easily measured, and has been chosen for use in this study because it is more easily measured, and not as intangible as the first area of benefits mentioned. These are the benefits to the local economy created by recreationists. These benefits are estimated through several sources of information and the use of the gross expenditure method. The first source of information is a record of the number of visitors to Clayton Lake Recreation Area for several years previous. The agricultural economics department at Oklahoma State University has done extensive work on the impact of travel related leisure time activities in Oklahoma. This work has been published and provides an additional needed source of information. Using these sources, it is possible to estimate a monetary value for benefits to the local economy derived from recreationists. With this information, it is possible to estimate the impact of recreation to the local economy.

3.3. Local Employment. If the plan to implement needed best management practices on the study area is carried out, there will be a benefit to the state of Oklahoma through increased income and employment. It is possible to estimate this benefit through two sources of information. The first source of information is the recommendation for needed work on the tract. From this the income to be added to the local area and state can be estimated. The second source of information is an input-output model that provides income multipliers. An income multiplier assesses the impact an added unit of income to a household has on the income of all other households in the state (or whatever region the model covers). Through these two areas of information, it is possible to estimate the benefits of increased employment and income. Fortunately, in 1981, Daniel C. Schooley at Oklahoma State University developed an input-output model for the Oklahoma forest products industry. This model will provide the means to assess the impact of best management practice installation to the local economy.

3.4. Fishery Resources. The possibility exists that installing best management practices on the study tract may affect water quality in the nearby Clayton Lake, to which the study area drains. In this case, the fishery resources of Clayton Lake may also be affected by the implementation of best management practices. It is not within the scope of this study to do a survey of the fish population of Clayton Lake, or to look at the impacts of increased or decreased sediment on that population. Thus, the best way to assess the impacts of best management practice implementation on the area of fishery resources is to consult secondary sources concerning fish in Oklahoma, and the impacts of sediment on this population. Miller and Robison's (1973) work on the fish species in Oklahoma, and the literature review of this study is relied upon to assess this area.

3.5. Site Productivity. Like fishery resources, affects to site productivity can not be easily quantified. A description of possible impacts to site productivityt brought about by the best management practice plan, as determined by visual observation of the area is made. In addition, information from Kozlowski (1982) is cited to demonstrate the importance of water to tree growth.

4. Analysis

This study will conclude with an analysis and discussion of results obtained in the preceding areas. The first section of the analysis will concern the impacts of installing erosion control structures according the the best management practice plan set forth by the Oklahoma State Department of Agriculture, Forestry Division. The second section of the analysis will concern what the repercussions will be if the study area is left as is until the time of next harvest. Both of these sections will also look at how these impacts are distributed, that is, who will feel or benefit from the impacts. The discussion will end with a look at the procedures developed in this study.

CHAPTER IV

RESULTS

A. Costs

1. Construction Costs

Construction costs for the project were compiled by the Oklahoma State Department of Agriculture, Forestry Division. The Division used local rates for equipment, labor and supplies. These rates are given in Table I. Table II gives a summary of labor and equipment times used in determining costs. Table III gives a summary of all construction costs to be incurred by the landowner should the best management practice plan be carried out. The costs in Table III are a least cost approach to restoration of the road area. There are no maintenance costs included in the table because the practices called for should be self-sustaining. These practices should stabilize the road area as needed without further upkeep. The construction costs for the road planned to be built at the time of next harvest is also not included. This is because the condition of the roads suggest that whether or not best management practices are installed at the present, road section D-D' will be needed for the next harvest. The cost of road section D-D' is therefore not relevant to the situation. The costs presented in Table III are a summary of the construction costs that will be incurred by the landowner if the best management practice management plan is undertaken. These

TABLE I

CONSTRUCTION COST RATES

Item	Rate
D-4 Bulldozer	$25 per hour
D-5 Bulldozer	$35 per hour
D-6 Bulldozer	$40-45 /hour
Small Backhoe	$20-25 /hour
Dump Truck, 5-8 cu. yd.	$25 per hour
Dump Truck, 10-14 cu. yd.	$30 per hour
Concrete slabs	$75/ cu. yd.
Hand Labor	$5 per hour

Source: Oklahoma State Department of Agriculture, Forestry Division, BMP Workshop, Antlers, Oklahoma, Oct. 26-27, 1982.

TABLE II

TIME NEEDED FOR CONSTRUCTION

Item	Rate
Road Construction (12 ft. road)	
D-4 Bulldozer	0.25 stations/hr., temporary
	0.5 stations/hr., permanent
D-5 Bulldozer	1.5 stations/hr., temporary
	0.8 stations/hr., permanent
D-6 Bulldozer	1.5 - 2.0 stations/hr., temporary
	1.0 stations/hr., permanent
Water Bars and Dips	½ hr./bar for bulldozer or grader
Rock Work	
Rock at site	1.5 hr./cubic yard
Rock picked up, loaded and hauled to site	3.0 hr./cubic yard

Source: Oklahoma State Department of Agriculture, Forestry Division, BMP Workshop, Antlers, Oklahoma, Oct. 26-27, 1982.

TABLE III

SUMMARY OF CONSTRUCTION COSTS FOR STUDY AREA

Practices	Number of Installations or Sites	Estimated Total Cost
Dips	2	$ 60.00
Water Bars	41	850.00
Check Dams	32	300.00
Rock surfacing and rip-rapping	2	80.00
Gully filling	5	250.00
Seeding and Planting	-	250.00
TOTAL CONSTRUCTION COSTS		$1,790.00

Source: Oklahoma State Department of Agriculture, 1983.

construction costs are current costs, rather than real or constant costs. They have not been deflated; the effects of changes in purchasing power have not been removed.

Although these costs are initially borne by the landowner, there exists the possibility that the landowner could write the costs off as a business expense for tax purposes. In this case, the effect of these costs would be distributed among the populace of Oklahoma and the United States.

No attempt has been made to quantify what construction costs for the best management practices would have been at the time of harvest in 1977. The best management practices needed now are a consequence of action not taken in 1977; it is highly likely that best management practices needed after harvest were not as extensive as those needed now.

2. Opportunity Costs

Opportunity costs are not a tangible cost as such, but rather a potential benefit that is lost to the landowner if he or she chooses to use his or her monetary resources to implement the best management practice plan rather than consuming or investing the money in another alternative. If the landowner has the choice of consuming the money now, as in a trip to Florida, that would represent a potential opportunity cost to the landowner of choosing to invest in best management practices. If the landowner has the alternative of an investment with a guarenteed rate of return, this represents another potential opportunity cost of choosing to invest in the best management practice plan. It is possible to estimate what this potential opportunity cost of alternative investments may be through the use of compound interest rates. Table IV summarizes these opportunity costs. It shows what $1790 (the amount needed to implement the best management practice plan) would be worth at the time of next harvest (1998) if it were invested at varying rates of interest compounded annually. Although this does not seem important at the present, it is important in the analysis of what incentives exist for the landowner to invest in a best management practice plan.

B. Areas to be Affected by Implementing Best Management Practices

1. Water Quality

Of the areas affected by the sediment loss from the study roads, water quality needs to be addressed first. Not only is water quality the first area to come to mind as being affected, but also it is an area that can affect other areas of interest. From the results given on sediment loss, it is possible to estimate an annual rate of sediment loss from the roads. A visual report then indicates the sediment delivery to stream channels. Several analyses of Clayton Lake water quality have been undertaken; the findings of these studies are presented. An estimation is presented of what effects best management practice construction will have on water quality as compared to the present situation. Sediment loss directly affects the level of water quality, and an analysis of the situation is needed.

1.1. Results of Road Measurements. Road measurements were accomplished through the procedure outlined in Chapter II. The results

TABLE IV

POSSIBLE OPPORTUNITY COSTS TO LANDOWNER

Interest Rate	Future Value*
2 %	$ 2,362
4	3,099
6	4,047
8	5,258
10	6,798
12	8,748
14	11,208
16	14,298
18	18,164
20	22,982

*Computation: Use of the formula for a future value of a present payment compounded annually at a given rate of interest. Specifically:

$$V_n = V_o \left[(1+i)^n \right]$$

Where:

V_n = Future Value

V_o = Present payment ($1790 from Table III)

i = Interest rate

n = Number of years (14 years in this instance, from 1984 until 1998, the proposed time of next harvest) are presented in Table V.

"Volume" as presented in Table V represents the soil lost by the road system since construction in 1977 until measurement in 1983. This volume of soil loss does not represent the amount of sediment delivery to Clayton Lake, but rather, the sediment removed from the road and delivered to a point where it has the potential to eventually reach Clayton Lake. Actual estimated sediment delivery to Clayton Lake will be evaluated later in this discussion.

The procedure used gives an estimate of not only gully erosion, but also the less intense rill erosion, and to some degree, sheet erosion. Although not as visually impressive as gully erosion, sheet and rill erosion are as important for their contribution to sediment production, and the resultant change in water quality. This procedure is significant in the fact that it does include all three types of erosion: gully, rill, and some sheet.

1.2. Annual Rates of Erosion Construction on the roads was completed in 1977. Measurement of total sediment loss was completed in 1983, creating a time period of 6 years. Using the procedure given in the preceding chapter, annual erosion is estimated as follows:

Annual Erosion = 1189.43 cu.m./6 years = 198.24 cu.m./yr

For the situation at hand, it is estimated that erosion has occurred for the last 6 years at approximately 198.24 cu.m./yr, and is likely to continue at nearly the same rate for some time into the future.

1.3. Sediment Delivery to Clayton Lake The next question to address is what part of this sediment loss has reached the stream channels and Clayton Lake. There is no evident deposition anywhere

TABLE V

RESULTS OF ROAD MEASUREMENTS

Road Section	Road Length (m)*	Road Area (m^2)*	Volume (m^3)*
Entrance	24.4	41.55	14.46
A-A'	661.37	2222.59	220.45
A'-B'	----------Fire Lane, Could Not Use Data----------		
B-B'	667.50	2251.72	376.47
B'-C'	654.69	1950.85	171.59
B'-C' Extension	18.07	52.36	7.27
C-C'	1453.10	5241.22	399.19
TOTALS	3479.13	11760.29	1189.43

*All figures have been rounded to the nearest hundredth (0.01) along the roadway. Some small deposits exist near the main stream channel leading away from the roads. From the visual estimates, it is estimated that perhaps all but 5 to 10% of the sediment has entered the stream. Upon entering the stream channel it is almost certain the majority of sediment is flushed rapidly down the channel due to the characteristically high flow velocities of the area. The stream channel leading from the road area was followed along its entire course to Clayton Lake during late summer when the stream bed was dry. Gravel deposits are evident near the study site. One of the larger deposits was measured and found to have a volume of 11.63 cubic meters. By visual estimate, this is estimated to be approximately one-tenth of all deposits evident. Perhaps 10 to 15% of the sediment loss from the roads is deposited in the stream channel, where it is eventually washed down to Clayton Lake. After the stream channel from the site joins the larger Peal Creek, few, if any, deposits are evident. These deposits are not necessarily from the study area, but could come from other areas draining into Peal Creek. Figure 9 shows schematically an estimate of what has happened to the sediment lost from the roads. Figure 9 shows that 75 to 85% of sediment is deposited in Clayton Lake. Because of the way the study roads have been constructed, sediment is transported in nearly a straight line to stream channels and then to Clayton Lake. Nearly all deposition of sediment is in Clayton Lake. These estimates are not unreasonable. If the higher estimate of 85% of yearly erosion is deposited in Clayton Lake, this is just enough sediment to cover 3.3 hectares of the reservoir with 0.51 centimeters of sediment yearly. This agrees with a summary put out by the United States Department of Agriculture (Oklahoma State Department of Agriculture, 1983) that

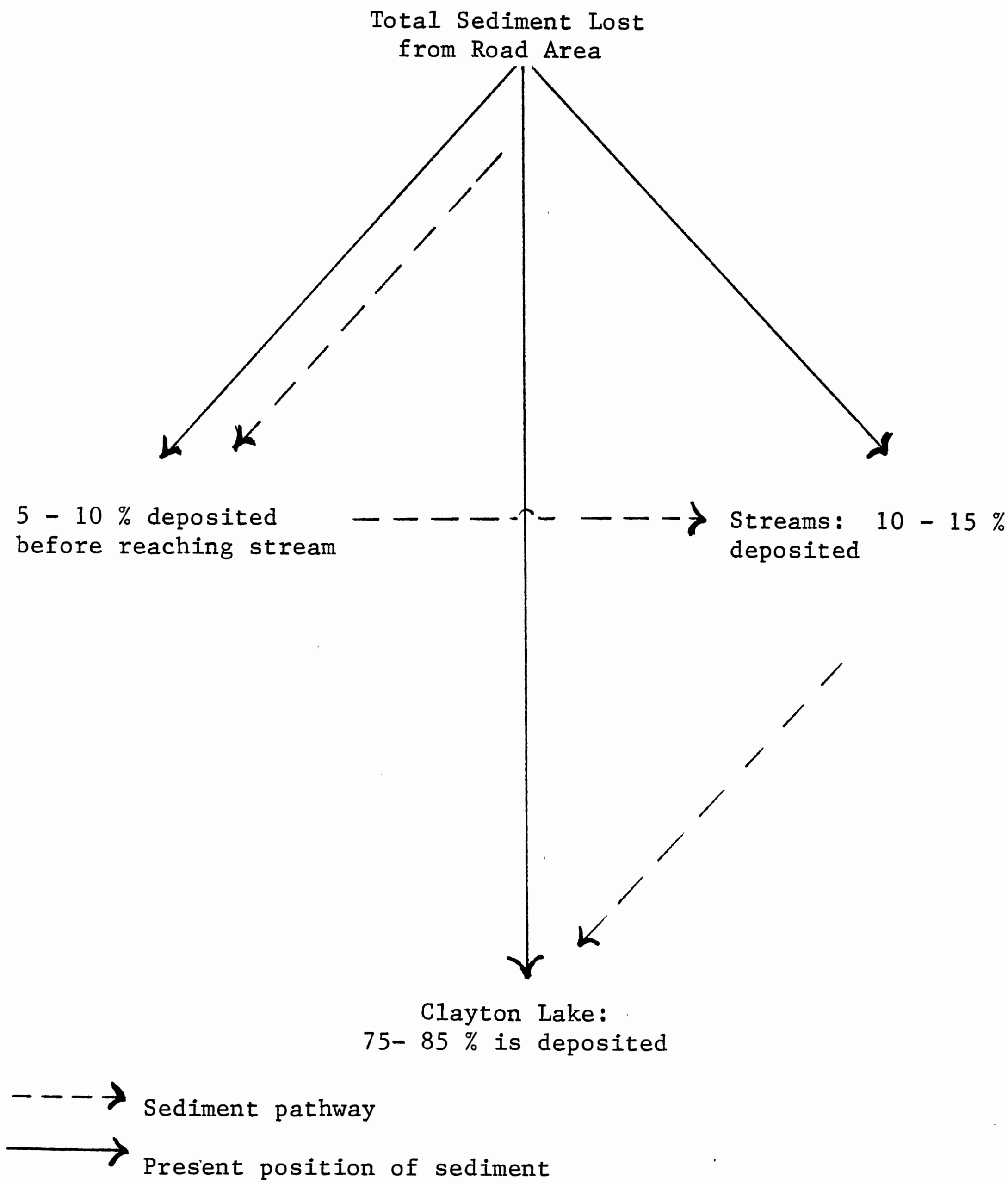


Figure 9. Present Position of Total Sediment Lost from Roads Since Construction in 1977

reports deposition towards the upper end of Clayton Lake occurrs at rates up to 0.51 centimeters/year, and towards the dam at 1.27 centimeters/year (more will be said about this summary in the following section). The estimates given for yearly erosion and sediment delivery to Clayton Lake mesh well with the evidence put forth by the United States Department of Agriculture.

One aspect that must be pointed out, although not quantified here, is that sediment contributes nutrients to the water. This can cause increased growth of plants and algae. This aspect needs to be mentioned when discussing affects to water quality.

1.4. Previous Analyses of Clayton Lake In the Oklahoma State Department of Agriculture 208 Task 223 Final Report (1982), several conclusions were made with regards to forest road construction and water quality. A survey of 20 headwater watersheds (one of which contains the study area) in the Ouachita Highlands provided a basis for the conclusions. A comparison of undisturbed watersheds with watersheds having recent or current forestry operations showed the latter to have higher levels of turbidity and total suspended solids in runoff. New road construction was considered to contribute to increases in sediment movement. The report did not present any cause and effect relationships. Also, the report stated that "the existing water quality standard on turbidity is not operationally useful because of the lack of information on natural background turbidity. . ." The report found that those watersheds with current or recent forestry operations negatively affected water quality.

Another report prepared by the Oklahoma State Department of Agriculture, Final Output Report for 208 Task 710 (1983), includes a summary prepared by the United States Department of Agriculture, Water Quality and Watershed Research Laboratory of Durant, Oklahoma. This summary presents their findings and conclusions about the condition of Clayton Lake after observation of the lake during summer months. The feeling of the researchers is that turbidity in Clayton Lake is caused primarily by organic material. They assert that sufficient organic material has built up on the lake bottom to cause some material to remain in suspension. Late summer temperatures increase anaerobic decomposition which produces gas; as the gas escapes to the surface it disturbs suspended organic matter and adds to water turbidity. The researchers report (Oklahoma State Department of Agriculture, 1983):

> The turbidity observed at Clayton Lake appears to be a natural result of the aging process of a warm water lake with a steep heavily wooded watershed subject to periodic intense precipitation during the season of heavy leaf fall (p. 52).

The idea that turbidity is caused by organic material, rather than sediment, does not indicate a total absence of sediment deposition in Clayton Lake, or of tubidity caused by sediment. As stated in the previous section, the researchers found evidence of sediment deposition occuring in the lake. In addition, the researchers observed Clayton Lake during the summer month of July. Turbidity caused by sediment would be much more evident in the spring time when heavy rains occur. The contribution of sediment to Clayton Lake cannot be discounted due to this summary.

1.5. Effects of Best Management Practices The next point to explore is what affects construction and implementation of best management practices will have on the sediment being transported from the study area to Clayton Lake. Although widely accepted and practiced, no studies have been undertaken to measure the amount of effectiveness of the proposed best management practices. It is not possible then to say construction of two waterbars decreases current erosion by 15%. However, each of the proposed practices is widely used and recognized as being highly effective in the control of erosion. If the best management practice management plan is undertaken, and control measures installed carefully and correctly, nearly all subsequent erosion due to poorly designed roads should halt. Undertaking of the best management practice plan should successfully inhibit further road erosion and subsequent deposition in adjoining stream channels and Clayton Lake.

2. Recreational Use

Clayton Lake was built solely for the purpose of recreational use (Oklahoma State Department of Agriculture, 1983). Anything that affects Clayton Lake affects the recreationists who visit it. Trying to assess the economic values of recreation is difficult. The gross expenditure method gives an idea of the importance of Clayton Lake recreationists to the local economy of Kiamichi Country. It is possible to do this for the Clayton Lake area by using data on visitation to Clayton Lake Recreation Area, and survey data on expenditures by recreationists in Oklahoma.

First, it is necessary to know the number of annual visitors to Clayton Lake Recreation Area. Table VI is a compilation of that information gleaned from several statistical abstracts of Oklahoma (University of Oklahoma, 1975, 1980, 1982). With this basis, it is possible to take recreational data available for Oklahoma and estimate how much money Clayton Lake Recreation Area visitiors have spent in the

TABLE VI

ANNUAL VISITORS TO CLAYTON LAKE RECREATION AREA, OKLAHOMA

Year	Visitors
1975	10,664
1976	13,709
1977	14,249
1978	14,827
1979	50,369
1980	90,517
1981	47,168

Source: University of Oklahoma, 1975, 1980, 1982.

Kiamichi Country area for the years listed.

A 1977 survey taken throughout Oklahoma at nearly 50 recreational sites by the Oklahoma State University Agricultural Economics department reveals some interesting data (Badger et al., 1980). Although Clayton Lake Recreation Area was not included in the survey, surrounding sites were included. It is not inappropriate to apply this data to the Clayton Lake area. The following list of information extracted from the report is important in arriving at a gross expenditure by recreationists (Badger et al., 1980):

1. The survey data represents only those visits occurring May 27, 1977 to September 5, 1977. This represents approximately 54% of visits occurring during the year. This places a seasonal constraint on all expenditures calculated.

2. Expenditures are based on an average group of 4.3 people.

3. For promotional purposes, Oklahoma has been broken down into six large regions or countries. Kiamichi Country, which includes Clayton Lake Recreation Area, is a five county area. Data from this area is considered most relevant and will be used.

4. Average group trip expenditures for outdoor recreationists in Kiamichi Country are included in Table VII.

Using this data, it is possible to arrive at a total amount spent by recreationists who visited Clayton Lake during the summer months of June, July and August. The following formula is used.

TABLE VII

AVERAGE GROUP EXPENDITURES FOR RECREATIONISTS IN KIAMICHI COUNTRY

Category	Average Expenditure	% Spent In Country
Lodging	$ 8	73 %
Food	70	46
Transportation	33	26
Recreation	8	77
Other	4	42
TOTAL	$123	45 %

Source: Badger et al., 1983.

$$\frac{\text{Annual \# Visitors to Clayton Lake} \times \text{0.54 Seasonal Constraint}}{\text{4.3 Average Group Size}} \times$$

Average Group Expenditure x 45% Spent in Kiamichi Country

= Total Seasonal Expenditure in Kiamichi Country by Clayton Lake Visitors

The average group expenditure of $123 was not the same prior to or after 1977. This amount must be adjusted for inflation. The Consumer's Price Index is used to adjust the amount for expenditures, and yields the results shown in Table VIII. Table VIII shows the estimated money spent in Kiamichi Country by Clayton Lake recreationists for the years 1975 through 1981.

The benefit that recreationists bring to the local economy cannot be refuted. As shown in Table VIII, nearly $500,000 was spent in the local Kiamichi Country area by recreationists in 1981. Those living in the local area may be interested in seeing this type of expenditure continue.

Attempts have been made to assess the impact of changing water quality on use of water based recreational facilities. However, water quality is only one of several variables that influence recreational use (Turner 1977). As pointed out in the literature review, many of the methods that attempt to measure recreational benefits have limitations. When changing water quality is introduced into these methods so as to gauge the impact of changing water quality, another problem exists. Namely, that of selecting the appropriate water quality variable to use in the model (Turner, 1977). It is difficult to adequately assess what impact a gradual change in water quality has on visitation to a recreational area and on associated economic benefits. Because of this difficulty, no attempt is made in this study to assess the impact of

TABLE VIII

TOTAL SEASONAL (JUNE, JULY, AUGUST) EXPENDITURE IN KIAMICHI COUNTRY BY RECREATIONISTS TO CLAYTON LAKE RECREATION AREA, OKLAHOMA

Year	Consumer Price Index*	Adjusted Group Expenditure	Adjusted Total Seasonal Expenditure
1975	161.2	$ 109	$ 65,688
1976	170.5	116	89,867
1977	181.5	123	99,044
1978	195.4	132	110,603
1979	217.4	147	418,426
1980	246.8	167	854,249
1981	272.4	185	493,125

* U.S. Bureau of the Census, 1982.

gradually changing water quality on recreational use.

3. Employment

As stated in Chapter III, to assess the effects implementing best management practices would have on local employment calls for the use of an input-output model. The input-output model used in this analysis was developed by Schooley and Jones (1983). The data was gathered in 1979 and reflects 1978 conditions. At present, this data is the most current available. For this analysis, it will be assumed that relationships have not changed greatly since 1978. The model is used in predicting economic impacts in the future due to changes brought about by market conditions, government regulations or incentives (Schooley and Jones, 1983). Data is presented for 31 different sectors. Forestry services are considered part of the agriculture sector, and it is this sector that will be focused upon for this study. There are several steps that must be followed in order to arrive at the impact on total household income from the increased demand for forestry services.

First, a summary of the increased demand for forestry services is needed. This increased demand is the same as construction costs for labor, equipment rental and supplies, as given in Table III. The figure of $1790 indicates the increased demand for output of forestry services, rather than increased income. Although this amount would be paid out for the services desired, it does not take into account expenses incurred by bulldozer or dump truck owners (gas, oil, maintenance, depreciation, taxes, etc.). The amount of $1790 indicates only increased revenue. Income is equal to the difference between revenue and expenses. This distinction between increase in demand for output and increased income must be emphasized for proper usage of the input-output model.

The first thing calculated is the increase in household income due to increased demand in the agriculture sector. This is accomplished by multiplying the amount of demand ($1790) by the technical coefficient for households under the agriculture sector in Schooley and Jones' technical coefficients matrix. This coefficient, 0.0936, represents the dollar amount of inputs that is required from households to produce a dollar's worth of output in the agriculture sector, or in another manner, for every dollar output that comes from the agriculture sector, $0.0936 must be put into the household sector (Schooley and Jones, 1983). Thus, the increase in direct income that could be attributed to the proposed management plan is:

$1790 x 0.0936 = $167.54 <u>increase</u> in direct income

However, the effect of increased direct income also affects the economy indirectly. This leads to the next step in applying income multipliers.

Income multipliers estimate the total change in household income to the entire state when payments to households in a given sector change by one dollar (Schooley and Jones, 1983). Schooley and Jones (1983) differentiated between two types of income multipliers. Type I income multipliers include only direct and indirect results of changes in household income to the state, and are based on the assumption that no change in household expenditures will occur when income paid to households change (Schooley, 1981). Type II income multipliers include not only direct and indirect effects, but also induced effects. These induced impacts are the changes in household spending that are created when changes in household income occur (Schooley and Jones, 1983). Type

II income multipliers assume a marginal propensity to consume, while type I multipliers assume there is no increased consumption due to increased income (Schooley, 1981). Both assumptions are unrealistic, and present two viewpoints. Habits of most people would probably lie somewhere between the two views.

For the study at hand, type I income multipliers are used. The increased demand for forestry services due to the study area are not so great as to cause people to greatly change their rate of consumption. Thus, their consumption habits are more in line with the basic premise of type I income multipliers. The type I income multiplier for Oklahoma for the agriculture sector is 2.91. This can now be applied to the increased income attributable to the best management practice management plan:

$167.54 x 2.91 = $487.54

This amount implies that the effect of carrying out the proposed best management practice management plan is to increase household income throughout the state of Oklahoma by $487.54. Much of this may occur in the immediate area where most employment and consequent spending will occcur.

It is also possible to estimate the increase in employment throughout the state due to this increased demand in forestry services. Coefficients from Schooley and Jones (1983) result in the following analysis. In the agriculture sector, there is an average of 0.0116 employees per $1000 of output. For this study, this results in:

0.0116 x 1.790 = 0.021 employees in the agriculture sector.

The indication is that 0.021 jobs would be created in the agriculture sector. Across all sectors, each job in the agriculture sector creates

2.36 jobs. This results in:

0.021 x 2.36 = 0.05 employees throughout Oklahoma.

These numbers are not of a substantial size. However, the important consideration is that the proposed management plan does have an effect, even if small in nature. The use of an input-output model shows that the proposed management plan for the area under question has an effect on both income and employment in Oklahoma.

4. Fishery Resources

Dr. Eugene Maughan, of the United States Fish and Wildlife Service at Oklahoma State University, asserts that there is a definite lack of information of how fishery resources in southeastern Oklahoma are influenced by an increase in sediment. Information pertaining to the effects of sedimentation on fishery resources is concentrated in the northeastern and northwestern United States. This information is not applicable in this region. It is possible to look at the fish species that reside in Clayton Lake and their respective habitats, and also at the conclusions put forth by the Oklahoma State Department of Agriculture regarding fishery resources.

Several fish species reside in Clayton Lake. Green sunfish (*Lepomis cyanellus*) are relatively small fish, and only a marginal game and food fish. It feeds primarily on insects and fish (Miller and Robison, 1973). The bluegill (*Lepomis macrochirus*) prefers clear, quiet waters with limited vegetation, and feeds mainly on microcrustaceans and insects. The bluegill often hybridizes with the green sunfish (Miller and Robison, 1973).

Three types of bass are found to some extent in Clayton Lake. The most prevalent is largemouth bass (Micropterus salmoides) . This bass can reach 11 pounds in weight and 25 inches in length. It is a highly successful lake and pond fish, feeding on fish, crayfish and insects. Spotted bass (Micropterus punctulatus) are not so prevalent, preferring small, clear spring-fed streams. They are able to tolerate turbid waters with silt bottoms better than smallmouth bass (Micropterus dolomieui) , the third type of bass found in the area. Smallmouth bass prefer cool, clear rocky streams (Miller and Robison, 1973), which explains why it is not found to a large degree at Clayton Lake.Spotted bass (Micropterus punctulatus) are not so prevalent, preferring small, clear spring-fed streams. They are able to tolerate turbid waters with silt bottoms better than smallmouth bass (Micropterus dolomieui) , the third type of bass found in the area. Smallmouth bass prefer cool, clear rocky streams (Miller and Robison, 1973), which explains why it is not found to a large degree at Clayton Lake. Channel catfish (Ictalurus punctatus) are also found in Clayton Lake. They feed on almost any organic materials, dead or alive (Miller and Robison, 1973). Relatives of the catfish, black bullheads (Ictalurus melas) may also occur at Clayton Lake.

The species listed do not depend upon gravel beds for spawning, such as the trout species (Salmo spp.) . There is no danger of excess sediment "cementing" spawning beds for the listed species. Reports put forth by the Oklahoma State Department of Agriculture (1983) stress that there is a lack of information on the subject area, but that there seems to be no immediate danger to fishery resources in Clayton Lake because of sedimentation.

Lackey (1976) brought up the consideration that long term impacts to fish populations may occur due to slow build ups of sediment. This potential source of impact to Oklahoma fish populations has not been researched.

5. Site Productivity

Site productivity of the area may be impacted in one or more of the following ways. First, water falling on the roads flows directly down the roads, making it unusable for nearby vegetation. Second, as is the case with all roads, the roadway takes up space that cannot be used for regeneration. Finally, removal of sediment from the roadway also removes some of the available nutrients that may be present on the roadway.

The flowing of water down roadways rather than off to the sides may have some minimal impact on vegetative growth. In general, water supply is the most important environmental factor determining distribution, species, composition and growth of forests (Kozlowski, 1982). Water deficits adversely affect seed germination, cause shrinkage of plant tissues, and inhibit shoot growth, wood production and root growth (Kozlowski, 1982). Although these effects pertain to greater water deficits than that being considered, they are significant because they point out the importance of water to tree growth. The roads do not prohibit all water from reaching vegetation, but only that that falls on the roadway. This may have a minimal impact on site productivity, especially since the area experiences long dry summers.

The roads take up an area of 11,760.29 square meters (Table V). This area is not available for regeneration. Had some of the roads been put to bed after the last harvest, the opposite would be true, and regeneration would add to overall productivity. The fact that the road area is not now available for regeneration is noted.

As sediment is removed from the road surface, some available nutrients may also be removed. At first this may not seem significant, as no regeneration is taking place on the road area. However, tree root systems are extensive. These nutrients are also not available for use by any tree whose roots may extend beneath the road surface. Once again, this may cause a minimal impact to site productivity near the roadways.

These three possible impacts on productivity due to the road area are not extensive in nature, but they do exist. Information on the relationship between roads and productivity is nearly non-existent. The possibility that productivity in the study area may be affected by the nature of the existing roads deserves mention.

CHAPTER V

DISCUSSION

A. Impacts

There will be no attempt to analyze implementing a best management practice plan from the viewpoint of welfare economics and decide if it is bad or good. Rather, certain economic aspects of this implementation will be pointed out. The purpose is to analyze, not judge.

This study is an example of a situation where an externality exists. Through the use of her land, a landowner is contributing to the detriment of water quality in the surrounding area. Springtime visitors to Clayton Lake, and the manager who resides at the lake, may both experience a decrease in their level of satisfaction because of this detriment. Because of this externality, there is also a breakdown of efficiency. Surely it would have done the situation justice, saved time and expense, and maintained others' satisfaction levels had this situation not been created.

There is no easy answer as how to achieve optimality in this case, or how to decide between alternatives. It is up to the parties involved to make the decision to the best of their ability. An analysis such as this may be helpful in making the decision, by defining the impacts of the alternatives.

By defining qualitatively the impacts of the alternatives available in this study, this study approaches the concept of a cost-benefit analysis. It does not delve into net benefits because many of the areas cannot be quantified due to the the involvement of externalities and non-market goods. This situation due to to its nature warrants a more qualitative approach, and must be viewed in that context.

1. Implementing Best Management Practices

Based on the previous estimates, it is now possible to assess the impacts of implementing best management practices on the study area, and the repercussions it will have. First, the landowner will bear a cost of $1790 in construction of best management practices. If the landowner writes the costs off as a business expense for tax purposes, the costs will be distributed among everyone in the United States and Oklahoma. In addition, should the landowner choose to sell the land, investing in the best management practice plan may ultimately add to the value of the land. As shown in the results, the landowner also stands to lose potential benefits by investing in the plan rather than in an alternative investment. The landowner, who does not live in the immediate area, may be more interested in seeing her resources earning a return in some other fashion. This is a problem not only for the absentee landowner, but also other private forest landowners who may not understand the impacts a harvesting operation or road construction has on water quality in nearby areas. Carrying out the best management practice management plan means that the landowner will entail construction costs of $1790, and may be mindful of certain existing opportunity costs.

Once the best management practice plan is carried out, certain results will occur. The first is that the road area should begin to stabilize, and erosion from the roads should halt. Once this process begins, sediment delivery directly from the roads in question to the stream channel, and subsequently to Clayton Lake, will also slow and halt. Although this will not entirely stop sediment deposition or turbidity in Clayton Lake, it will help to lessen it. These effects will be most noticeable in the springtime during high rainfall and stream flows. Those recreationists who frequent Clayton Lake in the springtime will benefit from this impact, as will the resident manager at Clayton Lake, who is very sensitive to changes in lake water quality.

As to recreation use, it is hard to accurately assess what small changes in water quality will have on use of water based activities. The affects on water quality will most likely be noticed in the springtime; thus, any recreationists who visit Clayton Lake in the spring (for example, fishermen), will benefit from this impact, and in turn, local merchants who do business with the recreationists will also benefit. Recreationists are responsible for bringing in a substantial amount of money to the local economy. Because the major impacts to water quality in terms of sediment delivery and turbidity occur in the spring, summertime visitors will most likely not notice any perceptible changes in water quality if the best management practice plan is undertaken. Springtime visitors most likely do not contribute very much to the local economy, and the increase or decrease of these visitors will not be felt to any great degree. Any impacts to recreation due to implementation of best management practices are negligible.

Implementing best management practices will influence local employment and income. The results of the input-output model demonstrate the importance of this affect. Granted, the affect will be small, but it does definitely exist, and cannot be ignored. By implementing the best management practice management plan the area will experience a degree of increased income and increased employment. This will have repercussions throughout Oklahoma in terms of increased employment and income. The input-output model showed that income throughout Oklahoma would increase by $487.54, and employment would be up 0.05 jobs.

Although it is felt by the Oklahoma State Department of Agriculture that there is no danger to fishery resources being caused by sediment, the lack of information on this subject area makes it difficult to accept this conclusion. Long term impacts of sediment build up may create an environment better suited for one fish species over another. For example, channel catfish and carp may replace bass or bluegill species. This change may take 40-50 years. If the best management practice plan is undertaken, and sediment delivery from the road area to Clayton Lake is halted, this process may be prevented to some degree. Although no one in the immediate future will benefit from this impact, future generations will benefit.

There may exist some minor impacts to site productivity because of the nature of existing roads. Diversion of water down roadways, area removed from the possibility of regeneration, and loss of nutrients may all have some minor impact on overall site productivity of the area. If the best management practice plan is implemented, all three of these impacts should be eradicated to some degree. Water will be diverted off of the roadway, some road area will be made available for regeneration, and sediment and related nutrient removal from the road area should halt. The landowner would benefit from these impacts at the time of next harvest, even if the impacts are only of slight consequence.

2. Not Implementing Best Management Practices

If the decision of the landowner is to leave the road area alone until the time of next harvest, different implications will be felt. First, the landowner will not bear any costs for construction, and will be free to do as he will with his money. This leaves open the opportunity of investing the money elsewhere. However, the landowner must be open to the idea that if the roads continue to erode at the present rate, they will be in worse condition by the next harvest, and need more rehabilitative work than what is called for at present, resulting in added future costs.

Water quality will continue to be adversely affected due to sediment deposition and related turbidity. Recreationists at Clayton Lake will feel this impact. Implementing best management practices on the study area will not halt all sediment deposition to Clayton Lake, but the study roads will stop contributing to the deposition.

As stated earlier, springtime recreational users at Clayton Lake will most likely be the only people to notice continued adverse change in water quality from not implementing best management practices. Once again, the impact of springtime visitors to Clayton Lake on the local economy is not great, but a decrease in their numbers could be felt in the local economy. Water quality change brought about by the study area would be slow, and recreationists may not notice this small change for some time, delaying the impact of their reactions until some future date. Impacts in the area of recreation from not implementing best management practices may be negligible.

The impact on employment and income associated with implementing best management practices is that if the best management practice management plan is not undertaken, no impacts will be felt in employment or income, and no one will benefit.

Fishery resources, from the information available, seem not to be presently adversely affected by the sediment being deposited in Clayton Lake. The stream channel in which the roads drain is dry much of the year, and has no fish population of any consequence. However, as previously stated, the delivery of sediment to Clayton Lake may slowly affect fish populations in the future. This impact is difficult to detect and quantify, but in the long run may be the most important impact to control. If the best management practice management plan is not enacted, the possibility of long term consequences to fish populations exists. Future generations will have to bear the consequences of this impact.

If the best management practice plan is not implemented, the effects to site productivity caused by the road area will continue. The effects on productivity caused by water being diverted down the roadway, area removed from regeneration, and loss of sediment and nutrients from the roadway are minor. If these impacts were extensively quantified, they may be found to be negligible, but the possibility of their existence deserves mention. Without implementation of best management practices, there is no possibility of the landowner benefiting from any increase in site productivity.

3. Procedures Developed

One of the objectives of this study was to develop procedures for use in future studies. This study has developed procedures for measuring past sediment removal from roads. It also has pointed the direction for ways to assess impacts of a proposed best management practice plan through survey data, input-output models and secondary sources of information. These procedures can be manipulated for use in other studies.

The procedure for measuring sediment loss from roads, and presented in detail in Chapter III, can be used in areas that have not been measured before for sediment loss. It can easily be modified to record sediment loss over time by setting up permanent measuring points, and measuring cross-sectional areas at different points in time. This will give an accurate erosion rate. This procedure is significant in the fact that it not only measures gully erosion, but also rill and some sheet erosion. An ideal situation to examine erosion loss from roads would exist if permanent measuring points could be set up at the time of road construction, so that the original road surface could be recorded. The potential for using this procedure in the future is evident.

There are a lot of grey areas that exist when attempting to quantify recreational values. This study has showed that survey data can be beneficial in determining the value of recreation through the gross expenditure method. For future studies in Oklahoma, this survey data can be beneficial.

The input-output model used can also be beneficial when calculating the impacts of a management plan on employment and income. The income and employment multipliers that are provided by the model give an accurate, fairly quick assessment of impacts caused by an increased demand for services. This type of information can be invaluable for an economic analysis.

This study has also shown that when assessing impacts of an action, a number of areas can not be easily quantified, and secondary sources of information need to be relied upon for a qualitative assessment. Even then, the information may be scanty or non-existent. In this type of situation, the need for further research in selected areas is pointed out.

The procedures used in this study for measurement of sediment loss and assessing impacts of proposed plans can easily be used in similar siturations.

4. Policy Issues

Compliance with the section 208 legislation at this time is still strictly voluntary. As stated earlier, people desire incentives for their actions. Likewise, landowners will desire incentives to comply with section 208 legislation. There are two possible areas of incentives that need to be dealt with. The first of these is the possible benefit the landowner may receive from the "market place." Land that is in good repair is more highly valued than land that needs improvement. The landowner who maintains his land may eventually recover costs in the sale of the land. Also, if the landowner uses his land for business purposes, improvements to the land can be treated as a business expense, and costs can be recovered at tax time. There are some incentives to the landowner brought about through the market place to comply with water quality management legislation.

The second area of incentives does not exist at the present time for the private forest landowner in Oklahoma. This is the possibility of some type of monetary remuneration from society. The problems inherent in this plan are obvious. To start up a viable program that would decide how to and how much to compensate a person for his actions would require extensive costs. The problem of where these resources would come from would need consideraton. Before a program of this sort could be implemented, much more information would be needed, standard criteria for compensation would have to be set, and resources would have to be gathered.

As policy now stands, compliance with section 208 laws are voluntary. Some incentives do exist for the landowner in the market place, but it appears unlikely that any sort of compensation program for landowners will emerge.

CHAPTER VI

SUMMARY AND CONCLUSIONS

There is increased awareness among foresters about water quality management and control. This study focused on a tract of private forest land in southeastern Oklahoma that needs best management practices implemented to reduce the degradation of water quality. Implementing water quality management practices carries associated costs and benefits. Both physical and economic impacts are present with the implementation of best management practices. These impacts are distributed among differing groups depending upon the nature of the impact. This study has estimated these impacts and how they are distributed. The physical and economic impacts estimated here, and their distribution, gives an overall view of the costs and benefits associated with implementing best management practices on this study area for water quality management. In addition, this study has developed basic procedures for analysis that can be used in future studies.

The physical and economic impacts of implementing best management practices are diverse, covering a broad spectrum of subject areas. The first of these is in the area of costs. The costs incurred with the implementation of best management practices are $1790 in construction costs and associated opportunity costs. In this case, costs are first and foremost; without these costs there are no best management practices. Once best management practices are constructed, there is a potential for both physical and economic impacts in several areas. Water quality in Peal Creek and nearby Clayton Lake should improve with the decrease of sediment delivery brought about by the best management practice plan. At the present, sediment is being removed from the road area at an approximate rate of 198 cubic meters a year. Recreational use of Clayton Lake is economically important to the local area. In 1981 alone, an estimated $493,125 (Table VIII) was brought into the local area by recreationists. Preservation of the water quality in Clayton Lake will help to maintain recreational use of the lake area. Implementing the best management practice plan increases demand for forestry and construction services. This will result in an increase in both employment and income. In other areas, fishery resources and site productivity may also be affected. Water quality controls installed now may prevent adverse effects to fish populations in the future; namely, the preference for one species over another due to decreased water quality. There is a potential for the productivity of the area to be increased by diverting runoff off of roadways, making it available to nearby trees, opening up additional areas for regeneration, and halting sediment and nutrient removal from the roadways. The potential impacts brought about by implementing best management practices on this study area are diverse in both subject and in degree of impact.

Each impact brought about by implementing the proposed best management practices would be distributed to some person or group. Construction and opportunity costs would be most acutely felt by the landowner. Should the landowner treat the investment as a business expense, costs may be diluted to the general populace of the United

States. In addition to costs, the landowner may experience intangible benefits through knowing that implementing best management practices has a potential to spur benefits in other areas, as itemized in the preceding paragraph. Any increases in productivity, however small, the landowner receives at the the next harvest.

Besides the landowner, others will experience impacts from the implementation of best management practices. Preservation of water quality in Clayton Lake, however slight or imperceptible, will help in the enhancement of esthetic values experienced by recreationists. In turn, the continued recreational use of Clayton Lake will benefit merchants and employees of the local area who provide goods and services for the recreationists. Implementing the best management practice plan calls for construction services. This increased demand will benefit local contractors and laborers. In turn, as demonstrated through the use of an input-output model, this demand will positively affect both income and employment in Oklahoma. As to fishery resources, the recipients of any potential benefits felt in this area are those fisherman and recreationists in the future who will still have the present day fish populations available for their use. Each and every impact brought about by the implementing of the best management practice plan to manage water quality will be felt by someone at sometime.

The final objective of this study was to develop procedures that could be used in the future for similar studies. This study not only presents a method for determining sediment volumes removed from road surfaces, but also points to the importance of using survey data, input-output models and secondary sources of information for analysis. It is felt that these procedures, or slight modifications of the same, can be used in similar studies.

Development of these procedures pinpointed several areas that lack conclusive or thorough information. For example, although generally accepted, there is little information that demonstrates the degree of effectiveness of best management practices in controlling erosion from actively eroding sites. Another area where information is lacking is on the effects of sediment on Oklahoma fish populations. Information is also lacking on the relationships between road construction and productivity (this area, however, may be unique to the situation at hand. A well constructed road will not have the potential of these roads to adversely affect productivity). These areas are important, and should be researched further. This type of information would make it easier to assess the impacts that a management plan has.

This study demonstrates the costs and benefits associated with a best management practice plan on a private tract of land in southeastern Oklahoma. It estimates the physical and economic impacts associated with the plan, and how these impacts are distributed. Basic procedures have been developed to help in further studies. It is hoped that this study will illuminate the importance of the forest landowner to preservation of water quality.

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APPENDIX A

HEWLETT PACKARD 9816 COMPUTER PROGRAM

```
10  DIM DEPTH1(40),DIST(40),AREA1(150),RD(45)
20 DISP "NUMBER OF PROFILES";
30 INPUT Pn
40 FOR K=1 TO Pn
41 GOSUB 500
50 DISP "PROFILE#";
60 INPUT PROF#
70 INPUT "NDIST",NDEPT
80 INPUT "DEPTH# 1",DEPTH1(1)
90 FOR J=1 TO NDEPT
100 DISP "DIST#",J;
110 INPUT DIST(J)
120 DISP "DEPTH",J+1
130 INPUT DEPTH1(J+1)
140 PAR=((DEPTH1(J)*.01)+(DEPTH1(J+1)*.01))/2*((DIST(J)-DIST(J-1))*.01)
150 AREA=AREA + PAR
180 NEXT J
190 AREA1(K)=AREA
191 PRINTER IS 701
200 PRINT "PROFILE#",PROF$
210 FOR I=1 TO NDEPT +1
220 PRINT DEPTH1(I),DIST(I)
230 NEXT I
240 PRINT "AREA IN SQUARE METERS = ",AREA
250 PRINT
260 PRINT
270 PRINTER IS 1
280 NEXT K
290 FOR L=1 TO PN-1
300 DISP "ROAD DISTANCE #",L;
310 INPUT RD(L)
320 VOL=(AREA1(L)+AREA1(L+1))/2*RD(L)
340 VOL1=VOL1+VOL
350 PRINTER IS 701
355 PRINT AREA1(L),AREA1(L+1),RD(L)
360 PRINT "VOLUME OF ROAD SEGMENT IN CUBIC METERS",L,VOL
370 PRINT "AREAS USED",L,L+1
380 PRINT
390 PRINT
400 PRINTER IS 1
410 NEXT L
411 PRINTER IS 701
```

```
412 PRINT "VOLUME OF TOTAL SEGMENT IN CUBIC METERS IS",VOL1
413 PRINT
414 PRINTER IS 1
420 GOTO 550
500 FOR JJ=1 TO 40
510 DEPTH1(JJ)=0
520 DIST(JJ)=0
530 NEXT JJ
540 RETURN
550 END
```

APPENDIX B

DESCRIPTION OF ROAD SECTIONS

Entrance Way: Directly to the east of U.S. Highway 271 is the entrance way to the study area. A one lane dirt road, about 25 meters long, leads in to a large open area. All other road sections join with this open area, and it is at the junction of the respective road section and the open area from where all measurements begin. To the southern edge of the entrance road exists a large active gully. The volume of sediment lost from this gully is presented in Table V. Runoff from the gully enters a culvert under the entrance road and then goes directly to the stream channel. This gully is eroding into deep subsoil and shows no sign of slowing its erosion rate.

Road A-A' (Road A): Starting from its junction with the open area at the entrance way, road A runs uphill in a general northerly direction. The slope initially is steep, ranging from 7 to 10%. In this initial section, finer sediments have been eroded away, revealing underlying bedrock or creating armored road surfaces. A few spots are continuing to erode into clay subsoil.

As the road continues northward, the slope begins to gradually taper off until it reaches 0 to 2%. In this area, some parts become ponded, and show little or no evidence of erosion.

All evident rill and gully erosion follows the course of the roadway. At the base of the hill runoff is diverted westwards towards

U.S. Highway 271, flows through a culvert and directly to the stream channel leading to Clayton Lake. In the few spots where runoff is diverted from the roadway, it still follows a drainageway parallel to the roadway, and then to the culvert. Thus, the chance of sediment delivery to anyplace other than the stream channel is unlikely.

One less than perfect circumstance for a representative measurement exists on road A. In the fall of 1982, a bulldozer worked on a section of road to construct a firebreak. In doing so, the road surface profile due to erosion since original construction in 1977 was altered. Thus, the cross-sectional areas obtained for this road length may be somewhat exaggerated. It must be kept in mind that the construction of the firebreak exposed more road surface to subsequent erosion. In this light, the cross-sectional areas for this particular length of road does not upset the balance of estimated sediment removal from road A.

Road A'B' (Road AB): Road AB commences at the northerly end of road A and proceeds in a general eastward direction to the northerly end of road B. Road AB lies on a ridgetop; slope varies between 0 and 2%. In this respect, any past contribution to erosion is slight. Unfortunately, in the fall of 1982, the entire road length of road AB was bulldozed for a firebreak. Any use of cross-sectional areas of road profiles from this section would be unrepresentative of any past erosion.

Road B-B' (Road B): Approximately parallel to and east of road A, road B commences at its junction with the open area at the entrance way, and proceeds uphill in a northerly direction. Slope along road B tends to be fairly constant, ranging from 6 to 9%. An intricate gully system follows the entire length of road B.

The northerly end of road B is on a deep clay and silt subsoil. Gully erosion in this area is extensive and shows no sign of slowing. Cross-sectional areas of the road profile in this section have large values, ranging from 0.3 square meters to 2.43 square meters.

Towards the lower, or southern, end of road B, underlying bedrock tends to be close to the road surface. Most of the finer sediments have been eroded away, exposing the bedrock surface. Along this section, erosion has consequently come to a virtual halt.

As on road A, runoff follows the course of the roadway. Ultimately, the runoff flows directly to the stream channel leading to Clayton Lake. Little, if any, runoff leads away from the roadway. If any runoff does lead away from the road, it joins with a larger drainage way that runs parallel to road B and joins with the stream channel leading from the site.

Road B'C' (Road BC): Road BC runs on an east-west line between the northern ends of roads B and C. Following a ridgetop, the road slopes between 0 and 5%. Evidence of past erosion exists, but much of the roadway is fairly well vegetated and has stabilized to some degree. At the time of measurement, small rivulets ran down the roadway and joined with road B to continue on their course. Thus, erosion is still active on this section of road, but has slowed considerably.

Extension to BC: At the eastern end of road BC, a short, 18 meter, section of road extends past the end of road C. This extension of road slopes from 5 to 8%, and is actively eroding into clay and silt subsoil. Runoff from the extension travels down either road C or road BC.

Road C-C' (Road C): Road C is the longest road section studied. Commencing from its junction with the open area at the entrance way, it runs northeasterly, then turns back towards the northwest. Towards the southerly end of road C, slope varies from 0 to 5%. Erosion is moderate; road surfaces tend to be armored or cut into subsoil. As the road progresses uphill, slopes range from 6 to 9%. Generally, road surfaces have become armored, with areas of deep gully erosion. Towards the top end of road C, slopes become gentler, and once again range from 0 to 5%. Vegetation is beginning to become established in this area, and has helped to halt any accelerated erosion.

As on roads A and B, runoff from road C proceeds directly down the roadway. Any runoff that does deviate from road C joins other drainageways that lead to the same stream channel as the runoff from road C. In this respect, the chance of sediment being delivered to anywhere other than the stream channel leading to Clayton Lake is remote.

VITA 2

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Master of Science

Thesis: AN ECONOMIC ANALYSIS OF ROAD REHABILITATION ON A PORTION OF CLAYTON LAKE WATERSHED

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