American Farmland Trust

The Economics of Soil Erosion

A Handbook for calculating the cost of off site damage.

THE ECONOMICS OF SOIL EROSION:
A Handbook for Calculating the Cost of Off-site Damage

Prepared by: American Framland Trust in cooperation with the Minnesota Soil and Water Conservation Board

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Acknowledgements

As recently as ten years ago, little attention was paid to the insidious effects of eroded soil once it left a farm field. Current research indicates that the economic cost of correcting off-site (off the farm) damage caused by soil erosion may be significant. According to the Conservation Foundation, the annual cost associated with off-site damage nationally may be as high as $6 billion (1980 dollars).

This handbook, produced in cooperation with the Minnesota Soil and Water Conservation Board, provides a method for local officials to assess the extent and cost of off-site damage in their area. It is intended to be used by non-experts without benefit of computers, as a preliminary assessment of off-site damage at the county or subwatershed level. It includes two Case Studies analyzing off-site damage in Kandiyohi and Redwood Counties of Minnesota. Though research in Minnesota provided baseline data for the Handbook, it may be used in any agricultural area of the country. We hope that the Handbook will serve as a vehicle to raise awareness of the environmental and economic problems associated with off-site damage throughout the country.

We wish to thank the Otto Bremer Foundation for providing the support needed to make this project possible. We'd also like to thank Diane Vosick, the principal author of the report, and the supervisors and staff of the Kandiyohi and Redwood Soil and Water Conservation Districts. Important technical assistance was provided by Greg Larson (Minnesota Soil and Water Conservation Board), William Stokes (Economist, Soil Conservation Service) and Philip Gersmehl (Professor of Geography, University of Minnesota). Many others, too numerous to mention, also offered important support and commentary to the project.

American Farmland Trust is committed to addressing important agricultural conservaiton issues. Through increased local awareness of off-site damage, attention to the problem can be focused at the source. It is our hope that the information generated by use of this Handbook will play a significant role in continuing to enhance the quality of rural life.

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Foreword

Goals

The American Farmland Trust/Minnesota Soil and Water Conservation Board study was designed to develop important information *concerning the cost of off-site damage* caused by soil erosion at the local (county) level. In particular, the study focused on the impacts of agriculturally derived sediment.

Three goals were established for the project. The first was to develop a Handbook that local officials could use to estimate the cost of off-site damage in their area. It is designed to provide a preliminary overview of the problem and a ballpark estimate of its cost.

The second goal was to raise the consciousness of the general public concerning the damage caused by soil erosion.

The third goal was to generate a dollar value for the off-site damage caused by sediment from agricultural sources in two watersheds in Minnesota. Experiences associated with the two study areas were the basis for the development of the Handbook. As categories of damage were explored, the study sites provided an opportunity *to test the availability* of information, and the best method of obtaining that information.

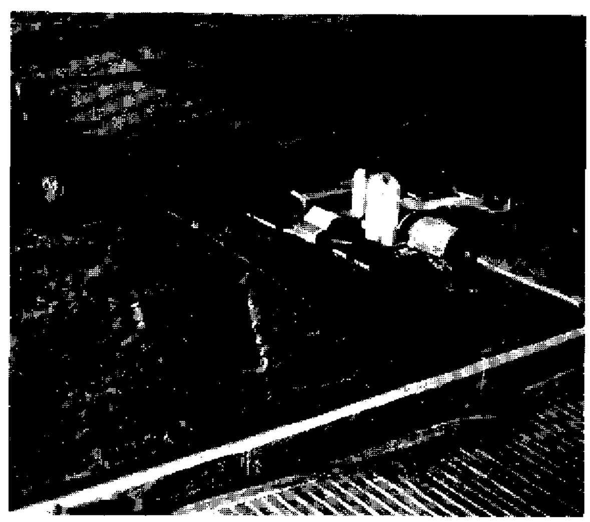
Background

In 1985, the Conservation Foundation published *Eroding Soil: The Off-farm Impacts*. The Conservation Foundation's research estimated the annual cost of off-site damage caused by sediment and associated contaminants was between $3.2 and $13.0 billion nationally. The single-value estimate was thought to be $6.1 billion, while the contribution from agricultural sources was estimated at $2.2 billion (Clark 1985, xiv).

The magnitude of the off-site problem had never before been analyzed in such a comprehensive manner. The Conservation Foundation book and follow-up conference in May 1985 stimulated dialogue about soil erosion and its off-site impacts.

In Minnesota, officials with the state's Soil and Water Conservation Board heard from local officials who wanted assistance in analyzing the cost associated with off-site damage. It was thought that this information could play a significant role in drawing local attention to the need for soil conservation.

Officials from the Board met with a representative from American Farmland Trust, a nonprofit organization committed to the conservation of agricultural land resources, and developed a proposal for a study to meet local needs. In late 1985, funding was provided by the Otto Bremer Foundation.



MN Soil & Water Conservation Board

Methodology

In April 1986, the project was initiated with a literature review. *Eroding Soils: The Off-Farm Impacts* was used as an outline for the study. It provided information on the various types of impacts to be analyzed, as well as a comprehensive list of off-site literature.

Early in the study, the Redwood River Watershed in Redwood County and Shakopee-Mud Creek Watershed in Kandiyohi County were selected for an economic analysis of off-site damage. The areas were chosen on the basis of their position in the watershed, diversity of topography and economy, availability of information, and Soil and Water Conservation District interest in the project.

During the summer of 1986, interviews were conducted which focused on the type and extent of off-site damage and the associated cost. Information was gathered for calendar year 1985. Though everyone contacted was cooperative, data was not always available. For this reason, the two case studies represent a best effort to analyze off-site costs. They provide an estimate of the problem, but should not be construed to represent an absolute dollar value.

The Handbook provides information about the various categories of damage, as outlined by the Conservation Foundation study, and the ways in which to calculate them. It offers a simple approach that can be performed without the aid of a computer or a background in economics. This approach will probably result in an understatement of total off-site damage because it eliminates the econometrics necessary to provide a comprehensive figure for damages in some categories.

Information concerning off-site damage is sorely lacking at the local level. The wide range of values provided at the national level by the Conservation Foundation further illustrates the information gap that exists for this problem. Any local efforts to assess off-site damage will provide important information. It is hoped that this Handbook can provide a useful guide for obtaining information about an important but little understood environmental problem.

Chapter One
How To Use This Handbook

An Introduction to Off-site Damage

A discussion about the cost of off-site damage due to soil erosion may cause people confusion; they don't understand what is meant by "off-site damage due to soil erosion." Understanding this concept is a prerequisite for using this Handbook.

The average annual loss of topsoil in the United States is estimated at 12 tons per acre (Pimentel 1976, 150).

"Sediment carried by water runoff clearly represents the dominant form of soil loss in the U.S., delivering approximately 4 billion tons per year of sediment to waterways in the 48 contiguous states. Three-quarters of the sediment comes from agricultural lands." (Ntl Research Council 1974, 150).

Sediment and associated contaminants that leave farm fields and move through the nation's waterways create a multitude of problems. A short list of the damage includes: siltation of reservoirs, pollution of drinking water, damage to natural biological systems, and impairment of the aesthetic quality of a recreational experience. The effects of sediment and the damage it causes once it has left the farm field, are the heart of the Handbook. The damage is referred to as "off-site" because it occurs away from the area from which the soil originally eroded. ("On-site" damage occurs on the farm field.)

Included in off-site damage are in-stream and off-stream impacts. In-stream refers to damage which occurs in a waterway, including reservoir siltation, harm to fisheries, reduced recreation, diminished property values alongside a waterbody, and any damage which can be attributed to sediment in the waterway.

Off-stream damage is associated with water which has been removed from the waterway. The cost of sediment removal for municipal water, damage to the cooling towers of power plants, and sedimentation in ditches are off-stream impacts.

Determining the cost of off-site damage due to soil erosion is a two-stage process. First, the researcher has the difficult task of establishing the link between sediment and the off-site impacts. For example, fisheries are known to be negatively affected by sediment. However, when other factors such as fishing pressure, intermittant flows, disease and drainage are present, it becomes very difficult to assess the extent of the damage due to sediment.

The second stage of the process attaches a dollar value to the damage caused by sediment (U.S. Dept of Commerce 1984,7). This is straightforward when the cost occurs in the context of the marketplace. In these cases, "hard data" which attaches a definite price to the service or commodity does exist. A complication arises when the service or commodity is not exchanged in the marketplace (Gregerson 1982,1)(Goldstein 1971,44). What is the dollar value of a duck or fish? When the economic data is "soft," this exercise becomes more difficult.

Data limitations and the difficulty of quantifying many of the costs limit the analysis to producing an "estimate" of off-site damage. This is both liberating and frustrating. It is liberating from the standpoint that it allows one to work with a variety of data. It is frustrating because we are a culture that likes the FACTS and wants them to be accurate.

In situations where lack of data requires a "best guess" estimate of damage, it is important to clearly state assumptions. Another information problem may be an inability to derive economic values for some impacts. In some instances, it may be impossible to "quantify" (attach a dollar value) to damage. Under these circumstances, a "qualitative" (descriptive) assessment is in order. This information may be invaluable for pointing out a specific problem which requires more research.

The intention of this analysis is to provide a first look at the problem of off-site damage due to soil erosion. The preliminary overview it provides may lead to a desire for more analyses covering specific categories of damage. It should be thought of as a tool for raising concern about the off-farm environmental and economic impacts of erosion.

Performing the Analysis

Under most circumstances, time and budget limitations will require that most information for this analysis be obtained from other sources. In some instances, it may be possible to generate primary data through the use of surveys and baseline studies. However, in most cases information will be found using interviews and reports.

Organization and thoroughness of data collection are necessities in this study. Abundant information will make any "best guess" more defensible. A step-by-step process for conducting the study follows:

A. *Step One. The Preliminary Assessment*—At the very outset make a few determinations.

1. Delineate the study area. It may be based on natural or political boundaries and should consider what information is available, the audience for the study, and the goals that have been established.
2. Determine the year of the analysis. All requests for information will require that the time period of the analysis be specified. Establishing this immediately is absolutely necessary. There is often a six-month to one year time lag in publishing fiscal and scientific information.
3. Make a preliminary list of the off-site damage in the study area. Use the Checklist (Table 1-1) for this determination.
4. Review the list of damage in the area. Consider the best method of data collection for each category. This may include reports, interviews or surveys. If a particular category of damage is totally unknown, determine the resource people who may be helpful.
5. Review the chapter in the Handbook entitled "Checklist" for each category of damage. Determine the kind of information needed to conduct the analysis. Develop interview questions based on the information needed. Use the literature cited under each category for further information.
6. Review the chapters which include the case studies. They may provide some guidance for the study site under analysis.
7. Establish a time line for data collection and the write-up. This will help to keep the study on schedule and provide a reason for terminating data collection. Remember, the write-up always takes longer as originally planned. Allow a liberal amount of time, and then add some more for procrastination.
8. Set-up interviews with the resource people.

B. *Step Two. Primary Sources of Information*—Surveys can be a cost effective means of gathering information.

1. Develop the survey. Test it with knowledgeable individuals to determine if the questions are clear and properly written to obtain the information needed. If a question has to be explained, it's not right. (See Appendix A for an example of a township interview.)
2. Send the surveys early allowing plenty of time for return. During the research for this report one month was given for the return of survey forms.
3. Always include a self-addressed stamped envelope in which the survey may be returned.
4. Allow enough time after the survey deadline for follow-up calling.

Table 1-1

CHECKLIST OF COSTS DUE TO OFF-SITE DAMAGE OF SOIL EROSION

I. IN-STREAM IMPACTS

A. Biological Damages-No Economic Analysis
   1. Fish Habitats
   2. Food Chain Effects
   3. Protection of Endangered Species

B. Recreation Damages
   1. Fishing
   2. Boating
   3. Swimming/Picnicking/camping
   4. Waterfowl hunting

C. Water Storage in Lakes and Reservoirs
   1. Dredging and Excavating
   2. Construction of Sediment Pools
   3. Replacement Capacity-No Economic Analysis
   4. Water Quality Treatment

D. Navigation
   1. Dredging/Dredge Spoil Disposal
   2. Delays to Commercial Shipping-No economic analysis.
   3. Accidents
   4. Damage to Engines-No economic analysis

E. Other In-stream Impacts
   1. Commercial Fisheries-No economic analysis
   2. Property Values-No economic analysis
   3. Intrinsic Values-No economic analysis

II. OFF-STREAM IMPACTS

A. Flood Damages
   1. Increased Flood Heights from Channel Aggradation-No economic analysis
   2. Increased Flood Volume and Effect on all Damage
   3. Direct Sediment Damages to Crops-Swamping

B. Water Conveyance Facilities
   1. Sediment Removal from Drainage Ditches (Open Ditches and Roads)
   2. Irrigation Canals
   3. Pumping Costs-no economic analysis

C. Water Treatment
   1. Municipal
   2. Industrial

D. Power Facilities

C. *Step Three. Interviews*

1. The day of the interview, review the questions developed based on the information needed for the Checklist.

2. Take copious notes or use a tape recorder. Don't hesitate to ask for clarification. After the interview thank people for their time. Offer to send them the final report.

3. Summarize the information gleaned from the interview immediately.

4. Call for clarification if necessary. It is extremely important to accurately represent direct quotes.

5. Follow-up on leads. During the early stages of the analysis, interviews usually provide numerous leads.

D. *Step Four. Literature Review*—During the data collection phase, it is important to gather published studies and reports. Review this information as the analysis proceeds. It takes time to find everything, especially if documents cannot be found locally.

Though it is possible to be deluged with paper, it is generally a good rule of thumb to collect *everything*, ensuring that everything one needs is available while the report is written.

E. *Step Five. Write-up*

1. When to Begin—Writing may begin as information is gathered, or at the end of the data collection period. Since there are individual categories of damage, one option is to write each section as data is collected.

2. The Mechanics of Writing

a. Start with an outline. This provides structure and clarity to the report.

b. Include a brief physical description of the area and literature review.

c. Cite all sources of second-hand information. It is unethical not to do so.

d. State assumptions and guesses clearly. This protects the reports credibility and provides a fair representation to the reader.

e. State conclusions and recommendations, even if it's thought the whole exercise was inconclusive. This will say something about the study area and the analysis process.

f. Remember the audience for the report. Be concise and clear.

g. Send first drafts to individuals concerned about being quoted. This is not only a courtesy, but it helps to build support and knowledge about the project in the community.

F. *Step Six. Communication*—It is incumbent upon the researcher, to make sure the analysis is read by the audience for which it is intended. Present the information to all the supporting agencies. Don't hesitate to use local media.

Finally, if political action is the end goal of the study, contact local politicians and agencies. A well-written document with an enthusiastic supporter can be a great influence in the promulgation of public policy.

Chapter Two
The Checklist

A. Introduction

Chapter Two is the centerpiece of this Handbook providing structure to the economic analysis. It is organized around each of the categories of sediment damage, and provides guidance in calculating those damages.

The Handbook outlines the most common ways to gather and present information on a local (county) level. Suggestions are based on two case studies and conversations with knowledgeable individuals.

To effectively use the Handbook, review the categories of damage which are likely to occur in the area under investigation. Learn what kind of damage might be expected and what types of information will be needed to perform the economic analysis. Use the Handbook to help formulate questions prior to an interview. A careful review of each category will eliminate a lot of follow-up calling to obtain overlooked information.

Use the worksheets that are provided at the end of each category. They will help to simplify calculations and keep information organized.

In some cases, information is provided about a type of damage for which there is no method of economic analysis. The damages are included in the outline (Table 1-1) for information purposes. Damages in the study site for which there is no economic analysis should be mentioned in the final report.

The analysis will be performed using basic calculations. Here are a few economic concepts and terms used in the Handbook. A basic economic text may be a good reference for more information. Also, the Soil and Water Conservation Service employs economists who can provide additional guidance and information.

Benefits vs. Cost—Under most circumstances, the analysis attempts to measure the cost associated with damage caused by agricultural sources of sediment. They will be costs incurred during the year under analysis. In some instances substantial expenditures for sediment removal may have occurred in the past (such as dredging). The Handbook will indicate how to convert the expenditure to an annual dollar value.

Sometimes the cost of the damage caused by sediment may be considered from the standpoint of the "benefits" to be derived from clean-up. An example of this is the analysis of recreation along the Redwood River. The hypothetical case of the economic value of recreation in the absence of siltation was considered. This economic value was then used to indicate the current financial loss to the community because of recreation foregone due to sediment. Though some economists argue that these two values may not be precisely equal, it is appropriate for our purposes of approximation to assume they are.

Amoritization of Costs for Conversion to an Annual Cycle—This is identical to what one would do when borrowing money for a home. Consider a cost which occurs all in one year or is represented in a budget as a single figure (ie. sediment pool construction in a new reservoir). It would be misrepresentative to attribute the entire value to a single year, especially since benefits from the project are expected to extend over a long period. Instead, the value will be amortized over a reasonable payback period (just as a home loan). This allows a calculation of the annual cost of the project.

Converting Historical Dollar Values to the Year Under Analysis—Since this analysis relies primarily on existing research, it may be necessary to use dollar values in an older study to indicate the cost of some damage today. Inflation and other factors will distort the value of that figure in present day dollars. Therefore, convert the historical value of the dollar to the year under analysis. This is done using the Consumer Price Index.

For example, assume the analysis requires a determination of the damage caused by flooding in 1985, but the only value that exists for flood damage was compiled in 1983. The value in 1983 would be converted to the value for 1985 by determining the Consumer Price Index for those years and plugging them into the following equation:

CPI for 1985/CPI for 1983 x $ Value of Flood Damage 1983 = $ Value of Flood Damage for 1985

Information on the Consumer Price Index is available through any library.

Limitations of the Analysis Presented in this Handbook

It is important to remember that the dollar value generated in the Handbook analysis is an approximation of the off-site cost of damage due to soil erosion. It will include estimated and rounded values. The economic values will be as accurate as the nearest value approximated. Therefore, if $1575.35 is rounded to $1575 it is accurate to the nearest dollar. If it is rounded to $1600 it is accurate to the nearest hundred dollar. This is important to indicate when presenting the report.

The Handbook does not perform a benefit/cost analysis. In some cases, the actual cost of removing sediment has been ignored (such as from a recreational area), and only the cost of the sediment damage has been considered (we only calculated the cost in terms of lost recreational days, not removing sediment). This gives a somewhat skewed picture. If the end goal of the analysis is to determine the cost effectiveness of removing sediment, then the benefits of clean-up will have to be compared to the costs.

B. Sediment

One of the most important determinations made in this analysis is how much of the sediment carried by a particular waterway originates from agricultural sources. The value will be used throughout the economic calculations to determine the portion of the entire damage caused by sediment generated from pasture and cropland erosion.

Once soil leaves a farm field and becomes airborne or starts moving through a waterway, it begins to create problems. It is with eroded soil and associated contaminants from agricultural sources that this study concerns itself. It will focus on sediment transported by water through a watershed. Throughout this report, eroded soil will be referred to as sediment. In *Eroding Soils: The Off-farm Impacts* Clark describes soil in the following manner.

". . . soil itself is not a homogeneous substance. Physically, it is usually a mix of different particle sizes: clays (less than 0.002 millimeters in diameter), silts (0.002 to 0.05 millimeters), sands (0.05 to 2 millimeters), and sometimes gravels. The seperate particles may be either highly consolidated, leaving very few voids, or loosely consolidated, with over 50 percent of the soil volume being air space.

Chemically, natural soil is a combination of mineral particles created by the weathering of rocks and organic substances, the latter resulting primarily from the decomposition of plant and animal residues. Soil also contains a number of different bacteria and other organisms. Human activities may have added additional chemical and biological components such as fertilizers and pesticides. All these factors-the chemical and biological constituents of the soil, as well as the size of the particles that compose it-influence how soil erodes and what types of problems it creates downstream." (Clark 1985, 19).

Eroded soil or sediment has many of the same properties as soil on a farm field. Sediment is thought to contain a higher proportion of clays and other fine particles than does the soil on the field. This is because the smaller particles require less energy to transport (Clark 1985, 29). One significant property of sediment is its ability to transport nutrients, bacteria and agricultural chemicals. These substances may be chemically bound to the soil and then may disassociate in solution. The other contaminants may also be transported independently to the waterway further increasing their concentration.

The primary focus of this study is damage caused by sediment from agricultural sources. However, it is important to recognize that there are many sources of sediment. They include natural weathering, urban erosion from construction sites, highway erosion, and streambank and channel erosion (Novotny 1981, 167). The degree to which each source contributes to sedimentation problems will vary depending upon the characteristics of the study site. Factors such as land use, soil type, topography and weather will influence the amount of soil eroded from the landscape.

There may be many sources contributing sediment to a waterway making this calculation difficult. Very few studies actually pinpoint the source of sediment in streams (Leedy 1979). Much attention has been paid to the sources of upland erosion, but few discuss the amount of sediment from each source actually delivered to a waterway.

Procedure

The information that is gathered concerning the damage sediment causes to each of the categories outlined in this chapter will generally relate to sediment from all sources. As an example, sediment in a reservoir may come from sources such as streambanks, agricultural areas, urban areas, and natural erosion. The principal concern of this study is to isolate the damage caused specifically by agricultural sources. To do this the percentage of total sediment which can be attributed to cropland sources must be determined.

Nationally, agricultural sources are estimated to contribute 33% of the sediment and associated nutrients found in streams (Clark 1985, 132). This is an average, and will vary widely between regions and watersheds.

A quick method to determine the percentage of erosion and associated contaminants attributable to agricultural sources does not exist. It will take work interviewing and scanning local literature to determine this value. Techniques exist for sampling and analyzing sediment to determine its source (Ritchie 1985); however, they usually require more time and money than an analysis of this sort permits.

To compensate for the fact that the value generated here is an approximation, gather as much information as possible to support the estimate. In some cases it may be preferable to give to give a range of percentages, and then present the economic analysis as a range of values. (ie. Cropland sources contribute between 30% and 55% of the sediment load in the Blue River.)

There are a few sources of information that are invaluable when performing this analysis. These sources will help simplify the task, while supplying evidence to support your conclusion.

Local Soil and Water Conservation District and Soil Conservation Service Personnel—Interviews with knowledgeable people will offer insight to the problem. These people will have first-hand knowledge of the study area and the sources of erosion. They also will be familiar with reports which deal directly with the amount of sediment contributed by agricultural sources.

National Resource Inventory Data (NRI)—The National Resource Inventory was first conducted in 1977 by the Department of Agriculture, Soil Conservation Service (SCS) to gather information concerning erosion rates nationally (It was repeated in 1982 and again in 1986–1987.) This survey was conducted by SCS employees using a series of statistically valid samples. Information on soils, land use practices, vegetation, extent of erosion, conservation practices and water resources was collected, then compiled to indicate the sources and extent of upland erosion for selected geographic regions.

For the two cases studies included in this Handbook, it was possible to get a computer print-out of the NRI data. The information is considered statistically more valid the larger the geographic area. Analysis by county is considered the largest-scale for which an analysis may occur (Dansdill 9/26/86, Interview).

The NRI data, is compiled by county, and provides very important tables indicating the source and rate of erosion, the amount of land in or needing treatment and cropping by soil capability class and subclass. From this information, it is possible to indicate the extent of the upland erosion problem in a particular area.

To receive this information send a written request to the state SCS office.

Soil Surveys—Soil Surveys exist for many counties, providing detailed maps and information about local soils. In particular, they cover the capability class of each soil map unit. This classification shows the suitability of soils for most kinds of field crops. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The capability subclasses are soil groups within one class, indicating the specific limitations of the soil, such as wetness, erosion, droughtiness and climate (USDA-SCS 1985, 61–62).

Analyzing the soils which occur in the watershed and noting their location and distribution on the maps will help to indicate the potential erosion problem which exists for an area.

208 Studies—Section 208 of the Federal Clean Water Act delegates to the states and some regional entities the responsibility of planning and developing solutions to non-point source pollution problems. This is part of a comprehensive program under the Clean Water Act which set has the goal "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." Funding for this endeavor was provided by the Environmental Protection Agency (MN PCA-Division of Water Quality 1980, 1).

The 208 Reports contain a wealth of information concerning water quality. Of particular importance are the small studies incorporated in the comprehensive report. The small reports provide information which is often specific to a particular geographic region.

United States Geological Survey Water Monitoring Information—The USGS has water monitoring stations on many rivers throughout the United States. Some of these stations monitor suspended sediment. However, limitation of this information is that it will indicate the sediment load in the river from all sources. The USGS information could be compared with rates of sediment delivery from agricultural sources, if they are known, providing data on the relative contribution from agricultural sources.

A word of caution: Comparing information generated from a variety of sources can be problematic. Because of the variety of techniques and statistical analyses performed in each individual study, the analysis could result in a comparison of apples and oranges. Worse yet, the data may be at two entirely different levels of accuracy. The comparisons will be mere indications, and should never be construed as hard facts.

Ask Everyone—Almost everyone interviewed for the two case studies was asked their opinion on the percent of agricultural sediment contributed to waterways. This yields a confusing array of information. At a minimum, it will indicate the diversity of opinion and complexity of the task; at best, it will provide some reasonable local estimates of the problem, by the people who should know best.

C. Biological Impacts

Biological damage is defined as the impact of sediment and associated contaminants on living organisms. For purposes of this analysis, living organisms include both plants and animals. The effects may be fatal (as in the case of fish kills) or they may be sub-lethal (as in the case of stunted or diseased fish).

According to La Roe (1986, 171-174), sediment in a waterway causes chemical and physical changes which affect the biological components of the ecosystem. Physical changes caused by sediment and its impact include the following:

1. Increased turbidity which reduces light penetration. This may hinder photosynthesis and diminish oxygen production. Turbidity can create a change in the lake or river plant life. It also creates visibility problems for fish that rely on sight as their primary hunting tool. Suspended algae and sediments may also absorb or reflect light, altering the temperature stratification of the water which reduces oxygen mixing. Suspended sediment associated with turbidity may cause physical damage to the gills of fish. Though not lethal, suspended sediment may lead to an increased susceptibility to disease.

2. Altered stream channel geometry. The river may become shallower and wider. This will alter the erosion pattern of banks and can have a deleterious effect on riparian habitat. A wider, shallower stream can cause an increase in temperature. These factors may combine to alter the species composition of fish and other aquatic life.

3. Filled interstices of gravel beds. Many fish species rely on the water that flows through the interstices in gravel beds to oxygenate their eggs. The addition of fine sediment can have dire consequences for reproduction. Accumulated silt can also smother invertebrates which require a gravel substrate.

Chemical changes in a stream or lake can also seriously influence the biological components. LaRoe (1986, 173) suggests the following changes as signficant.

1. The breakdown of organic materials washed into streams will increase the biochemical oxygen demand (BOD) on the system. Increased BOD will reduce the amount of dissolved oxygen available for fish, potentially resulting in fish kills.

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2. Nutrients associated with sediment may cause an over-enrichment or eutrophication of the water body. This leads to both lethal and nuisance algae blooms, changes in species composition, and possibly fish kills.

3. Insecticides and herbicides associated with sediment can be delivered to a stream. Many chemicals are bound to the sediment and therefore are unavailable in the water column. However, some of these chemicals will be absorbed from the sediment by plants and may enter the food chain. As these chemicals accumulate in the fatty tissue of higher organisms they can cause lethal effects.

How do you place an economic value on biological damage? Numerous attempts have been made to determine the dollar value of fish and wildlife. The state of Minnesota approached this question by developing a species valuation sheet for many game and nongame wildlife species. The values are used when justifying fines levied in the event of a pollution- related disaster, such as a fish kill caused by improper disposal of waste (Zappetillo 6/86, Interview). The list was developed through discussions with wildlife personnel.

Hammack and Brown (1974, 83) attempted to derive the marginal net benefits of waterfowl hunting through use of a cost/ benefit approach. Other evaluation methods include a measure of direct expenditures, determination of the market value of harvested game, the cost approach, unit-day-value method, and the willingness-to-pay techniques (Ntl. Research Council 1982, 13). It is generally agreed that none of the techniques is wholly satisfactory. In particular, an assessment of the quality of the experience is often missing. Finally, no one has attempted with any success to assign an economic value to the effects of nonpoint pollution on the subtler components of an ecosystem, such as invertebrates and other unobvious forms of life. This failure is especially vexing because some researchers believe that the biological changes due to nonpoint pollution constitute the largest category of environmental and economic damage associated with nonpoint pollution.

Procedure

It is difficult to attach defensible dollar values to the biological processes damaged by soil erosion. Nevertheless, it doesn't mean that this category should be ignored. It is worthwhile to include a discussion of the issues relating to biological damage in the narrative of the report prepared for your particular study area. Such items as physical and chemical changes in rivers, streams and lakes, and their affect on fish, wildlife and plant life should be addressed. Many of the biological issues related to hunting and fishing will be covered in the next section on recreation. However, the subtler issues such as changes in species composition and number, as well as affects on plant life and stream bed should be mentioned. Your report should also note the extent of damage to the aesthetic value of the resource. Though subjective, this assessment would, at a minimum, serve to draw attention to a very important issue.

D. Recreation

The deposition of sediment and associated nutrient and chemical contaminants can have serious economic consequences for water-based recreation. Sediment can lead to a decline in the success and pleasure of fishing. It makes lakes and rivers unpleasant and potentially hazardous for swimming and boating. Picnicking and camping is no fun along a stinky river or lake. Poor water quality may lead to a shift in tourism away from the polluted site, reducing the amount of tourist dollars flowing into the local economy.

The following is a list of recreation experiences which will be considered in the off-site damage evaluation. The affects of sediment and associated nutrients and chemicals on each activity will be considered.

1. *Fishing*—Fishing is one of the most popular summer activities for residents and nonresidents in Minnesota (MN-DNR 1985a, 4.023). Therefore, it is extremely important to note any ways that soil erosion may affect the fish resource. Turbidity caused by suspended sediment, algae and other material can alter many of the important physical characteristics of water. Changing the physical characteristics of a stream will change the carrying capacity (the amount) and composition (type) of fish and other aquatic organisms. (For a complete description of the physical and chemical changes due to sediment refer to the previous section entitled "C. Biological Impacts.")

Sediment may directly affect fish by abrading gills which may lead to fungal infections,

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altering food sources, reducing hunting success and eliminating breeding habitat (Clark, 1985,167). The effect of all or some of these changes may be the extirpation or decline of fish and other aquatic species and a change in the overall species composition.

Contaminants associated with sediment may also affect the fish population. In Minnesota, farm chemicals are thought to have a deleterious effect on Small Mouth Bass. (Peterson 6/30/86, Interview). Chemicals may also diminish the recreational experience by limiting the amount of fish one might catch and consume. According to one Minnesota Department of Natural Resources official (DNR), the issue of safe fish consumption has reached an unprecedented high.

Finally, as in all categories of recreation, sediment may have a negative impact on the aesthetic appeal of the fishing experience.

2. *Boating*—(Including canoeing, kayaking, sailing) Accumulated sediment in lakes, rivers or reservoirs can cause numerous problems for recreational boaters. In Redwood County, sediment which has filled Redwood Lake has made boating nearly impossible. Sandbars create navigation difficulties and pose potential safety risks. Water-skiiers who once used the entire 160 acre lake are now forced to ski in a very limited area, turning numerous tight circles (Steve Hammerschmidt 6/25/86, Interview). Algae blooms related to sediment-borne chemicals and nutrients may cause problems with engines and boat maintenance. Finally, the aesthetic appeal of boating on a stinky, turbid body of water may cause even the heartiest of boaters to go elsewhere.

3. *Swimming/Picnicking/Camping*—Sediment and turbidity may diminish the enjoyment of recreational experiences associated with a lake or river. Personal observations by John Madsen, Park Manager of Kandiyohi County Regional Park No. 7, suggests that people may be shifting their recreation to lakes of highest water quality within the county (7/21/86, Interview). Though little quantitative data exists to document recreational shifts based on water quality alone (Birch 1983, 31), intuition and observation suggest that water quality does play a role in the selection of recreation sites.

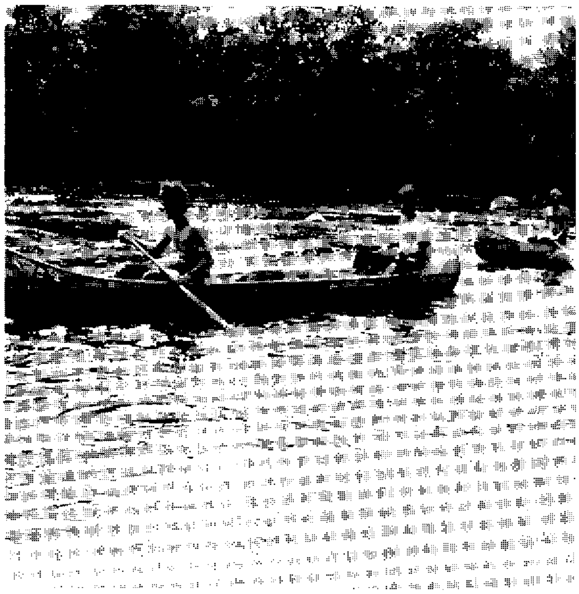
Beyond the lack of aesthetic appeal, turbidity may cause safety hazards for swimmers. Diving into unclear water may result in serious accidents. Searching for a missing swimmer is also made more difficult by poor water quality (Clark 1985, 73). Algae blooms as a result of chemical and nutrient inputs not only create a visual and odor problem, but may cause illness when water is ingested (Carmichael 1985, 275).

4. *Waterfowl Hunting*—Waterfowl hunting is dependent upon the availability of wetlands for duck production, and as sites for resting and feeding during migration. The role a wetland plays in waterfowl-related recreation is only a small part of its value to the ecosystem. Wetlands not only trap suspended sediment, but also may be a sink for toxins (Boto, 1979, 479). Wetlands also may reduce the rate of storm run-off (Larson, 1981,117), while possibly providing a site for groundwater recharge (US Dept. of the Army 1978a, 2).

Numerous attempts have been made to measure the impact of water quality on recreation. Computer models have been developed nationally in an attempt to shed light on the impact of a clean environment on the recreation dollar (Freeman, 1982) (Sutherland, 1982). Nationwide surveys of individual expenditures and preferences for recreation have been used to help direct recreational development toward activities for which there is high demand (USDI-NPS, 1986). Though both interesting and useful, the complexity of the analysis required by these models usually exceed the time and financial resources of local units of government interested in a ball park estimate of off-site damage.

Information concerning recreation and tourism gathered on a state level is most useful for purposes of a local off-site damage analysis. The value of tourism in Minnesota has become a heated political issue in recent years. The Minnesota Office of Tourism estimates that U.S. travelers spent nearly $4.8 billion in Minnesota in 1984 (MN-DEED 1985, 1).

Though not always easy to find, some studies have explored the actual dollar amount spent by recreationists in pursuit of leisure. A survey conducted along Minnesota's Cannon River found that in the summer of 1984 there were 85,000 visitors to the river who spent 200,000



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hours in pursuit of recreation (MN-DNR 1985b, 8). This activity generated nearly $700,000 in direct expenditures for fishing, canoeing and tubing.

The value of hunting and fishing in Minnesota (as it was in all states) was analyzed by the U.S. Deptartment of the Interior, U.S. Fish and Wildlife Service in 1980. Many states have produced outdoor recreation reports as a prerequisite for receiving Federal Land and Water Conservation Fund monies. The reports are updated every five years.

Seeking out available literature on the economic value of recreation to the area is important whether it is decided to make a qualitative or quantitative analysis of local off-site damage.

Important resource people for understanding recreation damage include state game wardens or conservation officers, state wildlife and fishery personnel, county recreation or park managers, resort owners and lake associations, and local sportsman and conservation organizations. When hard data is lacking, these people provide a good perspective on the situation in the watershed.

The two study sites considered in this Handbook required entirely different approaches for the evaluation of off-site damage to recreation. In Redwood County, siltation has rendered the Redwood River and Lake Redwood almost useless as sites for certain recreational activities. To assess the damage, a quantitative (economic) approach was employed. This permits an evaluation of the economic value of lost recreation to the community.

Damage to recreation caused by sediment in Kandiyohi County was more difficult to document. An accurate analysis of the affects of sediment on recreation experiences would have required an extensive survery of recreationists. Such a survey was beyond the scope of this project. Instead, resort owners were surveyed in an attempt to gather some indication of whether or not a problem exists. This approach resulted in a discussion of the qualitative (descriptive) aspects of off-site damage in the area.

Approach #1. Quantitative

To use a quantitative approach requires a fairly obvious problem, with a decline in recreational use that is obviously linked to water quality. The Redwood River and Redwood Lake fit this criteria. Interviews revealed that recreational use of the Redwood River and Lake Redwood had declined considerably in recent years. Redwood Lake was created in 1902 when a dam was constructed to provide power for a mill. It was once the site of fishing, waterskiing, and swimming (U.S. Dept. of Army 1978b, 1). Numerous individuals stated that with the exception of an occasional waterskiier, it is rarely used today. According to one recent report, soundings reveal that there is approximately 25 feet of sediment behind the dam. (MN-DNR1986a, Architects Drawings). An official of the Minnesota Deptartment of Natural Resources Dam Safety Program stated that 25 to 30 feet of sediment behind a dam is not uncommon in southern Minnesota (Regalia 6/27/86, Interview).

Procedure

The following evaluation technique is loosely based on a model suggested in *Procedures for*

Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning (Level C) (U.S. Water Resources Council, 1979). The procedures in this manual were developed by the Water Resources Council as a means to standardize the way in which costs and benefits are assigned to water projects by federal agencies. The recreation analysis will incorporate the simplest aspects of the procedure to provide an estimate of benefits or the dollar value that might exist in the hypothetical situation of a clean lake and river.

It should be noted that the method considers the dollar benefits of a hypothetical clean lake or river to be equal to the damage which is currently experienced for not having that resource available. Economists would argue that these two values may not necessarily be equal. However, for purposes of this analysis they are sufficiently close to be considered interchangeable (Browning 1983, 115).

In conducting the analysis it is assumed that each recreational activity associated with water may be assigned a dollar value. Future demand will be based on logic and knowledge of the local area. In some instances, it may be useful to assume that the clean resource will be used to capacity. It should be reiterated that this is a *simplified approach*. For a more detailed study, consult the model suggested by the U.S. Water Resources Council, or a Soil Conservation Service economist for details.

The following procedure uses two Worksheets and one Form. The Form is a summary of the values developed on the worksheet. Follow the directions closely to derive an approximation of damage to recreation.

Instructions for Form and Worksheets

1. Identify the resource. Consider each recreation site in the watershed seperately. i.e. lakes, rivers, wetlands. Place the name and size of the water body on a *Form and Worksheets*. (One worksheet will be for current use, the other will indicate hypothetical potential use.)

2. Start with the Form. Note the surrounding towns and the population within a 50-mile radius of the proposed study site. Include a list of other recreation facilities within the 50-mile radius. This question is asked for purposes of gaining an understanding of the region and the logical amount of use that could be expected in an improved recreation area. Put all information under number two on the *Form*.

3. What percentage of the current damage is due to the effects of sedimentation? Place this value on the *Form on line 3a*.
What percentage of the sediment and contaminants are contributed by cropland sources? Place this value on the *Form on line 3b*.
Multiply 3a times 3b to derive the percentage of damage attributable to cropland sources. This value will be needed to ensure accurate reporting of the damages. Put this figure on the *Form on line 3c*.

4. Refer to Worksheet No. 1. Check-off the recreational activities currently associated with the resource in *column a*.

5. What was the length of the recreational season for each of the categories checked in number five in the year under analysis? Break it down into the number of weekdays and the number of weekend days appropriate to the year in question for each activity. Place these values in *column b (weekday) and c (weekend day) of Worksheet No. 1*. (Seasons include fishing season, tourist season, etc.)

6.*Based on reports or interviews with knowledgeable local personnel, what are the current daily use estimates of the water body for each category of recreational activity. Recreation economists consider any recreational activity within a certain day to be a "recreation unit." Therefore, for each recreation activity consider how much participation occurs each day by all individuals. Consider what the average number of participants are on a weekday and weekend day separately.

*The estimate should take into account competing recreational opportunities in the local area. The amount of expected use should be adjusted accordingly. The SCS considers a 50-mile radius to be a reasonable distance from which the majority of users might originate.

Example: If, on an average weekday, a lake is used by two boats with two individuals fishing in each boat, you would have an average of four units per day. Put these values for each recreation activity in *columns d (weekdays) and e (weekend days) of Worksheet No.1.*
Note: Do not be intimidated, this is an important estimate based your best information.

7. Multiply *column b* × *d* for each recreation activity on Worksheet No.1. This provides the total number of units for each activity during weekdays. Put this in *column f.*

8. Multiply *column c* × *e* for each recreation category on Worksheet No.1. This provides the total number of units for each activity during weekend days. Put this in *column g.*

9. Add the values in *columns f and g* on Worksheet No.1 to derive the total number of units for each activity. This yields the total number of units for all days. Place this in *column h.*

10. Add together all the units in *column h Worksheet No.1.* Place this value at the bottom. This is the total of all recreation units for current activities.

11. Start Worksheet No. 2. Consider the hypothetical case: What level of recreation use would the area receive assuming sediment input is curtailed or sediment is removed?
Check-off the recreational activities expected to be associated with an unpolluted area. Do this in *column a of Worksheet No. 2.*

12. What is the length of the recreation season for each of the recreation categories checked in number eleven above? Break it down into the number of weekdays and the number of weekend days appropriate to the year in question for each activity. Place these values in *columns b and c of Worksheet No.2.* (The seasons will probably be the same length as the recreation activities considered on Worksheet No.1.)

13. *Based on reports or interviews with knowledgeable local personnel, what is a reasonable estimate of use in each recreation category assuming the hypothetical case of a clean lake or river? One way to simplify this task is to consider the "capacity" of the resource. Ask the question "Is it reasonable to expect that the facility will be used to capacity on weekdays or weekends?" Remember that the analysis is only interested in an increase in demand due to the removal of sediment.

Example—If there is a total capacity of six picnic tables, each occupied once during a Saturday, the total anticipated demand is:
6 picnic tables x 5 members/family (average) = 30 recreational units
Place the values for weekday and weekend day use in *columns d and e of Worksheet No. 2.* In some instances an area will not be used to full capacity. Under these circumstances use experience and educated judgements.

14. Multiply *columns b* × *d* for each recreation category on Worksheet No.2. This provides the total number of seasonal units for each recreation experience for weekdays. Put this in *column f.*

15. Multiply *columns c* × *e* for each recreation category on Worksheet
No. 2. This provides the total number of seasonal units for each recreation experience for weekend days. Put this in *column g.*

16. Add *columns f and g* on Worksheet No.2 to derive the total number of units for each activity. Place this value in *column h.* This yields the total number of units for all days.

17. Add together all the values in column h and place at the bottom of Worksheet No. 2. This yields the total number of recreation units in the hypothetical event of a clean resource.

18. Return to the *Form.* Determine the value of a recreation activity/day in the year under analysis by consulting with the regional SCS or Army Corps of Engineer economist. The value is obtained from The U.S. Water

*The estimates should take into account competing recreational opportunities in the local area. The amount of expected use should be adjusted accordingly. The SCS considers a 50-mile radius to be a reasonable distance from which the majority of users might originate.

Resources Council document: *Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning (Level C).* It is an average economic value for all activities. Should reports exist that document the value of recreation activities in the local community, use those values. Place this value under *number 4 on the Form.*

19. Calculate the economic value of current recreation by multiplying the number of units of current recreation use from Worksheet No. 1 x the unit/day value from number 4. Do this under *number 5 five on the Form.*

20. Calculate the dollar value of expected or hypothetical recreation by multiplying the number of units of projected use from Worksheet No. 2 × the unit/day value from number 4. Do this under *number 6 of the Form.*

21. Calculate the difference in dollar value of the polluted vs. unpolluted resource by subtracting the *value from number 5 from the value of number 6 on the Form.* Do this under *number 7 of the Form.*

22. To calculate the amount of damage that is attributable to cropland sources, multiply the value of total damage derived in question number 7 on the Form x the value from 3c on the Form. This yields the best estimate of what might be the total amount of damage caused by cropland sources. Do this under *number 8 of the Form.*

Boating accidents associated with sediment

23. Determine the number of boating accidents and their associated damage value which could be attributed to sediment or turbidity. Place this on *line 9 of the Form and total.* This information is often available from the County Sheriff.

24. Determine the percentage of damage attributable to agricultural sources of sediment. Multiply the total in line 9 x the percentage of sediment due to cropland sources. Place this on *line 10 of the Form.*

Total Recreation Damage

25. Determine the overall recreation damage caused by sediment. Add the total recreation damage from number 8 of the Form to damage from boating accidents, number 9. Place this on *line 10 of the form.*

FORM

1. Name of Resource(s) Size

2. Towns and Population within a 50-mile radius:

   Town Population

   Other Recreation Sites

3a. Percentage of damage linked to sediment and associated contaminants ____________

3b. Percentage of sediment and contaminants contributed by cropland sources ____________

3c. Percentage of damage attributable to cropland sources (3a) ____________ x (3b) ____________ = ____________

4. Value of a daily recreation unit ____________

5. Economic value of current recreation:
   Total from Worksheet No. 1 ____________ x Unit/Day Value (No. 4 above) ____________ = Total value of current recreation ____________

6. Economic value of current recreation in the hypothetical unpolluted area:
   Total from Worksheet No. 2 ____________ x Unit /Day Value (No. 4 above) ____________ = Total value of unpolluted recreation ____________

7. Economic benefit of recreation in an unpolluted area:
   Total vlaue of unpolluted recreation (No. 6) ____________ - Total value of current recreation (No. 5) ____________ = Value of unpolluted resource ____________

This calculates the amount of economic benefit that might be realized in an unpolluted resource. It also represents the amount of economic damage caused by sedimentation at the present time.

8. Total amount of damage attributable to agricultural sources: Total recreation damage (No. 7) ______________ x Percentage due to agricultural sources (No. 3c) ___________ = Total amount of damage receration due to agricultural sources ____________________________

9. List boating accidents which may have resulted from sediment and turbidity and the amount of damage associated with them.

Accident	Damage

Total --------------------------------

10. Total amount of accident damage attributable to cropland sources. Total Damage (No. 9) x Percentage due to cropland sources (No. 3c) = ___________________ Total Accident damage.

C. Total Recreation Damage

Category	Cost
A. Recreation----------------	___________________
B. Boating Accidents---------	___________________
C. Total---------------------	___________________

Worksheet One

Year ________

Current Use

	a	b	c	d	e	f	g	h
Recreation Activity	Activity	# of Weekdays in Season	# of Weekend days in Season	# of Occasions on Weekdays	# of Occasions on Weekend days	Multiply Column b x d	Multiply Column c x e	Add Column f + g
1. Fishing (summer) a. Warmwater								
b. Sport								
Fishing (Winter) c. Ice Fishing								
2. Picnicking								
3. Boating								
4. Camping								
5. Swimming								
6. Waterfowl Hunting								
7. Tubing								

Total Recreation Units ______

(Sum of Column H)

Worksheet Two

Year ________

Hypothetical Use

Recreation Activity	a Activity	b # of Weekdays in Season	c # of Weekend days in Season	d # of Occasions on Weekdays	e # of Occasions on Weekend days	f Multiply Column b x d	g Multiply Column c x e	h Add Columns f + g
1. Fishing (summer) a. Warmwater								
b. Sport								
Fishing (Winter) c. Ice Fishing								
2. Picnicking								
3. Boating								
4. Camping								
5. Swimming								
6. Waterfowl Hunting								
7. Tubing								

Approach #2—Qualitative

It is often difficult to provide an economic value for the damage caused to recreation by sediment. This is the result of a number of problems.

1. Sediment-related damage is often masked by other, more immediate problems. For example, high water due to unusual amounts of precipitation in 1985 and 1986 masked the effects of sediment in Kandiyohi County.

2. Data may not exist. In Kandiyohi County for example, waterfowl hunting and wetlands are very important recreation features. It attracts sportsman from the Twin Cities and many other areas. Local officials suggested that wetlands in the county were experiencing some siltation, depending upon adjacent land use and the source of flow into the wetland. It was thought that the amount of siltation was significant enough to warrant concern. Yet, no hard information existed in the County to document the siltation, or whether or not it was having an affect on waterfowl-related recreation.

3. Time and economic resources may be limited. A stituation may exist which requires a major survey or some other effort to accurately assess the total problem.

No matter where the study site, there will always be sources of qualitative (non-numerical) information which will be useful in drawing attention to some of the local problems associated with sediment damage. Documenting these problems in a narrative report will achieve the purpose of raising questions about the extent of the problem.

Your narrative report should include a well-organized, systematic discussion of the damage that is thought to occur. An analysis of each category of recreation activity mentioned in this section will provide a framework for the discussion.

In cases where a thorough analysis exceeds the resource limitations of the project budget, a small survey or questionaire may be used to provide a better understanding of the problem. The results may not be statistically valid, but they will provide a backdrop from which to propose future research needs.

Another approach may be to point out the overall value of recreation to the local economy. One might emphasize the value of recreation to the local economy as compared to other economic activities. The analysis should include a review of all the ways the recreation dollar may be impacted by off-site damage. This data is often available through state departments of tourism or economic development and other organizations which promote business.

If any cost associated with off-site damage is obtained, it should be reported and incorporated into the total.

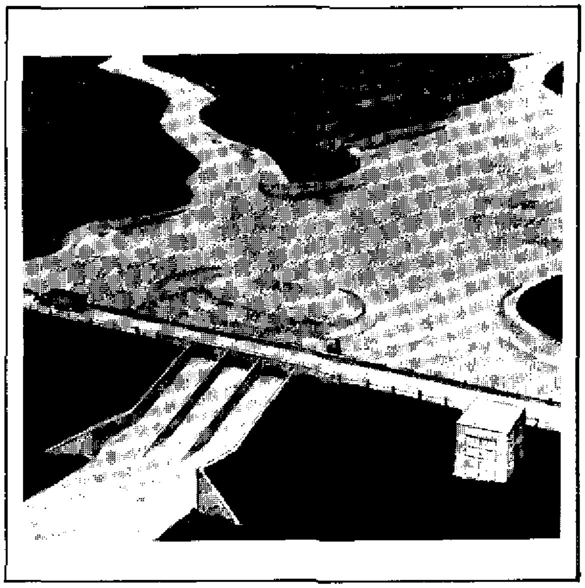
Example: A short questionaire reveals that some resort owners have found it necessary to remove sandbars caused by sediment from off-site sources. This figure should be included in the final economic assessment, even though it may not reflect all the damage by all the resorts in the community. When information is incomplete, that fact should be clearly stated in the final report.

Qualitative data can serve the purpose of providing excellent insight into current or future problems. This will help to focus the attention of local officials as interest in off-site damage continues to grow.

E. Water Storage in Lakes and Reservoirs

Water storage in lakes and reservoirs is impacted by sediment and associated contaminants (Clark 1985, 147). As sediment enters a lake or reservoir, it may settle and stay in the reservoir, remain suspended or move in and then out of the water body. The actions of the sediment will have different affects on the storage facility.

Sediment which settles out of suspension may begin to fill the reservoir, thus limiting the water-storage capacity and impacting flood control, municipal and industrial water use and power production (Clark 1985, 147).



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This storage depletion occurs at variable rates throughout the country (Dendy 1968, 135). It may occur at an almost negligable rate or as high as a loss of 10% of capacity per year (Campbell 1986, 209). Overall, it is thought to occur most quickly in small reservoirs (Dendy 1968, 137).

Sediment and associated contaminants may have an affect on water quality (Clark 1985, 77). Recreation and water consumption may be impacted by high turbidity, as well as algae blooms associated with nutrients.

The rate of water evaporation is also affected by sediment. As sediment fills a reservoir, the water level can be raised, thereby increasing the surface area of the water. The increase in surface area can cause an increase in evaporation.

It should be noted that some of evaporation's detrimental impacts can be offset by the benefits of turbidity. Suspended particles at the surface may reflect heat, which serves to lower the surface temperature of water and decrease evaporation (Clark 1985, 80).

The growth of aquatic plants and algae blooms are associated with sediment in a reservoir. Sediment provides habitat for the establishment of aquatic plants which may increase the loss of water through evapotranspiration. Nutrients associated with sediment create conditions favorable for algae blooms (Clark 1985, 79).

Damage to water storage facilities may be remedied in the following manner:

1. Dredging to remove accumulated sediment and increase water storage capacity.
2. Building a new dam at another site. Replacement may be required sooner than predicted for the original dam.
3. Establishing a "sediment pool" in a new reservoir. The pool is part of the reservoir where sediment may be trapped without impacting the storage space needed by water. The cost of construction is increased as a result of this design feature.
4. Purchasing water from other suppliers. Local water may be lost due to lack of storage capacity or excessive evaporation and transpiration.
5. Removing weeds through mechanical or chemical methods. These measures help to reduce evaporation and improve water quality.

Procedure

Data gathering for this category requires that one determine the governmental entity responsible for the dam, lake or reservoir. Federal agencies often have jurisdiction in these areas. The Army Corps of Engineers, Soil Conservation Service and local municipalities will provide the best information.

The following are methods for calculating the cost of sediment related damages at water storage facilities. Basic econometric techniques will be employed to adjust for situations where dollar values are not considered on an annual basis. The process is presented in a straightforward step-by-step process. Appendix B is provided to simplify calculations. Use the attached worksheet to calculate each item that applies to the study site.

1. Place the name of the reservoir or lake on the Worksheet.

2. State the primary purpose of the reservoir or lake. (Municipal and industrial water, recreation, flood control, power production, etc.)

3. Describe the facility to the best of your ability.

4. Describe the impact sediment and associated contaminants have had on the facility.

5. Select the technique(s) below that best provide an annual cost of the effects of sediment on your facility.

Part A. Dredging

Dredging costs occur over a number of years, with benefits to be appreciated for years into the future. It would be an unfair over-representation of off-site damage to report the total cost of dredging all in one year. Yet it would be an under-representation of damage if dredging occurred three years ago and was not reported in the study year. Therefore, this analysis will treat dredging much like a home mortgage. The cost will be "amortized" over the life of an actual or hypothetical payback period to derive an annual cost.

Cost information for dredging may be available as a total budget, or may appear as a cost/cubic yard of sediment removed.

A-1. Total amount spent for dredging (This is usually in cost/cubic yard × number of cubic yards of sediment removed.)

A-2. Convert the expenditure into an annual cost based on the assumption that the money was borrowed. If the money was not borrowed, it will still be treated as an annual expense. Put the annual interest rate and the length of the borrowing period on the Worksheet. If money was not borrowed, use the annual interest rate. The length of borrowing time should be based on the period of time that benefits are supposed to be realized for the dredging operation.

A-3. Find the Interest Table in Appendix B that corresponds most closely to the interest rate you have chosen. In the left column find the number of years of borrowing. Determine the capital recovery factor. Put this on the worksheet.

Example- Assume that the interest rate is 8%, and that it is borrowed for 20 years. The capital recovery factor would be .10185.

A-4. Multiply the total cost of the project (A-1) × The capital recovery factor (A-3) × Percentage of sediment contributed by agricultural sources (Determined previously in this chapter under Sediment). This gives the annual cost of dredging due specifically to agricultural sources.

Part B. Replacement Structure

Every year that sediment is deposited in a reservoir, valuable water storage capacity is lost. Eventually the lost storage may be replaced by the construction of a new facility. To understand the total impact of sediment and the cost associated with diminished reservoir capacity, some consideration should be given to the future replacement cost of the reservoir.

An analysis of future reservoir replacement would require making assumptions concerning the cost and time of future replacement. This value would then have to be "discounted" to show what it means in present-day dollars. Replacement cost has been omitted from this analysis due to the difficulty of the calculation and the uncertainty of the assumptions. Replacement structures are mentioned because they are an important cost which occurs in the future but iscaused by today's sediment.

Part C. Sediment Pools

The cost of a sediment pool in new construction can be obtained easily by analyzing total cost and the percentage of cost attributable to the sediment pool. The annual cost of the sediment pool would be calculated in a manner similar to dredging costs. It is slightly different in that it should also include the annual cost of maintenance and operation. Refer to Part C of the Worksheet.

C-1. What is the total cost of the project?

C-2. What is the length of the payback period for project funding or the number of years benefits will be realized?

C-3. What is the current interest rate on borrowed money?

C-4. Turn to Appendix B and find the appropriate interest Table. In the left column find the number of years of borrowing. Determine the capital recovery factor.

C-5. Determine the annual cost of the entire project. Multiply the total cost of the project (C-1) × the capital recovery factor (C-4).

C-6. What percentage of the total cost can be attributed to the sediment pool?

C-7. What are the annual sediment related operation and maintenance costs?

C-8. Determine the annual cost associated with the sediment pool. Multiply the total annual cost of the project (C-5) × percentage of cost associated with the sediment pool (C-6) + annual sediment-related operation and maintenance cost (C-7).

C-9. It would be unfair to attribute the entire cost of the sediment pool to cropland sources. Therefore, it is necessary to multiply the cost of the sediment pool times the percent of sediment contribution which derives from agricultural sources. Multiply the total annual cost of the sediment pool (C-7) × the percentage of sediment contributed by agricultural sources.

Part D. Purchasing of Alternative Water Supplies

Municipal water suppliers will have figures concerning the amount of water required by local users and its cost. If a reservoir or lake no longer has sufficient capacity, it may be necessary to seek other sources.

This analysis will not explore the costs associated with increased evaporation caused by an increase in surface area due to sediment nor the counteracting effects of turbidity. This is a rather complex analysis requiring very specific and difficult to obtain information.

Refer to the Worksheet, Part D, for an analysis of alternative water supplies.

Cost to Municipalities

D-1. What is the total amount of water supplied by the municipality to meet local demand?

D-2. How much of the annual supply is produced by the municipality from the reservoir or lake under investigation?

D-3. What is the cost to the municipality of producing water locally?

D-4. How much of the annual supply is purchased from outside sources?

D-5. What is the cost to the municipality of water purchased from outside sources?

D-6. What percentage of the water which is purchased from sources outside the municipality is due to reduced storage capacity in the reservoir? This relates to reduced storage capacity outside the sediment pool. In other words, if no sediment existed to reduce capacity, how much more water could be provided annually.

D-7. Determine the amount of water which is purchased annually because of reduced storage capacity. Multiply the amount of water purchased from outside sources (D-4) × percentage which would be unnecessary without sediment (D-6).

D-8. Determine the cost of water supplied outside the municipality.
Multiply the amount of water purchased due to reduced storage (D-7) × the
cost of water supplied by outside sources (D-5).

D-9. Determine the cost of this water in the hypothetical event that it *was* provided by the reservoir. Multiply the amount of water purchased due to reduced storage (D-7) × the cost of water produced from the reservoir (D-3).

D-10. Determine the additional cost of water due to sediment. Substract the cost of water in the hypothetical event that it was provided by the reservoir (D-9) from the cost associated with purchasing water from outside suppliers (D-8).

D-11. Determine the percentage of this cost attributable to a reduction in reservoir capacity due to agriculturally derived sediment. Multiply the additional cost due to sediment (D-10) × the percentage of sediment contributed by cropland sources.

Cost to Consumers

The preceding value is the cost of sediment to the municipality. This may understate the total cost of sediment, since the municipality will probably pass additional costs on to the consumer. The following is an alternative method of calculating the cost of municipal water based on the expense to the consumer. Either method may be used, depending upon the availability of information.

D-12. What is the total annual cost of water to consumers?

D-13. What would the annual cost be without outside purchases of water?

D-14. Determine the additional cost of outside purchases. Subtract the cost to consumers without outside purchases (D-13) from the annual cost of water to consumers (D-12).

D-15. What percentage of the cost is due to sediment reducing storage capacity? It is important to note that this question asks specifically about the amount of increase due to sediment. This is because rates may be determined by many variables.

D-16. Determine the amount of annual cost increase caused by sediment. Multiply the additional cost of outside purchases (D-14) × the percentage of cost due to sediment (D-15).

D-17. Determine the cost of water due to cropland sources. Multiply the annual increase of cost due to sediment (D-16) × the percentage of sediment contributed by cropland sources.
Note: Use either this this value (D-17) or the cost to the municipality (D-11). Using both would create a situation of double counting since the municipality passes its costs to the consumer.

Part E. Water Treatment

Occasionally, chemical treatment is required to restore water quality to a reservoir or lake damaged as a result of nutrients attached to sediment. If so, the government agency with jurisdiction over the water body will have records of annual treatment costs. Obtain specific figures covering annual treatment costs and their "best guess" of the percentage of treatment needed due to sediment borne contaminants.

This should not be confused with treatment costs outside the reservoir. Those will be handled later in the section on municipal water supplies.

For purposes of this analysis the annual cost of weed removal will also be considered. Refer to the Worksheet under Part E.

Chemical Treatment

E-1. What is the cost of chemical water treatment within the lake or reservoir on an annual basis?

E-2. What percentage of this treatment is required because of sediment borne contaminants?

E-3. Multiply the chemical cost of treatment (E-1) X the percentage required because of sediment-borne contaminants (E-2) to determine the cost of treatment needed because of sedimentation.

E-4. Multiply the percentage of treatment required by sedimentation (E-3) x the percentage of sedimentation caused by cropland sources. This gives the total damage due to cropland.

Mechanical Treatment

E-5. What is the annual cost for the mechanical removal of weeds?

E-6. What percentage of this activity is needed because of sediment related problems?

E-7. Multiply the annual cost of removal (E-5) x the percentage of activity due to sediment (E-6) to get the total damage due to sediment.

E-8. Multiply the total damage due to sediment (E-7) x the percentage of contribution due to cropland sources for the total damage caused by cropland.

Part F. Total Cost

Refer to the Worksheet under Part F. Add together the cost associated with each category to determine the total cost of sediment damage to water storage facilities.

Water Storage-Worksheet

1. Name of Reservoir of Lake

2. Purpose of this Facility

3. Description

   Waterholding capacity
   Size of sedminet pool
   Proposed life-span of project
   Realistic life-span of project
   Rate of sedimentation

4. Effects of Sedementation

   Reduced size of storage
   Water quality problems
   Impacts on recreation
   Impacts on fisheries

5. Calculate the damage caused by sedimentation in categories appropriate to your area.

Part A. Dredging

A-1. Amount spent for dredging project ____________________

A-2. Annual interest rate or current return on investment __________
Length of loan or period of benefit ________________

A-3. Capital Recovery Factor ________________________________

A-4. Annual cost of dredging (A-1) x (A-3) x amount of sediment contributed by cropland sources.

____

____

Part B. Replacement Structure - No economic analysis

Part C. Cost of Sediment Pool

C-1. Total cost of project ______________________________

C-2. Length of payback period ______________________________

C-3. Current Interest rate or return on investments __________

C-4. Capital Recovery Factor ______________________________

C-5. Annual cost of project (C-1) x (C-4)

____

C-6. Percent of total cost associated with sediment pool ______

C-7. Annual sediment related operation and maintenance cost

____

C-8. Annual cost of sediment pool (C-5) x (C-6) + (C-7) _______

____

C-9. Total annual cost of sediment pool due to sediment from agricultural sources (C-7) x percent on contribution by agricultural by agricultural sources ____________________

____

Part D Alternative Water Supplies

Cost to Municipalities

D-1. Total volume of water ______________________________

D-2. Volume produced by local sources ________________________

D-3. Cost of water from local sources ________________________

D-4. Amount of water purchased from outside suppliers _________

D-5. Cost of water from outside suppliers ____________________

D-6. Percentage of water purchased from outside suppliers to accomodate diminished water capacity _______________

D-7. Amount of water purchased due to inadequate storage capacity (D-4) x (D-6)

D-8. Cost of water provided by outside suppliers due to reduced storage (D-7) x (D-5)

D-9. Cost of water in hypothetical situation where reservoir has no silt (D-7) (D-3) ______________________

D-10. Additional cost of water due to sediment (D-8) -(D-9)

____

____

D-11. Cost attributable to agricultural sediment (D-10) x percentage of sediment contributed by agriculture ______________________

____

<u>Cost to Consumers</u>

D-12. Annual cost of water to consumers ______________________

D-13. Annual cost to consumers without outside purchase ______________________

____

D-14. Additional cost due to outside purchases (D-12) - (D-13)

____

D-15. Percentage of cost due to lost storage capacity ______________________

____

D-16. Amount of annual cost increase due to sediment (D-14) x (D-15)

____

D-17. Annual cost increase due to sediment from agricultural sources (D-16) x percentage of sediment from cropland sources.

Part E. <u>Water Treatment</u>

<u>Chemical Treatment</u>

E-1. Annual cost of chemical treatment ______________________

E-2. Percentage of treatment due to sediment borne contaminants

____

E-3 Cost of treatment due to sediment (E-1) x (E-2)

____

E-4 Total damage due to cropland sources (E-3) x Percent contributed by agricultural sources.

____

<u>Mechnical Treatment</u>

E-5. Annual cost of mechnical removal of weeds ______________________

E-6. Percentage due to sediment ______________________________

E-7. Total damage caused by sediment (E-5) x (E-6)

____

E-8. Cost of agricultural sediment (E-7) x percent contribution by cropland sources ______________________________

Part F <u>Total Cost of Sediment in Water Storage Facilities</u>

<u>Category</u>	<u>Cost</u>
A. Dredging----------------------------------	________________
B. Replacement Facility--------------------	Not calculated
C. Sediment Pool--------------------------	________________
D. Water from Outside Supplies------------	________________
E. Water Treatment------------------------	________________
Total----------------------------------	________________

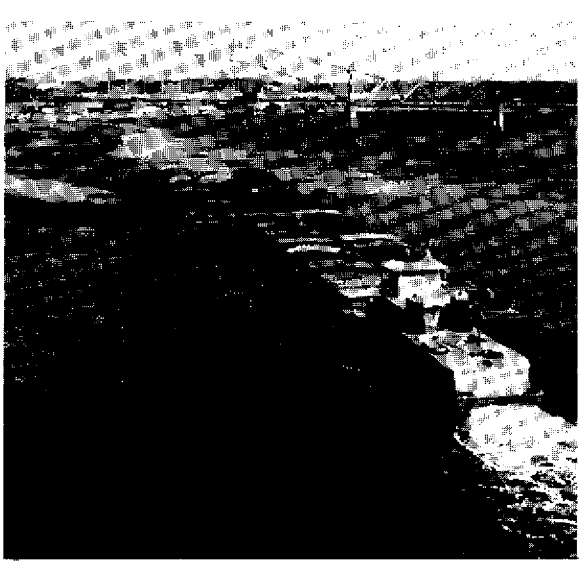
F. Navigation

Accumulated sediment in navigable waterways necessitates dredging and dredge spoil disposal, causes shipping delays, accidents and excessive wear and tear on engines (Clark 1985, 83).

The removal of sediment from navigable channels is costly. Annual dredging of the Mississippi River costs $170 million. Total dredging costs for the nation are between $300–$350 million (American Farmland Trust, chart). Annually the Army Corps of Engineers removes 800,000 to 1 million cubic yards of sediment from the Mississippi River between Minneapolis, Minnesota, and Guttenberg, Iowa (Hinton 10/8/86, Interview).

Dredge spoil disposal can be very costly. When the dredge spoil contains toxic material, or is removed in an environmentally sensitive location, the cost of disposal can exceed the cost of dredging. Depending upon the situation and asssociated regulations, toxic material may require disposal in a confined site. A Michigan study found that the cost of disposal in confined sites ranged from $3.00 to $20.00 a cubic yard (Birch 1983,48).

It should be noted that the cost of dredging may be offset when dredge spoil is used for beneficial purposes. An official from the Army Corps of Engineers explained that much of the sediment dredged from the upper portion of the Mississippi produces a clean sand which is used for road sanding, backfill and beach restoration. In 1985, 84% of the material dredged from the Upper Mississippi was placed at locations where beneficial uses could occur (US Dept of the Army 1985,1).



Soil Conservation Service

Accumulated sediment causes accidents and traffic delays. Barges which escape tows and move outside the river channel often run aground on sandbars (Adams 10/8/86, interview). Shoaling can occur within the designated channel and result in shipping delays. In 1986, shipping ceased for a week at Crats Island near Wabasha, Minnesota, while a shoal was removed. (Hinton 10/8/86, Interview).

Common sense suggests that sediment-laden water will have deleterious effects on boat propellers and other equipment. Little documentation exists to substantiate this claim, but it is important to at least consider it in the context of the problems silt creates.

Procedure

A local investigation into the damage caused by sediment to navigable waterways should focus on dredging and dredge spoil removal (they will be considered together for purposes of this analysis). Information on accidents which occur due to sediment does exist, but is often difficult to obtain. The economic value of delays in shipping and damage to engines is also difficult to ascertain, and will not be considered.

The first step of this investigation calls for a determination of what private or governmental entity has jurisdiction over the waterway in question. The Army Corps of Engineers, local units of government and private interests all dredge harbors and waterways. The Corps maintains records on permits and other activities related to navigable waterways, and is a logical place to start.

Refer to the worksheet at the end of this section to perform the following cost calculations.

Part A. Dredging and Dredge Spoil Removal

Dredging may be performed in a local area on an annual basis, a semi-annual basis or infrequently. When major expenses for dredging are incurred on an infrequent basis, the value of that damage should be calculated to reflect an annual cost. This procedure was demonstrated in Water Storage (Section E) under Dredging (Part A).

In waterways such as the Mississippi, dredging and dredge spoil disposal occurs annually. The regional offices of the Army Corps of Engineers produce an annual summary of dredging activities which indicate where dredging occurs and its cost. Along some stretches of the river, dredging may occur on an annual or semi-annual basis. For purposes of this analysis, dredging which occurs every three years may be divided by three to derive an annual expenditure.

Generalized cost data on dredging and dredge spoil disposal can be misleading. The cost will vary depending upon the type of equipment used, the type of material dredged, environmentally related disposal regulations and other locally determined variables (Birch 1983, 26).

Most agencies have the cost of dredging presented in cost per cubic yard of sediment removed. The toughest aspect of obtaining this information may be determining where dredging occurred. This will require reviewing annual reports and maps produced by the Army Corps of Engineers.

A-1. Determine the cost of dredging and dredge spoil removal. If the Agency maintains separate records of cost per cubic yard and number of yards of sediment removed; multiply the cost of dredging and disposal x the amount of dredged material to get a total cost.

A-2. If dredge spoil is sold for other purposes, place the value of the sold spoil on the Worksheet. (This is usually not the case.)

A-3. Determine the net cost of dredging and disposal. Subtract the value of sold spoil (A-2) from the gross cost of dredging and disposal (A-1).

A-4. Determine the cost of dredging attributable to cropland sources. Multiply the net cost of dredging and disposal (A-3) x the percentage of sediment due to cropland sources.

Part B. Accidents

Along the Mississippi, navigation accidents such as groundings occur regularly. These are primarily caused by navigation errors in which barges escape from the channel and run aground. Occasionally accidents occur where a shoal has developed in the main channel. In this case, it is possible to attribute damage to sediment. Records for a specific area are difficult to obtain. In areas under the jurisdiction of the Army Corps of Engineers, reports are sent to a regional headquarters. Therefore, determining accidents within a local area can be difficult. It is possible to make a formal request to the Army Corps of Engineers for information on groundings within the channel. Virtually any grounding is a "reportable marine casualty." A grounding is definitely reported if there is loss of life, damage to a critical portion of the vessel or damage in excess of $25,000 for the whole accident (Adams 10/8/86, Interview).

B-1. List the accidents and the damage estimates which occurred for the year under investigation. Add the value of these accidents together. Remember that these accidents should be a direct result of sediment.

B-2. Determine the amount of damage due to cropland sources. Multiply the total value of accidents (B-1) x the percentage of damage due to cropland sources.

B-3. List the fatalities which may have occurred as a result of the groundings. The Conservation Foundation analysis assigned a value of $1 million to a life lost due to sediment. Though it is reasonable and simple to argue for a higher value for human life, the one million dollar figure is used to draw attention to a profound impact associated with sediment. Use discretion to decide whether to assign an economic value to the loss of life. You may prefer to present the fact in a narrative without the dollar figure.

Part C. Total Cost

Determine the total cost of sediment to navigation by totaling all the categories of damage. (*See worksheet on page* 33)

G. Commercial Fisheries

Determining the economic link between sediment and associated contaminants to commercial fisheries is extemely difficult. No studies exist on a national scale which directly assess the economics of sediment damage (Clark 1985, 160). Locally, wildlife biologists and fishery associations may have analyzed this problem; however, in general information is difficult to obtain.

Impacts to commercial fisheries are the same as those outlined in this chapter in Section C-Recreation for recreational fisheries. Because commercial fisheries are valued in the market place, an analysis of the economic impact of sediment on the fish resource should be straightforward. The difficulty lies in making the connection between lethal and sublethal damage and sediment.

Procedure

For purposes of a local analysis, gather all information pertinent to local commercial fishing. A narrative discussion of the economic importance of commercial fisheries to a local area could be a dramatic means of presenting whatever information is available.

H. Property Values

Water quality is thought to have an impact on riparian property values. A study of six lakes in Wisconsin showed that water quality was a significant variable in property values (MN PCA 1980, 33). The extent to which water quality affects actual value is often difficult to determine because of other variables. Such factors as difference in accessibility, distance from population centers, size, improvements, view, topography, and tree abundance all may mask the influence of water quality on value (Warne 8/86, Interview) (MN PCA 1980, 33).

During the case study of Redwood County, an attempt was made to measure the impact of sediment on Lake Redwood. Lake Redwood has been degraded by siltation, yet despite this unequivocal link, the analysis showed no obvious effects on property values. Property values along Lake Redwood remain the highest in Redwood Falls where they are situated on the only lake in the area. Since 1981, property values have declined in most areas of the community except along the lake. Though it was generally agreed that sediment and the negative impact it has on recreation may diminish property values slightly on Lake Redwood, assigning an actual dollar value would be totally arbitrary (Hammerschmidt 6/25/86, Interview).

Inconsistency in the way in which tax assessments are made over time further complicates an analysis of property values. Another difficult problem to overcome is the lack of information on real estate trends in a particular community, and the influence the trends might have on property values.

Other techniques for measuring property values were considered. An attempt was made to locate a "comparable" lake which lacked sediment problems. Unfortunately, Lake Redwood is a body of water within a city, which is unique in Southern Minnesota. Comparable lakes in the immediate vicinity do not exist.

Another attempt was made to determine if there is a state analysis of lake shore property values which show a tight concentration of values around one average figure. This also proved inappropriate. In Minnesota, average lake shore footage appraises between $20 and $400 a lake shore foot. Not surprising, tremendous variation can occur on one lake (Warne 8/86, Interview).

Navigation-Worksheet

1. Name of waterway ______________________________

Part A. Dredging and Disposal

A-1. Cost of dredging and spoil removal

____

A-2. Value of dredge spoil which is sold for other purposes ($/cubic yd.) ______________________________

A-3. Net cost of dredging and dredge spoil removal (A-1) x (A-2)

____

A-4. Cost of dredging and spoil removal (A-3) x percentage of sediment attributable to agricultural sources

____

Part B. Accidents

B-1. List the accidents and damage which occured in the investigation year.

Accident	Cost

B-2. Determine the amount of damage due to cropland sources (B-1) x percentage of sediment due to agricultural sources

____

B-3. List any fatalities caused by an accident due to sedimentation. (These may be multiplied by $1,000,000 to derive an economic value).

____
____
____

Part C. Total Cost of Sediment to Navigation

Category	Cost
A. Dredging and Spoil Disposal--------	______________
B. Accidents	
Equipment---------------------------	______________
C. Total--------------------------------	______________

It was impossible for this study to assess the damage caused by sediment to property values.

Procedure

A narrative analysis of suspected impacts to property values is a means of bringing attention to this issue. Unless a situation exists where all other influencing variables can be controlled, a *quantitative analysis of property* values will be difficult to perform.

I. Intrinsic Benefits

There are intrinsic benefits that can be derived from clean water that do not lend themselves to quantification. Intrinsic benefits are the sum of the aesthetic benefits, ecological benefits, preservation values and option values associated with a clean resource (Freeman 1982, 163). They represent the benefits that are experienced by "non-users," people who do not make direct use of the water body. This is in contrast to "user" benefits, which are tied to actually using the water for purposes such as recreation, irrigation, industrial processes and commerical fisheries (Fisher 1984, 164).

An analysis of available research by Fisher and Raucher (1984,32) confirms the hypothesis that intrinsic benefits are often large in relation to recreation use benefits. For that reason relying on direct use values alone would significantly understate the total benefits of water quality improvement. In a study cited by Clark (1985, 161), preservation values along the South Platte River of Colorado were found to be twice the value of current recreational use. Fisher and Raucher found during their analysis that intrinsic values range from .5 to 1.4 times the magnitude of user benefits. Freeman cited a national study which estimated that the aesthetic benefit of fishing alone was $2.2 billion in 1978 dollars. The Freeman study concluded that total non-user aesthetic values of all forms of recreation are equal to .25 of national recreation benefits. That would place them within the range of $.5 to $4.0 billion annually. Within the range he placed the point estimate at $1.2 billion.

Clearly, the intrinsic value of clean water is high for the American public. It is important to consider this fact as the problem of sedimentation is explored in this analysis. A formula or method for calculating intrinsic benefits is not provided because of the broad range of values that have been cited here. Determining an economic measure of intrinsic value requires careful study. It employs statistically valid interviews or surveys to determine people's willingness to pay for clean water. This type of survey generally goes beyond the scope of the analysis in this Handbook.

Procedure

If your local analysis presents the economic assessment of sediment-related damage as a range of values, consider using the range of intrinsic values provided by Fisher and Raucher as a means of demonstrating the importance of intrinsic benefits. Since their research is principally based on recreation, use the local economic analysis for recreation in your study as the basis for calculating intrinsic values. This would mean multiplying the range provided by Fisher and Raucher times the values derived for recreation in the study site. This may be a difficult value to defend, though it may fit nicely into a qualitative (descriptive review) of the problem. Under these circumstances it will be important to substantiate the analysis with supporting evidence and clearly state all assumptions.

J. Flood Damage

According to a 1978 report published by the U.S. Water Resources Council, the Upper Mississippi Region experiences annual flood damages of about $235 million (1975 dollars). They predicted that without any future flood control action, damages would reach $380 million by the year 2000. Average annual flood damage in the Prairie Coteau Region of South-

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western Minnesota was estimated by the Soil Conservation Service to be $5,747,000 (1977 dollars) . Flooding is considered a major economic concern along the Upper Minnesota River (MN-So MN River Basin Commission 1977, IV-13).

Sediment plays a significant role in flood damage. The bulk of annual sediment delivery arrives in the spring during snowmelt and after major storms (Swenson 1964, 223) (US-EPA 1979,6) (Dingels 10/86, Interview). Accumulated sediment may cause bed aggradation which results in higher flood water. Suspended sediment will also increase flood volume. As flood waters recede, sediment settles out of suspension directly impacting agricultural and urban areas. Sediment may require physical removal from urban locations, and it may reduce fertility in floodplains or cause damage to already established crops (Clark 1985, 85-88).

A phenomenon known as "swamping" is a long-term effect of flooding. It refers to a situation where drainage is impeded due to the existence of a berm. The berm or dike which develops is a result of sediment deposited by subsiding flood waters. Initially the berm may help to keep floodwater contained in the channel. However, after a number of years of build-up, the berm will impede drainage following a flood. Since flood damage is a function of how long an area is innundated by high water, swamping will increase total damage (Stokes 6/27/86, interview).

The aggradation of stream beds due to sediment deposition was mentioned by the Conservation Foundation study as playing a signficant role in damage caused by flooding. Unfortunately, very little information exists to document bed aggradation in most rivers, and the economic damage it may cause. Because of the lack of information, it will not be considered in the economic analysis.

Flooding is an issue of major concern in agricultural areas. Numerous government programs exist to provide relief from the impacts of floods. During this study reports which discussed the annual cost of flood damages in the two study sites were found. The information was supplemented by conversations with knowledgeable field personnel.

The first step in analyzing the impact of sediment and flooding requires establishing whether or not a problem exists. Note: Flooding is defined as an event where water from a river channel breaches its banks. An area does not experience flooding if the primary problem is impeded drainage in the spring.

The best source of flood information is the District Conservationist of the Soil Conservation Service. The Southern Minnesota River Basin Report listed the following sources of assistance for flood related problems (VI-2). Studies associated with these projects may yield important information about flooding within a study site.

Public Law (P.L.) 566—The SCS administers this program which provides a means of solving watershed protection and flood prevention problems which cannot be adequately met by other programs.

Resource Conservation and Development Projects (RC&D)—Authorized by the federal government and administered by SCS, this program seeks to expand opportunities for conservation districts, local units of government and individuals to improve their communities in multi-county areas. Flood prevention measures such as structures and land stabilization are permitted under this program.

Public Law (P.L.) 87–639—This program authorizes the Secretary of the Army (Army Corps of Engineers) and the Secretary of Agriculture (SCS) to make joint investigations and surveys of watershed areas for flood prevention, or the conservation, development, utilization, and disposal of water.

Another source of flood-related information is the local Federal Crop Insurance representative. Use of this data will provide a partial analysis of damage, because not all farmers carry crop insurance. If data exists for selected farms in the flood plain, it may be possible (based on appropriate maps) to make some assumptions about total damage for all farms.

County engineers have figures about flood damage to roads and bridges. Other local officials may be knowledgeable about other urban impacts. If a federal disaster for flooding was declared, the Agricultural Stabilization and Conservation Service (ASCS) and the Federal Emergency Management Agency would be involved in funding cooperative assistance programs.

Procedure

If an investigation of flood damage has not been conducted in the local area, there are other approaches to take to the problem. The first is to look for an analysis which has been performed on a comparable river. This technique will work if land use and major physical characteristics are the same.

Federal flood investigations often report cost damage in terms of cost per acre. Under these circumstances consider using that figure (based once again on the similarity between the study site and the comparable river) and multiplying it times the amount of land which is in the flood plain under study.

Refer to the Worksheet to perform the following analysis.

Part A. Amount of Total Flood Damage Caused by Increased Flood Volume due to Sediment

The most desirable data for this analysis would unequivocally indicate values for direct sediment damage (ie. sediment removal from urban locations). If this information does not exist, the following procedure may be used to estimate overall flood damage. The assumption made in (A-4) is particularly controversial. It relies on research used by the *Conservation Foundation in Eroding Soils: The Off-farm Impacts.* If the following procedure is used for your analysis, clearly indicate the assumption made in (A-4) in the report.

A-1. Put the total amount of damage caused by annual flooding on the Worksheet. Most reports present this figure broken down into categories. Add them together for a total, or determine the amount of sediment- related damage for each category. Do not add damage associated with swamping in this total. (Swamping will be analyzed seperately.)

A-2. Find the maximum amount of suspended sediment that has been analyzed for the river. If this analysis does not exist, look for a comparable river where this information may be available. The U.S. Geological Survey or local water quality studies are good sources.

A-3. Determine the percentage of increase in flood volume due to suspended sediment. To do this refer to the graph at the end of this section. Given the amount of suspended sediment in parts per million, determine the percent increase in water volume.

A-4. Find the value of damage caused by increased flood volume due to sediment. To do this it will be necessary to assume that the value of flood damage due to suspended sediment is directly proportional to the amount of increased volume. Multiply the total amount of flood damage (A-1) × the percentage of volume increase due to sediment (A-3).

A-5. Determine the amount of damage due to cropland sources. Multiply the amount of damage due to sediment (A-4) × the percentage of sediment due to cropland sources.

Effect of Suspended Sediment on Weight and Volume of Water

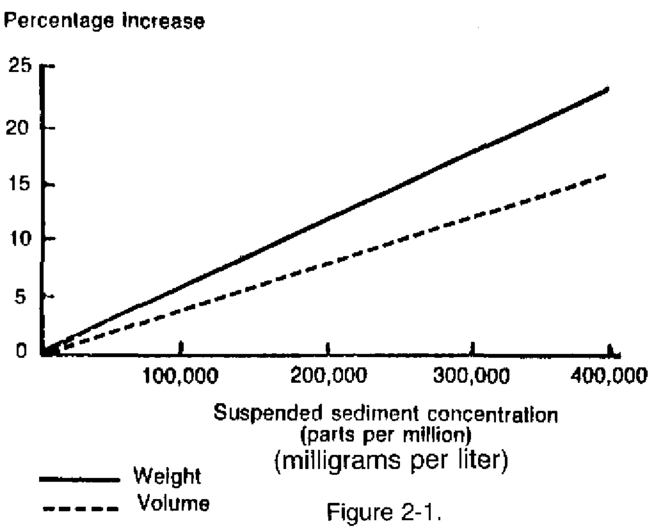

Figure 2-1.

Part B. Damage Due to Swamping

B-1. Place the amount of damage due to swamping (if it is available) under number one.

B-2. Assuming that this damage that completely attributable to sediment, determine the amount of damage due to cropland sources. Multiply the damage caused by swamping (A-1) x the percentage of sediment due to cropland sources.

Part C. Total Flood Damage

Add the damage due to swamping and damage caused by increased flood volume to get a total value of sediment-related flood damage.

FROM: Clark, E., Haverkamp, J. and W. Chapman. 1985. *Eroding Soils: The Off-Farm Impacts.* The Conservation Foundation. Washington, D.C. p. 89

Flood Damage-Worksheet

Part A. Amount of Total Flood Damage Caused by Increased Flood Volume Due to Sediment

A-1. Total amount of flood damage ______________________________

A-2. Maximum amount of suspended sediment ____________________

A-3. Percentage of increase in flood volume due to suspended sediment (refer to graph) __________________________________

A-4. Economic value of the damage caused by sediment (A-1) x (A-3)

____

A-5. Amount of damage due to agricultural sources (A-4) x Percentage of sediment contributed by cropland sources

____

Part B. Damage due to Swamping

B-1. Total damage due to swamping ________________________

B-2. Amount of damage due to agricultural sources (B-1) x percentage of sediment contributed by cropland sources.

____

Part C. Total Flood Damage

Category	Cost
A. Increased Volume---------------	______________
B. Swamping------------------------	______________
C. Total---------------------------	______________

K. Water Conveyance Facilities

Water conveyance facilities are defined as those structures which transport water outside a reservoir, lake or river channel. They include such things as drainage ditches from farm fields, roadside ditches and irrigation canals (Clark 1985, 90). The primary impact of sediment to these facilities is siltation. In Redwood County, the county ditch inspector estimated that one inch of sediment is deposited in open ditches annually. Since ditch design usually allows two feet for siltation below the culvert, the expected clean-out schedule is approximately 15 to 25 years for most county ditches.

Sediment in conveyance facilities causes numerous problems. Deposition in ditches impedes run-off from farm fields and delays planting. Along roadsides, it clogs culverts which can result in wash-outs. Sediment may slow drainage which leads to saturation and accelerated deterioration of roads (Boomgarden 6/16/86, Interview). As irrigation channels become clogged, they transport less water. An additional problem associated with sediment in all conveyance facilities are weeds; they restrict flow and increase the rate of siltation.

Drainage and roadside ditch clean-out are reasonably straightforward to calculate. It is estimated that removing sediment from Ohio's 3,650 miles of drainage ditches costs $1 million annually (Forster 1985, 142). Extrapolating from data gathered in Illinois, one researcher estimated that over $6.3 million may be spent annually for sediment removal from roadside ditches (Taylor 1978, 3). Indiana's counties spend more than $7 million annually to clean roadside ditches (Indiana Governor's Soil Resources Commission 1984, 2).

Procedure

The main sources of information for damage to conveyance facilities on a local scale are:

1. County highway engineers and ditch inspectors
2. Township chairman or clerks
3. State Highway Department engineers
4. Individuals from governmental agencies in charge of water distribution and allocation

At the township level, records may be sketchy. Accounting records in other governmental agencies may be inaccessible or difficult to underestand. These problems may result in an understatement of the total cost of sediment removal (Taylor 1978, 3). Since this is a category where "hard" information should be obtained, it is worth a little diligence to get the best possible data.

Before determining the final value of the cost of maintenance of water conveyance facilities, reconsider what percentage of the cost should be attributed to agricultural sources. In the case of drainage ditches, one individual interviewed estimated as much as 100% of the maintenance cost could be related to agriculturally derived sediment. This is particularly true if one assumes that all ditch-related erosion, including bank sloughing is due to agricultural activity.

Refer to the Worksheet at the end of this section to perform the analysis.

Part A. Drainage Ditches

The economic analysis for drainage ditches will present a simple formula for assessing dredging costs. To use the formula, gather specific information on the cost of clean-out, cycle of clean-out and total footage of open ditches in the area.

The analysis will investigate sediment removal from open ditches only. Though sediment may impact tile systems, efforts will be focused on the area of greatest and most obvious damage.

Sediment in drainage ditches may come from a few major sources: sheet and rill erosion, wind erosion or bank sloughing. Following one major wind storm during November in Redwood County, one foot of sediment was depos-

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ited on top of a frozen drainage ditch for a distance of 100 yards (Sanders 6/17/86, Interview). The worst erosion in roadside and drainage ditches can be seen in ditches which parallel the direction of prevailing winds, according to some experts.

In Minnesota, ditch maintenance is a two-step process. After a ditch is constructed, it is necessary to return within 5 to 10 years to dredge sediment. The sediment deposited during the first ten years is primarily due to bank erosion, which develops because it is difficult to establish vegetation in the initial years following construction (Olson 1986, 14A). Following this clean-out, the ditch will last between fifteen to twenty-five years depending on land use, terrain, erodibility of the soils and engineering (Sanders 6/17/86, Interview).

The following analysis will estimate clean-up cost. This should be used when time is a major constraint or when annual cost figures are unavailable. When annual cost figures exist, they may be used in lieu of the estimation method. One warning: Annual values should provide an accurate picture of clean-out cost over time. Should they be excessively large or small for a particular year, the estimate method may be preferrable.

A-1. How many feet of open ditches are in the study site?

A-2. What is the cost of clean-out per running foot?

A-3. What is the average clean-out cycle in the study site?

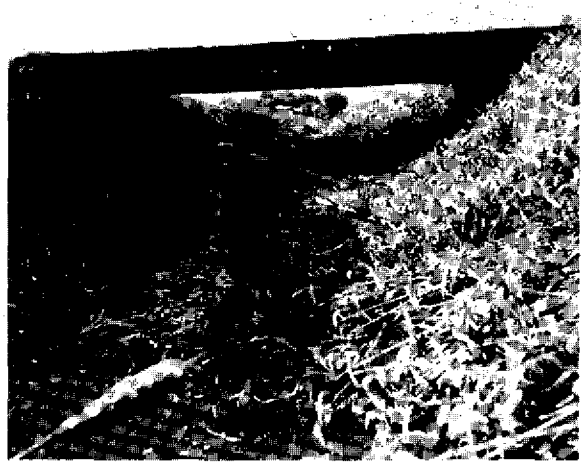
A-4. Determine the total cost of all ditch clean-out. Multiply the length of open ditches (A-1) x cost of clean-out (A-2).

A-5. Determine the average annual clean-out cost. Divide the total cost of ditch clean-out (A-4) by the clean-out cycle for the ditches in the study site (A-3).

A-6. Determine the amount of damage caused by agricultural sources. Multiply the total annual cost of clean-out (A-5) x percentage of sediment contributed by cropland sources. (This may be 100%.)

Part B. Roadside Maintenance

Jurisdiction for roadside ditches depends on the type of road. In Minnesota, townships, counties and the state perform roadside maintenance. The American Farmland Trust study



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found that the most efficient way to gather data from townships was to send a questionaire to the Township Clerk. A sample of this questionaire is included in Appendix A. Information concerning state and county highways was obtained through interviews with highway engineers; and in the case of the state, with the regional accountant.

The affects of sediment on roads and roadside maintenance is fairly complex. At its simplest, most agencies keep records of expeditures for sediment removal. In most cases, however, this figure is just the tip of the ice berg; it usually indicates clean-out that occurs as a result of an emergency or extreme conditions. So, though easily obtained, it is safe to say this figure understates the enormity of the problem.

Sediment may have some very costly impacts to roads. A portion of reconstruction cost generally involves ditch clean-out and reconstruction. Another more complicated cost relates to the total reconstruction process. Water which saturates a road bed because of impeded drainage will have the effect of accelerating the need for reconstruction. In one study area, the County Engineer went so far as to say that roads were rebuilt on a 30 to 35 year cycle versus a 40 to 45 year cycle (Boomgarden, Interview 6/16/86). In an another area, 50 miles away, the County Engineer disputed that claim and felt that impeded drainage was a minor cause of damage when compared to other deteriorating impacts. (Danielson 8/9/86, Interview).

To perform a thorough economic analysis of all possible costs to roads associated with off-site impacts of sediment over their life-span would require complicated econometrics. Because this study is merely a guide, to provide a back-of-the-envelope assessment of the problem, the analysis will be based on the most easily obtained information.

The following information should be compiled for all roads within the watershed under study.

B-1. What is the annual cost of sediment removal, and associated maintenance in the study area? Remember to include culvert repair, washout damage and any other costs associated with sediment. The most accurate means of determining this value would be to compile clean-out costs for a number of years and determine an average. Make sure that the clean-out cost for the year in question is representative.

If the study site comprises a portion of a county, pro-rate the amount of damage by the percentage of roads which fall in the study area. (i.e. The county shows a total clean-out cost of $11,000. Thirty-six percent of the entire county roads fall within the study site. Therefore, you would have to multiply $11,000 × .36 to determine the cost associated with your study area.)

B-2. Total cost due to agricultural sources. Multiply the cost of sediment removal × the percentage attributable to cropland sources may be 100%).

Part C. Irrigation Canals

Cost of clean-out for irrigation canals may be gathered from the unit of government which regulates water allocation. Either the governmental agency or local contractor that performs the clean-out will have cost information and some idea of the extent of the problem and cycle of clean-out. The costs associated with irrigation ditch maintenance include dredging and weed removal. The method for calculating clean-out will follow the same format as drainage ditch dredging.

C-1. What is the total length (in feet) of irrigation canals in the study area?

C-2. What is the cost of clean-out per running foot?

C-3. How often must irrigation canals be cleaned?

C-4. Determine the cost of clean-out. Multiply the length of canals (C-1) x the cost of clean-out (C-2).

C-5. Determine the average annual cost of clean-out. Divide the cost of clean-out of all canals (C-4) by the life cycle of the irrigation canals (C-3).

C-6. Determine the amount of annual damage attributable to agricultural sources. Multiply the average annual cost of clean-out (C-5) x the percentage of sediment from agricultural sources (may be as high as 100%).

Determine the cost of weed control (if handled seperately from clean-out)

C-7. What is the average cost of weed control per running foot?

C-8. How frequently must weed control occur?

C-9. Determine the average cost of total weed control. Multiply cost of weed control (C-7) x the total length of irrigation canals (C-1).

C-10. Determine the average annual cost of weed control. Divide the total cost of weed removal (C-9) by the cycle of clean-out (C-8).

C-11. Determine the cost associated with agricultural sources of sediment. Multiply the annual cost of weed removal (C-10) x the percentage of damage caused by agricultural sources.

Total Annual Cost of Irrigation Canal Clean-out

C-12. Add together the cost of weed control (C-11) + cost of clean-out (C-6).

Part D. Total Conveyance Facility Damage

Add together the cost of conveyance facility clean-out to determine the total damage in this category.

Water Conveyance-Worksheet

Part A. Drainage Ditches

A-1. Total number of feet of open ditch ________________

A-2. Cost of clean-out per running foot ________________

A-3. Average clean-out cycle __________________________

A-4. Total cost of all ditch clean-out (A-1) x (A-2)

____

A-5. Average annual clean-out cost (A-4) divided by (A-3)

____

A-6. Amount of damage caused by agricultural sources (A-5) x percent of sediment due to agricultural sources ____________

Part B. Roadside Maintenance (repeat for all levels of government and add together)

B-1. Annual cost of sediment removal and related maintenance in your area ________________________________

B-2. Total cost due to agricultural sources (B-1) x percent contribution from agricultural sources __________________

Part C. Irrigation Ditches

C-1. Length of irrigation canals in study site ______________

C-2. Cost of clean-out per running foot ____________________

C-3. Cycle of clean-out ________________________________

C-4. Cost of clean-out (C-1) x (C-2) ______________________

C-5. Average annual cost of clean-out (C-4) divided by (C-3)

____

C-6. Amount of annual damage attributable to cropland sources (C-5) x percent contribution by cropland sources ________

Weed Control

C-7. Cost of weed control per running foot ____________________

C-8. Cycle of weed control ____________________

C-9. Total cost for all weed control (C-7) x (C-1) ____________

C-10. Average annual cost of weed control (C-9) divided by (C-8)

____

C-11. Total damage attributable to agricultural sources (C-10) x percentage due to agricultural sources ____________________

____

Total Cost of Sediment to Irrigation Canal Maintenance

C-12. Cost of weed control (C-11) + cost of clean-out (C-6)

____

D. Total Cost of Sediment to Conveyance Facilities

Category	Cost
A. Open Ditches--------------------	____________
B. Roads	
Townships----------------------	____________
County-------------------------	____________
State and U.S.-----------------	____________
C. Irrigation----------------------	____________
D. Total---------------------------	____________

L. Municipal and Industrial Water use

The various demands placed on water by all types of consumers usually necessitates some level of treatment. Municipalities require clean potable water and industries require water for processing and cooling operations. Municipal water supplies are expected to meet federally established health standards. Industrial use generally requires removal of some sediment.

Local water treatment needs will vary depending upon the source of water and the use. Different amounts of sediment, total dissolved solids (TDS), chemical pollutants, nutrients and algae will combine to require a treatment process unique for each location. Seasonal variation in water flow and temperature will also influence the water-treatment needs.

Casual analysis of water-treatment for Marin County, California suggests that as turbidity increases, treatment cost increases (Thiesen 10/86, Interview). A similar relationship was explored in a Michigan study; it found that statistical significance existed for a model which linked cost and turbidity, though the model required further refinement (Birch 1983, 45).

Water-treatment relies on a variety of processes for purification including filtration, flocculation (where chemicals are added to cause particles to coagulate and settle out of solution), sedimentation (the process where floc is separated from water by precipitation and sedimentation) and disinfection. Flocculation and coagulation processes are used to remove sediment, color and organic matter; softening reduces hardness by removing the mineral constituents; and activated carbon removes foul tastes and odors. Clarification , filtration and oxidation are all used to remove iron and manganese. Flouride is added in some water systems to prevent tooth decay (Lehr 1980,4).

For purposes of understanding water treatment a brief discussion of the constituents of impure water is needed.

Sediment and associated nutrients—Sediment is defined as inorganic erosional material. It is composed of large and small particles of broken down rocks and minerals which may be transported throughout the waterway. The associated nutrients include a variety of organic material such as plant detritus and animal wastes.

Suspended sediment and organic matter can cause turbidity problems in water. Sediment may cause excessive wear and tear on machinery for industrial users. The organic constituents of water can create taste and odor problems as well as fuel the growth of algae and bacteria.

Total Dissolved Solids (TDS)—This refers to both the suspended and dissolved mineral constituents in water. It includes such things as carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates of calcium, magnesium, sodium, and potassium with some traces of iron, manganese and a few others. It is the mineral constituents which determine the hardness or softness of water. These minerals, usually in ionic form, are removed through the process of adding chemicals. National Secondary Drinking Water Regulations recommend a level of 500 milligrams per liter of dissolved solids in drinking water. Above this level water often tastes offensive, though may not necessarily pose a health risk (Lehr 1980,55). TDS may be contributed through agricultural runoff or as a natural constituent of the water supply. TDS poses a significant problem in the irrigated areas of the arid west.

Agricultural chemicals—Pesticides in domestic water supplies rarely exceed federally established standards (Clark 1985, 124).

Fertilizers and their various chemical components are known to create health problems. The decomposition of ammonia fertilizer produces nitrates. Ingestion of nitrates has lead to methemoglobinemia, a potentially fatal disease of infants (Lehr 1980, 29).

The removal of all chemical pollutants requires specialized and costly water-treatment. Detection of these chemicals also requires expensive testing, which often exceeds the resources of local communities.

Algae—These organismes are a group of single and multi-cellular plants with no leaves, stems or flowering parts. The many varieties of algae can cause a multitude of problems in water-treatment. They affect taste, odor and color of water, and can combine with chemicals to interfere with the water-treatment processes.

Procedure

Begin by interviewing the treatment or industrial plant manager who has firsthand experience with local treatment needs and cost. Ask about each of the following categories: chemical treatment (softening), maintenance or clean-up, filtering and wear and tear on equipment. The latter category is almost impossible to document so will not be included in the economic analysis.

(Table 2-1) *Cost of Sediment and Hardness Removal in Municipal Water Treatment for Granite Falls, Minnesota*

Fiscal Year 1985

Chemical	Amount	Cost	Total
Lime	315,000 lbs	$74.55/ton	$11,742
Soda ash	165,900 lbs	$8.70/100wt	$14,433
Sodium aluminate	14,800 lbs	$ .71/lb	$10,508
Aluminum sulfate	1,800 lbs	$10.35/100wt	$ 186
Polyphosphate	1,784 lbs	$1.84/lb	$ 3,283
Polymer	780 qts (9.5 lbs/gal)	$.965/lb	$ 1,788
Total			$41,940
Total water treatment labor costs			$48,000

Part A. Chemical treatment (softening)

A very tricky aspect of this analysis is the fact that sediment removal often occurs along with treatment for hardness, because the same chemicals that treat for hardness or TDS will help to eliminate sediment problems. This creates difficulties when attempting to measure the portion of sludge disposal costs which should be attributed to agricultural sources.

One way to deal with the problem is to ask the plant manager what chemicals would be unnecessary if sediment was not a problem. Another is to provide information on all treatment processes and suggest in a narrative that some proportion of cost is due to sediment.

A conservative approach is to stick to chemicals which definitely deal directly with sediment. According to Birch (1983,25), alum (hydrated aluminum sulfate), soda ash, activated carbon and chlorine are chemicals which relate directly to turbidity. Various polymers, which are referred to by number, also assist in the sediment removal process. A list of the chemicals used for sediment and hardness removal in Granite Falls, Minnesota, is included in Table 2-1. It shows the wide variety of chemicals, their quantities, and cost associated with the treatment process (Opdahl 10/86, Interview).

Refer to the Worksheet and answer the following questions.

A-1. List the type, quantity and cost of chemicals used for sediment removal in the water-treatment plant under analysis. Total these to derive the cost of sediment removal. Note that some sediment removal may be incidental to other processes.

A-2. Determine the amount of water-treatement needed to remove sediment from agricultural sources. Multiply the cost of chemicals (A-1) x the percentage of sediment due to agricultural sources.

A-3. What are the type, quantity and cost of chemicals used for the removal of other agriculturally derived material, i.e. fertilizers, animal waste etc.?

A-4. Add together (A-2) and (A-3) for a total of chemical treatment costs.

Part B. Maintenance and Sludge Disposal

This category includes the cost of removing sludge from settling or sedimentation facilities and its disposal. This may be a routine part of maintenance, or may occur on specified days throughout the year. Consider the cost of labor and any associated mechanical costs. Also, if sludge disposal occurs in a particular landfill, consider the cost to the muncipality to dispose of the sludge. Plant managers in Michigan felt that the greatest potential savings from reducing raw water turbidity was in the area of sludge removal (Birch 1983, 46).

B-1. What is the cost of labor associated with sludge removal? It will usually be found as a part of the labor and maintenance budget. Determine what proportion of the annual budget is allocated to this activity. (ie. If 25 days of the year are spent in clean-up operations for one person, find the number of total working days for that person and divide into 25 to determine the percentage of time spent in clean-up. Multiply this times the total annual cost of labor for that person, to determine the cost of labor.)

B-2. What is the cost of hauling the sludge?

B-3. What is the cost of sludge disposal at the landfill?

B-4. What is the total cost of sludge disposal? Cost of labor (B-1) + cost of hauling (B-2) + cost of disposal (B-3).

B-5. Cost of sludge removal due to agriculturally derived sources. Multiply the total cost of disposal (B-4) x percentage due to agricultural sources.

Part C. Filtration

Numerous types of filtration may occur at a water-treatment plant. Therefore, inquire specifically about filtration throughout the process and ascertain if efficiency is in any way reduced due to sedimentation.

C-1. List the filtration procedures, and the cost of replacement and maintenance. Add them at the bottom.

C-2. What percentage of the wear and tear on the filters is due to sediment or agriculturally-related damage?

C-3. Determine the amount of damage caused by agriculturally derived sediment. Multiply the cost of filtration (C-1) x the percentage due to agricultural sources.

Part D. Total Cost to Municipality or Industry to Remove Sediment and Associated Contaminants from Water Supplies

Add together the total values for chemical treatment (A) + sludge disposal (B) + filtration (C).

Water Treatment-Worksheet

A. Sediment and Contaminant Removal

A-1. Cost of chemicals for sediment removal

	Chemiccal	Amount	Cost
a.			
b.			
c.			
d.			
e.			

Total--

A-2. Cost due to agricultural sources of sediment (A-1) x percent of sediment due to agricultural sources ____________

A-3. Cost of chemicals for contaminant removal

	Chemical	Amount	Cost
a.			
b.			
c.			
d.			
e.			

Total--

A-4. Total Cost (A-2) + (A-3) ____________________________

B. Maintenance and Sludge Disposal

B-1. Cost of labor associated with sludge removal _____________

B-2. Hauling cost of sludge ___________________________________

B-3. Cost of sludge disposal at landfill ______________________

B-5. Cost of sludge due to agriculturally derived sources (B-4) x percentage due to agricultural sources ____________
____

C. Filtration

C-1 List of Filtration Procedures | Cost

a.

b.

c.

d.

e.

Total--

C-2. Percentage of damage or excessive cleaning due to sediment or agricultural contaminants ________________________________

C-3. Amount of damage due to agriculturally derived sediment (C-1) + (C-2)

D. Total Cost to Municipality or Industry of Sediment and Associated Contaminants in Water Supply

Category	Cost
A. Sediment Removal--------------	________________
B. Maintenance & Sludge ---------	________________
C. Filtration--------------------	________________
D. Total-------------------------	________________

M. Power Facilities

Sediment and associated contaminants can affect power production and maintenance in various ways at different facilities. Sediment behind a dam can hinder power production at a hydroplant by reducing storage and displacing water needed to produce electricity (Regalia 6/27/86, Interview). Within the plant, sediment can cause excessive wear on turbines.

At a nuclear plant, sediment can cause damage to intakes and on heat exchange surfaces. Algae, which is an outgrowth of the contaminants brought by sediment, can foul surfaces. Algae growth requires cleaning with chlorine or other disinfectants. Sediment-ladened water which is splashed over the surfaces of cooling towers will deposit sediment at the bottom of the tower basin. Periodic cleaning of the basins is necessary to remove the sediment. Finally, cooling ponds associated with coal-fired plants may suffer siltation as sediment settles from the water (Neils 8/6/86, Interview).

Generally, routine sediment removal and replacement is sufficient to handle problems associated with sediment. Infrequently, a power facility may incur significant costs when a major storm delivers a large sediment load to the plant, causing a shutdown for cleaning. This may create the need to purchase power from outside suppliers. For Northern States Power (NSP) in Minnesota and Wisconsin, a shutdown could result in a cost of $.5 million dollars if the additional power is purchased from a more costly oil-fired power plant (Neils 8/6/86, interview).

The most knowledgeable person to talk with concerning the cost of sediment to a power facility is the plant manager, who is also familiar with the plant's budget. The cost of routine maintenance due to sediment is usually a small portion of the operating budget of a large production facility. For NSP, sediment-related expenses were estimated at less than 1% of the budget. As an example, the Monticello Nuclear Power plant, with an annual operating budget (excluding fuel) of $30 million will have sediment-related expenses of less than $10,000.

Procedure

The cost of sediment damge to power facilities will be analyzed in two broad categories. The first will be a method to calculate costs purchasing outside energy. In this case, the additional cost of purchasing power will be considered the cost of sediment-related damage. (It is important to note that this will yield an incomplete analysis.) To truly understand whether or not it is cost effective to remove sediment from the reservoir, a benefit/cost relationship which considers the cost of sediment removal as well as the cost of purchasing outside power would have to be performed.

The second category of sediment damage relates to maintenance and operation at all power facilities which rely on water. This will require analyzing all costs in the general budget associated with sediment and related contaminants.

Refer to the worksheet at the end of this section and answer the following questions.

Part A. Cost of Power due to Sedimentation at Hydropower Plants

A-1. How much power is purchased from sources other than the hydropower facility?

A-2. What is the cost of power produced from outside suppliers?

A-3. How much power purchased from outside sources could be produced by the hydropower facility given the removal of sediment and increased water storage capacity?

A-4. What is the cost of power produced by the hydropower facility?

A-5. What is the difference in cost between power produced outside the power facility and power produced at the power facility? Subtract the cost of power produced at the hydropower plant (A-4) from the cost of power purchased from outside suppliers (A-2)*

A-6. Determine the cost of purchasing outside power. Multiply the amount of power which could be produced by the hydropower facility if sedimentation was not a problem (A-3) x the difference in cost of the between the facilities (A-5).

A-7. Determine the cost of power production due to sediment from agricultural sources. Multiply the cost of purchasing outside power, and therefore the cost of sediment to power production (A-6) × the percentage of sediment due to agricultural sources.

Part B. Maintenance and Operation Costs

The following is a guideline to follow in asking questions about maintenance and operation expenses at a power facility. First, you must determine the type of operation and the points in which sediment and associated contaminants may cause problems. This list is by no means complete. Individual plants may have unique experiences with sediment.

B-1. What is the annual cost of replacing intake tubes?

*If power is more expensive at the hydropower facility, this analysis is invalid. This would be the case if the answer to this question is a negative number.

B-2. What is the annual cost of replacing or removing corrosion from heat transfer plates?

B-3. What is the annual cost of replacing turbines or other parts which are corroded by sediment?

B-4. What is the cost of chlorine for removal of algae from facility surfaces?

B-5. What is the annual cost of removing sediment from cooling tower basins and intake facilities?

B-6. What is the annual cost of removing sediment from cooling ponds?

B-7. What is the annual cost of removing weeds in cooling ponds?

B-8. What is the annual cost of disposing of sediment?

B-9. What is the annual labor cost attributable to these functions?

B-10. Total all costs associated with maintenance and operations.

B-11. Determine cost due to sediment from agricultural sources. Multiply the total cost (B-10) x the percentage of contribution from agricultural sources.

Part C. Total Damage to Power Facilities

Determine the total damage caused by sediment to power facilities. Add the last values from the cost of power from outside facilities (A-7) + maintenance and operation (B-11).

Power Facilities-Worksheet

A. Cost of Power due to Sedimentation at Hydropower Facilities

A-1. Amount of power purchased from outside sources ____________

A-2. Cost of power from outside sources ____________

A-3. Amount of power that could be produced to replace outside sources if sediment was removed from reservoir ____________

A-4. Cost of power produced by hydro-power facility ____________

A-5. Difference in cost of power (A-2) - (A-4) ____________

A-6. Cost of purchasing outside power (A-3) x (A-5) ____________

A-7. Cost of power production due to sediment from agricultural sources ____________

B. Maintenance and Operation Costs

B-1. Annual cost of replacing tubes ____________

B-2. Anual cost of corrosion ____________

B-3. Annual cost of replacing turbines ____________

B-4. Annual cost of algae removal (chlorine) ____________

B-5. Annual cost of sediment removal from tower basins ____________

B-6. Annual cost of sediment removal from cooling ponds ____________

B-7. Annual cost of weed removal ____________

B-8. Annual cost of sediment disposal ____________

B-9. Annual labor cost associated with above functions ____________

B-10. Total (B-1) + (B-2) + (B-3) + (B-4) + (B-5) + (B-6) + (B-7) + (B-8) + (B-9) ____________

B-11. Cost due to sediment from agricultural sources (B-10) x percentage of sediment contributed by agricultural sources

____

C. Total Damage to Power Facilities

Category	Cost
A. Costof power from outside facility-------	____________
B. Maintenance and operation cost-----------	____________
C. Total-------------------------------------	____________

Chapter Three
Redwood County

Executive Summary

The cost associated with off-site (off the farm) damage caused by soil erosion is receiving increasing national attention. The combined private and public costs of remedying damage caused by sediment once it has left the farm may be greater than the cost of damage on-site (on the farm) at the present time.

As interest increases, efforts are being made to determine the type and cost of impacts at the state and local level. The goal of the investigation in the Redwood River Watershed, Redwood County, is to provide information about the location and cost of the damage. In addition to providing data concerning the specific problem in Redwood County, the analysis supplied important field experience for the development of this Handbook for local officials.

The cost of off-site damage due to soil erosion in the Redwood River Watershed of Redwood County for 1985 was $65,571. The following three categories of damage contributed to the total:

Recreation	$ 8,066
Flooding	$18,743
Water Conveyance	$38,762
Total	$65,571

The figure derived for 1985 is not comprehensive. Some damage caused by sediment did not lend itself to economic valuation. The cost of damage associated with recreation above and below Lake Redwood could not be determined. No defensible technique exists to assess the economic damage caused to biological systems, such as fish in the Redwood River. Finally, the effect of sediment in Lake Redwood on property values could not be ascertained.

A few categories were determined not to be affected by sediment. Problems associated with the dam at Highway 19 are not aggravated by sediment in Lake Redwood (Figure 3-2). Though sediment does impact storage capacity for the hydropower plant, it is not a limiting factor to power production.

A number of data problems were encountered during this study. Information for some categories of damage does not exist. Lack of baseline data, particularly relating to biological systems, makes it nearly impossible to determine the effects of sediment.

Another problem is that very little information is presented in the context of a watershed. In most cases, economic information is available only on a county or regional basis. Attempting to reduce information from a county scale to a watershed scale complicates the analysis.

Finally, sediment-related damage is often masked by other variables. In the case of flooding, damage caused by water makes it difficult to assess the proportion of the damage due to sediment.

This study did not perform original research on the sources of sediment in the Redwood River. Based on available information, it is estimated that the majority of sediment, or roughly 75 percent, is caused by upland erosion. Streambank erosion is severe in localized areas and is estimated to contribute slightly less than 25 percent of the sediment load. The relative importance of each source of sediment is a topic which should be explored further.

The following list outlines potential damages investigated in the study, with major findings in each category highlighted. For documentation of the conclusions, supporting evidence and an outline of the assumptions made in each analysis, refer to sections within this Chapter.

Physical Data

- The study site is the Redwood River Watershed within the political boundaries of Redwood County. It occupies an area of approximately 199 square miles or 127,360 acres.
- The majority of written evidence suggests that upland erosion from agricultural activities is the primary source of sediment to the Redwood River. For purposes of this investigation, 75% of the sediment in the River is attributed to agricultural sources, while 25% is attributed to streambank erosion and other minor contributors.
- 1985 was an unusually wet year with total precipitation of 32.2 inches at Redwood Falls. This is 7.29 inches above normal.
- Agricultural land use dominates the landscape. Cropland occupies 88% of all non-federal land in the county.
- 91% of all cropland is in row crops. 65% of all cropland is estimated to need some conservation treatment for erosion.
- The estimated annual average wind and water erosion for cultivated cropland in Redwood County is 7.1 tons per acre.
- 88% of the sediment delivered to the River at Marshall is estimated to leave the Redwood River Watershed. 56% of the sediment delivered to the waterway in Redwood Falls is estimated to reach the outlet. (Figure 3-3)

IN-STREAM IMPACTS

Biological

- Silt is known to influence benthic invertebrate communities in the Redwood River. In general, the communities are considered to be in approximate adjustment with the changes that are occurring in the river.
- It is difficult to determine the exact damage caused by sediment to fish. Lack of baseline data plus the possibility that natural barriers have always limited fish populations above Redwood Lake hinder this analysis.
- Two factors limit the development of a recreational fishery for the river above Lake Redwood. They are fluctuations in flow and sediment loading.
- The stocking of crappie, northern pike and blue gill maintain a population of sport fish at Lake Redwood.
- Natural reproduction of game fish may occur below the dam. This segment of the river may have the greatest potential for recreational fishing development.
- No threatened or endangered species occur in the study site.

Recreation

- The value of recreation lost on Lake Redwood due to siltation was estimated to be $10,755 in 1985. The amount of benefits lost to the community due to agricultural sources of sediment was $8,066. This analysis assumes that in a hypothetical clean lake, fishing, recreational boating and picnicking would all increase above current use levels.
- Bullhead fishing in April and May is the primary use of the Redwood River above Lake Redwood.
- Though game fish are known to occur in the river segment above Lake Redwood, this area receives little recreational use.
- The Redwood River below the dam receives

a substantial amount of recreational use by canoeists, tubing enthusiasts, fishermen and individuals interested in nature study.

• With improved water quality (including reducing sediment), it is believed that all river segments would receive more recreational use.

Water Storage

• 25 feet of sediment is known to have accumulated since the early 1900's behind the dam at Redwood Falls.

• Sediment is not known to be the cause of structural problems with the dam.

• Sediment is not the principal factor limiting power production from the hydropower plant.

• At the present time, there are no plans to remove sediment from Lake Redwood.

Property Values

• Though property values may be negatively impacted by sediment in Lake Redwood, it is impossible to isolate the extent of this damage.

OFF-STREAM IMPACTS

Flooding

• Swamping is thought to increase average annual flood damages by $24,990. The portion of the cost caused by agriculturally derived sediment is $18,743.

• No analysis has been performed to determine whether or not bed aggradation is occurring or has occurred along this stretch of the Redwood River. This would further increase flood damage.

• Sediment does not appreciably increase the volume of flood water in the Redwood River.

Water Conveyance

A. Drainage Ditches

• The approximate annual cost of removing sediment from the 133 miles of ditches in the watershed is $24,698. This amount is entirely attributable to damage caused by agricultural sediment.

B. Roads

• The cost of all sediment-related road maintenance is probably understated due to accounting procedures.

• *Township Roads*—The total value of sediment-related maintenance in 1985 for township roads within the study site was $8,744. The entire amount is attributable to agricultural sources. Townships reported spending between zero and 11% of their annual budget on sediment related maintenance.

• *County Roads*—Cost of culvert repair and sediment removal for County and County-State Aid Highways was $2,828. The entire value is attributable to agricultural sources of sediment.

• Sediment in road ditches may have long-term deleterious affects on county roads. It was estimated that impeded drainage due to sediment may accelerate the need for complete reconstruction by ten years.

• *State Highways*—Culvert and ditch repair on state roads cost $2,342 in 1985.

C. Irrigation

• Only two active permits for withdrawls from the Redwood River exist in the study site. The only cost associated with irrigation occurs at the zoo in Redwood Falls. Removing accumulated sediment in 1985 was $200. The total cost due to agricultural sources of sediment is $150.

A. Physical Description

Over 150 years ago a tall-grass prairie blanketed the landscape surrounding the Redwood River. Grassy swales and wetlands covered the area which is now Redwood County. The River itself was a meandering prairie stream bordered by willow and cottonwood trees (Waters 1977, 235).

Once the agricultural richness of the prairie was realized, settlers began changing the prairie They replaced it with crops while digging ditches to dry out the rich soils for planting.

The area under consideration for this case study is the Redwood River Watershed within the political boundaries of Redwood County located in southwestern Minnesota (Fig 3-1, 3-2). The watershed is approximately 199 square miles or 127,360 acres.

The *entire* Redwood River watershed is 739 sq. miles (Fig. 3-3). It originates on the iron shaped Coteau des Prairies. The Coteau is an elevation of the plains which rises out of northeastern South Dakota and extends southeastward to cover part of southwestern Minnesota. Its northern tip just touches the North Dakota border and its eastern edge cuts to the southwestern corner of Minnesota (Waters 1977, 288).

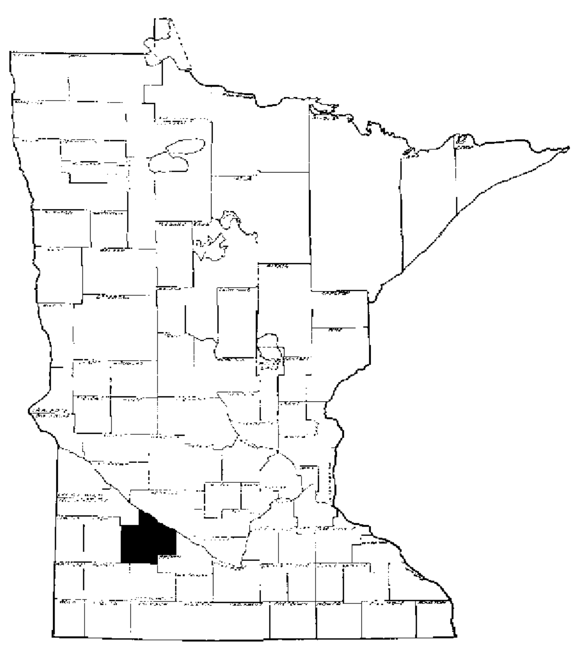


Figure 3-1. Redwood County Location

The river originates in intermittant streams at the the top of the Coteau at approximately 1,750 feet. As it comes off the Coteau to the northeast, it drops 300 feet in fifteen miles through wooded ravines. At Marshall, the River reaches the lowland plain and flows east toward the Minnesota River with a very slight gradient of only two to three feet per mile. At Redwood Falls it takes another big tumble into the Minnesota River Valley, dropping 100 feet in one mile. (Waters 1977, 295). The river flows through Lincoln, Pipestone, Murray and Lyon counties before reaching Redwood.

Major tributaries within Redwood County include Ramsey and Clear Creek. Numerous open ditches flow into the river. In 1960, the Redwood River was straightened by the Army Corps of Engineers between the County border and the town of Seaforth, a distance of 20.7 river miles (US Dept of the Army-Army Corps 1960, 1). Agricultural activities have been influential in determining the current character of the Redwood River.

Geology

The surface materials and landforms of Redwood County are a product of recent glaciation. The surface of the county is largely a glacial till lowland plain between 1,000 and 1,200 feet above sea level. It lies above cretaceous shales and sandstones, which in turn are above granitic gneisses and schist. The granitic rocks, which are exposed in places along the Minnesota River Valley, are some of the oldest known rocks in North America (USDA-SCS 1985, 2), dating back over three billion years (MN-Southern MN River Basin Commission 1977, II-4).

The Coteau des Prairies from which the Redwood River originates is a unique landform on the prairie landscape. It exists because it rests in part on a base of hard quartzitic rock, the remains of an ancient mountain range. Ridges of this very old rock resisted erosion for hundreds of millions of years and glaciers

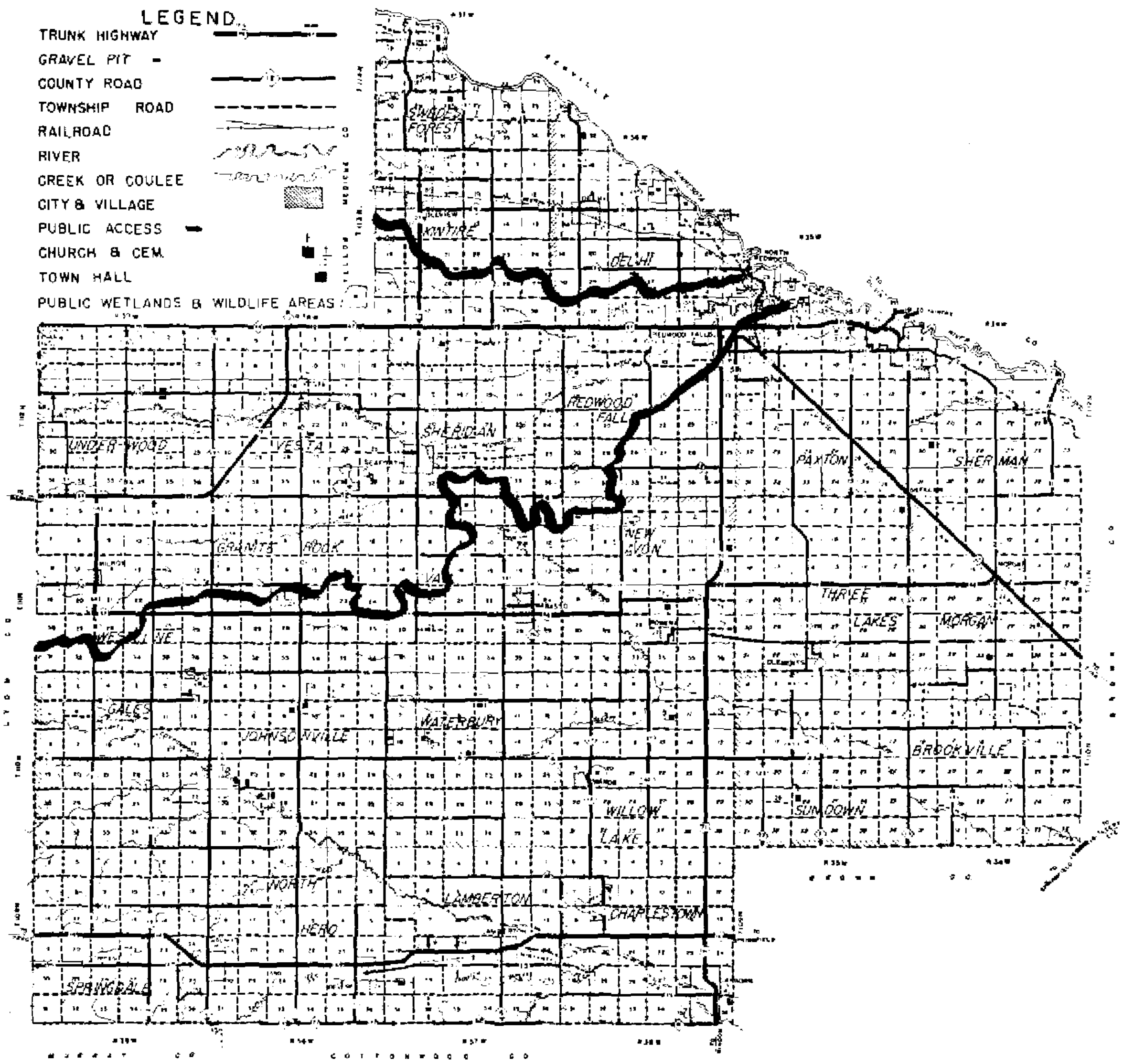


Figure 3-2. Watershed Boundary Within Redwood County
Redwood County. Highway Map. 1982. Thomas O. Nelson Co. Fergus Falls, Minnesota.

deposited high moraines on top of them (Waters 1977, 288).

The upland soils formed mostly in glacial till. Areas along the creeks, rivers and some hills formed in gravelly or sandy glacial drift.

Soils

The area under investigation in this study falls within six general soil associations. There are three upland associations which include the Canisteo-Ves, Canisteo-Normania-Okoboji and Canisteo-Ves-Storden Associations. They constitute 50, 3, and 20 percent of the watershed area respectively. The Estherville-Mayer Association occurs on outwash plains, terraces and moraines, and along rivers. It constitutes 15 percent of the study area. The Millington-Du Page Association corresponds to flood plains, occupying 9 percent of the total area of the watershed in Redwood County. The Terril-Swanlake-Storden Association occurs on river

REDWOOD RIVER WATERSHED UNIT

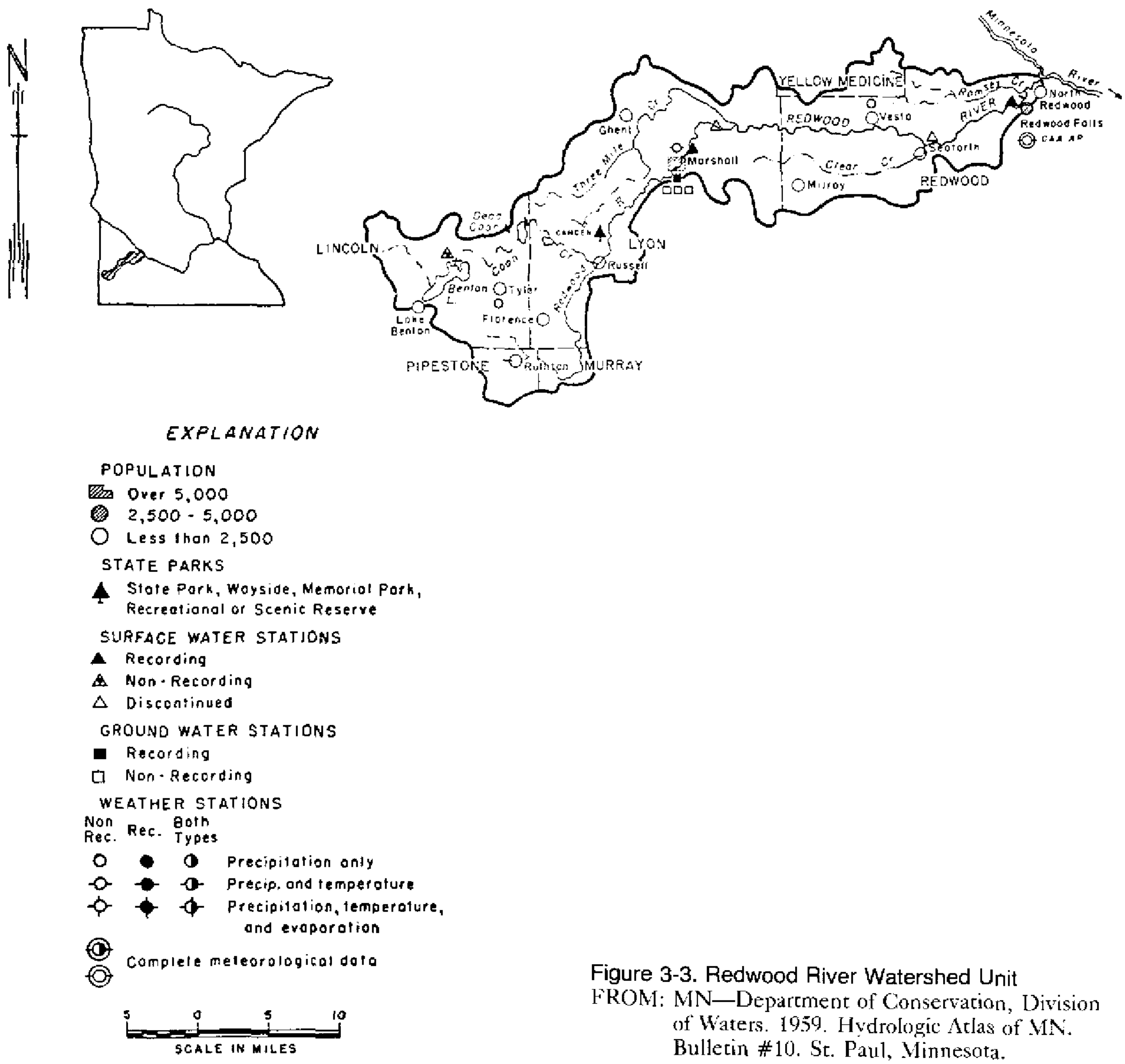


Figure 3-3. Redwood River Watershed Unit
FROM: MN—Department of Conservation, Division of Waters. 1959. Hydrologic Atlas of MN. Bulletin #10. St. Paul, Minnesota.

bluffs and foot slopes, and occupies only 3 percent of the watershed.

The following is a discussion of the general soil associations taken from the Soil Survey for Redwood County (USDA-SCS 1985, 7).

The Canisteo-Ves Association is made up of soils that are in broad areas of ground moraines. The slopes are short. Local relief ranges from two to ten feet in elevation. The Canisteo soils are poorly drained. Typically the surface layer is black clay loam about nine inches thick. The biggest limitations on this soil are wetness and fertility imbalance due to the high content of lime. The Ves soils are well drained. The surface layer is typically about ten inches thick and is black loam. Erosion is the main concern in management of Ves soils.

The Canisteo-Normania-Okoboji Association is made up of soils that are in broad areas of ground moraines that have short, irregular, convex knolls. These knolls range from one to ten feet above the floor of the lowland till plain. The Canisteo soils are poorly drained. Wetness is the main limitation of this soil. The Normania soils are moderately well drained, and are in broad, slightly concave to slightly convex areas. Typically the surface layer is black loam about six inches thick. The Okoboji soils are very poorly drained and occur within shallow, closed depressions. The surface layer is typically black silty clay loam about eight inches thick. Wetness is the main limitation on Canisteo and Okoboji soils. Tile drainage is needed to make these soils suitable for crops.

The soils which make-up the Canisteo-Ves-Storden Association are found in broad areas of ground moraines. The slopes are short with local relief ranges from two to twenty feet in elevation. The Storden soils are well drained, and occur on the steeper side slopes. The surface is usually about eight inches thick and a grayish brown loam. Erosion may be a hazard on the steeper slopes. Wetness may be a problem on the Canisteo and Ves soils.

The Estherville-Mayer Association is made up of soils in broad areas of outwash plains and terraces and on the adjacent escarpments. The Estherville soils are well drained. The surface layer is black sandy loam about nine inches thick. The Mayer soils are poorly drained. The surface is typically black loam ten inches thick. Wetness is a limitation in the swales, broad wet areas and depressions. Erosion is a hazard on the escarpments.

Soils in the Millington-Du Page Association are located on bottom lands along streams and rivers. The soils are subject to flooding and are often dissected by stream channels. The Millington soils are poorly drained. Typically the surface is made up of a black loam about eight inches thick. The Du Page soils are moderately well drained. They are on higher positions on the bottom lands and subject to occasional flooding. The surface is typically a black loam about nine inches thick. Flooding is the main concern for managing these soils.

The soils that make up the Terril-Swanlake-Storden Association are on bluffs, escarpments and associated foot slopes and fans along the Minnesota and Redwood rivers. The bluffs and escarpments are 100 to 200 feet above the flood plain. The Terril soils are moderately well drained. They are located on foot slopes. The suface layer is typically black loam about ten inches thick.

The Swanlake soils are well drained and on summits and shoulders along bluffs and escarpments. The surface layer is often black loam about nine inches thick. The Storden soils are well drained, and on convex summits and side slopes. Typically, the surface layer is dark grayish brown loam about eight inches thick. The main concern with these soils is the hazard of erosion. They are typically in pasture and woodland.

Hydrology and Climate

The average annual precipitation for Redwood County is 25 inches annually (USDI-Geological Survey 1970, Atlas 1). Of this, nineteen inches, or 80 percent, usually falls in April through September. In two years out of ten, the rainfall in April through September is less than fifteen inches. The heaviest one-day rainfall during the period of record (1961-1975) was 3.95 inches at Lamberton on September 21, 1968. Thunderstorms occur on about 45 days each year, and most occur in summer (USDA-SCS 1985, 2).

Rainfall data illustrates the fact that this area had an extremely wet year in 1985, with total precipitation for 1985 reaching 32.2 inches at Redwood Falls. This was 7.29 inches above normal (Smith 12/12/86, Interview).

The average seasonal snowfall is 38 inches. The greatest snow depth at any one time during the period of record was 23 inches (USDA-SCS 1985, 2).

Average annual run-off recorded at Redwood Falls in 2.20 inches (USDI-Geological Survey 1970, Atlas One). During the years of monitoring, at Redwood Falls (1911-1912, 1935-1966) the maximum discharge of the river was 19,700 cubic feet per second and the minimum discharge was no flow. The average discharge for 32 years was 99 cubic feet per second (USDI-Geological Survey 1970, Atlas Three).

Discharge records also exist for the tributaries which feed into the Redwood River within the county. The maximum and minimum discharge for Clear Creek at Seaforth, MN from 1959-1963 was 56 cubic feet per second and no flow, respectively. Ramsey Creek at Redwood Falls had a maximum discharge of 41 cubic feet per second and a minimum of no flow for the same years of monitoring (USDI-Geological Survey 1970, Atlas Three).

The highest average monthly rainfall generally occurs in June. This does not correspond with the highest average percent of annual flow which generally occurs in April. This is due to the fact that highest flow occurs during spring break-up. The highest sediment yield generally corresponds to high flow. The high yield can be explained by realizing that this is an important time for sediment transport of stored sediment. In addition, streambank erosion, channel scouring and upland erosion are all taking place during this period of high flow (Otterby 1978, 14).

The average temperature in the summer for Redwood County is 70F. The average daily maximum temperature is 82F. The highest recorded temperature for the period 1961 to 1975 occurred at Lamberton on July 11, 1966 and was 104F . In winter, the average temperature is 16F, with an average daily minimum temperature of 6F. The lowest temperature on record occurred at Lamberton January 22, 1970, and was -34F (USDA-SCS 1985, 1).

Most years, there are a minimum of 124 frost free days in Redwood County. In five years out of ten there are 143 frost free days. (USDA-SCS 1985, 109). The freeze-free growing season generally starts about the second week of May and ends during the first week of October (MN-Southern MN Basin Commission 1977, II-1).

Land Use

According to the 1982 National Resource Inventory Data, the following land use occured in Redwood County on non-federal land (in 1,000 acres): 493.7 acres in cropland, 22.9 acres in pastureland, 6.5 acres in ungrazed forest land, and 18.7 acres in minor land uses, which include farm buildings and mining and gravel operations. These values add up to a total of a total of 541,800 rural acres.

Non-rural, non-federal land use includes (in 1,000 acres): 3.5 acres in urban and built-up land, 16.5 in rural transportation, and 2.4 in small water areas.

Land use in the county is dominated by agriculture. Cropland occupies 88 percent of all the land in Redwood County, and is 91 percent of all the rural land. The next largest category of County land use is pastureland which occurs on four percent of the area. Other minor land use includes (agricultural dwellings) and rural transportation. Small water areas (water bodies less than 40 acres and perennial streams) occupy less than one percent of the entire area.

B. Sediment

The Redwood River has a long history of transporting sediment. Graphic evidence of this fact is Lake Redwood at Redwood Falls. In 1902, a private dam was constructed to provide power for a mill and a 160 acre reservoir for the community (US Dept of Army-Army Corps of Engineers 1978b, 2-1). Accumulated sediment behind the dam has rendered the lake virtually unusable (Schnobrick 6/25/86, Interview). Though there is no source of information on the original depth of the lake, recent engineering work shows approximately 25 feet of sediment behind the dam at Redwood Falls (MN-DNR 1986a, Architects Drawings).

The Minnesota Pollution Control Agency 208 Study indicates that sedimentation continues to be a problem in the Minnesota River Basin (MN PCA 1979, 211). Recent work on the Redwood River suggests that substantial amounts of silt continue to be transported to the outlet at the Minnesota River (MacFarlane 1978)(Otterby 1978)(Alvarez 1986). It is the object of this section to discuss sedimentation in the River and attempt to determine the percentage of sediment which may be attributed to agricultural sources.

In any waterway, there are potentially many sources of sediment. It may originate within the stream from streambanks and channel scouring, or it may be the result of wind and water erosion outside the stream. Upland agricultural activities, municipal run-off from new construction, road construction, gravel mining and drainage ditches all may contribute sediment to a waterway.

Agricultural Land Use and Erosion

A report by the Southern Minnesota River Basin Commission claims that the major source of sediment in the Minnesota River Basin is sheet erosion from cropland (1977, IV-7). The study maintains that other types of upland erosion, such as gullying and roadside erosion, may be locally severe but do not constitute a significant source of sediment pollution.

If the amount of land in agricultural production is used as an indication of a potential source of sediment, then the assessment made by the Commission for the whole river basin would be true for the Redwood River also.

National Resource Inventory Data for 1982 (USDA-SCS 1982) indicates that cropland occupies 88 percent of all nonfederal land in Redwood County (493,700 acres). Most of the cropland or 91 percent is in row crops (447,400 acres). The NRI data estimates that 65 percent of all cropland needs some conservation treatment for erosion (322,800 acres). The estimated annual average wind and water erosion for cultivated cropland (488,600 acres) in 1982 is 7.1 tons per acre.

There are approximately 127,360 acres of land in the Redwood River Watershed in Redwood County. If the same percentages of land use that exist for the county are true for the watershed, then there are approximately 112,077 acres of cropland in the study site. If the average wind and water erosion from cropland is 7.1 tons per acre, then annual erosion from cropland in the Redwood River Watershed is 795,746 tons.

Most eroded soil is redeposited on the field, leaving a small fraction to actually reach the River. A study of sediment delivery by Otterby and Onstad (1978) estimated that in the Redwood River Watershed, an average of 4.25 percent of all field erosion is transported to the waterway from fields in the upper reaches (around Marshall), while an average of .64 percent of total field erosion is transported to the waterway from fields in the lower reaches (Redwood County). In a statewide comparison, delivery of sediment in Redwood County is considered to be medium low, while in Lyon County the potential for sediment delivery is medium (MN-PCA 1979, 395). Assuming that .64 percent of all field erosion finds its way to the Redwood River within Redwood County, and there are 795,746 tons of sediment eroding annually, Redwood County alone contributes and estimated 5,093 tons of sediment to the Redwood River from cropland sources. This figure does not include erosion from any other agricultural sources such as forests, pastures, and farmsteads which constitute one, four and less than three percent of the county, respectively. The NRI data indicates that erosion from pastures and farmsteads is minor. Forest land was thought to have an erosion rate of 13.1 tons/acre, which would be significant in localized areas, but small on a county-wide scale.

Another part of the study by Otterby and Onstad analyzed sediment transport to the outlet for 12 watersheds throughout Minnesota. Based on USGS measurements of suspended sediment and Soil Conservation Service flow-duration curves they estimated the average annual sediment yield for the Redwood River. In Redwood County there were two monitoring sites. Their research estimated that average annual sediment yield was 25 tons per square mile in the Redwood Falls area and 61 tons per square mile in the Marshall area. The interesting aspect of this analysis was that they made the assumption that 100 percent of the suspended sediments measured by USGS could be attributed to upland erosion from agricultural sources. Since bedload could not be measured, this was considered to be either insignificant or contributed by other sources.

Research suggests that a substantial portion of sediment carried by the river is suspended silt and even finer materials (MacFarlane 1978)(Alvarez 12/31/86, Interview). Upland erosion contributes most of the fine-grained sediment that enters a river system, while streambank erosion contributes the coarse sediments that settle in the main and side channels (Upper Mississippi River Basin Association 1984, 1). Given the fact that the soils of the area are predominantly loams and these by definition are 7 to 27 percent clay, 28 to 50 percent silt and less than 52 percent sand (USDA-SCS 1985, 103) one would expect to find a high proportion of fine material in the waterways where upland erosion is occurring.

Observations by Tom Alvarez, who floated some stretches of the river in 1986, indicate that during the spring large amounts of fine sediment move down the River. His observations also indicate that spring flooding is very efficient in flushing sediment from the river (Alvarez 12/31/86, Interview).

MacFarlane, in his study of benthic organisms, felt that the majority of suspended sediment carried by the Redwood River was from agricultural sources. At his three study sites (Camden State Park, Vesta in Redwood County, and Ramsey below the dam), he noted siltation when flows decreased during the summer (Fig 3-4). The most serious siltation occurred at the Vesta site. Water was turbid gray from spring breakup until midwinter. During low flow in the summer, silt accumulated everywhere and reached several inches in depth in the quieter parts of the channel (MacFarlane 1978, 124).

Of the three sites McFarlane analyzed, he found the least sediment accumulation at the Camden site, followed by Ramsey then Vesta. His observations at the Ramsey site indicate that material finer than silt moves through the

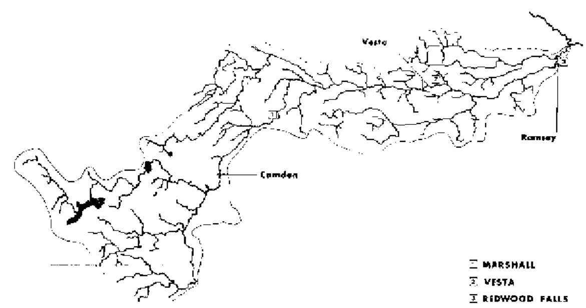


Figure 3-4. MacFarlane Study Sites
FROM: MacFarlane, Malcolm. 1978. "Effects of Silt on Benthic Macro-Invertebrates in the Redwood River, Redwood County, Minnesota". Dissertation. University of Minnesota. St. Paul, Minnesota.

reservoir to the outlet. Water at this site was turbid gray through the spring and gradually cleared through the summer. Like Alvarez, he found spring flooding to be very efficient in flushing accumulated bottom sediments from all three sites (MacFarlane 1978, 33).

A DNR Fisheries, found a ⅛ to ¼ inch layer of silt on all bottom substrates at his five study sites along the river. He too noticed that major storm events were efficient in flushing sediment (Hogg 1/6/87, Interview).

No sampling has been performed to determine the composition of the reservoir sediment. Observations suggest that the top layers are a black silty muck.

Streambank Erosion

The other major source of sediment to the Redwood River is from streambank erosion. The PCA *208 Study* considered this problem statewide. Based on data collected by the Soil Conservation Service, the entire Redwood River Watershed is listed as a having moderate level of streambank erosion when compared to other areas of the state (MN-PCA 1979, 396). In the headwater areas of the Redwood River, streambank erosion occurs at a medium-high rate. Lower reaches are considered to have a medium rate (MN-PCA 1979, 202).

The analysis, based on air photos and survey information, showed a total of 19.1 miles of eroded streambanks, with 4.9 miles considered to be severely eroded, 4.7 miles of moderate erosion, and 9.5 miles of negligable erosion (USDA-SCS 1978). Total length of the River is approximately 227 miles.

The categories were defined as the following:

Negligible—an eroding section greater than 10′ × 3′ × 1′ (length × height × recession) but less than 100′ × 10′ × 1′.

Moderate—100′ × 10′ × 1′ to 200′ × 10′ × 1′

Severe—greater than 200′ × 10′ × 1′

Tom Alvarez noted that on stretches of the river where channel work had been performed banks were vegetated and quite stable. He observed some areas of bank erosion, particularly where debris or islands (areas where a large portion of the bank had fallen into the river) were found. Generally, however, he felt that the streambank problem was not severe and felt that the SCS estimate of erosion was reasonable though should be used cautiously (Alvarez 12/31/86, Interview).

A biologist for SCS, who floated the river in 1986 felt that streambank erosion was not a primary source of sediment. During observations in June of 1986 he felt that Three Mile Creek in Lyon County was delivering large loads of suspended sediment to the Redwood River (Fink 8/12/86, Interview).

During a river survey in 1985 and 1986, streambank erosion was assessed to be moderate to severe. Erosion was particularly bad in areas where cultivation was close to the river (Hogg 1/6/87, Interview).

There is no question that streambanks are contributing sediment to the river. Large accumulations of debris, particularly in Lyon County, are good indications of eroded streambanks (Leedy 1979,13)(Alvarez 12/31/86, Interview). Additionally, sandbars of coarse material can be found throughout the River's length. Coarse material is thought to be the dominant particle size contributed by streambanks (Upper Mississippi River Basin Association 1984, 1).

Diane Vosick

Streambank erosion, Potter Farm, Redwood County, Minnesota

Following spring floods, Ken Marotzke, an area farmer, experiences both erosion and deposition on his 150 acre floodplain field. He mentioned that sand accumulates in some areas to the extent that it makes cultivation impossible (7/86, Interview).

Finally, it is possible to locate specific areas with serious problems. Danny Potter, who farms between Seaforth and Redwood Falls, has an area on his farm which has receded substantially over the last five years. The establishment of a vegetated sandbar on the inside of the river has caused substantial undercutting in his pasture along the outside meander.

The issue concerning streambank erosion is not only to what extent it is actually contributing sediment, but whether or not the erosion is natural or man induced. Some would argue that the river is young and therefore still actively searching for equilibrium. Under these circumstances, it could be said that sediment due to streambank erosion is natural. Others would argue that the change in drainage practices over the last 80 years has substantially altered river hydraulics, producing a "new" river which is attempting to create a new channel.

In the case of the Redwood River, it is important to understand stream channel geometry change. The following is a discussion taken from a study performed by John Leedy in 1979.

"Stream channels are sensitive to the prevailing hydrologic conditions and will develop morphologic (structural) characteristics which will be in equilibrium with these conditions. The two principal hydrologic factors which affect channels are surface runoff and sediment yield. Surface runoff mainly determines streamflow and the cross-sectional capacity of the stream. Sediment yield, or the amount of sediment entering a stream controls the channel pattern and aspects of channel geometry, such as the depth-width ratio. The amount of sediment a stream will carry depends on volume and velocity. If you increase those factors, you will increase the sediment-carrying capacity of the stream. Therefore, if rapid drainage increases the amount and velocity of water flowing down the river, it would follow that the river would be capable of carrying more sediment. If the sediment is not delivered totally from upland sources, then the river will seek sediment from the channel and streambanks."

The *208 Study* suggests that on an annual basis in almost all waters of the Minnesota River Basin, most sediment may be attributed to agricultural activities. They feel that these activities accelerate upland and streambank erosion, and also lead to drainage ditch erosion (MN-PCA 1979, 202).

Observations of increased severity of streambank erosion where cultivation is close to the river also support the concept that part of the problem is man-induced (Hogg 1/6/86, Interview).

On the other side of this issue, a Regional Soil Scientist for the SCS feels that 60 to 85 percent of the sediment delivered to the waterway is "natural" (Paulson 7/30/86, Interview). A SCS geologist however, feels that the Redwood River is very complex, and that upland sources of sediment are not the primary contributor of sediment (Alvarez 12/31/87, Interview).

To further complicate this problem, erosion which is occurring within the channel and floodplain may be transporting sediment deposited as a result of agricultural activities years ago (Phillips 1986, 248). In this case, what may appear as "natural" may be agricultural sediment which was eroded and deposited during the earlier part of the century.

Community opinion on this topic is divided also. One individual interviewed felt that 100 percent of the sediment in the river was due to agricultural inputs. Another individual felt that all sediment originated from streambank erosion. Clearly, this is an area that deserves further study.

Other Sources of Sediment

Other potential sources of sediment in the area include, new municipal construction, drainage ditches, roadside ditches and gravel operations.

Municipal—The following towns and cities exist within the study site: Milroy (pop. 242), N. Redwood (pop. 206), Redwood Falls (pop. 5,210), Seaforth (pop. 20) and Vesta (pop. 360) (Spadaccini 1983, 339) (Fig 3-2). With the exception of Redwood Falls, all the towns are quite small. The likelihood of new construction from any of the municipalities releasing significant amounts of sediment into the river is unlikely, especially in light of the depressed economy.

Drainage Ditches—During improvement, clean-out or construction in drainage ditches, erosion does occur. Bank slumping and the channel itself may also provide sediment. According to the *208 Study* there is medium potential for erosion from drainage ditches in Redwood County when compared to other areas of the state. Drainage ditch and gully erosion are caused by agricultural activites. For this reason, the amount of sediment contributed by ditches and gullying will be considered as part of the overall sediment contribution due to agricultural sources.

Roadside Ditches—Roadside ditch erosion is not considered to be a significant source of sediment in the Minnesota River Basin (MN-Southern MN River Basin Commission 1977, IV-7). Sediment contribution from roadside ditches may occur in localized areas. However, in the annual cycle of sediment delivery to the waterway, these are considered minor.

Gravel Operations—According to records at the Pollution Control Agency, no discharge permits exist for gravel mining in Redwood County (MN-PCA 1986a). A permit would be required if water was discharged to the River. This would indicate that gravel mining does not contribute sediment to the River.

Conclusion

Attempting to determine the sources of sediment in the Redwood River based on existing data is purely speculative. Recent research on the River suggests that the majority of sediment is from agricultural sources. National Resource Inventory data for 1982 supports this idea, indicating that a majority of land in the watershed is under cultivation, and that an average of 7.1 tons per acre of sediment is eroded from cropland annually. A recent study of sediment delivery also assumes that a majority of the sediment in the river is derived from agricultural sources (Otterby 1978). Also contributing sediment is erosion from drainage ditches, which is expected to have a medium level of occurance when compared to the state as a whole (MN-PCA 1979, 468).

The other major source of sediment in the river is from streambank erosion. Some individuals maintain that streambank erosion is a naturally occurring phenomenon and should not be construed as caused by agricultural activities. Others maintain that streambank erosion is due to a change in the river brought about by increased drainage and improper farming practices.

The SCS estimates that there are approximately 19.1 miles of streambank erosion along the Rewood River. This compares with an overall river length of 227 miles. There is no doubt that this problem is quite severe in localized areas.

For purposes of this analysis, it will be assumed that agricultural activities contribute 75 percent of the sediment in the Redwood River. Streambank erosion has been combined with minor sources such as municipal construction, roadside ditches and gravel operations. These sources are estimated to contribute 25 percent. Though it could be argued that streambank erosion is also related to agricultural activity, the amount of natural vs. agriculturally induced erosion is difficult to assess. For purposes of this analysis streambank erosion will be treated seperately.

This estimate should not be construed as anything but a best guess based on research and intuition. Without further sediment analysis, it is impossible to definitively determine the sources of sediment in the River.

C. Biological

The impacts of sediment on biological communities is not completely understood. The chapter entitled "Checklist" discusses some of the biological damage caused by sediment. Due to the difficulty of assigning economic values to living organisms, the cost of sediment-related damage to biological systems will not be determined.

Biological damage is defined as injury to plants or animals at any trophic level. Of particular concern in sedimentation studies is the impact sediment may have on primary producers (plants) and invertebrates. These are the lowest members of complex food webs which support fish and other wildlife.

Benthic Organisms

In a 1978 thesis entitled *Effects of Silt on Benthic Macroinvertebrates in the Redwood River, Redwood County, Minnesota*, M.B. MacFarlane considers the impact of sedimentation on macroinvertebrate communities at three sites on the river. In his literature review, he states that some research suggests that the deposition of fine sediment in streams reduces the abundance of benthic invertebrates. However, he states that no unanimous opinions exist concerning the main effect of silt on benthic invertebrate communities

His results suggest that the three communities under investigation vary in many respects, some of which are related to silt directly, some indirectly and some not at all. Variations exist in the population, density and presence of certain species at the different sites. In general, he concludes that the Redwood River has been undergoing incremental change as a result of increasing silt and nutrient loads, and its communities are in approximate adjustment with that change.

The most serious generalized effect he did notice for the Redwood was the impact of extreme discharges during certain periods of the year. High flow has a major destabilizing influence at all three communities. Extreme discharge scoured the substrate and depleted the benthic populations.

From MacFarlane's research, it can be concluded that although a variety of effects due to sediment were noted for the benthic macroinvertebrate community, some which were deleterious in certain locations, he did not notice an overall catastrophic alteration of the community due to sediment.

Fisheries

The Department of Natural Resources has been conducting a survey of the Redwood River in 1985 and 1986 to determine the existing condition of the fishery, and evaluate its potential for improved management. The survey has also generated data from which to evaluate the effects of proposed channel work for the entire River.

The two principal limiting factors for fish in the River are fluctuation in flow and siltation. No natural reproduction of game fish was found above the dam at Redwood Falls (Hogg 1/6/87, Interview). It is difficult to assess the total damage caused to fish populations in this area because it is unknown what species and in what numbers were present historically. Natural barriers at Redwood Falls may have always prevented migration up river (Hogg 6/24/86, Interview). At the present time it would be impossible to establish a self-sustaining game fishery above the dam in Redwood County because of water quality problems (1/6/86, Interview).
The survey found that invertebrate populations may be limiting at certain sites along the River. The habitat where invertebrate populations are low, would be physically unsuitable to game fish.

At Lake Redwood, crappie, northern pike and blue gill are stocked on a regular basis. No natural reproduction occurs in these populations. The shallowness of the Lake Redwood due to siltation occasionally results in winter fish kills.

Below the dam, natural reproduction of game fish may occur. In this area flow is the most critical variable affecting the population (Hogg 1/6/86, Interview).

Endangered and Threatened Species

The Minnesota Department of Natural Resources Natural Heritage Program was contacted concerning the presence of any threatened or endangered species associated with the Redwood River (Coffin 9/25/86, Interview). According to their records there are no species listed.

D. Recreation

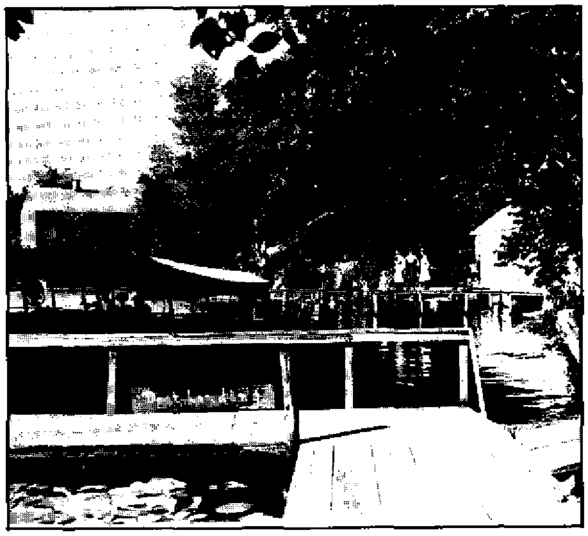
". . . the dam will form a beautiful lake which is to be stocked with fish and which can be used for boating, bathing and other purposes." *Redwood Falls Gazette,* May 9,1900.

"The problem of what to do about Lake Rewood steadily filling with silt from upstream has been facing Redwood Falls for a long time. . ." *Redwood Falls Gazette,* July 2, 1957.

Recreation at Lake Redwood since the reservoir was established in 1902 has deteriorated. It is a casualty of silt that has accumulated over the past 80 years almost filling the 35 foot deep basin (MN-PCA 1986b, 14). Boat use in the 1980's is almost nonexistant, restricted to the day before fishing season opens when people use the boat launch to check if their engines are working properly.

The loss of this recreation resource is particularly tragic in light of the fact that there are no other recreational lakes in the county. Lake Redwood once provided opportunities for boating, picnicking, swimming and fishing. As recently as 1974, fisherman were seen frequently on the Lake (Thoreson 7/1/86, Interview). Today, much of the lake-based recreation needs of the community are exported to other areas in the region.

In general, the southwestern corner of the state (Region Eight according to the DNR, which includes Lincoln, Lyon, Pipestone, Murray, Cottonwood, Rock, Nobles, Jackson and Redwood counties) is deficient in offering some recreational opportunities to area residents. Region Eight has 1.51 percent of total state acres in parks, or 80 acres per1000 people, in contrast to the statewide average of 104 acres per 1000 people and 1.91 percent of the state total footage in swimming beaches, or 50 feet per 1000 people in contrast to a statewide average of 106 feet per 1000 people (MN-DNR 1985a, Chapter 3). The Region has only a .1 percent share of the State's "Fishing Lakes" (MN-DEED 1978, 7).



Minnesota Historical Society
Boat landing, Lake Redwood, Redwood Falls, Minnesota, circa, 1915

The real loss of Lake Redwood is experienced by the community. Residents often complain about the lack of recreational resources in the immediate vicinity (Thoreson 7/1/86, Interview). A 1968 survey by the Redwood Falls Planning Commission revealed that using natural areas, and hunting and fishing are by far the most popular forms of outdoor recreation for County residents. The *1985 MN State Comprehensive Outdoor Recreation Plan* (SCORP) indicates that a desire for more water-oriented facilities ranked third among statewide households surveyed about their preference for recreational facilities. In Region Eight, 43.0 percent of those surveyed requested more natural park-like areas, 41.9 percent requested more swimming beaches, 38.4 percent expressed a desire for more campground facilities, and 34.0 percent wanted to see more picnic facilities (MN-DNR 1985a, 4.062).

Analysis

Because siltation in Lake Redwood has had a measurable impact on recreation use, it is possible to develop an economic approximation of the loss of this resource. The Redwood River above and below the dam have also suffered damage due to sedimentation. However, because it has not had as noticeable an affect on recreational use, and because some of the environmental problems in these areas are related to factors other than sediment, they will be treated with a narrative discussion only. No attempt will be made to measure associated economic impacts.

Redwood River Above Redwood Lake—According to various interviews, the principal recreational use of the River above the Lake is for fishing, hunting and snowmobiling (Thoreson 7/1/86, Interview). Occasionally canoeists will attempt to float the River between bridges, however debris hampers this recreational use (Salmon 7/1/86, Interview).

Hunting for wood ducks is a common fall activity along the River. Muskrat, mink and beaver trapping also occurs here. Neither activity is known to be impacted by sediment (Thoreson 7/1/86).

Snowmobiling is a winter activity that uses the frozen river as a trail. It is not impacted directly by sediment, though may be indirectly affected by the presence of debris caused by streambank erosion.

Fishing is potentially most sensitive to the effects of siltation. According to one expert, the river receives a fair amount of local use for bullhead fishing; one or two people can be found fishing at most bridge crossings on April and May weekends. Though game fish such as walleyes were found to inhabit the river above the dam, there does not appear to be appreciable use for sport fishing (Hogg 1/6/87). Use of this segment of the River has declined in recent years.

The deleterious affects of sediment to fisheries were discussed in this Chapter under biological impacts. The fact that both flow and sediment limit fish populations in this section of the river confuses an economic analysis. Another complication is the fact that it is unclear to what extent natural fish populations ever occurred in this stretch of the River. The falls near Ramsey Creek may have been a barrier to upstream migration. Finally, the lack of convenient public access to this segment of the River may hinder recreational use.

Redwood River Below the Dam—The Redwood River takes on a whole new character as it plunges 100 feet from Redwood Lake to the Minnesota River. What was once a sleepy prairie river changes into a scenic rushing stream cutting through deep gorges as it flows through Ramsey Park.

The segment from below the dam to the outlet at the Minnesota River receives significant recreational use. Tubing, canoeing, fishing, nature study and hiking are all possible along this stretch. Ramsey Park offers a scenic campground with 28 camping sites, a picnic ground and small zoo.

Ramsey could clearly be described as a water-based park. Immediately after school closes in June, for approximately two weeks, between 30 and 40 children a day float the River in inner tubes from below the power plant to the park bridge (Salmon 7/1/86, Interview). Canoeists can be found launching their boats at the Park for a 90 minute float to the River outlet.

Fishing is particularly good in this area because Ramsey Creek, which flows into the Redwood at the Park, is managed for brown trout. For the first three weeks after the trout season opens, there is tremendous use of the River. Twenty to 30 people per day may be seen fishing during this peak period. During July fishing continues at a rate of about five to ten people per week. By summer's end fishing shifts exclusively to Ramsey Creek, where five to ten people a week can be found angling for trout (Salmon 7/1/86, Interview).

Camping and fishing attract a substantial amount of local use, with some tourists from Iowa visiting the Park. During summer weekends, all camp sites will be occupied. During the week the average is five to ten units. Up to 50 seperate camping units have been recorded staying in the park during the Fourth of July holiday (Salmon 7/1/86, Interview).

Poor water quality, however, may be diminishing the total number of people using the River. If water quality was improved, visitor use of the area would probably increase (Salmon 7/1/86, Interview).

A DNR Fisheries Technician feels that this River segment offers the best possibility for improved fish management. Natural reproduction is thought to occur in this stretch of the River. The presence of sauger and walleye create the potential for quality sport fishing.

The principal limiting factor for improved fish management on this segment of the River is fluction in flow. It would be necessary to maintain a minimum flow through the summer to sustain a game fish population. Because the issue of flow is the most critical physical factor in this segment, and because it limits River use for canoeing, tubing and fishing, it is not possible to analyze the impact of sediment on recreational use.

Lake Redwood—The value of recreation lost to the community due to sediment in Lake Redwood was approximately $10,755 in 1985. Agriculturally derived sediment is estimated to constitute 75 percent of the silt in the Lake. The amount which may be attributed to agricultural erosion is $8,066 or 75% of the total. These figures were derived by following the procedures outlined in the Chapter entitled "Checklist," and are based on a number of important assumptions. The economic value represents an educated, conservative approximation of the value of recreation to the community in the hypothetical situation that the Lake is free of silt. The Worksheets for calculating this value may be found at the end of this section.

The following is a brief discussion of the assumptions made for the Lake Redwood analysis. The most critical assumption is that use of Lake Redwood would increase if silt were removed. This assumption is supported by interviews with many members of the community, *The State Comprehensive Outdoor Recreation Plan*, and based the population of the surrounding area.

The second assumption is that the value of a recreation unit or the economic value of one individual participating in one recreational activity is $5.49/day. This is based on Soil Conservation Service methods for evaluating federal water projects (Stokes 12/9/86, Interview). This value could be criticized as high for some activities and low for others. It should be perceived as a generalized value.

The third assumption is that there would be no upgrading of existing recreational facilities. In other words, though a clean lake may support swimming, it was not included in the hypothetical analysis because swimming areas are not present on Lake Redwood.

The amount of current recreational use for each activity included in the analysis is based on interviews. Unfortunately, no census data exists for recreational use of the Lake. The hypothetical values on Worksheet Two are based on conservative guesses, historical use, and what the resource might logically sustain. The units or occasions on the worksheet represent individual participation. It is assumed, that there are an average of five individuals per family unit (Madsen 7/21/86, Interview). For recreational boating and waterskiing, an average of 3 individuals was used in the calculation.

Warmwater Fishing—The season is from April and May. Current use is limited to weekends and is very occasional. In a hypothetical situation, the Lake would experience an increase in use, particularly from outside the local community (Thoreson 7/1/86, Interview).

Sport Fishing—Most sport fishing occurs between the season opener (May 18th in 1985) and labor day. Currently, there is almost no use of the Lake even though it is periodically stocked with blue gills, northern pike and crappie. In a clean situation the lake mangement could be adjusted to better suit demand. It is resonable to assume that five boats with two people on a weekend day could be supported by fishing in Lake Redwood (Hogg 1/6/87, Interview).

Ice Fishing—The season for game fish extends from approximately December through February 15. Current use is very occasional based on observations. With improved stocking, more ice fishing could be sustained. (Hogg 1/6/87, Interview).

Picnicking—The season was determined to be from Memorial day through Labor Day. Occasional travelers use the picnic tables along the Lake at Perk's Park (Thoreson 7/1/86, Interview). With an improved resource, more picnicking in association with boating and fishing may occur. This area is expected to see an increase in demand for picnicking by 1995 (MN-DNR 1985a, B.022).

Recreational Boating- Boating season is from Memorial Day through Labor Day. Current use for waterskiing is restricted to one group of individuals (Hammerschmidt 6/25/86, Interview). In previous years, there were as many as five or six waterskiing boats on the weekend (Thoreson 7/1/86). With a clean lake, more recreational boaters would use the area.

Total Value of Benefits Lost to Recreation Due to Agricultural Sources of Sediment

Category	Cost
Redwood River Below Dam	Undetermined
Lake Redwood	$8,066
Redwood River Above Lake	Undetermined
Total	$8,066

E. Water Storage

Sediment in Redwood Lake impacts recreation, the dam at State Trunk Highway 19, and power production at the hydroelectric plant. Recreation was discussed in detail in the previous section.

Sediment in the reservoir has not resulted in any direct cash outlays to remedy the problem. Members of the community have discussed the possibility of dredging the Lake, however this plan has not progressed beyond the talking stage. Estimates of the cost of such an operation have not been obtained (Finley 6/3/86, Interview).

The Dam

During 1986, The Public Utilities Commission in cooperation with a private engineering firm and the Department of Natural Resources Division of Dam Safety have been developing plans to repair the dam just beneath the Highway 19 bridge. Over the past few years, it has been discovered that structural work is necessary to improve the dam's safety. Sediment exerts some pressure on the dam, however it is not a significant part of the safety problem (Regalia 6/27/86, Interview).

The major factor impacting the dam relates to the original construction. According to a private engineering consultant, 99 percent of the safety problems are due to poor construction (6/20/86, Interview).

Based on interviews, it is clear that sediment is not a significant part of the problem creating the need to repair the dam.

Power Production

Sediment in Lake Redwood has displaced water storage capacity that could be used for power production. According to the Public Utilities Commission, this limits the amount of power that can be produced at the local hydroelectric plant.

Other factors are also known to render increased power production unfeasible (Weber 6/30/86, Interview). A 1983 report by the University of Minnesota Hydraulics Lab evaluated the potential for increased power production for existing dams in the State of Minnesota. The report considered a number of variables in exploring the feasibility of increased power production, but did not consider the effects of siltation behind the dams (Gulliver 6/30/86, Interview). Increased power production by the Redwood Falls facility was determined to be unfeasible based upon inadequate flow.

An official at the Public Utilities Commission also stated that even if there were more storage capacity in the lake, the draw-downs which would be necessary to provide power during peak demand in August would be met with citizen resistance.

Sediment does appear to have a negative impact on power production. Unfortunately, the economic implications could not be determined in light of complicating factors related to flow.

In response to questions concerning the impact of sediment on turbines and other power plant equipment, no measureable damage has been noted.

FORM

1. Name of Resource(s) — Size

Lake Redwood — 160 acres

2. Towns and Population within a 50-mile radius

Town	Population
Redwood, Lyon County	Area Population
Portions of: Murray, Yellow Medicine Chippewa, Kandiyohi, Renville, Meeker, McLeod, Sibley, Nicollet Counties	161,000

Other Recreation Sites

Very few lakes except on the periphery of 50-mile radius

Renville and Redwood Counties have no state parks

Within county are 13 Wildlife Managements Areas

3a. Percentage of damage linked to sediment and associated contaminants_________________(100%)_____________________

3b. Percentage of sediment and contaminants contributed by cropland sources_____________(75%)______________________

3c. Percentage of damage attributable to cropland sources. (3a)____(1.0)____ x (3b)____(.75)________=__(.75)or 75%

4. Value of a daily recreation unit__________($5.49)_______

5. Economic value of current recreation:

Total from Worksheet No. 1_____(176)____x Unit/Day Value (No. 4 above).

__($5.49)___= Total value of current recreation__ ($966.24)__

6. Economic value of recreation in the hypothetical unpolluted area.

Total from Worksheet No.2__(2135)_____x Unit/Day Value (No.4 above)__($5.49)__= Total value of unpolluted recreation________________($11,721.15)________________

7. Economic benefit of recreation in an unpolluted area:

Total value of unpolluted recreation (No.6)_($11,721.15)

Total value of current recreation (No.5)_($966.24)_=Value of unpolluted resource__($10,754.91_)

This calculates the amount of economic benefit that might be realized in an unpolluted resource. It also represents the amount of economic damage caused by sedimentation at the present time.

8. Total amount of damage attributable to agricultural sources:

Total recreation damage (No.7)_($10,754.91)___x percentage due to agricultural sources (No.3c)___(.75)__=Total amount of damage to recreation due to agricultural sources

____________($8.066.18)______________

B. Boating Accidents

9. List boating accidents which may have resulted from sediment and the amount of damage associated with them.

Accident	Damage
Ø	

TOTAL---Ø

10. Total amount of accident damage attributable to cropland sources.

Total Damage (No. 9) x Percentage due to cropland sources (No. 3c) = __________(Ø)____________Total Accident damage.

C. <u>Total Recreation Damage</u>

Category	Costs
A. Recreation	($8,Ø66.18)
B. Boating Accidents	(Ø)
C. Total	($8,Ø66.18)

Worksheet One

Year 1985

Current Use

Recreation Activity	a Activity	b # of Weekdays in Season	c # of Weekend days in Season	d # of Occasions on Weekdays	e # of Occasions on Weekend days	f Multiply Column b x d	g Multiply Column c x e	h Add Columns f + g
1. Fishing (summer) a. Warmwater	x	45	16	0	2	0	32	32
b. Sport	x	68	35	0	1	0	35	35
Fishing (Winter) c. Ice Fishing	x	55	20	0	1/2	0	10	10
2. Picnicking	x	60	33	0	10	0	66	66
3. Boating	x	60	33	0	3	0	33	33
4. Camping	0							
5. Swimming	0							
6. Waterfowl Hunting	0							
7. Tubing	0							

Total Recreation Units 176
(Sum of Column H)

Worksheet Two

Year 1985

Hypothetical Use

	a	b	c	d	e	f	g	h
Recreation Activity	Activity	# of Weekdays in Season	# of Weekend days in Season	# of Occasions on Weekdays	# of Occasions on Weekend days	Multiply Column b x d	Multiply Column c x e	Add Columns f + g
1. Fishing (summer) a. Warmwater	x	45	16	1	3	45	48	93
b. Sport	x	68	35	2	10	136	350	486
Fishing (Winter) c. Ice Fishing	x	55	20	0	1	0	20	20
2. Picnicking	x	60	33	5	20	300	660	960
3. Boating	x	60	33	3	12	180	396	576
4. Camping	0							
5. Swimming	0							
6. Waterfowl Hunting	0							
7. Tubing	0							

Total Recreation Units 2,135
(Sum of Column H)

F. Property Values

Some of the most valuable residential property in Redwood Falls borders Lake Redwood. An attempt was made to determine if siltation of the reservoir had diminished property values along the Lake.

According to the County Appraiser, real estate values along the Lake have remained strong despite a generally depressed real estate market in rural areas. Lots along Lake Redwood are appraised for an average of about $20,000. This compares with lots elsewhere in the city which appraise for around $9,000 (Hammerschmidt 6/25/86, Interview).

The principal value of the Lake by homeowners is aesthetic. The steeply sloping banks on the east side create some access problems for recreational use. A few homeowners have experienced lakeshore damage in recent years due to high water and unusual amounts of precipitation and runoff (Schnobrich 6/25/86, Interview) (Galles 7/1/86, Interview). This damage does not appear to be linked to sediment in the reservoir.

Lakeshore property would probably be even more valuable if Lake Redwood were free of sediment. However, lake homes are already at the top of the real estate market, and that the increase in value would be small (Hammerschmidt 6/25/86)

Any attempt to measure the effects of sediment on property values would require a comparison of Lake Redwood with a similar lake that is free of sediment. Since there are no comparable lakes in the immediate vicinity, this analysis was impossible.

G. Flooding

Flooding has always been a problem along the rivers flowing off the Coteau des Prairies to the Minnesota River. Major floods occur one or two years out of ten and are generally associated with spring break-up in April (MN-Southern MN River Basin Commission 1977, IV-11). The average annual flood damage for the Yellow Bank, Lac Qui Parle, Yellow Medicine, Redwood and Cottonwood Rivers is estimated at $5,747,000 in 1977 dollars (MN-Southern MN River Basin Comm. 1977, IV-13).

The Redwood River is estimated to have 46,400 acres in floodplain (MN-Southern MN River Basin Commission 1977, IV-13). By definition, the floodplain corresponds to the area innundated by a major flood with the probability of occurance every 100 years. During a preliminary study of the Redwood River in 1980 it was estimated that the average annual acreage of flooding is 32,788 acres. The total economic damage caused by annual flooding is estimated to be $2,087,776 (1980 dollars) broken down accordingly: crop damage, $1,277,620; other agricultural damage, $148,115; soil damage, $255,524; transportation damage, $229,516; and indirect damage, $177,001 (USDA-SCS et. al.1980, 31). A detailed analysis of the Redwood River Basin is currently underway. Early findings suggest that 1980 values may have overestimated total damage (Stokes 1/12/87, Interview).

The average annual acreage affected by flooding in Redwood County is 405 acres. The floodplain, or area of 100 year floods, is an area of 4,425 acres (Stokes 1/9/87, Interview). Economic data for flood damage is currently being collected.

Most damage associated with flooding is a result of excess water. However, sediment associated with floodwater can increase the total amount of flood damage. Bed aggradation, or the elevation of the river channel through the deposition of previously eroded sediment, can cause water which might normally remain in the channel to breach the river banks. Large quanitities of sediment in suspension may increase the volume of flood water, thereby increasing flood damage. Finally, sediment deposition over a long period of time may result in swamping.

Bed Aggradation

According to a SCS geologist, the Redwood River does not show evidence of bed aggradation. His opinion is based on casual observations of the bottom substrate. He feels that further research is needed to totally understand the dynamics of the river (Alvarez 12/31/86, Interview).

An analysis of sediment yield by Otterby and Onstad found that 88 percent of the sediment leaving the fields around Marshall reached the outlet at the Minnesota River. Downstream in the Redwood Falls area, 56 percent of the sediment leaving a field reaches the outlet (MN-PCA 1979, 191). Clearly some deposition is occurring within the watershed. Where it is occurring and its affect on stream bed aggradation are uncertain.

In light of the lack of research on the Redwood it is impossible to determine if bed aggradation contributes to annual flood damage.

Increased Volume Due to Sediment

A method for calculating the increase in floodwater volume due to sediment was outlined in the Checklist. It is based on research performed by the Conservation Foundation and assumes that the percentage increase in floodwater caused by sediment is directly proportional to the percentage of damage associated with flooding.

It is extremely difficult to isolate the individual cost of sediment-related flood damage from water-related damage. The procedure provided in the checklist is a means of providing an overall estimate of the cost of sediment. Such damages as the cost of culvert clean-out, removal of sediment deposited on farm fields and in urban areas, and the value of reduced yields caused by the deposition of infertile material on the floodplain would be reflected in this figure.

There has been little monitoring of suspended sediment in the Redwood River. The highest maximum average of monthly sediment concentrations at Redwood Falls was found to be 332 milligrams per liter (Otterby 1978,6). The highest maximum of average monthly concentrations upstream, was found to be 1,367 milligrams per liter at Marshall in Lyon County. Neither of these values is large enough to appreciably increase the volume of floodwater. Therefore, it was impossible to determine a dollar value of sediment damage using this method. (See Worksheet at the end of this section.)

An effort was made to try to determine specific flood damage information. Individuals from the Federal Crop Insurance Program and the Agricultural Stabilization and Conservation Service (ASCS) were contacted. Records of individual claims by farmers insured under the Federal Crop Insurance Program do exist. However, data concerning the specific cause of the claim is not maintained in the program files. Crop insurance is comprehensive and covers many types of damage. It was impossible to obtain specific information about the type of damage sustained by individuals. Another limitation of this information is that not all farmers are covered by the insurance (Archer 7/10/86, Interview).

The Agricultural Stabilization and Conservation Service (ASCS) cooperatively funds repair projects associated with flood damage. For ASCS to become involved, the county must be declared a Federal Flood Disaster Area. Since no major floods have occurred along the Redwood River in recent years there has been no involvement by ASCS in response to flood-related damage. In the event of a major event this would be a good source of economic information (Miller 7/10/86, Interview).

Sediment damage occurs along the Redwood following spring flooding. One farmer estimated that in the last four years he has lost $120,000 to flooding. This value includes the loss of crops, fertilizer and indirect expenses which are sediment-related. Each year he loses a portion of his 150 acre floodplain field. Sand which is deposited in piles of up to sixteen inches in depth create havoc with his farm machinery. Gullying also contributes to his problems (Marotzke 7/86, Interview).

It was impossible to determine a generalized value for sediment-related flood damage. A complete analysis would have required surveying all farmers in the floodplain. The current SCS analysis of flooding along the Redwood River will provide overall estimates of the economic cost of flood damage. Within these estimates, a portion can be attributed to problems associated with sediment.

Swamping

One hundred percent of the damage caused by swamping is attributable to sediment. Delays in planting or damage to crops already in the field are a result of impeded drainage caused by this phenomenon. The SCS study on the Yellow Medicine River estimates that the average annual cost of swamping damage is $34.28 per acre (Stokes 1/12/87, Interview).

Approximately 729 acres of land in Redwood County is potentially impacted by swamping (Stokes 1/12/87, Interview). Based on the cost generated in the Yellow Medicine study, the cost of this damage in Redwood County alone is approximately $24,990. Previous calculation estimate that 75 percent of the sediment in the Redwood River is derived from agricultural sources. Therefore, the total cost of swamping caused by sediment eroded from farm fields is $18,743.

Some important assumptions were made for this calculation. First, swamping is a legitimate man-caused damage. Although some individuals remain skeptical that this phenomenon is exacerbated by man's activities, the SCS maintains that it is a significant part of all flood damage, and that man's activities contribute to a majority of the problem.

The second assumption is that the cost assessment of damage caused by swamping in the Yellow Medicine River Basin is transferrable to the Redwood River Basin. This requires that the rivers be geomorphologically similar, and that land-use practices are the same.

It is generally believed that the five rivers which arise from the Coteau des Prairies are similar in most physical respects (Waters 1977, 290). It is important that land-use be similar also, because the estimate of the average annual value of swamping depends on a similarity in cropping between the two basins. In other words, the percentage of corn to soybeans to small grains must be similar since the cost of damage will vary depending upon the crop. Land-use in the two basins is sufficiently similar to assume that a generalized value for swamping damage in one basin will be true for the other (MN-Southern MN. River Basin Commission 1977, II-6).

Total Cost of Sediment Damage Associated With Flooding

Category	Cost
Bed Aggradation	Undetermined
Increased Flood Volume	Undetermined
Swamping	$18,743
Total	$18,743

Flood Damage-Worksheet

Part A. Amount of Total Damage Caused by Increased Flood Volume Due To Sediment

A-1. Total amount of flood damage _____ (2,087,776) entire river _____

A-2. Maximum amount of suspended sediment_______ (332 mg/l) _______

A-3. Percentage of increase in flood volume due to suspended sediment (refer to graph) ________ (negligable)_______

A-4. Economic value of the damage caused by sediment (A-1) x (A-3) ________________________ (undetermined) ___________________

A-5. Amount of damage due to agricultural sources (A-4) x Percentage of sediment contributed by cropland sources ______________________ (undetermined) ____________________

Part B. Damage due to Swamping

B-1. Total damage due to swamping ___________ ($24,990) _______

B-2. Amount of damage due to agricultural sources (B-1) x percentage of sediment contributed by cropland sources. ___________ ($24,990) x (.75) = ($18,743) ____________

Part C. Total Flood Damage

Category	Cost
A. Increased Volumne------------_____	(undetermined)_____
B. Swamping---------------------_____	($18,743)___________
C. Total------------------------______	($18,743) __________

H. Water Conveyance Facilities

Drainage Ditches

According to the County Ditch Inspector, there are 195 open ditches of between 400 and 450 miles in length in Redwood County. Annually between $50,000-$100,000 is spent cleaning sediment from these ditches (Sanders 6/17/86, Interview).

The sources of sediment include sheet and rill erosion from upland agricultural areas, bank sloughing and bottom scouring within the ditch and tile lines. During the two-stage process of establishing a ditch, sources of sediment will vary in importance. For the first five years following the excavation of a ditch, bank sloughing is a large contributor to sediment. Once vegetation has been established, upland erosion becomes the principal contributor of sediment.

Knowledgeable County officials estimate that approximately one inch of sediment is deposited in the county ditches annually (Boomgarden 6/16/86, Interview), based on the fact that ditch design calls for culvert placement 24" above the bottom of the ditch. Most ditches do not require maintenance for at least 15 years after establishment and some ditches exceed 20 years. Based on these observations, the one-inch-per-year estimate is reasonable.

The County Ditch Inspector believes the two principal sources of sediment to the Redwood River are from upland wind erosion of agricultural land and streambank erosion. He feels little sediment is transported out of open ditches to the River (Sanders 7/15/86, Interview). The County Engineer feels that 75 percent of the sediment in the Redwood River orginates from agricultural sources (Boomgarden 6/16/86, Interview).

Within the Redwood River Watershed in Redwood County, there are nineteen open ditches of approximately 132.5 miles in length (Redwood County Ditch Map 1985). The average annual cost of removing sediment is approximately $24,698.

The calculation used to determine this value is based on the method outlined in the checklist and attached as a worksheet at the end of this section. This method is an estimate of maintenance cost which is used in lieu of gathering actual cost figures for 1985.

It was impossible to get direct cost figures. One problem was that cost information is dispersed among individual ditch files; to gather this data would have required an exceptional amount of labor. In addition, clean-out projects often span a number of years so determining actual annual figures for each project would have been difficult.

Finally, maintenance is not necessarily provided on a routine basis with equal geographic representation. Some years attention is focused away from the Redwood River Watershed.

The method employed to make this estimate was suggested by Gene Sanders, the County Ditch Inspector (7/15/86, Interview). It assumes a clean-out cycle of 17 years (a compromise between the 15-20 estimate) and that the cost of cleaning a ditch in 1985 is $.60 a running foot.

It is assumed that 100 percent of the cost of ditch clean-out can be attributed to sediment from agricultural sources. Ditches are an outgrowth of agricultural activities. Therefore, sedimentation resulting from bank sloughing and channel scouring within the ditch are an indirect result of agricultural activity.

Summary of Cost of Ditch Maintenance
Total Ditch Maintenance $24,698

Road Maintenance

Township Roads—Surveys were sent to ten townships within the study area (Appendix A). Eight responses were received summarized in Table 3-1. For townships where information was not obtained, average values of sediment removal per mile was determined based on information from participants. The survey from Honner township was removed from the analysis, as values given appear to reflect general

Table 3-1 - Township Survey Results

AREA	Total Maintenance Budget	Percent of Budget Spent on Sediment	Total Sediment Budget	Total Miles of Township Road	Cost of Sediment per per mile	Miles in Study Site	Cost of Sediment Removal in Study Site
Delhi	$22,000	0	0	32	0	8.8	0
Granite Rock	$18,400	4%	$750	44	$17.05	25.8	$440
*Honner	$9,000	83%	$7,500	7	$1,071.43	4.7	$5,036
Kintire	$29,000	3%	$870	36	$24.17	13	$314
Redwood Falls	$28,000	10%	$2,800	26	$107.69	17	$1,831
Sheridan	$18,136	11%	$2,000	40.6	$49.26	37	$1,823
Underwood	$19,000	10.5%	$2,000	44	$45.45	44	$2,000
Vail	$20,800	0	0	38	0	10.8	0
TT Vesta				40	x $34.80	40	$1,392
TT Westline				46	x $34.80	28	$974
						TOTAL	$8,774

* Honner removed from sample due to extreme values
TT Did not respond to survey
x Average Based on other surveys

road construction and maintenance and were not strictly related to sediment removal.

A substantial portion of a township budget is spent in snow removal and other maintenance-related expenses. Repairing clogged and washed- out culverts and dredging ditches are expenses that relate directly to sediment. In most cases, sediment-related maintenance is performed in response to landowner requests.

The percentage of an annual township budget spent on sediment-related maintenance varied. Two townships reported spending no money on sediment removal while five others spent between three and eleven percent of their 1985 budget for it. This translates to a dollar value of between zero and $2,800. Seven surveys reported that this value varies little or not at all. One township stated that sediment-related maintenance varies between zero and fifteen percent of their annual budget.

The total value of sediment-related maintenance for township roads in the study area is $8,774. The entire amount is attributed to agricultural sources. This is based on the fact that encroachment of farm fields is a problem on township roads where sediment related problems are found (Danielson 7/14/86, Interview) . For the two areas which did not respond, an average value of sediment maintenance of $34.80 per mile of township road was used to calculate costs.

County Roads—Ditch clean-out and culvert repair are common maintenance problems associated with sediment along County Roads and County-State Aid Highways. The cost of sediment-related maintenance for Redwood County in 1985 was found in the "Analysis of Routine Maintenance" under each type of road in the County Highway Budget.

During construction, clean-out may be required for sediment derived from the road itself. However, once a road has been established, the primary source of sediment into the roadside ditch is from upland agricultural activity. The County Engineer feels that most sediment removed from roadside ditches is due to agricultural sources (Boomgarden 6/16/86, Interview).

The County Engineer believes that the item in the budget addressing sediment removal understates the economic damage caused by sediment to roads. He feels that impeded drainage will have the long-term effect of saturating the road bed and accelerating deterioration. This may shorten the period between major reconstruction from between 40 to 45 years to between 30 to 35 years. He also stated that sediment removal is not indicated in reconstruction budgets, thus further understating the total annual maintenance associated with sediment (Boomgarden 6/16/86, Interview).

There are 512 miles of County and County-State Aid Highways in Redwood County, 121.3 miles of which are in the study area. The cost of sediment related maintenance for both types of County roads (but excluding municipal road maintenance) in 1985 was $11,479 for the entire county. This translates to a cost of $22.42 per mile.) The cost associated with sediment removal for the study area in 1985 was $2,720.

The average cost of sediment removal for 1982 to 1985 is $23.31 per mile. This is slightly higher than the value for 1985. Since the averaged value gives a better indication of overall

Diane Vosick

Road damage, Redwood County, Minnesota

maintenance we will use this value for calculating the average annual cost due to sediment. Total for the study site using the average value generated for four years is $2,828. Based on observations by Peter Boomgarden, this entire value will be attributed to agriculturally derived sediment.

State Highways—Two State Trunk Highways, 19 and 273 fall within the study area. Total mileage for each segment is 28 and two miles respectively, for a total of 30 miles.

Maintenance related to agriculturally derived sediment is a small part of the overall highway budget. Culvert and ditch sediment removal occurs when there is a landowner request, or when the Area Maintenance Foreman, discovers an area in need of maintenance (Boyum 1/14/87, Interview).

Costs related to sediment removal are found in two accounting categories entitled Drainage and Roadside Maintenance. The categories include a wide range of maintenance functions. Activities in the Drainage category specific to sediment removal include culvert and ditch cleaning. In the Roadside Maintenance category, washout repair is the only item pertinent to the study.

To determine the percentage of cost in each category that can be ascribed to agriculturally derived sediment it was necessary to contact the Area Foreman. Half of the expenses in 1985 associated with Drainage are attributable to agricultural sediment, plus 10% of the Roadside Maintenance budget (Boyum 1/14/87, Interview). This is in agreement with the percentages suggested by the Area Foreman at the Kandiyohi study site.

Before calculating the actual cost of sediment removal it was necessary to convert the highway budget from a fiscal to a calendar year. Fiscal Year 1986 and Fiscal Year 1985 were divided in half and added to derive an approximation of total dollars spent in calendar year 1985.

Cost associated with sediment-related maintenance for Highways 19 and 273 for calendar year 1985 was $2,333 and $9 respectively. This results in a total cost of $2,342.

Because of a change in the accounting system for the State Highway Department, it was impossible to get more than two years worth of data. The lack of data prevents a detrmination of how consistent these expenditures might be with previous years.

Summary of Road Costs

The total cost associated with sediment removal from area roads is as follows:

Category	Cost
Township Roads	$ 8,744
County and CSAH	$ 2,828
State	$ 2,342
Total	$13,914

Irrigation

Five irrigation permits exist for withdrawls from the Redwood River. In 1985 only two permits were active, one held by the City of Redwood Falls for their zoo, and another by Green Lake Nursery for irrigation of plant stock (MN-DNR 1986b, Irrigation records for Redwood County).

Withdrawals by the city are used to maintain a duck pond at the zoo in Ramsey Park from Memorial to Labor Day. Annual maintenance associated with sediment removal from this operation is approximately $200 annually (Salmon 10/86, Interview). The cost associated specifically with agriculturally derived sediment is $150.

At the Green Lake Nursery, sediment is not known to appreciably affect equipment. Nozzles associated with watering occasionally clog, however are easily cleaned. No excessive wear and tear is known to occur on the pumps and lines.

Cost Summary Associated with Irrigation

Total Irrigation $150

Overall Summary of the Cost of Maintenance due to Agriculturally derived sediment for Water Conveyance Facilities in Kandiyohi County

Category	Cost
Ditches	$24,698
Roads	$13,914
Irrigation	$ 150
Total	$38,762

Water Conveyance - Worksheet

Part A. Drainage Ditches

A-1. Total number of feet of open ditch ________(699,811) ________

A-2. Cost of clean-out per running foot__________($.60)______________

A-3. Average clean-out cycle ________________ (17 years) __________

A-4. Total cost of all ditch clean-out (A-1) x (A-2)
____________ (699,811) x ($.60) = ($419,886.60) ____________

A-5. Average annual clean-out cost (A-4) divided by (A-3)
____________($419,886.60)/(17 years) = ($24,968.04) ___________

A-6. Amount of damage caused by agricultural sources (A-5) x percent of sediment due to agricultural sources ____________________
_________________($24,968.04) x (1.0) = ($24,968) ___________

Chapter Four

Kandiyohi County

Executive Summary

The goal of the investigation in the Shakopee-Mud Creek Watershed of Kandiyohi county is to provide information as to where damage is occurring and the cost associated with the damage. In addition to providing data concerning the specific problem in Kandiyohi County, the analysis supplied important field experience for the development of the "Handbook" for local officials (the largest component of the report).

Determining the total cost associated with off-site damage caused by eroding soils was impossible for the Shakopee-Mud Creek Watershed. The only hard figure determined for the watershed was the cost of sediment damage to water conveyance facilities such as drainage and roadside ditches. The total cost in 1985 (the year of the investigation) for this category was $16,440.

Unfortunately, it is safe to say that this small figure is only the tip of the iceberg. A number of factors precluded a comprehensive economic analysis.

The first complication was lack of available data. The study was a compilation of existing information. In many categories, economic data simply do not exit. Further information problems included a general gap in knowledge concerning the affects of sediment on many types of activities, an inability to measure the economic impacts of sediment, and dated information.

A second limitation was the size of the study site. The fact that the watershed was very small (150 square miles), and occupied only a portion of the county complicated obtaining good information. When economic information was obtained, it was often so small relative to the entire county that the analysis appeared somewhat ridiculous. It also required that many estimates be made when analyzing information corresponding to the entire County.

Finally, in certain categories, such as damage to biological systems, no reliable techniques exist to attach a defensible dollar value to the impacts.

Very significant, yet unquantifiable sediment-related damage may be occurring to recreation. Outdoor recreation provides an important economic base to the community. Kandiyohi County is strongly identified as an area of abundant recreation opportunities. This investigation suggests that poor water quality may be negatively impacting the recreational experience. Polluted water may be causing economic damage to the recreation-associated businesses of the County. The potential economic impact of sediment and water quality on recreation demand requires further analysis.

The following is a list of the off-site impacts investigated during this study. The major findings are mentioned under each category. For a complete discussion with supporting data, refer to the narrative section of this report.

Physical Data

- The study area constitutes slightly more than 150 square miles or approximately 96,000 acres of the Shakopee-Mud Creek watershed within Kandiyohi County (Fig. 4-2).

• Evidence suggests that approximately 90 percent of the sediment which enters the waterways of the Shakopee-Mud Creek watershed is derived from agricultural sources.

• The overall estimated average annual erosion for cultivated crops in the County is approximately 6.1 tons per acre or 3,904 tons per square mile.

• Average annual sediment yield to the County's waterways is thought to be between 16–40 tons per square mile.

• Agriculture plays a dominant role in County land-use patterns. Agriculturally related use constitutes 93 percent of the total non-federal land area, with cultivated cropland occupying 75 percent of the total.

• Precipitation in 1985 was substantially above normal. The annual average is approximately 26 inches. In 1985, precipitation recorded at the Willmar monitoring station was 36.5 inches.

IN-STREAM IMPACTS

Biological

• No endangered or threatened species are known to occur in the study site.

• One wet prairie, listed on the Minnesota State Planning Agency Critical Areas List does occur in the site. Sediment is not thought to be adversely impact this area.

Recreation

A. Swimming, Boating, Resort Use and Camping

• The value of direct and indirect expenditures for outdoor recreation to Kandiyohi County in 1985 were approximately $10 million.

• Poor water quality in the study site is attributable to sediment, agricultural chemicals and septic system overflow.

• Poor water quality is impacting recreation facilities aesthetically and financially. Some expenditures by resort owners have been incurred to remedy water quality-related problems. During an informal resort survey, two respondents of the eight surveys returned felt that poor water quality had caused financial loss to their business. The extent to which damages were due to high water, agriculturally derived sediment, or chemical contamination could not be determined.

• Weed and algae growth, swimmer's itch and swimming area siltation are all water quality problems noted by resort owners.

• County residents may be shifting their recreational use of lakes away from the most polluted lakes to the least polluted lakes. The least polluted lakes appear to be in the Norway Lake Chain (within the study site).

• No boating accidents were linked to sediment related problems in 1985.

B. Fishing

• In general, the pan fisheries of the area do not appear to be negatively impacted by sediment.

• Walleye reproduction is impacted by sediment. However, the percentage of damage caused to this fishery by sediment versus other factors such as fishing pressure preclude a direct assessment of sediment-related damage.

C. Waterfowl Hunting

• Area wetlands are experiencing siltation at an undetermined rate. The impact on waterfowl reproduction and migration is unknown.

• Windborne sediment creates problems on upland sections of Wildlife Management Areas by providing a seed bed for noxious weeds.

• Agricultural chemicals may be impacting food webs in area wetlands. Lack of research prevents any conclusive statements about this impact.

Water Storage

• The Swan Lake reservoir is predicted to function beyond its 50 year life span. Because of upstream sediment entrapment, it is believed that silt accumulation in the reservoir is not significant at the present time.

Property Values

- Lake shore property values have remained stable compared to other real estate in the rural community. A link between property values and water quality could not be determined for this portion of the watershed.

OFF-STREAM IMPACTS

Flooding

- Flooding is not considered a problem along Shakopee Creek.

Water Conveyance

A. Drainage Ditches

- There are 42 miles of drainage ditches in the study site. Clean-out occurred along one ditch in 1985 and cost $4,335.
- There is almost no compliance with a state law which requires a 16½ foot vegetated strip along all drainage ditches that were constructed, improved or maintained since 1977.
- Total dredging and sediment-related maintenance costs for the 500 miles of drainage ditches in the county for 1985 was approximately $1 million.

B. Roads

- *Township Roads*—Six townships were surveyed in the study site to determine sediment-related maintenance cost. Five townships responded. Total cost of sediment-related maintenance (culvert and roadside ditch clean-out) on 112.5 miles of township roads in 1985 is $4,906.
- Encroachment of cultivated fields on to right-of-ways causes some sediment-related problems.
- *County and County-State Aid Highways*—The 1985 cost of roadside clean-out and maintenance for a portion of the 92.8 miles of County and County State Aid Highways in the study site was $487. The average value for clean-out over the last three years is $649.
- Clogged roadside ditches may lead to long-term damage of road beds. The cost associated with this impact could not be determined, but could be significant in some areas.
- *State Highways*—The two segments of state trunk highways in the study site had a cummulated cost of sediment related maintenance of $6,550 in 1985.

A. Physical Description

The Shakopee and Mud Creek Watershed in Kandiyohi County is a picturesque landscape of rolling hills dotted with lakes and wetlands. Shakopee Creek, the dominant creek in the area, flows from West Norway Lake in the northwest, east through the Norway chain to Lake Andrew, south to Lake Florida and then southwest through Swan Lake to the county line. (See Fig. 4-1). Kandiyohi County was predominantly a tall-grass prairie interspersed in a prairie border landscape. Oaks and tall grasses blanketed the hills, while prairie potholes teamed with waterfowl.

The watersheds under investigation in this study fall within the political boundaries of Kandiyohi County in west central Minnesota (Fig 4-2). The Shakopee Creek and Mud Creek Watersheds are located in the northwest corner of Kandiyohi County. They are subwatersheds of the Chippewa River, a subwatershed of the Minnesota River.

For purposes of this investigation, the Shakopee and Mud Creek watersheds were combined to form an area of approximately 150 square miles or 96,000 acres within Kandiyohi County. Both of the Watersheds span areas greater than the County, and both represent the upper reaches of the Chippewa River (Fig 4-3). Though Mud and Shakopee Creek are considered subwatersheds of the Chippewa

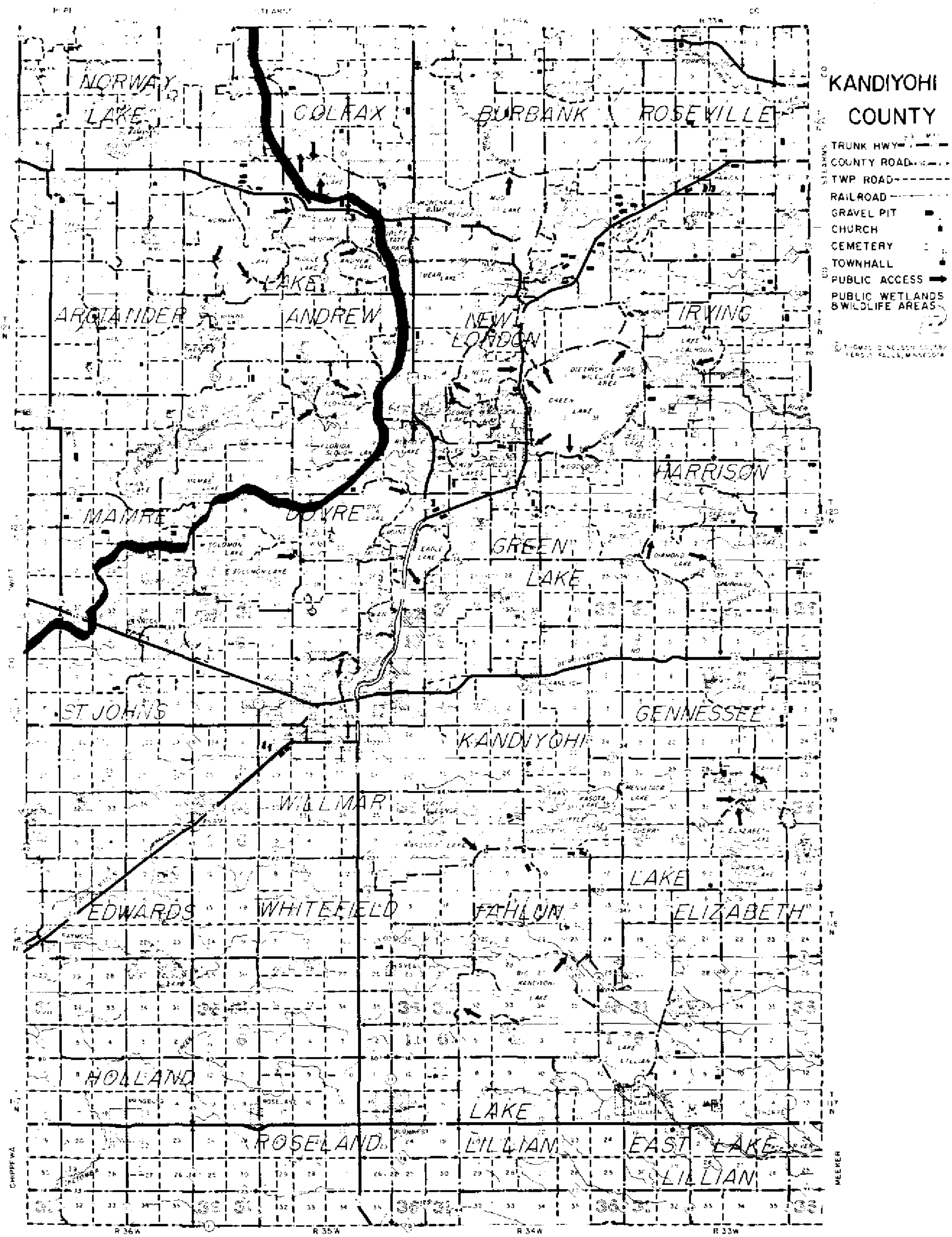


Figure 4-1. Watershed Boundary Within Kandiyohi County
FROM: *Kandiyohi County 1982* Map. Thomas O. Nelson Co. Fergus Falls, Minnesota.

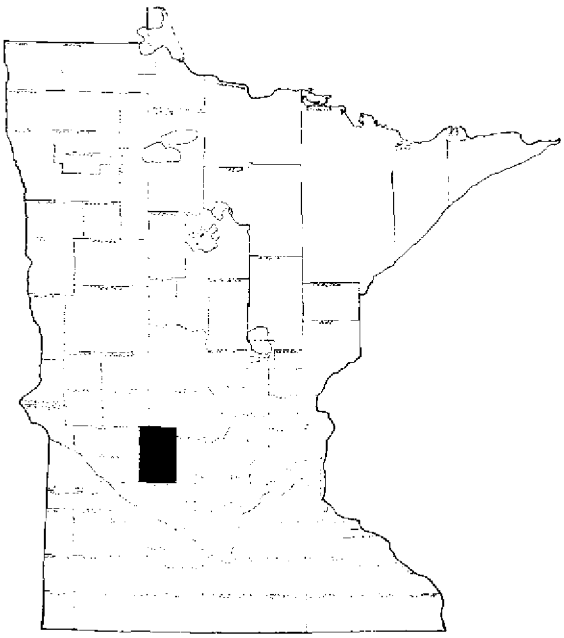


Figure 4-2. Kandiyohi County Location

River, they will be referred to as "the Watershed" throughout this report.

Geology

Landforms in the area are glacial in origin, with lateral and terminal moraines dominanting the landscape. The moraines were formed along the northeast flank of a retreating ice lobe that occupied the Minnesota River as its central mass. These events created a relatively rough topography with many discontinuous sandy and gravelly ridges with relatively abundant lakes and depressions. The relief is in the magnitude of 100 to 150 ft (USDA-SCS 1955, 4); with the highest point reached at Mt. Tom in Sibley State Park (1,375 ft.).

The oldest rocks in the watershed are hard crystalline granitic and metamorphic rocks that date from the Precambrian Period. They are overlain by shales and sandstones of the Cretaceous Age. The upper layers consist of often thick layers of pleistocene glacial drift including till, clay, silt, sand and gravel (USDI-Geological Survey 1968, Atlas Two).

Soils

The soils in the area developed from glacial till. Three major associations dominate the watershed (Fig. 4-4).

The Lester-LeSueur Association covers an area from the northwest corner of the watershed east to Highway 71 and south to Florida Slough. It extends westerly to the northwest corner of the County and angles to the southeast down to an area just west of Florida Slough. It occurs on rolling to hilly well-drained areas, is a light colored loamy soil, formed in prairie-border regions (MN-DEED 1980a, 1-10).

Wedged between the Lester-LeSueur Association and Highway 104 to the west is the Clarion-Nicollet- Webster Association. It was formed under level to rolling terrain where the vegetation was tall-grass prairie. Because it formed under prairie grasses it is a calcareous soil, which is well and moderately well-drained.

From the western border of the County to Highway 104 is the Langhei-Barnes Association. It is in a group of soils which form on hilly topography under prairie. Due to the prairie influence the soils are calcareous, and light in color.

A minor soil association in the southwestern tip of the watershed is the Winger-McIntosh Association. These are level, poorly and moderately well drained soils and also formed underneath prairies (MN-DEED 1980a, 1-10).

Hydrologic Information

Average annual precipitation in the Watershed is approximately 26 inches in the northwestern corner, increasing slightly to the southeast (MN-DEED 1980a,1-5). In recent years, precipitation has been well above normal; it is generally believed that the area is in a "wet cycle." In 1985, precipitation reached 36.5 inches, or 8.8 inches over norm (Smith12/12/86, Interview). Approximately 75–80 percent of the rainfall occurs during the 135 to 150 day growing season. The average date of the latest killing frost is May 15, and the first killing frost

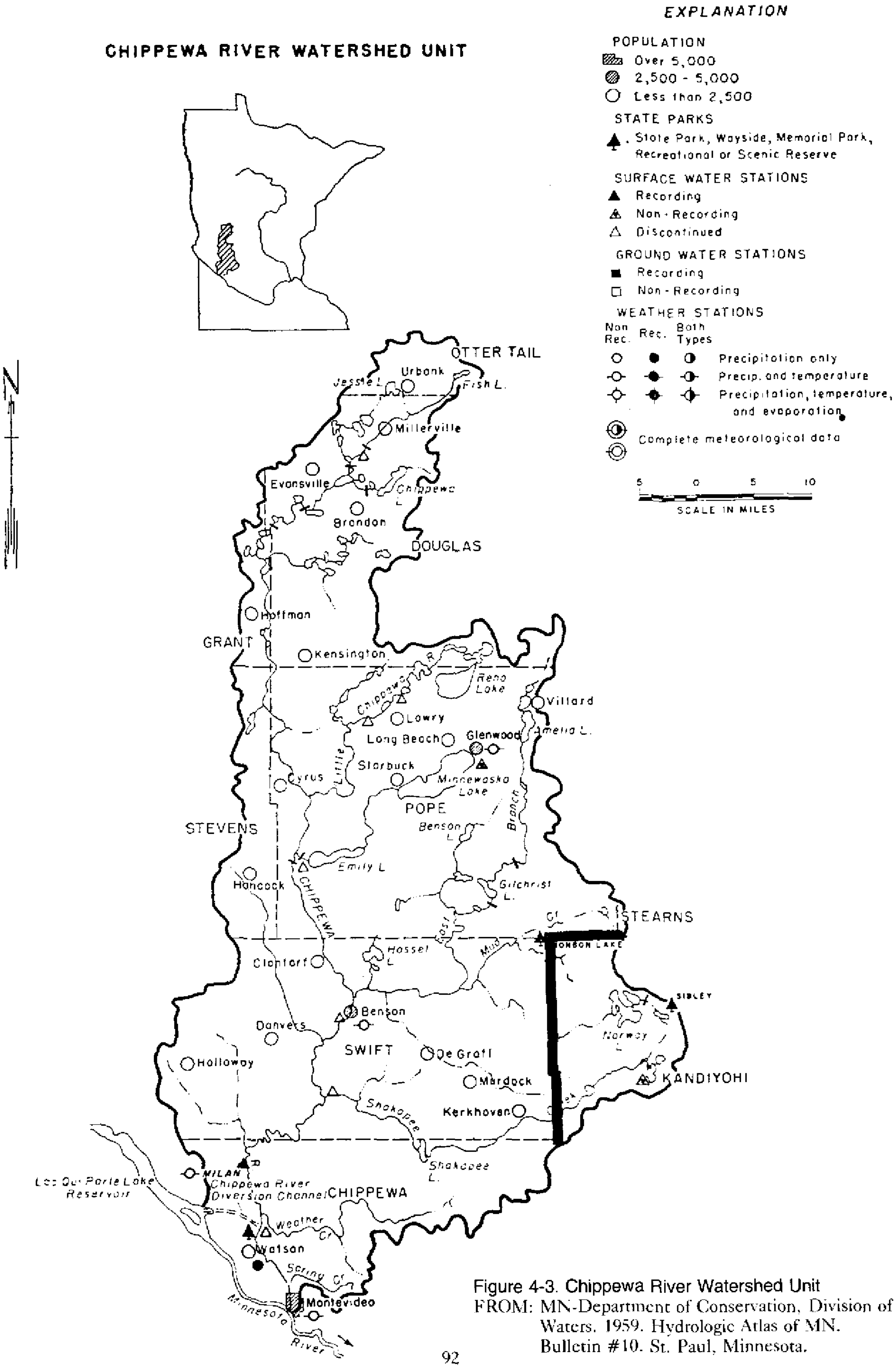


Figure 4-3. Chippewa River Watershed Unit
FROM: MN-Department of Conservation, Division of Waters. 1959. Hydrologic Atlas of MN. Bulletin #10. St. Paul, Minnesota.

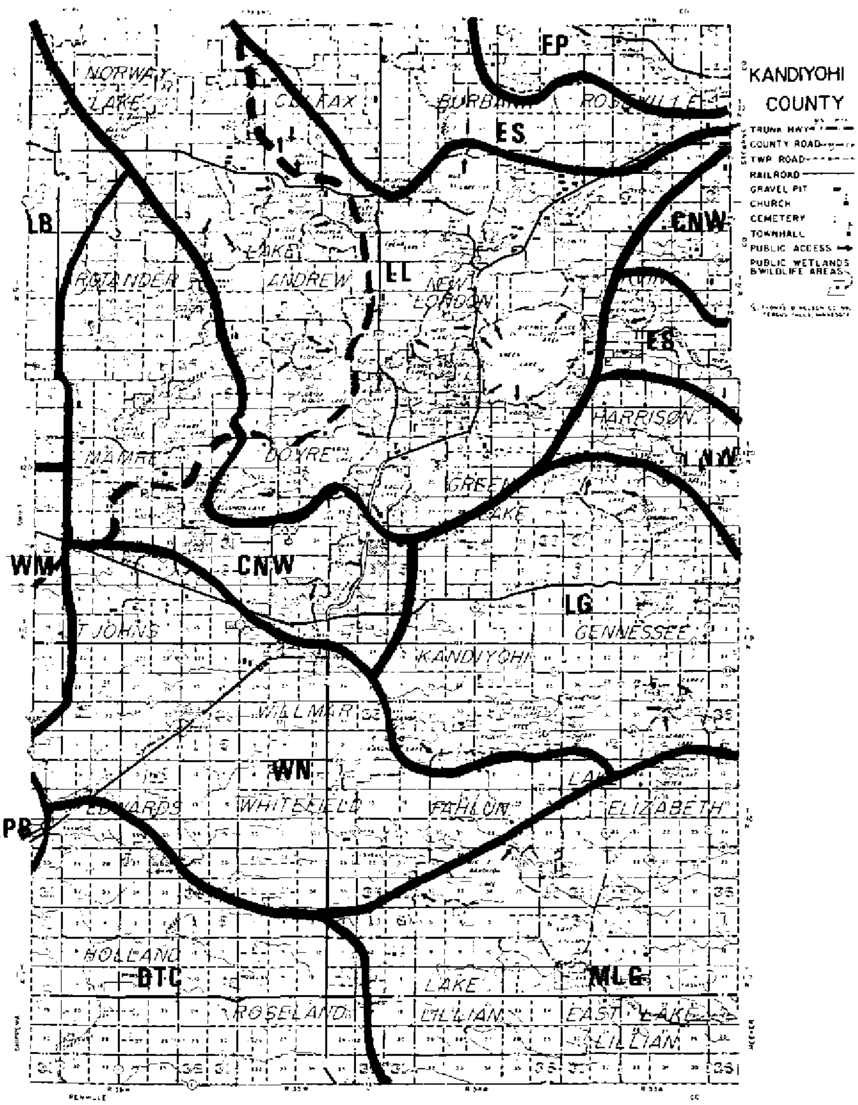


Figure 4-4. Kandiyohi County Soil Map
FROM: MN-DEED, Region 6E Development Commission. 1980b. *Water Resources.* pg 10–11. Willmar, Minnesota.

I. Level, poorly and moderately well-drained soils formed under prairies:

—Forada-Peat Assc. (FP)
—Marna-Lura-Guckeen Assc. (MLG)
—Wedster-Nicollet Assc. (WN)
—Winger-McIntosh Assc. (WN)

II. Nearly level to rolling, well and moderately well-drained soils and associated calcareous soils formed under prairie:

—Clarion-Nicollet-Webster Assc. (CNW)
—Doland-Tara-Canisteo Assc. (DTC)
—Lerdal-Guckeen Assc. (LG)

III. Level to rolling, sandy and gravelly, draughty soils formed under prairie:

—Estherville-Salida Assc. (ES)

IV. Hilly, well-drained, light colored calcareous soils formed under prairie:

—Langhei-Barnes Assc. (LB)

V. Rolling to hilly well-drained, light colored, loamy soils, prairie border soils:

—Lester-LeSueur Assc. (LL)

is September 25th (USDA-SCS 1955,4) The average annual snowfall is 45 inches (MN-DEED 1980a, 1-5).

Average annual runoff for the Chippewa River is 1.9 inches (USDI-Geological Survey 1968, Atlas One). Limited gauging of Shakopee Creek at its outlet near Benson, Minnesota, showed average annual runoff to be 3.72 inches., based on monitoring between 1950–1954. Since these data were collected during part of the wet cycle of the 1950's, it may be somewhat misleading. Additional information generated during the same brief monitoring showed maximum discharge to be 2,681 cubic feet per second, while the minimum discharge was zero. The average annual discharge was 96.6 cubic feet per second.

Generally, the highest average percent of annual flow occurs in April for rivers in the Minnesota River Basin (Otterby 1978,16). This corresponds to spring break-up. The highest average monthly percent of annual rainfall occurs in June (Otterby 1978,15).

Weather conditions change frequently and quickly within the course of a day and throughout the year. The mean annual temperature is 44°F. Summers are short with warm, moist weather and an occasional intense heat wave when temperatures may reach as high as 110°F. Winters are characteristically long, cold and dry, with temperatures that can dip to −35°F for several days in a row. Winter temperatures are frequently compounded by high winter winds. The prevailing winds are from the northwest in the winter and from the south in the summer (MN-DEED 1980a, 1-5).

Land Use

According to the 1982 National Resource Inventory, the following land use occurs in Kandiyohi County on non-federal land (in 1,000 acres): cropland, 366.3; pastureland, 51.5; rangeland, 1.0; forest, 12.7; minor rural land-use, 36.1; for a total of 467.6 in rural land. Other land-use (in 1,000 acres): urban and built-up, 7.6; rural transportation, 12.8; and small water areas, 3.4. These figures indicate that agriculture plays a dominant role in land use of the County. Agriculturally-related land-use (excluding forests) constitutes 93 percent of the total land area in Kandiyohi County, with cultivated cropland alone occupying 75 percent of the total non-federal land area.

In the northwest section of the County, wetlands, lakes and recreational facilities are very important. Agricultural use dominates in this area, but the importance of recreation is demonstrated by the amount of land devoted to recreational purposes. The importance of recreation will be explored in greater detail in this report.

B. Sediment

The gently undulating topography of northwestern Kandiyohi County, its climate, soils and land-use all play a vital role in determining the amount of sediment contributed to the creeks, lakes and rivers of the watershed. These factors also influence the amount of sediment which originates from agricultural sources.

Very little hard data exist which actually analyzes water-borne sediment and attributes it to a source. In 1955 a flood control project was initiated for Shakopee Creek. At that time, an extensive analysis was conducted by the Soil Conservation Service and a workplan entitled *Shakopee Creek Watershed: Subwatershed of the Chippewa River Tributaries and Hawk Creek Watershed* was published. *The Minnesota River Basin Plan* produced by the Southern Minnesota River Basin Commission in 1977 also provides a good general analysis of problems related to agricultural land use in the basin. *The Minnesota 208 Plan*, published by the Minnesota Pollution Control Agency provides an excellent overview of the water quality problems which affect the state. The 208 Plan is a particularly valuable tool in that it generated many small reports on individual water quality topics.

The determination of the amount of sediment contributed by agricultural sources for this watershed will be a synthesis of reports and numerous interviews. In light of the fact that current information is not available for the watershed, this value should be considered a best guess based on logic and available information. In cases where there was conflicting information, the data with the greatest accuracy or greatest refinement for the geographic area were chosen. Information that was most current was given more weight over older information. The opinions expressed in local interviews were assumed to be reliable. People with direct experience were considered the most knowledgeable sources on the topic.

In any given area there are potentially many sources of sediment. It may originate within the stream from streambanks and channel scouring, or it may be the result of wind and water erosion outside the stream. Agriculture, municipal run-off from new construction, road construction, and mining activities all may contribute sediment.

NRI data for Kandiyohi County indicates that 93 percent of the area in the county is employed in some agricultural activity (USDA-SCS 1982). Farming dominates the Shakopee and Mud Creek subwatersheds. Only the town of Sunburg (pop. 130) and Norway Lake (pop. 20) occur within the study site (Spadacinni 1983, 335).

For the county as a whole, land-use other than agriculture breaks down as follows: mines, quarries, and gravel pits, less than one percent; urban built-up, two percent; small water body, less than one percent; rural transportation, three percent; and ungrazed forest, two percent.

The NRI data indicates that 45 percent of irrigated and non-irrigated cropland could use some form of erosion control treatment. The overall estimated average annual erosion for cultivated crops in the county is thought to be 6.1 tons per acre for both wind and water (USDA-SCS 1982). Approximately 46 percent of the County's cropland is eroding within the tolerable soil loss limit (T), while 40 percent falls between T and 2T, and fifteen percent is greater than 2T.

Soil erosion from agricultural sources is a problem. Both wind and water transport soil over the rolling terrain. Not all of the soil which begins to move is transported to creeks, wetlands and lakes. A retired District Conservationist for the Soil Conservation Service stated that the majority of sediment is deposited at the base of the hills (Swanson 7/21/86, Interview). It is generally accepted that the bulk of erosion occurs within the farm field.

According to the *208 Report*, Kandiyohi County falls within an area which has a medium, to a medium-low potential for sediment delivery to a water body (MN-PCA 1979, 394). The average annual sediment yield is considered to be 16–40 tons per square mile. If 75 percent of the Watershed is in cultivated crops (assuming the proportion in the Watershed is equal to the County as a whole) and the average erosion rate for cultivated cropland is 6.1 tons per acre, then approximately two to six percent of the total erosion is reaching the waterways. Even if we delivery is analyzed conservatively, assuming that there are 16 tons per square mile per year delivered from the entire Watershed, delivery is equal to approximately 2,403 tons of sediment annually.

Sheet and wind erosion were thought to be the primary sources of soil erosion in the 1955 Watershed assessment. At that time, slight to moderate erosion had occurred on 76 percent of the Shakopee Creek watershed (This would include areas of the Watershed outside the County.) Gully, streambank, and roadside ditch erosion were not considered significant. Sediment damage in the Watershed was thought to be limited mainly to the silting of drainage and road ditches. It was thought that practically all of the upland sheet erosion was deposited at the breaks in slope and in depressional areas on the upland. (USDA-SCS 1955,6).

Interviews concerning the current status of the watershed show some similarities to the previous study. Sheet and wind erosion are still considered the most significant contributors of sediment in the watershed. The District Conservationist for SCS felt that wind generated 20 percent of the erosion in the area, while sheet and rill erosion was responsible for 75 percent (Corrigan 7/26/86, Interview).

In general, streambank erosion is not considered a serious problem. Yearly surveys by SCS personnel indicate that the area below Swan Lake experiences minor bank erosion problems (USDA-SCS 1986, unpublished survey results). This information is corroborated by an unpublished report to the Minnesota Soil and Water Conservation Board which considers streambank erosion negligable when compared to other locations in the state (USDA-SCS 1978).

Roads contribute sediment in localized areas. The wet summers of 1985–1986 have caused particular problems along newly reconstructed County Road 40, between U.S. 71 and Co. Rd 5. Seeding and cleaning of the ditches has occurred twice in the last two years due to sedimentation and has cost between $15,000 and $20,000 (Danielson 8/9/86, Interview).

Gravel pit operations occur in the watershed, and may contribute sediment to the waterways in localized areas. A gravel pit which closed its operation 20 years ago near Games Lake is believed to have been a signficant contributor of sediment to that lake during its ten years of operation. Local residents felt that water quality deteriorated during that period (Madsen 7/21/86, Interview).

Records at the Minnesota Pollution Control Agency indicate that there are no active discharge permits for gravel pit operations in Kandiyohi County. A permit would be necessary if the mining activity discharged to a waterway (MN-PCA 1986).

Some notable changes have occurred in sediment loads and water quality in recent years. The first is a concern that County Drainage Ditch No. 29 carries a significant amount of sediment and associated contaminants to West Norway Lake. This has caused a decline in the water quality in this lake and throughout the chain (Getsfried 7/23/86, Interview). Another concern is that nutrient loading into the recreational lakes has caused a significant deterioration of water quality.

Throughout the Norway Chain of Lakes, the subjective assessment by landowners and individuals familiar with the lakes is that weed growth has increased and water quality has declined. Fortunately for the resorts in this chain, the decline has not been as great as some of the other lakes in the County. One Park Manager feels that the lakes in the Norway Chain are receiving more recreational use when compared to other lakes because their water quality is relatively better (Madsen 7/21/86, Interview).

No specific data exist for pinpointing why these problems have been occurring. High water in recent years has caused bank erosion on Norway Lake and some problems with septic systems. Controversy surrounds whether the primary source of nutrients to the lake in the form of nitrogen and phosphorous is from agricultural sources or domestic septic system inputs. (This subject requires further analysis on a lake by lake basis.)

Watershed Topography is Favorable for Sediment Entrapment

The picture of sediment flow through Shakopee Creek is interesting. Because of the intermittant lakes and wetlands along the River's course, much of the sediment is trapped as it moves through the Watershed. An example of this settling and filtering occurs at Henschen and Swan Lake located between Games Lake and Lake Andrew. These two small lakes trap sediment and nutrients which move out of Norway and Games Lake (in addition to direct inputs) before they reach Lake Andrew. For this reason, Lake Andrew has maintained good water quality (Getsfried 7/23/86, Interview)(Lais 7/22/86, Interview).

A Hydrologist for the Minnesota Department of Natural Resources feels that there is a tremendous amount of sediment which flows through the portion of Shakopee Creek above the Swan Lake Reservoir. It is the gentle drop of the River in combination with the various water basins for entrapment that prevent much of the sediment from continuing its movement (Getsfried 7/23/86, Interview).

From Lake Andrew, the Creek meanders south through broad marshy lowlands to Florida Slough. Sediment is trapped along the way and in the slough, so that water which backs-up from Florida Slough into Lake Florida has undergone some filtration. From Florida Slough, the creek flows through low marshes westward to Swan Lake. In 1986, weeds were mechanically and chemically removed from four segments of the Creek midway between County Highways One and Five. This was done to improve flow from Florida Slough and lower the level of Lake Florida. The growth of weeds in this area could have been due to the accumulation of sediment in the channel, and favorable weather during the dry years of the 1970's (Getsfried 9/8/86, Interview).

Though no sampling has been done in Swan Lake, it is believed that sedimentation is occurring at a slower rate than was originally predicted. The reservoir at Swan Lake is anticipated to outlast its original project design, which according to the Shakopee Creek workplan is 50 years (USDA-SCS 1955, 12)(Cherp 7/30/86, Interview). Below Swan Lake to the County border, the creek is not thought to carry much sediment (Danielson 8/9/86, Interview).

The Mud Creek subwatershed is a small amount of the entire area under consideration. The area is characterized by rough topography and many small lakes and marshes. County Ditch 15 is the primary water channel in the area. Agriculture dominates this region also, though forest and pasture are common on steep slopes. No information specific to sediment movement in this portion of the watershed was found.

Conclusion

The fact that most land is devoted to agriculture in the County makes it reasonable to conclude that as much as 90 percent of the sediment which occurs in the watershed is due to agricultural sources. The other ten percent may be contributed by roads and roadside ditches, gravel pits, streambank and stream channel scouring, and bank sloughing of drainage ditches. Each of these other minor contributors may at times provide significant amounts of sediment in a localized area; however, when analyzed for the whole area over time, they are minor.

C. Biological

The impacts of sediment and associated contaminants on the biological components of the Watershed are not well documented. LeRoy Dahlke, Area Wildlife Manager expressed concern that sediment accumulating in the areas wetlands may have negative affects on waterfowl production in the future (Dahlke 7/23/86, Interview). Hydrologic variability, and its influence on the natural fluctuations in wetland depth and conditions, further complicates an analysis of sediment damage. An extreme case of siltation would have to occur before impacts on breeding or migrating waterfowl would be observed.

Agricultural chemicals are suspected of causing disruption in food webs in aquatic environments (USDI-Fish and Wildlife 1982, 15), but no data exist documenting any damage. This is not only due to the lack of data, but the fact that the relationship of farm chemicals to aquatic organisms has not been extensively researched.

The Minnesota Department of Natural Resources' Natural Heritage Program was contacted concerning the presence of any endangered species in the area (Coffin 9/25/86, Interview). Within the Watershed are two colonial nesting bird sites. Located on islands one mile south of Lake Florida, these sites are listed by the state's Natural Heritage Program. None of the species using this particular site are threatened or endangered. Neither the species nor the site are afforded any legal protection.

A wet prairie located two miles north of Florida Slough is recognized by the Minnesota State Planning Agency as a Critical Area. The White Lady Slipper *(Cypripedium candidum)*, an orchid protected by state law and listed as a Species of Special Concern by the MN Department of

Natural Resources, is known to occur on the site. The prairie would not be impacted by sediment in Shakopee Creek.

In summary, the extent and economic value of biological damage in the Watershed are unknown. Of major concern should be the long-term affects of siltation and agricultural chemicals on wetlands and associated biota.

D. Recreation

Value of Outdoor Recreation to the Community

Travel and tourism play an important economic role in the state of Minnesota. In 1984, an estimated $4.8 billion was spent on business and recreation travel (MN-Commission on Minnesotan's Outdoors 1986, 59).

Visitors to an area need a variety of goods and services. Businesses that provide lodging, food, entertainment, recreation, and retail items all receive economic benefits from travel. In addition, the dollars spent for direct services may be spent again in the local community; indirectly increasing the local economic benefits.

There have been few studies which evaluate the economic benefits of recreation to some Minnesota communities. At Lake Minnewasha in Pope County, it was estimated that there were $1,081,000 of direct sales to tourists visiting the Lake from outside the County (1974 dollars). These dollars were then spent again within the community to raise the total direct and indirect benefits from tourism to $2,846,000 (Christopherson 1976, 46).

Recreation use along the Cannon River in southeastern Minnesota resulted in direct expenditures by tourists of $700,000 in 1984. Two thirds of the total expenditures were by fisherman (MN-DNR 1985b, 19).

Kandiyohi County is part of the Little Crow Lake Resort Region of west central Minnesota. Within the Watershed there are eight public and private campgrounds with 228 sites, nine public and private swimming beaches, fourteen permanent lakes of over 150 acres, six resorts with 39 housekeeping units, and eight public water access sites (MN-DEED 1980a, Chapter 3). Recreational activities such as hunting, fishing, swimming, boating, picnicking and skiing are made possible by the abundant facilities and water resources of the area.

In 1984, travel to Kandiyohi County resulted in total expenditures of $28,517,000 (MN-DEED 1985, 12). Not all of these expenses can be attributed to outdoor recreation. It is estimated that eleven percent of the total dollars spent for tourism and travel are spent specifically for outdoor recreation in Region 6E (MN-Outdoors 1986,65)(Fig. 4-5). Assuming that eleven percent is accurate for each county within the region, then the direct value of outdoor recreation to Kandiyohi County in 1984 was $3,136,870. If the same "multiplier" or the factor by which direct expenditures are multiplied to indicate the indirect benefits the local economy is the same as Pope County (2.4), the indirect benefits of outdoor recreation would be $7,528,488. The total benefit to the County from expenditures for outdoor recreation would be $10,665,358 (1984 dollars), or $10,816,201 in 1985 dollars.

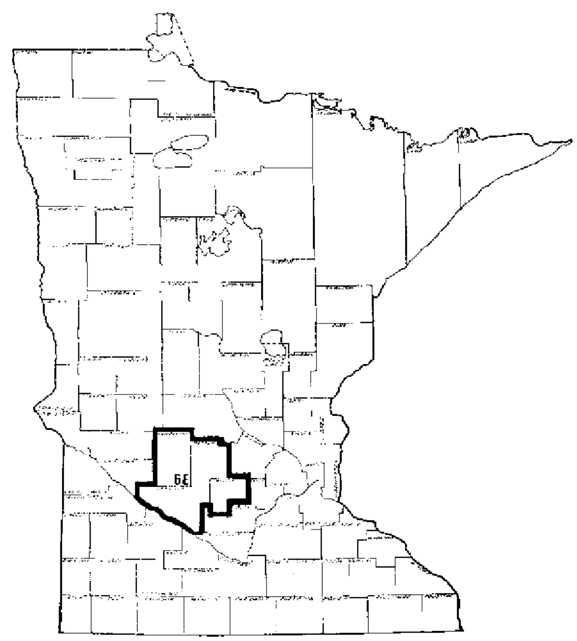


Figure 4-5. Region 6E

Sediment and Water Quality

An unpublished response by the Minnesota Pollution Control Agency to the *Draft Environmental Impact Statement for the Bemidji Wastewater Treatment System* demonstrated how significant water quality is to tourist activity. A Wisconsin study of visitor use for an oligotrophic and eutrophic lake, provided a basis for estimating that a 9.5 percent reduction in visitor days to the Bemidji area could occur if effluent continued to be discharged into Lake Bemidji. This would result in a reduction of direct tourist income between $408,321 to $754,774 annually, depending upon the gross estimates that are used. The total loss of direct and indirect income based on tourist activity would be between $1,095,522 and $1,698,242 to the Bemidji area (MN-PCA 1980, 35).

The AFT/Minnesota Soil and Water Conservation Board study is concerned about two particular aspects of water quality: sediment and nutrients and chemicals associated with sediment. Though not all water quality problems are the result of sediment and associated contaminants, they can be substantial contributors. The Regional DNR Hydrologist feels that water quality in the county will continue to deteriorate unless steps are taken to curtail agricultural non-point pollution (Getsfried 7/22/86, Interview).

The Minnesota Pollution Control Agency has analyzed the water quality of nine lakes within the County. Two were considered mesotrophic, while all the rest were classified as eutrophic (MN-PCA 1985,11). This sample comprises less than five percent of the County's 194 lake basins (greater than ten acres.)

Kandiyohi County has had its share of water quality problems. For years, lake associations, state and federal agencies, and private citizens have been working toward improving water quality. This commitment was further demonstrated in 1986, when lake associations and government agencies began meeting to discuss strategies for addressing water quality issues (Block 7/23/86, Interview).

In recent years high water has caused a great deal of concern among residents (Little 8/6/86, A-1), causing turbidity and algae problems, accelerated bank erosion, property damage and poor fishing.

The following is a discussion of the various recreational components of Kandiyohi County and the impact of poor water quality on those activities. Under most circumstances, it was impossible to calculate the actual dollar damage caused to recreation by sediment and associated nutrients. Nevertheless, recreation is such an important part of the area economy that it warranted a thorough discussion. This is an area that demands further research with an eye towards understanding the impact of water quality on the local economy.

Resorts

A survey was sent to 22 resorts and campgrounds in Kandiyohi County to gather general information about sediment, water quality and its effects on business (Appendix C). Though the primary interest of the study was in the Norway Chain of Lakes, a County-wide survey was thought to be a better indicator of overall opinion. Of the 22 surveys, eight or 36 percent were returned. All resorts which responded were seasonal and had between six and nineteen housekeeping cabins, camping or both.

The questions people chose to answer varied considerably. Four surveys responded to the question concerning the problems associated with high water (Question 7). Resorters reported problems with poor fishing, murky water, shoreline erosionand maintaining docks. Two surveys reported spending a total of $2,100 to repair damage caused by high water.

Seven resort surveys responded to the question asking whether or not poor water quality affected their operation (Question 9). Algae and weeds were mentioned as a problem on six, with swimmers' itch reported on the seventh.

Algae and weeds are often perceived by the public as an indication of pollution. Studies indicate that people will consider the relative degree of pollution before selecting a site for water-related recreation. In addition, researchers have found that the presence of algae is often noted by layman as an index of water pollution (MN-PCA 1982, 30).

The presence of algae and other weed problems could have serious consequences for water-based recreation. Long-time area residents indicated that weed and algae growth have increased in the lakes. In particular, Games and Andrew were mentioned as having increased weed and algae growth during the last ten to fifteen years (Madsen 7/21/86, Interview) (Lais, 7/22/86, Interview).

In response to the question on damage related to sediment (Question 11), two responded with concern about the siltation of swimming areas and lakeshore bank erosion. The presence of silt in the swimming areas could lead to additional weed growth.

Sediment and poor water quality were blamed for a reduction in business at two locations. Kandiyohi Park No. 1 reported a loss of 25 camping units per weekend due to weather and sediment-related problems. A private resorter felt that they had lost 30 to 40 visitors during 1985 because of poor water quality. The estimated monetary loss from this reduction was $6,000 and $500, respectively. Of the eight responses, only two reported a drop in attendence in 1985, while one reported an increase in visitors and four reported the same number (one was new in business and had nothing to compare).

Because of the small response to the survey, it is impossible to establish the impact of water quality on business. Further monitoring of business trends would be necessary to make any definite conclusions linking water quality and visitor use.

The decrease in use of County Park No. 1 would support an observation that there has been a shift in the use of the county parks away from the more polluted areas to the less polluted areas. County Park No. 7, on Games Lake, has experienced constant increase in demand for their swimming area. The Games lake swimming area is relatively clean when compared to other County Parks. Unlike most other resorts in the area, the County Parks are used by a majority of County residents.

With the exception of the County Parks, the majority of visitors to the resorts surveyed were from outside the County. Among resorters, the number of people from outside Minnesota varied from 32 to 70 percent of their visitors. Travel expenditure models indicate that more money is spent the farther one gets from home (MN-DNR 1985b, 19).

Finally, in response to the question concerning the impact water quality might have on their resort business in the future (Question 20), three respondents felt that business will deteriorate if water quality continues to deteriorate. Another felt that one more year of high water and its associated destruction would put them out of business.

This short survey with it's limited response does indicate a few trends. Water quality is impacting business both aesthetically and financially. Though not all resorters had hard figures, their responses indicate that remedies for water quality problems vary from actual cash outlays to buried costs associated with increased maintenance. The fact that two resort operators indicated that business had been impacted by poor water quality should sound an alarm. Though more research would be needed to conclusively link poor water quality to a trend in declining business, the fact that this may be occurring should be of concern to businesses which serve recreationists.

Fishing

Though fishing has been mentioned as poor during the recent high water years, there is no current evidence to suggest that the fisheries in the Watershed have been significantly impacted by sediment and associated contaminants. The pan fishery which consists of sunfish, bluegill and crappies is very good in watershed lakes. High water has benefited the natural reproduction of northern pike. Walleye are probably the most sensitive to sedimentation since they require rocky shoals for natural reproduction. Sedimentation may have played a significant role in eliminating any natural reproduction by walleye (Dilley 7/22/86, Interview).

The cost of stocking walleye could be partially attributed to the damage to reproduction caused by sediment. However, because fishing pressure, management techniques and many other variables must be considered, it is unknown to what extent this damage may be attributed to sediment.

Some carp spearing occurs along Shakopee Creek. Below the Swan Lake flood control structure, small populations of northern pike live in pools. Their distribution is dependent upon flow, and they are considered to exist in very small numbers.

Fishing is very popular in this region. In terms of the frequency with which people fish, it ranked third behind bicycling and swimming (MN-DEED 1980a, 4-21).

Boating Accidents

Boating accidents are occasionally seen as a cost of sediment problems. When boats run aground due to poor visibility and shoaling the accident may be attributed to sediment.

According to figures at the Department of Natural Resources, there was only one County boating accident in 1985. This was a collision unrelated to water quality (Ethier 10/8/86, Interview).

Waterfowl

Wetlands and their associated Wildlife Management Areas and Waterfowl Production Areas are an important asset to recreation in the Watershed. Within the Chippewa River Watershed in Kandiyohi County there are 20 federal Waterfowl Production Areas totaling over 3,920 acres, and two state Wildlife Management Areas totalling 511 acres (MN-DEED 1980a, 3-26) Hunters, trappers and birdwatchers all benefit from the abundance of publicly-owned wetlands.

In a 1961 census of waterfowl hunters in the Watershed, the majority stated their place of origin as Willmar, the Twin Cities and St. Cloud (MN-Department of Conservation 1964, 18). Current use also indicates travel from these areas. Kandiyohi County is known as a good waterfowl hunting area, and receives intense use during the hunting season. Local Wildlife Management Areas receive daily use during the hunting season (Dahlke 7/23/86, Interview).

There are three types of damage attributable to sediment and associated contaminants which occur to wetlands and their associated uplands: siltation of the wetland due to water flowing into the basin, wind erosion which deposits silt on the uplands and in the water body, and contamination of water due to agricultural chemicals.

Siltation of wetlands from either wind or water-borne sediments is considered to be a problem throughout the County (Dahlke 7/23/86, Interview). Sediment is thought to be a particular problem in areas where drainage ditches flow into the wetland or where the upland area is not well buffered from agricultural activities (Kerschbaum 7/25/86, Interview). The extent of this problem is not well known. The impact of silt on waterfowl reproduction and fall use of the Wildlife Management Areas and Wildlife Protection Areas is not well researched, either. For these reasons it was impossible to document either the immediate or long-term biological and economic damage that may occur.

Researchers have established that wetlands provide a valuable service by filtering sediment (Boto 1979, 479). Wetlands in the Shakopee Creek Watershed provide a sink for the sediment loads which are transported by the Creek. Therefore, Lake Andrew, Florida and Swan Lakes do not receive as high as sediment loads as might be expected (Danielson 8/9/86, Interview) (Getsfried 7/23/86, Interview)(Lais 7/22/86, Interview). Evidence for the entrapment of the sediment can be seen in the form of alluvial fans into the two small lakes between Games and Andrew.

It is thought that the slow meandering nature of the Creek and its associated vegetation may trap sediment flowing between Lake Florida and Swan Lake. The recent need to remove weeds between County Roads One and Five, may have in part been due to the accumulation of sediments and associated weed growth (Dahlke 9/86,Inteview).

No evidence exists at this time to conclusively link sediment and damage to wetlands. Therefore, it would be too speculative to attach a dollar figure to the damage which might be occurring. Nevertheless, it is important to recognize the importance of wetlands to the recreational community, and the potential cost of losing those wetlands.

A Michigan study which attempted to document the economic value of coastal wetlands found that the average economic return derived from non-consumptive recreation, waterfowl hunting and trapping of furbearers was $148, $42, and $30 per acre per year, respectively. These figures represent direct dollar returns for each activity. The replacement cost for a wetland for purposes of waterfowl breeding was found to be $21,500 per hectare for purchased replacement ($8,704 per acre) and $59,000 per hectare for constructed replacement ($23,887 per acre) (Jaworski 1979, 445).

Another type of damage associated with sediment in this watershed is due primarily to wind borne material. It is not uncommon to encounter silt in the northwest corner of the Wildlife Management Areas. The silt is a nuisance when it provides a seed bed for the growth of noxious weeds such as thistle.

Region 6E spent $60,000 spraying thistle on Wildlife Management Areas in 1985 (Dahlke 7/23/86, Interview). Unfortunately, because spraying is routine, and not all spraying can be attributed to weeds in silt beds, it is impossible to document the exact cost of spraying due to sediment. Of the two Wildlife Management Areas in our study site, Sunburg was not sprayed in 1985, but Oleander was. In the case of Oleander, a thistle problem exists, but the portion due to silt a cannot be distinguished.

The final damage which may be occurring to wetlands in the study site is related to farm chemicals. Little research has been done to understand the effects of these chemicals on waterfowl reproduction and feeding behavior. A study conducted by the U.S. Fish and Wildlife Service in the region found no evidence of significant accumulations of chlorinated phenoxy herbicide in residue sediments of selected Waterfowl Production Areas (USDI-Fish and Wildlife 1982b, 12). The report concluded with a warning about the potential deleterious affects that insecticides applied to grain fields may have on wetlands and wildlife foods, but that more research was needed to understand the problem.

Little research exists to analyze the affects of sediment and associated contaminants on the wetland ecosystem. No monitoring has been performed to understand the rate of siltation which is occurring in the agricultural areas of Minnesota. Given the importance of outdoor recreation to Kandiyohi County, this is an area that demands further research.

E. Water Storage

One reason for selecting the Shakopee Creek Watershed for the AFT/Minnesota Soil and Water Conservation Board study was the presence of a flood control structure at the outlet of Swan Lake. Constructed in the late 1950's for $27,229, it was designed with a drop spillway and capacity of ¾" runoff in 24 hours over the entire Watershed above the structure (USSCS 1955, 91). The study was interested in whether or not this structure would function for its projected life span, and to determine any costs associated with premature replacement if that was necessary.

Intermittent wetlands are thought to create a sink where a large part of the sediment load may settle. Because of these features, it is thought that little sediment is deposited in Swan Lake. An engineer for the SCS in southern Minnesota, estimated that the structure would probably exceed its expected life span (Cherp 7/30/86, Interview). (This is a purely speculative analysis, since no sampling has been done in the Watershed to establish siltation rates.)

The study also explored the possibility of determining the amount of original cost dedicated to a sediment pool. The original design records are kept in the National Archive in Kansas City and were not obtained.

Because the reservoir is predicted to exceed its proposed design specifications, no monetary damage could be documented for the Swan Lake flood-retarding structure.

F. Property Values

A discussion of the attempts made to measure the impact of sediment and poor water quality on property values can be found in Chapter Two in the Section entitled "Property Values." The County Assessor for Kandiyohi County was contacted concerning current land and property values for this analysis (Oelslanger 7/14/86, Interview).

The numerous variables which determine the value of property make it difficult to attach a dollar value to sediment damages. The depressed rural economy of the 1980's overshadows any other influences which may be at work in the real estate market, according to the Assessor. However, he did feel that the depressed economy has not affected demand for lakeshore property. Lakeshore values have leveled, but are holding their own when compared to other property.

A study analyzing the role of lake quality in riparian property values for 60 artificial lakes in Wisconsin found that water quality is a significant variable in explaining property values, when all other factors that determine value are held constant (MN-PCA 1982, 33). Therefore, as water quality deteriorated, property values fell.

Kandiyohi County has the advantage of being close enough to the Metropolitan Area (two hours) to benefit from demand for recreational housing. If pollution plays a role in the ultimate value of a piece of property, the market for lakeshore property could be adversely impacted by current water quality problems. To capture the full economic benefit of the demand for recreational housing, good water quality in the County's Lakes will be essential.

G. Flood Damage

Earliest concern about flooding in the watershed was in the area below Swan Lake. The work done in the late 1950's by the SCS was designed to retard water in the Swan Lake reservoir and to increase the size of the Shakopee Creek channel below the reservoir to accomodate high flow (US-SCS 1955, 11).

Currently, flooding is not considered a problem along Shakopee Creek in Kandiyohi County. The primary problem associated with too much water in the spring and after storm events is poor drainage. The Creek is not known to flood outside its banks (Swanson 7/21/86, Interview)(Corrigan 8/12/86, Interview).

No signficant economic damage from flooding is thought to occur in this Watershed.

H. Water Conveyance Facilities

Drainage Ditches

According to the County Auditor, there are approximately 500 miles of drainage ditches in Kandiyhohi County. In 1985 an estimated $1 million was spent to clean sediment from these ditches (Block 12/19/86, Interview).

During 1986, Kandiyohi Soil and Water Conservation District personnel flew over 85 percent of the drainage ditches in the County. They assessed whether or not farmers were complying with a law which requires a 16½ foot vegetated strip along drainage ditches which have been constructed, improved or maintained since 1977. There is virtually no compliance with the state law. In most cases, fields extend to the top of the slope along the ditch. Only ditches that have been part of a Federal Soil Conservation Service project, and have easements along their length show conformity (Block 12/29/86, Interview).

The lack of buffer strips along established ditches suggests that sheet and rill erosion may be an important contributor of sediment and contaminants to the County's waters. In addition, the lack of vegetation can lead to problems with bank sloughing and gullying.

Cost of Clean-Out—In the Shakopee-Mud Creek watershed there are approximately 220,772 feet or 42 miles of drainage ditches. County ditches 15, 29, 27 and 62 and Judicial Ditch 16 all fall within the area under investigation. According to County records, only County Ditch 62 had maintenance performed in 1985 at a cost of $4,335. This is miniscule when compared to the overall maintenance figure of $1 million in 1985 for the County as a whole.

A few reasons exist for the low proportion of maintenance in the study site. The first is that clean-outs occur in response to petitions by landowners. In this area, farmers obviously don't see a need at this time for clean-out. This does not necessarily mean that the ditches lack sediment, it merely indicates that for whatever reason the people who pay the clean-up bill are not interested in cleaning ditches at this time.

Another reason is due to geography. The southern part of the County has the majority of ditches. This is an area of flat terrain and intensive agriculture, two factors which could combine to create a greater need for clean-outs.

Finally, in the rougher terrain of the northwestern part of the County, natural removal of suspended sediment from ditches may be more efficient. The sloping topography may provide more energy for sediment transport, resulting in less sediment deposition in ditches.

The 1985 value for clean-out may understate the actual long-term clean-out cost. First, it does not include the administrative costs associated with the request. Second, maintenance does not occur on a regular basis, so it will be difficult to calculate an average annual value for maintenance. As an example, County Ditch 27 was cleaned in 1986 at a cost of $18,553. This is four times the expenditures made in 1985 in this area.

Finally the 1985 budget figure fails to represent the cost of performing all the maintenance required on a 20-year cycle. This analysis would include multiplying the total length of ditches (220,772 feet) in the study site times the current clean-out cost per running foot ($.65), and dividing by 20 years. The net result is a value of $7,175 in annual expenditures for ditch maintenance. This figure is not used in the cost accounting because it is somewhat theoretical, and does not represent the actual cash outlays for the year under analysis.

For purposes of this investigation, the entire clean-out cost will be attributed to sediment problems derived from agricultural sources. Drainage and ditching are agricultural activities that generate eroded soil.

Summary of Cost of Ditch Maintenance

Total Ditch Maintenance	$4,335

Road Maintenance

Township Roads—Surveys were sent to six townships within the study area (Appendix A). Of the six townships, five returned the survey. Table 4-1 summarizes the data collected. For questions where information was inadequate, and for Lake Andrew Township which did not participate in the survey, averages based on other survey responses were taken to derive the cost of sediment-related maintenance per mile.

A substantial part of the total township budget is spent in snow removal and other maintenance-related expenses. Repairing clogged and washed-out culverts, and dredging clogged ditches are expenses which relate directly to sediment.

Three townships reported that they clean culverts and roadsides on annual basis. Two

Table 4-1 - Township Survey Results

AREA	Total Maintenance Budget	Percent of Budget Spent on Sediment	Total Sediment Budget	Total Miles of Township Road	Cost of Sediment per per mile	Miles in Study Site	Cost of Sediment Removal in Study Site
Arctander	$28,000	3%	$840	32	$26.25	32	$840
Colfax	$24,692	10%	$2,470	34	$76.25	7.8	$567
Dorre	$39,250	10%	$3,925	33	$118,94	6.8	$809
Mamre	$25,287	1%	$253	32	$7.91	21.2	$168
Norway Labe	$23,800			26	x $56.44	26	$1,467
TLake Andrew					x $56.44	18.7	$1,055

TOTAL - $4,906

TT - Did not respond to survey

x - Average based on other surveys

townships indicated that they perform sediment removal as requested. Four townships stated that the proportion of cost related to sediment removal in the overall budget varies little from year to year. One township reported that sediment-related maintenance varies depending upon weather. Another reported that clean-out costs may vary up to five percent of the budget. The difference in the percentage of budget spent for sediment related clean-out (between one and ten percent) is probably due to variations in topography and interest in this particular type of maintenance.

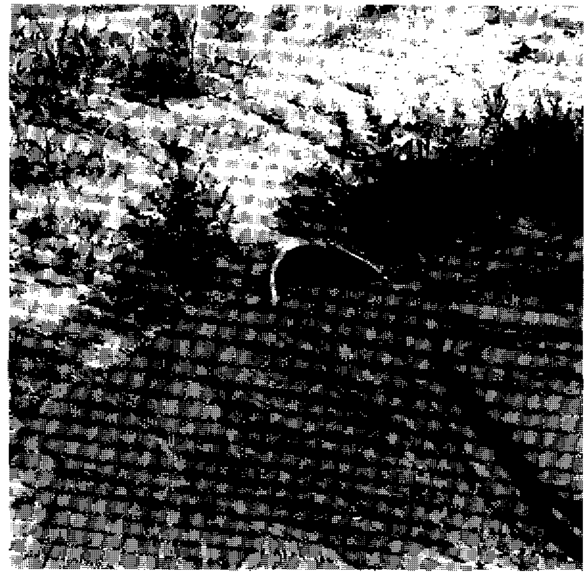
According to the County Engineer, sediment-related problems tend to be worse on township roads as compared to county roads due to encroachment of farm fields on the right-of-ways (Danielson 7/14/86, Interview).

The total dollar value for sediment-related maintenance for the townships in 1985 was $4,906. This translates to a cost of $43.61 per mile of township road in the study site. Township costs are low because budgets are small, limiting the amount of maintenance that can be performed.

County Roads—Ditch clean-out and culvert repair are common maintenance problems associated with sediment along County Roads and County-State Aid Highways. The cost of sediment-related maintenance was found in the General Maintenance section of the Kandiyohi County Highway Budget.

During construction, clean-out may be required for sediment derived from the road itself. However, once a road has been established the primary source of sediment into the roadside ditch is from upland agricultural activity.

Some controversy surrounds the degree to which sediment in roadside ditches actually reduces the life span of a road. Sediment in the ditches will impede drainage and result in the saturation of the road bed. One County Engineer estimates this accelerates the need for reconstruction by ten years (Boomgarden 6/16/86, Interview). The Kandiyohi County Engineer feels other factors such as initial con-



Diane Vosick

Clogged culvert, County Road 40, Kandiyohi County, Minnesota

struction and engineering play a greater role in determining the life of a road (Danielson 7/14/86, Interview). Both engineers agree that to some extent, the actual damage caused by sediment is understated by routine maintenance buget figures. They both feel that some reconstruction costs should be attributed to sediment, although determining the exact percentage would be speculative.

County maintenance figures will also understate the total cost of sediment in another important way. Some ditch clean-out cost will be buried as part of reconstruction. It is impossible to distinguish this figure from the total cost of construction.

County road maintenance budget figures were easily obtained for three years beginning in 1983. The cost of maintenance per mile was averaged over the three years, and compared to the cost per mile of maintenance in 1985. The three year average is higher than the figure spent in 1985.

In 1985 it cost the county $5.61 per mile to perform sediment-related maintenance along 73.2 miles of County-State Aid Highways. This translates to a total cost of $411. County Road maintenance cost $3.89 per mile along 19.6

miles within the study site for a total cost of $76. The combined total for both County and County-State Aid Highways was $487. The average over three years is $6.46 per mile and $9.00 per mile or $473 and $176 for County-State Aid Highways and County Roads respectively. Total cost for County and State-Aid Highways using the average values would be $649. Since three years of data were available for averaging, this figure will be used to represent cost.

State Highways—Two State Trunk Highways (104 and 9) fall within the study site. Total mileage for each segment is eighteen and twelve miles respectively for a total of 30 miles.

Maintenance related to agriculturally derived sediment is a small part of the overall highway budget. As is the case with both County and township roads, ditch clean-out and culvert repair is usually the result of a specific request. In particular, wind erosion was mentioned as a problem. On east-west roads silt accumulates on the north side of the ditch. On north-south roads the problem occurs on the west side. Prevailing winter winds are from the northwest and move tremendous amounts of exposed soil during winter storms (Gieske 7/14/86, Interview).

Costs related to sediment removal are found in two accounting categories entitled Drainage and Roadside Maintenance. The categories included a wide range of procedures. Activities in the Drainage category specific to sediment removal include culvert and ditch cleaning. In the Roadside Maintenance category, washout repair is the only item pertinent to this study.

To determine the percentage of cost in each category that could be ascribed to agriculturally derived sediment it was necessary to contact the Area Foreman for Kandiyohi County. He feels that 50 percent of the Drainage cost category was maintenance related to sediment removal in 1985. Ten percent of Roadside Maintenance could be attributed to agricultural sediment. He mentioned that a manpower shortage in recent years had reduced the amount of roadside maintenance that had been performed (Gilb 12/18/86, Interview).

Cost associated with maintenance for Trunk Highways 104 and 9 for calendar year 1985 were $4,899 and $1,651, respectively. This results in a total cost due to sediment of $6,550.

Because of a change in the accounting system for the State Highway Deptartment, it was impossible to get more than two years worth of data. The lack of data prevents a determination of how consistent these expenditures might be with previous years.

One slight complication arose when calculating the cost of sediment-related maintenance for state highways. Unlike other budgets, the state is operated on a fiscal year beginning July 1st and ending June 30th. Therefore, it was necessary to use half of the budget from fiscal year 1985 and half the budget for fiscal year 1986 to derive costs for calendar year 1985.

Summary of Road Costs

The total cost associated with sediment removal from area roads is as follows:

Category	Cost
Township Roads	$ 5,906
County and CSAH	$ 649
State	$ 6,550
Total	$12,105

Irrigation

Only one irrigation permit for withdrawls from surface water exists in the study site. But because of wet conditions in 1985, no water was used.

A request for information concerning the impacts of sediment on irrigation was placed in the local newspaper. No responses were received.

Summary of Irrigation Costs

Total cost to Irrigators -0-

Overall Summary of the Cost of Maintenance due to Agriculturally derived sediment for Water Conveyance Facilities in Kandiyohi County

Category	Cost
Ditches	$ 4,335
Roads	$12,105
Irrigation	-0-
Total	$16,440

Chapter Five

Conclusions and Recommendations

The following conclusions are grouped in two categories. The first pertains to the Handbook. The second relates to the two case studies in Redwood and Kandiyohi Counties.

Handbook

• It is possible to analyze off-site damage associated with agricultural sources of erosion on a local scale. The degree of success of this endeavor depends on availability of information and the investigator's willingness to make estimates.

• Both quantitative and qualitative information can be used to demonstrate the impact of off-site damage. Qualitative information is particularly useful when analyzing the impacts of sediment on biological systems (which to this point have eluded economic analysis).

• Scale of investigation will influence the amount of available data. Generally speaking, more information is available on a county or regional basis than on a specific area within a watershed. Conducting an investigation on a county level may be more efficient for gathering data.

• The Handbook provides an initial overview of the type and extent of off-site damage in an area. More sophisticated econometric techniques will be needed to improve the accuracy of the economic information. A more thorough analysis will require a greater commitment of economic and human resources to develop primary information.

• It is not always possible to find cost figures for a particular study year. In some cases it is necessary to amoritize or average cost data so that single-year estimates can be determined.

• Little written information is available on the subject of off-site damage on a sub-county scale. To compensate for this problem it is necessary to interview individuals knowledgeable about the local area. This is beneficial in that it provides first-hand information about the problem. The strength of the data generated by this technique depends on the reliability of information provided by the individual interviewed.

Case Studies

• The cost of off-site damage due to soil erosion in Redwood and Kandiyohi Counties for 1985 were $65,571 and $16,440, respectively.

• These values understate the total cost of damage. In some instances it was impossible to determine a dollar value for damage.

• Topography acts favorably in Kandiyohi County to trap sediment within the watershed. This has effectively protected the Swan Lake Reservoir from serious siltation problems. In contrast, sediment transport in the Redwood River appears very efficient. Since the early 1900's, 25 feet of sediment has accumulated behind the dam at Redwood Falls.

• Investigation of off-site damage in Redwood County was easier than Kandiyohi County because more information was available, the watershed was larger, and damage caused by sediment was more obvious.

• The relative position of a sub-watershed within a larger watershed may have an impact on the extent of off-site damage. Damage was more obvious in Redwood County located at the lower end of the Redwood River Watershed, than in the Shakopee-Mud Creek Watershed located at the upper end of the Chippewa River Watershed in Kandiyohi County.

• Investigations at a county level understate the cost of off-site damage in a very significant manner. As sediment travels down stream the cumulative environmental affects of silt will increase economic damages. As an example, though commercial navigation did not exist in either watershed, sediment transported from the study sites may eventually create expensive naviagation problems on the Minnesota and Mississippi Rivers. Downstream flooding and recreation damage are also aggravated by increasing amounts of silt.

Recommendations

• An economic analysis of off-site damage on a regional and state level should be performed to provide a more comprehensive analysis of the economic cost of damage caused by sediment.

• Simplified survey methods should be developed for local officials which would permit them to gather baseline economic information. This information plus existing information would improve the amount of data available for the analysis.

• More research on the actual environmental effects of sediment should be conducted for many of the categories considered.

• Local officials should be made more aware of the potential impact of sediment and associated contaminants in their local area.

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Appendix A

OFF-SITE DAMAGES CAUSED BY SOIL EROSION TOWNSHIP ASSESSMENT

TOWNSHIP NAME: ____

1. What was your total road maintenance budget for 1985?

2. How many miles of township roads are in your township?

3. Do you clean-out roadside ditches and culverts on an annual basis? If not, how often does the township encounter this sort of maintenance?

4. What would you estimate the township spends on an annual basis on ditch and culvert clean-out and associated road repair? If you do not have this specifically identified in your budget, then what percentage of your total road maintenance budget would you guess is spent on erosion related problems?

5. How much does this vary from year to year?

6. Does the township have any specific problem roads due to erosion related problems? If so, where are they?

7. Does the township sustain any sediment damage during floods? If so, what type of damages are there, and what does it cost to repair them?

8. Does the township have any other problems associated with erosion which affects something other than roads? If so, what is it and what does it cost the township?

Do you have any additional comments?

Thank you again for your cooperation.

Appendix B

PARTIAL PAYMENT TO AMORTIZE 1 PAYABLE AT END OF EACH PERIOD

YEARS	5% NOMINAL ANNUAL RATE	5½% NOMINAL ANNUAL RATE	6% NOMINAL ANNUAL RATE	6½% NOMINAL ANNUAL RATE	YEARS
1	1.0500 000 000	1.0550 000 000	1.0600 000 000	1.0650 000 000	1
2	0.5378 048 780	0.5416 180 049	0.5454 368 932	0.5492 615 012	2
3	0.3672 085 646	0.3706 540 747	0.3741 098 128	0.3775 757 019	3
4	0.2820 118 326	0.2852 944 853	0.2885 914 924	0.2919 027 404	4
5	0.2309 747 981	0.2341 764 362	0.2373 964 004	0.2406 345 376	5
6	0.1970 174 681	0.2001 789 476	0.2033 626 285	0.2065 683 122	6
7	0.1728 198 184	0.1759 644 178	0.1791 350 181	0.1823 313 693	7
8	0.1547 218 136	0.1578 640 118	0.1610 359 426	0.1642 372 971	8
9	0.1406 900 800	0.1438 394 585	0.1470 222 350	0.1502 380 329	9
10	0.1295 045 750	0.1326 677 687	0.1358 679 582	0.1391 046 901	10
11	0.1203 888 915	0.1235 706 532	0.1267 929 381	0.1300 552 058	11
12	0.1128 254 100	0.1160 292 312	0.1192 770 294	0.1225 681 661	12
13	0.1064 557 652	0.1096 842 587	0.1129 601 053	0.1162 825 571	13
14	0.1010 239 695	0.1042 791 154	0.1075 849 090	0.1109 404 806	14
15	0.0963 422 876	0.0996 255 976	0.1029 627 640	0.1063 527 830	15
16	0.0922 699 080	0.0955 825 380	0.0989 521 436	0.1023 775 740	16
17	0.0886 991 417	0.0920 419 723	0.0954 448 042	0.0989 063 265	17
18	0.0855 462 223	0.0889 199 163	0.0923 565 406	0.0958 546 103	18
19	0.0827 450 104	0.0861 500 559	0.0896 208 604	0.0931 557 517	19
20	0.0802 425 872	0.0836 793 300	0.0871 845 570	0.0907 563 954	20
21	0.0779 961 071	0.0814 647 754	0.0850 045 467	0.0886 133 343	21
22	0.0759 705 086	0.0794 712 319	0.0830 455 685	0.0866 912 043	22
23	0.0741 368 219	0.0776 696 472	0.0812 784 847	0.0849 607 802	23
24	0.0724 709 008	0.0760 358 037	0.0796 790 050	0.0833 976 975	24
25	0.0709 524 573	0.0745 493 529	0.0782 267 182	0.0819 814 811	25
26	0.0695 643 207	0.0731 930 713	0.0769 043 467	0.0806 947 983	26
27	0.0682 918 599	0.0719 522 817	0.0756 971 663	0.0795 228 776	27
28	0.0671 225 304	0.0708 143 996	0.0745 925 515	0.0784 530 522	28
29	0.0660 455 149	0.0697 685 720	0.0735 796 135	0.0774 743 976	29
30	0.0650 514 351	0.0688 053 897	0.0726 489 115	0.0765 774 422	30
31	0.0641 321 204	0.0679 166 543	0.0717 922 196	0.0757 539 335	31
32	0.0632 804 189	0.0670 951 895	0.0710 023 374	0.0749 966 481	32
33	0.0624 900 437	0.0663 346 865	0.0702 729 350	0.0742 992 365	33
34	0.0617 554 454	0.0656 295 769	0.0695 984 254	0.0736 560 953	34
35	0.0610 717 072	0.0649 749 266	0.0689 738 590	0.0730 622 606	35
36	0.0604 344 571	0.0643 663 488	0.0683 948 348	0.0725 133 205	36
37	0.0598 397 945	0.0637 999 295	0.0678 574 274	0.0720 053 400	37
38	0.0592 842 282	0.0632 721 659	0.0673 581 240	0.0715 347 995	38
39	0.0587 646 242	0.0627 799 139	0.0668 937 724	0.0710 985 416	39
40	0.0582 781 612	0.0623 203 434	0.0664 615 359	0.0706 937 260	40
41	0.0578 222 924	0.0618 909 001	0.0660 588 551	0.0703 177 915	41
42	0.0573 947 131	0.0614 892 731	0.0656 834 152	0.0699 684 229	42
43	0.0569 933 328	0.0611 133 667	0.0653 331 178	0.0696 435 230	43
44	0.0566 162 506	0.0607 612 757	0.0650 060 565	0.0693 411 874	44
45	0.0562 617 347	0.0604 312 651	0.0647 004 958	0.0690 596 841	45
46	0.0559 282 036	0.0601 217 512	0.0644 148 527	0.0687 974 344	46
47	0.0556 142 109	0.0598 312 858	0.0641 476 805	0.0685 529 973	47
48	0.0553 184 306	0.0595 585 424	0.0638 976 549	0.0683 250 549	48
49	0.0550 396 453	0.0593 023 035	0.0636 635 619	0.0681 124 000	49
50	0.0547 767 355	0.0590 614 501	0.0634 442 864	0.0679 139 255	50
51	0.0545 286 697	0.0588 349 523	0.0632 388 028	0.0677 286 146	51
52	0.0542 944 966	0.0586 218 603	0.0630 461 669	0.0675 555 319	52
53	0.0540 733 368	0.0584 212 975	0.0628 655 076	0.0673 938 164	53
54	0.0538 643 770	0.0582 324 534	0.0626 960 209	0.0672 426 740	54
55	0.0536 668 637	0.0580 545 778	0.0625 369 634	0.0671 013 722	55
56	0.0534 800 978	0.0578 869 756	0.0623 876 472	0.0669 692 339	56
57	0.0533 034 300	0.0577 290 020	0.0622 474 350	0.0668 456 332	57
58	0.0531 362 568	0.0575 800 578	0.0621 157 359	0.0667 299 909	58
59	0.0529 780 161	0.0574 395 863	0.0619 920 012	0.0666 217 702	59
60	0.0528 281 845	0.0573 070 692	0.0618 757 215	0.0665 204 735	60

Annual Compounding
FROM: Estes, Jack C. 1976. Compund Interest and Annuity Tables. McGraw Hill Book Co: New York, New York.

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	7% NOMINAL ANNUAL RATE	7½% NOMINAL ANNUAL RATE	8% NOMINAL ANNUAL RATE	8½% NOMINAL ANNUAL RATE	YEARS
1	1.0700 000 000	1.0750 000 000	1.0800 000 000	1.0850 000 000	1
2	0.5530 917 874	0.5569 277 108	0.5607 692 308	0.5646 163 070	2
3	0.3810 516 657	0.3845 376 282	0.3880 335 140	0.3915 392 485	3
4	0.2952 281 167	0.2985 675 087	0.3019 208 045	0.3052 878 926	4
5	0.2438 906 944	0.2471 647 178	0.2504 564 546	0.2537 657 519	5
6	0.2097 957 998	0.2130 448 912	0.2163 153 862	0.2196 070 840	6
7	0.1855 532 196	0.1888 003 154	0.1920 724 014	0.1953 692 212	7
8	0.1674 677 625	0.1707 270 232	0.1740 147 606	0.1773 306 533	8
9	0.1534 864 701	0.1567 671 595	0.1600 797 092	0.1634 237 233	9
10	0.1423 775 027	0.1456 859 274	0.1490 294 887	0.1524 077 051	10
11	0.1333 569 048	0.1366 974 737	0.1400 763 421	0.1434 929 316	11
12	0.1259 019 887	0.1292 778 313	0.1326 950 169	0.1361 528 581	12
13	0.1196 508 481	0.1230 641 963	0.1265 218 052	0.1300 228 662	13
14	0.1143 449 386	0.1177 973 721	0.1212 968 528	0.1248 424 382	14
15	0.1097 946 247	0.1132 872 363	0.1168 295 449	0.1204 204 614	15
16	0.1058 576 477	0.1093 911 571	0.1129 768 720	0.1166 135 439	16
17	0.1024 251 931	0.1060 000 282	0.1096 294 315	0.1133 119 832	17
18	0.0994 126 017	0.1030 289 578	0.1067 020 959	0.1104 304 127	18
19	0.0967 530 148	0.1004 108 994	0.1041 276 275	0.1079 014 015	19
20	0.0943 929 257	0.0980 921 916	0.1018 522 088	0.1056 709 744	20
21	0.0922 890 017	0.0960 293 742	0.0998 322 503	0.1036 954 120	21
22	0.0904 057 732	0.0941 868 710	0.0980 320 684	0.1019 389 233	22
23	0.0887 139 263	0.0925 352 780	0.0964 221 692	0.1003 719 258	23
24	0.0871 890 207	0.0910 500 795	0.0949 779 616	0.0989 697 546	24
25	0.0858 105 172	0.0897 106 716	0.0936 787 791	0.0977 116 825	25
26	0.0845 610 279	0.0884 996 124	0.0925 071 267	0.0965 801 651	26
27	0.0834 257 340	0.0874 020 369	0.0914 480 962	0.0955 602 540	27
28	0.0823 919 283	0.0864 051 993	0.0904 889 057	0.0946 391 357	28
29	0.0814 486 518	0.0854 981 081	0.0896 185 350	0.0938 057 657	29
30	0.0805 864 035	0.0846 712 358	0.0888 274 334	0.0930 505 753	30
31	0.0797 969 061	0.0839 162 831	0.0881 072 841	0.0923 652 359	31
32	0.0790 729 155	0.0832 259 887	0.0874 508 132	0.0917 424 664	32
33	0.0784 080 653	0.0825 939 728	0.0868 516 324	0.0911 758 763	33
34	0.0777 967 381	0.0820 146 084	0.0863 041 101	0.0906 598 358	34
35	0.0772 339 596	0.0814 829 147	0.0858 032 646	0.0901 893 685	35
36	0.0767 153 097	0.0809 944 680	0.0853 446 741	0.0897 600 615	36
37	0.0762 368 480	0.0805 453 271	0.0849 244 025	0.0893 679 904	37
38	0.0757 950 515	0.0801 319 709	0.0845 389 361	0.0890 096 556	38
39	0.0753 867 616	0.0797 512 443	0.0841 851 297	0.0886 819 284	39
40	0.0750 091 389	0.0794 003 138	0.0838 601 615	0.0883 820 056	40
41	0.0746 596 245	0.0790 766 282	0.0835 614 940	0.0881 073 700	41
42	0.0743 359 072	0.0787 778 858	0.0832 868 407	0.0878 557 568	42
43	0.0740 358 953	0.0785 020 052	0.0830 341 370	0.0876 251 245	43
44	0.0737 576 913	0.0782 471 012	0.0828 015 156	0.0874 136 299	44
45	0.0734 995 710	0.0780 114 630	0.0825 872 845	0.0872 196 061	45
46	0.0732 599 650	0.0777 935 352	0.0823 899 085	0.0870 415 434	46
47	0.0730 374 421	0.0775 919 020	0.0822 079 922	0.0868 780 731	47
48	0.0728 306 953	0.0774 052 724	0.0820 402 660	0.0867 279 519	48
49	0.0726 385 294	0.0772 324 676	0.0818 855 731	0.0865 900 501	49
50	0.0724 598 495	0.0770 724 102	0.0817 428 582	0.0864 633 395	50
51	0.0722 936 519	0.0769 241 141	0.0816 111 575	0.0863 468 835	51
52	0.0721 390 147	0.0767 866 757	0.0814 895 903	0.0862 398 282	52
53	0.0719 950 908	0.0766 592 661	0.0813 773 506	0.0861 413 945	53
54	0.0718 611 007	0.0765 411 247	0.0812 737 003	0.0860 508 710	54
55	0.0717 363 264	0.0764 315 521	0.0811 779 629	0.0859 676 075	55
56	0.0716 201 059	0.0763 299 053	0.0810 895 180	0.0858 910 096	56
57	0.0715 118 286	0.0762 355 927	0.0810 077 963	0.0858 205 332	57
58	0.0714 109 304	0.0761 480 689	0.0809 322 748	0.0857 556 803	58
59	0.0713 168 900	0.0760 668 318	0.0808 624 729	0.0856 959 948	59
60	0.0712 292 255	0.0759 914 178	0.0807 979 488	0.0856 410 586	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	9% NOMINAL ANNUAL RATE	9½% NOMINAL ANNUAL RATE	10% NOMINAL ANNUAL RATE	10½% NOMINAL ANNUAL RATE	YEARS
1	1.0900 000 000	1.0950 000 000	1.1000 000 000	1.1050 000 000	1
2	0.5684 688 995	0.5723 269 690	0.5761 904 762	0.5800 593 824	2
3	0.3950 547 573	0.3985 799 668	0.4021 148 036	0.4056 591 953	3
4	0.3086 686 621	0.3120 630 025	0.3154 708 037	0.3188 919 564	4
5	0.2570 924 570	0.2604 364 173	0.2637 974 808	0.2671 754 954	5
6	0.2229 197 833	0.2262 532 826	0.2296 073 804	0.2329 818 746	6
7	0.1986 905 168	0.2020 360 296	0.2054 054 997	0.2087 986 667	7
8	0.1806 743 778	0.1840 456 084	0.1874 440 176	0.1908 692 763	8
9	0.1667 988 021	0.1702 045 426	0.1736 405 391	0.1771 063 831	9
10	0.1558 200 899	0.1592 661 517	0.1627 453 949	0.1662 573 206	10
11	0.1469 466 567	0.1504 369 258	0.1539 631 420	0.1575 247 041	11
12	0.1396 506 585	0.1431 877 142	0.1467 633 151	0.1503 767 456	12
13	0.1335 665 597	0.1371 520 575	0.1407 785 238	0.1444 451 173	13
14	0.1284 331 730	0.1320 680 923	0.1357 462 232	0.1394 665 871	14
15	0.1240 588 827	0.1277 436 950	0.1314 737 769	0.1352 480 015	15
16	0.1202 999 097	0.1240 346 957	0.1278 166 207	0.1316 443 997	16
17	0.1170 462 485	0.1208 307 825	0.1246 641 344	0.1285 448 518	17
18	0.1142 122 907	0.1180 461 037	0.1219 302 222	0.1258 630 182	18
19	0.1117 304 107	0.1156 128 384	0.1195 468 682	0.1235 306 897	19
20	0.1095 464 750	0.1134 766 953	0.1174 596 248	0.1214 932 653	20
21	0.1076 166 348	0.1115 936 973	0.1156 243 898	0.1197 065 219	21
22	0.1059 049 930	0.1099 278 440	0.1140 050 630	0.1181 342 647	22
23	0.1043 818 800	0.1084 493 824	0.1125 718 127	0.1167 465 900	23
24	0.1030 225 607	0.1071 335 107	0.1112 997 764	0.1155 185 815	24
25	0.1018 062 505	0.1059 593 925	0.1101 680 722	0.1144 293 198	25
26	0.1007 153 599	0.1049 093 986	0.1091 590 386	0.1134 611 196	26
27	0.0997 349 054	0.1039 685 169	0.1082 576 423	0.1125 989 359	27
28	0.0988 520 473	0.1031 238 883	0.1074 510 132	0.1118 298 968	28
29	0.0980 557 226	0.1023 644 387	0.1067 280 747	0.1111 429 332	29
30	0.0973 363 514	0.1016 805 845	0.1060 792 483	0.1105 284 815	30
31	0.0966 855 995	0.1010 639 940	0.1054 962 140	0.1099 782 438	31
32	0.0960 961 861	0.1005 073 947	0.1049 717 167	0.1094 849 922	32
33	0.0955 617 255	0.1000 044 141	0.1044 994 063	0.1090 424 091	33
34	0.0950 765 971	0.0995 494 491	0.1040 737 064	0.1086 449 545	34
35	0.0946 358 375	0.0991 375 575	0.1036 897 051	0.1082 877 563	35
36	0.0942 350 500	0.0987 643 673	0.1033 430 638	0.1079 665 187	36
37	0.0938 703 293	0.0984 260 006	0.1030 299 405	0.1076 774 443	37
38	0.0935 381 975	0.0981 190 090	0.1027 469 250	0.1074 171 697	38
39	0.0932 355 500	0.0978 403 196	0.1024 909 840	0.1071 827 092	39
40	0.0929 596 092	0.0975 871 883	0.1022 594 144	0.1069 714 084	40
41	0.0927 078 853	0.0973 571 597	0.1020 498 028	0.1067 809 027	41
42	0.0924 781 420	0.0971 480 333	0.1018 599 911	0.1066 090 833	42
43	0.0922 683 675	0.0969 578 336	0.1016 880 466	0.1064 540 666	43
44	0.0920 767 493	0.0967 847 847	0.1015 322 365	0.1063 141 681	44
45	0.0919 016 514	0.0966 272 880	0.1013 910 047	0.1061 878 796	45
46	0.0917 415 959	0.0964 839 025	0.1012 629 527	0.1060 738 498	46
47	0.0915 952 455	0.0963 533 282	0.1011 468 221	0.1059 708 663	47
48	0.0914 613 892	0.0962 343 905	0.1010 414 797	0.1058 778 407	48
49	0.0913 389 289	0.0961 260 279	0.1009 459 041	0.1057 937 954	49
50	0.0912 268 681	0.0960 272 796	0.1008 591 740	0.1057 178 512	50
51	0.0911 243 016	0.0959 372 756	0.1007 804 577	0.1056 492 173	51
52	0.0910 304 065	0.0958 552 274	0.1007 090 040	0.1055 871 820	52
53	0.0909 444 343	0.0957 804 201	0.1006 441 339	0.1055 311 042	53
54	0.0908 657 034	0.0957 122 048	0.1005 852 336	0.1054 804 064	54
55	0.0907 935 930	0.0956 499 926	0.1005 317 476	0.1054 345 680	55
56	0.0907 275 373	0.0955 932 484	0.1004 831 734	0.1053 931 196	56
57	0.0906 670 202	0.0955 414 860	0.1004 390 556	0.1053 556 378	57
58	0.0906 115 709	0.0954 942 633	0.1003 989 822	0.1053 217 406	58
59	0.0905 607 595	0.0954 511 784	0.1003 625 796	0.1052 910 832	59
60	0.0905 141 938	0.0954 118 653	0.1003 295 092	0.1052 633 544	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	11% NOMINAL ANNUAL RATE	11½% NOMINAL ANNUAL RATE	12% NOMINAL ANNUAL RATE	12½% NOMINAL ANNUAL RATE	YEARS
1	1.1100 000 000	1.1150 000 000	1.1200 000 000	1.1250 000 000	1
2	0.5839 336 493	0.5878 132 388	0.5916 981 132	0.5955 882 353	2
3	0.4092 130 696	0.4127 763 551	0.4163 489 806	0.4199 308 756	3
4	0.3223 263 515	0.3257 738 808	0.3292 344 363	0.3327 079 108	4
5	0.2705 703 095	0.2739 817 720	0.2774 097 319	0.2808 540 390	5
6	0.2363 765 636	0.2397 912 454	0.2432 257 184	0.2466 797 811	6
7	0.2122 152 695	0.2156 550 465	0.2191 177 359	0.2226 030 757	7
8	0.1943 210 542	0.1977 990 200	0.2013 028 414	0.2048 321 856	8
9	0.1806 016 644	0.1841 259 707	0.1876 788 888	0.1912 600 042	9
10	0.1698 014 271	0.1733 772 102	0.1769 841 642	0.1806 217 819	10
11	0.1611 210 071	0.1647 514 437	0.1684 154 043	0.1721 122 783	11
12	0.1540 272 864	0.1577 142 151	0.1614 368 076	0.1651 943 390	12
13	0.1481 509 925	0.1518 953 016	0.1556 771 951	0.1594 958 241	13
14	0.1432 282 015	0.1470 300 825	0.1508 712 461	0.1547 507 101	14
15	0.1390 652 395	0.1429 243 614	0.1468 242 396	0.1507 637 513	15
16	0.1355 167 470	0.1394 323 792	0.1433 900 180	0.1473 883 932	16
17	0.1324 714 845	0.1364 425 881	0.1404 567 275	0.1445 124 801	17
18	0.1298 428 701	0.1338 681 666	0.1379 373 114	0.1420 487 264	18
19	0.1275 625 041	0.1316 405 294	0.1357 630 049	0.1399 281 952	19
20	0.1255 756 369	0.1297 047 839	0.1338 787 800	0.1380 957 330	20
21	0.1238 379 300	0.1280 164 837	0.1322 400 915	0.1365 067 060	21
22	0.1223 131 011	0.1265 392 673	0.1308 105 088	0.1351 246 265	22
23	0.1209 711 818	0.1252 431 115	0.1295 599 650	0.1339 193 964	23
24	0.1197 872 113	0.1241 030 208	0.1284 634 417	0.1328 659 881	24
25	0.1187 402 421	0.1230 980 307	0.1274 999 698	0.1319 434 409	25
26	0.1178 125 750	0.1222 104 398	0.1266 518 581	0.1311 340 882	26
27	0.1169 891 636	0.1214 252 118	0.1259 040 937	0.1304 229 541	27
28	0.1162 571 454	0.1207 295 054	0.1252 438 691	0.1297 972 788	28
29	0.1156 054 695	0.1201 123 000	0.1246 602 068	0.1292 461 412	29
30	0.1150 245 985	0.1195 640 959	0.1241 436 576	0.1287 601 556	30
31	0.1145 062 669	0.1190 766 723	0.1236 860 570	0.1283 312 264	31
32	0.1140 432 854	0.1186 428 892	0.1232 803 263	0.1279 523 480	32
33	0.1136 293 791	0.1182 565 256	0.1229 203 096	0.1276 174 403	33
34	0.1132 590 547	0.1179 121 454	0.1226 006 383	0.1273 212 131	34
35	0.1129 274 900	0.1176 049 859	0.1223 166 193	0.1270 590 521	35
36	0.1126 304 409	0.1173 308 646	0.1220 641 406	0.1268 269 247	36
37	0.1123 641 641	0.1170 861 006	0.1218 395 924	0.1266 213 002	37
38	0.1121 253 508	0.1168 674 484	0.1216 397 998	0.1264 390 818	38
39	0.1119 110 713	0.1166 720 412	0.1214 619 665	0.1262 775 496	39
40	0.1117 187 267	0.1164 973 431	0.1213 036 256	0.1261 343 115	40
41	0.1115 460 086	0.1163 411 076	0.1211 625 982	0.1260 072 613	41
42	0.1113 908 633	0.1162 013 421	0.1210 369 577	0.1258 945 425	42
43	0.1112 514 619	0.1160 762 773	0.1209 249 987	0.1257 945 171	43
44	0.1111 261 735	0.1159 643 403	0.1208 252 102	0.1257 057 390	44
45	0.1110 135 424	0.1158 641 318	0.1207 362 523	0.1256 269 303	45
46	0.1109 122 683	0.1157 744 059	0.1206 569 363	0.1255 569 610	46
47	0.1108 211 884	0.1156 940 524	0.1205 862 064	0.1254 948 314	47
48	0.1107 392 624	0.1156 220 813	0.1205 231 248	0.1254 396 568	48
49	0.1106 655 589	0.1155 576 093	0.1204 668 576	0.1253 906 534	49
50	0.1105 992 433	0.1154 998 481	0.1204 166 635	0.1253 471 269	50
51	0.1105 395 676	0.1154 480 934	0.1203 718 826	0.1253 084 621	51
52	0.1104 858 607	0.1154 017 160	0.1203 319 279	0.1252 741 133	52
53	0.1104 375 209	0.1153 601 537	0.1202 962 763	0.1252 435 969	53
54	0.1103 940 076	0.1153 229 035	0.1202 644 625	0.1252 164 837	54
55	0.1103 548 359	0.1152 895 157	0.1202 360 715	0.1251 923 930	55
56	0.1103 195 698	0.1152 595 879	0.1202 107 337	0.1251 709 867	56
57	0.1102 878 179	0.1152 327 601	0.1201 881 197	0.1251 519 651	57
58	0.1102 592 282	0.1152 087 099	0.1201 679 358	0.1251 350 619	58
59	0.1102 334 844	0.1151 871 487	0.1201 499 202	0.1251 200 406	59
60	0.1102 103 020	0.1151 678 182	0.1201 338 394	0.1251 066 913	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

Annual Compounding

YEARS	13% NOMINAL ANNUAL RATE	13½% NOMINAL ANNUAL RATE	14% NOMINAL ANNUAL RATE	14½% NOMINAL ANNUAL RATE	YEARS
1	1.1300 000 000	1.1350 000 000	1.1400 000 000	1.1450 000 000	1
2	0.5994 835 681	0.6033 840 749	0.6072 897 196	0.6112 004 662	2
3	0.4235 219 701	0.4271 221 947	0.4307 314 804	0.4343 497 588	3
4	0.3361 941 974	0.3396 931 901	0.3432 047 833	0.3467 288 719	4
5	0.2843 145 434	0.2877 910 955	0.2912 835 465	0.2947 917 481	5
6	0.2501 532 321	0.2536 458 704	0.2571 574 957	0.2606 879 076	6
7	0.2261 108 038	0.2296 406 583	0.2331 923 773	0.2367 656 994	7
8	0.2083 867 196	0.2119 661 101	0.2155 700 238	0.2191 981 278	8
9	0.1948 689 020	0.1985 051 669	0.2021 683 838	0.2058 581 379	9
10	0.1842 895 558	0.1879 869 780	0.1917 135 408	0.1954 687 376	10
11	0.1758 414 545	0.1796 023 222	0.1833 942 714	0.1872 166 937	11
12	0.1689 860 847	0.1728 113 211	0.1766 693 269	0.1805 593 835	12
13	0.1633 503 411	0.1672 399 012	0.1711 636 635	0.1751 207 919	13
14	0.1586 674 959	0.1626 206 298	0.1666 091 448	0.1706 320 815	14
15	0.1547 417 797	0.1587 572 163	0.1628 089 630	0.1668 959 329	15
16	0.1514 262 445	0.1555 023 244	0.1596 154 000	0.1637 642 550	16
17	0.1486 084 385	0.1527 432 135	0.1569 154 359	0.1611 237 596	17
18	0.1462 008 548	0.1503 921 647	0.1546 211 516	0.1588 863 402	18
19	0.1441 343 943	0.1483 799 284	0.1526 631 593	0.1569 824 868	19
20	0.1423 537 884	0.1466 511 339	0.1509 860 016	0.1553 566 708	20
21	0.1408 143 279	0.1451 610 103	0.1495 448 612	0.1539 640 464	21
22	0.1394 794 811	0.1438 729 970	0.1483 031 654	0.1527 680 465	22
23	0.1383 191 328	0.1427 569 775	0.1472 308 130	0.1517 386 033	23
24	0.1373 082 605	0.1417 879 502	0.1463 028 406	0.1508 508 096	24
25	0.1364 259 276	0.1409 450 182	0.1454 984 079	0.1500 838 993	25
26	0.1356 545 063	0.1402 106 089	0.1448 000 136	0.1494 204 595	26
27	0.1349 790 727	0.1395 698 653	0.1441 928 839	0.1488 458 159	27
28	0.1343 869 291	0.1390 101 668	0.1436 644 905	0.1483 475 475	28
29	0.1338 672 246	0.1385 207 472	0.1432 041 657	0.1479 150 996	29
30	0.1334 106 503	0.1380 923 874	0.1428 027 939	0.1475 394 732	30
31	0.1330 091 921	0.1377 171 673	0.1424 525 613	0.1472 129 724	31
32	0.1326 559 291	0.1373 882 625	0.1421 467 511	0.1469 289 987	32
33	0.1323 448 684	0.1370 997 777	0.1418 795 755	0.1466 818 816	33
34	0.1320 708 076	0.1368 466 081	0.1416 460 366	0.1464 667 377	34
35	0.1318 292 209	0.1366 243 248	0.1414 418 099	0.1462 793 548	35
36	0.1316 161 634	0.1364 290 780	0.1412 631 480	0.1461 160 934	36
37	0.1314 281 904	0.1362 575 162	0.1411 067 982	0.1459 738 048	37
38	0.1312 622 899	0.1361 067 176	0.1409 699 339	0.1458 497 619	38
39	0.1311 158 243	0.1359 741 317	0.1408 500 959	0.1457 415 997	39
40	0.1309 864 810	0.1358 575 299	0.1407 451 425	0.1456 472 661	40
41	0.1308 722 306	0.1357 549 625	0.1406 532 069	0.1455 649 785	41
42	0.1307 712 901	0.1356 647 231	0.1405 726 603	0.1454 931 877	42
43	0.1306 820 921	0.1355 853 163	0.1405 020 814	0.1454 305 461	43
44	0.1306 032 572	0.1355 154 314	0.1404 402 284	0.1453 758 815	44
45	0.1305 335 711	0.1354 539 184	0.1403 860 162	0.1453 281 731	45
46	0.1304 719 639	0.1353 997 682	0.1403 384 961	0.1452 865 319	46
47	0.1304 174 928	0.1353 520 947	0.1402 968 383	0.1452 501 836	47
48	0.1303 693 262	0.1353 101 194	0.1402 603 167	0.1452 184 532	48
49	0.1303 267 306	0.1352 731 583	0.1402 282 958	0.1451 907 524	49
50	0.1302 890 585	0.1352 406 102	0.1402 002 194	0.1451 665 683	50
51	0.1302 557 386	0.1352 119 464	0.1401 756 002	0.1451 454 533	51
52	0.1302 262 661	0.1351 867 021	0.1401 540 115	0.1451 270 173	52
53	0.1302 001 954	0.1351 644 682	0.1401 350 796	0.1451 109 199	53
54	0.1301 771 327	0.1351 448 849	0.1401 184 768	0.1450 968 639	54
55	0.1301 567 300	0.1351 276 356	0.1401 039 162	0.1450 845 901	55
56	0.1301 386 7[illegible]9	0.1351 124 416	0.1400 911 463	0.1450 738 724	56
57	0.1301 227 105	0.1350 990 577	0.1400 799 465	0.1450 645 132	57
58	0.1301 085 816	0.1350 872 679	0.1400 701 236	0.1450 563 402	58
59	0.1300 960 807	0.1350 768 821	0.1400 615 081	0.1450 492 030	59
60	0.1300 850 199	0.1350 677 329	0.1400 539 516	0.1450 429 702	60

YEARS	15% NOMINAL ANNUAL RATE	15½% NOMINAL ANNUAL RATE	16% NOMINAL ANNUAL RATE	16½% NOMINAL ANNUAL RATE	YEARS
1	1.1500 000 000	1.1550 000 000	1.1600 000 000	1.1650 000 000	1
2	0.6151 162 791	0.6190 371 230	0.6229 629 630	0.6268 937 644	2
3	0.4379 769 618	0.4416 130 223	0.4452 578 731	0.4489 114 480	3
4	0.3502 653 516	0.3538 141 185	0.3573 750 695	0.3609 481 019	4
5	0.2983 155 525	0.3018 548 125	0.3054 093 816	0.3089 791 140	5
6	0.2642 369 066	0.2678 042 936	0.2713 898 702	0.2749 934 387	6
7	0.2403 603 636	0.2439 761 095	0.2476 126 771	0.2512 698 077	7
8	0.2228 500 896	0.2265 255 774	0.2302 242 601	0.2339 458 078	8
9	0.2095 740 150	0.2133 156 020	0.2170 824 868	0.2208 742 591	9
10	0.1992 520 625	0.2030 630 117	0.2069 010 831	0.2107 657 770	10
11	0.1910 689 830	0.1949 505 356	0.1988 607 515	0.2027 990 342	11
12	0.1844 807 761	0.1884 327 944	0.1924 147 333	0.1964 258 934	12
13	0.1791 104 565	0.1831 318 343	0.1871 841 100	0.1912 664 771	13
14	0.1746 884 898	0.1787 774 299	0.1828 979 733	0.1870 492 036	14
15	0.1710 170 526	0.1751 712 633	0.1793 575 218	0.1835 748 018	15
16	0.1679 476 914	0.1721 645 308	0.1764 136 162	0.1806 938 131	16
17	0.1653 668 623	0.1696 434 484	0.1739 522 494	0.1782 920 262	17
18	0.1631 862 874	0.1675 195 831	0.1718 848 526	0.1762 807 572	18
19	0.1613 363 504	0.1657 232 318	0.1701 416 556	0.1745 901 910	19
20	0.1597 614 704	0.1641 987 802	0.1686 670 324	0.1731 647 123	20
21	0.1584 167 914	0.1629 013 828	0.1674 161 691	0.1719 595 618	21
22	0.1572 657 713	0.1617 945 424	0.1663 526 353	0.1709 383 976	22
23	0.1562 783 947	0.1608 483 167	0.1654 465 820	0.1700 714 859	23
24	0.1554 298 296	0.1600 379 680	0.1646 733 862	0.1693 343 385	24
25	0.1546 994 023	0.1593 429 337	0.1640 126 153	0.1687 066 717	25
26	0.1540 698 058	0.1587 460 303	0.1634 472 266	0.1681 716 014	26
27	0.1535 264 815	0.1582 328 312	0.1629 629 420	0.1677 150 133	27
28	0.1530 571 309	0.1577 911 756	0.1625 477 527	0.1673 250 650	28
29	0.1526 513 265	0.1574 107 763	0.1621 915 252	0.1669 917 888	29
30	0.1523 001 982	0.1570 829 047	0.1618 856 833	0.1667 067 719	30
31	0.1519 961 796	0.1568 001 344	0.1616 229 508	0.1664 628 970	31
32	0.1517 328 006	0.1565 561 326	0.1613 971 408	0.1662 541 308	32
33	0.1515 045 161	0.1563 454 881	0.1612 029 828	0.1660 753 495	33
34	0.1513 065 655	0.1561 635 693	0.1610 359 798	0.1659 221 956	34
35	0.1511 348 546	0.1560 064 055	0.1608 922 891	0.1657 909 581	35
36	0.1509 858 572	0.1558 705 881	0.1607 686 235	0.1656 784 733	36
37	0.1508 565 329	0.1557 531 882	0.1606 621 677	0.1655 820 416	37
38	0.1507 442 569	0.1556 516 861	0.1605 705 086	0.1654 993 570	38
39	0.1506 467 613	0.1555 639 122	0.1604 915 760	0.1654 284 490	39
40	0.1505 620 850	0.1554 879 974	0.1604 235 929	0.1653 676 322	40
41	0.1504 885 308	0.1554 223 301	0.1603 650 330	0.1653 154 645	41
42	0.1504 246 290	0.1553 655 201	0.1603 145 846	0.1652 707 117	42
43	0.1503 691 063	0.1553 163 675	0.1602 711 201	0.1652 323 166	43
44	0.1503 208 590	0.1552 738 363	0.1602 336 696	0.1651 993 736	44
45	0.1502 789 300	0.1552 370 315	0.1602 013 988	0.1651 711 069	45
46	0.1502 424 890	0.1552 051 800	0.1601 735 895	0.1651 468 513	46
47	0.1502 108 156	0.1551 776 134	0.1601 496 237	0.1651 260 367	47
48	0.1501 832 843	0.1551 537 542	0.1601 289 693	0.1651 081 743	48
49	0.1501 593 523	0.1551 331 028	0.1601 111 681	0.1650 928 449	49
50	0.1501 385 480	0.1551 152 273	0.1600 958 254	0.1650 796 888	50
51	0.1501 204 620	0.1550 997 539	0.1600 826 013	0.1650 683 971	51
52	0.1501 047 386	0.1550 863 596	0.1600 712 029	0.1650 587 071	52
53	0.1500 910 687	0.1550 747 646	0.1600 613 781	0.1650 503 898	53
54	0.1500 791 839	0.1550 647 271	0.1600 529 093	0.1650 432 512	54
55	0.1500 688 509	0.1550 560 376	0.1600 456 094	0.1650 371 241	55
56	0.1500 598 667	0.1550 485 151	0.1600 393 169	0.1650 318 652	56
57	0.1500 520 553	0.1550 420 026	0.1600 338 927	0.1650 273 513	57
58	0.1500 452 634	0.1550 363 646	0.1600 292 170	0.1650 234 770	58
59	0.1500 393 580	0.1550 314 835	0.1600 251 865	0.1650 201 515	59
60	0.1500 342 231	0.1550 272 577	0.1600 217 120	0.1650 172 971	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	17% NOMINAL ANNUAL RATE	17½% NOMINAL ANNUAL RATE	18% NOMINAL ANNUAL RATE	18½% NOMINAL ANNUAL RATE	YEARS
1	1.1700 000 000	1.1750 000 000	1.1800 000 000	1.1850 000 000	1
2	0.6308 294 931	0.6347 701 149	0.6387 155 963	0.6426 659 039	2
3	0.4525 736 811	0.4562 445 069	0.4599 238 607	0.4636 116 780	3
4	0.3645 331 137	0.3681 300 037	0.3717 386 709	0.3753 590 154	4
5	0.3125 638 643	0.3161 634 882	0.3197 778 418	0.3234 067 820	5
6	0.2786 148 021	0.2822 537 641	0.2859 101 292	0.2895 837 031	6
7	0.2549 472 428	0.2586 447 254	0.2623 619 994	0.2660 988 095	7
8	0.2376 898 916	0.2414 561 840	0.2452 443 589	0.2490 540 919	8
9	0.2246 905 102	0.2285 308 333	0.2323 948 239	0.2362 820 801	9
10	0.2146 565 967	0.2185 730 482	0.2225 146 413	0.2264 808 893	10
11	0.2067 647 916	0.2107 574 364	0.2147 763 862	0.2188 210 645	11
12	0.2004 655 819	0.2045 331 132	0.2086 278 089	0.2127 489 990	12
13	0.1953 781 386	0.1995 183 074	0.2036 862 073	0.2078 810 735	13
14	0.1912 302 181	0.1954 401 277	0.1996 780 583	0.2039 431 510	14
15	0.1878 220 950	0.1920 984 119	0.1964 027 825	0.2007 342 570	15
16	0.1850 040 103	0.1893 431 211	0.1937 100 839	0.1981 038 628	16
17	0.1826 615 693	0.1870 596 999	0.1914 852 711	0.1959 371 677	17
18	0.1807 059 953	0.1851 593 036	0.1896 394 570	0.1941 452 695	18
19	0.1790 674 523	0.1835 720 996	0.1881 028 390	0.1926 584 229	19
20	0.1776 903 593	0.1822 425 665	0.1868 199 812	0.1914 213 045	20
21	0.1765 300 350	0.1811 261 256	0.1857 464 327	0.1903 896 170	21
22	0.1755 502 493	0.1801 866 820	0.1848 462 577	0.1895 276 075	22
23	0.1747 214 054	0.1793 947 980	0.1840 901 996	0.1888 062 232	23
24	0.1740 191 703	0.1787 263 162	0.1834 542 973	0.1882 017 187	24
25	0.1734 234 282	0.1781 613 074	0.1829 188 261	0.1876 945 919	25
26	0.1729 174 705	0.1776 832 551	0.1824 674 779	0.1872 687 583	26
27	0.1724 873 621	0.1772 784 184	0.1820 867 195	0.1869 109 054	27
28	0.1721 214 404	0.1769 353 267	0.1817 652 846	0.1866 099 822	28
29	0.1718 099 152	0.1766 443 781	0.1814 937 692	0.1863 567 913	29
30	0.1715 445 468	0.1763 975 150	0.1812 643 056	0.1861 436 621	30
31	0.1713 183 850	0.1761 879 615	0.1810 702 987	0.1859 641 852	31
32	0.1711 255 565	0.1760 100 099	0.1809 062 108	0.1858 129 969	32
33	0.1709 610 895	0.1758 588 447	0.1807 673 859	0.1856 856 029	33
34	0.1708 207 698	0.1757 303 978	0.1806 499 044	0.1855 782 333	34
35	0.1707 010 209	0.1756 212 289	0.1805 504 633	0.1854 877 226	35
36	0.1705 988 044	0.1755 284 261	0.1804 662 768	0.1854 114 109	36
37	0.1705 115 368	0.1754 495 222	0.1803 949 937	0.1853 470 617	37
38	0.1704 370 199	0.1753 824 258	0.1803 346 284	0.1852 927 934	38
39	0.1703 733 818	0.1753 253 628	0.1802 835 030	0.1852 470 220	39
40	0.1703 190 279	0.1752 768 279	0.1802 401 991	0.1852 084 139	40
41	0.1702 725 991	0.1752 355 427	0.1802 035 171	0.1851 758 458	41
42	0.1702 329 364	0.1752 004 217	0.1801 724 424	0.1851 483 711	42
43	0.1701 990 513	0.1751 705 426	0.1801 461 163	0.1851 251 920	43
44	0.1701 701 004	0.1751 451 216	0.1801 238 120	0.1851 056 361	44
45	0.1701 453 638	0.1751 234 925	0.1801 049 144	0.1850 891 364	45
46	0.1701 242 272	0.1751 050 889	0.1800 889 026	0.1850 752 149	46
47	0.1701 061 658	0.1750 894 294	0.1800 753 355	0.1850 634 685	47
48	0.1700 907 317	0.1750 761 043	0.1800 638 396	0.1850 535 570	48
49	0.1700 775 425	0.1750 647 654	0.1800 540 984	0.1850 451 938	49
50	0.1700 662 712	0.1750 551 165	0.1800 458 440	0.1850 381 368	50
51	0.1700 566 389	0.1750 469 054	0.1800 388 494	0.1850 321 819	51
52	0.1700 484 070	0.1750 399 179	0.1800 329 221	0.1850 271 570	52
53	0.1700 413 718	0.1750 339 716	0.1800 278 993	0.1850 229 167	53
54	0.1700 353 592	0.1750 289 111	0.1800 236 429	0.1850 193 387	54
55	0.1700 302 206	0.1750 246 046	0.1800 200 360	0.1850 163 193	55
56	0.1700 258 289	0.1750 209 397	0.1800 169 794	0.1850 137 713	56
57	0.1700 220 755	0.1750 178 207	0.1800 143 891	0.1850 116 213	57
58	0.1700 188 676	0.1750 151 663	0.1800 121 940	0.1850 098 069	58
59	0.1700 161 259	0.1750 129 073	0.1800 103 338	0.1850 082 758	59
60	0.1700 137 826	0.1750 109 848	0.1800 087 574	0.1850 069 837	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

Annual Compounding

YEARS	19% NOMINAL ANNUAL RATE	19½% NOMINAL ANNUAL RATE	20% NOMINAL ANNUAL RATE	20½% NOMINAL ANNUAL RATE	YEARS
1	1.1900 000 000	1.1950 000 000	1.2000 000 000	1.2050 000 000	1
2	0.6466 210 046	0.6505 808 656	0.6545 454 545	0.6585 147 392	2
3	0.4673 078 950	0.4710 124 482	0.4747 252 747	0.4784 463 122	3
4	0.3789 909 377	0.3826 343 389	0.3862 891 207	0.3899 551 857	4
5	0.3270 501 666	0.3307 078 539	0.3343 797 033	0.3380 655 748	5
6	0.2932 742 921	0.2969 817 036	0.3007 057 459	0.3044 462 284	6
7	0.2698 549 022	0.2736 300 248	0.2774 239 263	0.2812 363 570	7
8	0.2528 850 604	0.2567 369 435	0.2606 094 224	0.2645 021 805	8
9	0.2401 922 023	0.2441 247 940	0.2480 794 617	0.2520 558 149	9
10	0.2304 713 094	0.2344 854 232	0.2385 227 569	0.2425 828 412	10
11	0.2228 909 005	0.2269 853 296	0.2311 037 942	0.2352 457 430	11
12	0.2168 960 219	0.2210 682 250	0.2252 649 649	0.2294 856 079	12
13	0.2121 021 529	0.2163 487 047	0.2206 200 011	0.2249 153 270	13
14	0.2082 345 628	0.2125 514 675	0.2168 930 552	0.2212 585 336	14
15	0.2050 919 063	0.2094 748 227	0.2138 821 198	0.2183 129 335	15
16	0.2025 234 484	0.2069 678 578	0.2114 361 350	0.2159 273 513	16
17	0.2004 143 070	0.2049 156 392	0.2094 401 469	0.2139 868 456	17
18	0.1986 755 939	0.2032 293 223	0.2078 053 857	0.2124 027 537	18
19	0.1972 376 496	0.2018 393 632	0.2064 624 532	0.2111 058 536	19
20	0.1960 452 907	0.2006 907 465	0.2053 565 307	0.2100 415 524	20
21	0.1950 543 994	0.1997 395 606	0.2044 439 388	0.2091 664 291	21
22	0.1942 294 304	0.1989 504 912	0.2036 896 187	0.2084 457 036	22
23	0.1935 415 560	0.1982 949 577	0.2030 652 575	0.2078 513 516	23
24	0.1929 672 666	0.1977 497 051	0.2025 478 730	0.2073 606 809	24
25	0.1924 872 993	0.1972 957 260	0.2021 187 290	0.2069 552 408	25
26	0.1920 858 078	0.1969 174 260	0.2017 624 956	0.2066 199 779	26
27	0.1917 497 128	0.1966 019 702	0.2014 665 923	0.2063 425 751	27
28	0.1914 681 881	0.1963 387 661	0.2012 206 684	0.2061 129 302	28
29	0.1912 322 512	0.1961 190 527	0.2010 161 900	0.2059 227 413	29
30	0.1910 344 341	0.1959 355 697	0.2008 461 085	0.2057 651 745	30
31	0.1908 685 173	0.1957 822 910	0.2007 045 936	0.2056 345 966	31
32	0.1907 293 142	0.1956 542 086	0.2005 868 168	0.2055 263 590	32
33	0.1906 124 937	0.1955 471 553	0.2004 887 750	0.2054 366 217	33
34	0.1905 144 358	0.1954 576 610	0.2004 071 466	0.2053 622 104	34
35	0.1904 321 122	0.1953 828 333	0.2003 391 738	0.2053 004 992	35
36	0.1903 629 877	0.1953 202 600	0.2002 825 649	0.2052 493 148	36
37	0.1903 049 387	0.1952 679 282	0.2002 354 154	0.2052 068 574	37
38	0.1902 561 853	0.1952 241 574	0.2001 961 410	0.2051 716 365	38
39	0.1902 152 355	0.1951 875 443	0.2001 634 241	0.2051 424 166	39
40	0.1901 808 374	0.1951 569 162	0.2001 361 682	0.2051 181 741	40
41	0.1901 519 411	0.1951 312 934	0.2001 134 606	0.2050 980 602	41
42	0.1901 276 653	0.1951 098 569	0.2000 945 416	0.2050 813 711	42
43	0.1901 072 703	0.1950 919 220	0.2000 787 785	0.2050 675 233	43
44	0.1900 901 350	0.1950 769 162	0.2000 656 444	0.2050 560 328	44
45	0.1900 757 379	0.1950 643 609	0.2000 547 007	0.2050 464 981	45
46	0.1900 636 413	0.1950 538 556	0.2000 455 818	0.2050 385 861	46
47	0.1900 534 772	0.1950 450 654	0.2000 379 834	0.2050 320 207	47
48	0.1900 449 368	0.1950 377 102	0.2000 316 518	0.2050 265 725	48
49	0.1900 377 606	0.1950 315 557	0.2000 263 758	0.2050 220 514	49
50	0.1900 317 306	0.1950 264 057	0.2000 219 794	0.2050 182 995	50
51	0.1900 266 636	0.1950 220 964	0.2000 183 158	0.2050 151 861	51
52	0.1900 224 059	0.1950 184 903	0.2000 152 629	0.2050 126 024	52
53	0.1900 188 282	0.1950 154 728	0.2000 127 190	0.2050 104 583	53
54	0.1900 158 217	0.1950 129 478	0.2000 105 990	0.2050 086 790	54
55	0.1900 132 954	0.1950 108 349	0.2000 088 324	0.2050 072 025	55
56	0.1900 111 725	0.1950 090 668	0.2000 073 603	0.2050 059 771	56
57	0.1900 093 885	0.1950 075 872	0.2000 061 336	0.2050 049 602	57
58	0.1900 078 895	0.1950 063 491	0.2000 051 113	0.2050 041 164	58
59	0.1900 066 298	0.1950 053 130	0.2000 042 594	0.2050 034 161	59
60	0.1900 055 712	0.1950 044 460	0.2000 035 495	0.2050 028 349	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	21% NOMINAL ANNUAL RATE	21½% NOMINAL ANNUAL RATE	22% NOMINAL ANNUAL RATE	22½% NOMINAL ANNUAL RATE	YEARS
1	1.2100 000 000	1.2150 000 000	1.2200 000 000	1.2250 000 000	1
2	0.6624 886 878	0.6664 672 686	0.6704 504 505	0.6744 382 022	2
3	0.4821 754 988	0.4859 127 729	0.4896 580 736	0.4934 113 404	3
4	0.3936 324 369	0.3973 207 780	0.4010 201 135	0.4047 303 483	4
5	0.3417 653 293	0.3454 788 284	0.3492 059 348	0.3529 465 120	5
6	0.3082 029 617	0.3119 757 574	0.3157 644 282	0.3195 687 881	6
7	0.2850 670 688	0.2889 158 150	0.2927 823 508	0.2966 664 329	7
8	0.2684 149 035	0.2723 472 791	0.2762 989 979	0.2802 697 526	8
9	0.2560 534 667	0.2600 720 334	0.2641 111 354	0.2681 703 963	9
10	0.2466 652 120	0.2507 694 102	0.2548 949 820	0.2590 414 793	10
11	0.2394 106 322	0.2435 979 253	0.2478 070 935	0.2520 376 154	11
12	0.2337 295 303	0.2379 961 186	0.2422 847 695	0.2465 948 907	12
13	0.2292 339 810	0.2335 752 752	0.2379 385 355	0.2423 231 022	13
14	0.2256 471 276	0.2300 580 800	0.2344 906 512	0.2389 441 198	14
15	0.2227 664 213	0.2272 417 634	0.2317 381 620	0.2362 548 416	15
16	0.2204 406 051	0.2249 750 219	0.2295 297 542	0.2341 039 818	16
17	0.2185 547 835	0.2231 430 410	0.2277 507 309	0.2323 769 974	17
18	0.2170 204 340	0.2216 574 724	0.2263 129 516	0.2309 859 908	18
19	0.2157 685 424	0.2204 495 409	0.2251 479 123	0.2298 627 611	19
20	0.2147 447 703	0.2194 651 915	0.2242 018 701	0.2289 539 055	20
21	0.2139 059 812	0.2186 615 982	0.2234 323 343	0.2282 172 935	21
22	0.2132 176 967	0.2180 046 062	0.2228 054 958	0.2276 194 824	22
23	0.2126 522 006	0.2174 668 266	0.2222 943 108	0.2271 337 902	23
24	0.2121 871 074	0.2170 261 962	0.2218 770 526	0.2267 388 407	24
25	0.2118 042 655	0.2166 648 747	0.2215 362 042	0.2264 174 498	25
26	0.2114 889 084	0.2163 683 922	0.2212 576 002	0.2261 557 645	26
27	0.2112 289 905	0.2161 249 817	0.2210 297 583	0.2259 425 919	27
28	0.2110 146 640	0.2159 250 544	0.2208 433 524	0.2257 688 712	28
29	0.2108 378 627	0.2157 607 824	0.2206 907 949	0.2256 272 562	29
30	0.2106 919 694	0.2156 257 665	0.2205 659 049	0.2255 117 839	30
31	0.2105 715 487	0.2155 147 690	0.2204 636 414	0.2254 176 083	31
32	0.2104 721 313	0.2154 234 988	0.2203 798 896	0.2253 407 885	32
33	0.2103 900 389	0.2153 484 372	0.2203 112 880	0.2252 781 173	33
34	0.2103 222 423	0.2152 866 974	0.2202 550 890	0.2252 269 830	34
35	0.2102 662 451	0.2152 359 093	0.2202 090 456	0.2251 852 579	35
36	0.2102 199 889	0.2151 941 263	0.2201 713 195	0.2251 512 081	36
37	0.2101 817 759	0.2151 597 492	0.2201 404 061	0.2251 234 200	37
38	0.2101 502 055	0.2151 314 636	0.2201 150 737	0.2251 007 408	38
39	0.2101 241 213	0.2151 081 888	0.2200 943 138	0.2250 822 307	39
40	0.2101 025 691	0.2150 890 363	0.2200 773 005	0.2250 671 226	40
41	0.2100 847 607	0.2150 732 755	0.2200 633 570	0.2250 547 909	41
42	0.2100 700 452	0.2150 603 055	0.2200 519 293	0.2250 447 253	42
43	0.2100 578 853	0.2150 496 317	0.2200 425 632	0.2250 365 091	43
44	0.2100 478 368	0.2150 408 474	0.2200 348 866	0.2250 298 025	44
45	0.2100 395 330	0.2150 336 182	0.2200 285 948	0.2250 243 279	45
46	0.2100 326 708	0.2150 276 685	0.2200 234 378	0.2250 198 592	46
47	0.2100 269 999	0.2150 227 719	0.2200 192 109	0.2250 162 113	47
48	0.2100 223 135	0.2150 187 420	0.2200 157 464	0.2250 132 335	48
49	0.2100 184 406	0.2150 154 252	0.2200 129 067	0.2250 108 028	49
50	0.2100 152 399	0.2150 126 955	0.2200 105 792	0.2250 088 185	50
51	0.2100 125 948	0.2150 104 489	0.2200 086 714	0.2250 071 987	51
52	0.2100 104 088	0.2150 085 998	0.2200 071 076	0.2250 058 765	52
53	0.2100 086 023	0.2150 070 780	0.2200 058 259	0.2250 047 971	53
54	0.2100 071 093	0.2150 058 255	0.2200 047 753	0.2250 039 160	54
55	0.2100 058 754	0.2150 047 946	0.2200 039 142	0.2250 031 967	55
56	0.2100 048 557	0.2150 039 462	0.2200 032 083	0.2250 026 096	56
57	0.2100 040 129	0.2150 032 479	0.2200 026 298	0.2250 021 302	57
58	0.2100 033 165	0.2150 026 731	0.2200 021 555	0.2250 017 390	58
59	0.2100 027 409	0.2150 022 001	0.2200 017 668	0.2250 014 196	59
60	0.2100 022 652	0.2150 018 108	0.2200 014 482	0.2250 011 588	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

YEARS	23% NOMINAL ANNUAL RATE	24% NOMINAL ANNUAL RATE	25% NOMINAL ANNUAL RATE	26% NOMINAL ANNUAL RATE	YEARS
1	1.2300 000 000	1.2400 000 000	1.2500 000 000	1.2600 000 000	1
2	0.6784 304 933	0.6864 285 714	0.6944 444 444	0.7024 778 761	2
3	0.4971 725 133	0.5047 183 397	0.5122 950 820	0.5199 022 767	3
4	0.4084 513 881	0.4159 255 089	0.4234 417 344	0.4309 993 338	4
5	0.3567 004 241	0.3642 477 149	0.3718 467 396	0.3794 964 454	5
6	0.3233 886 522	0.3310 741 602	0.3388 194 987	0.3466 232 355	6
7	0.3005 678 200	0.3084 215 527	0.3163 416 530	0.3243 262 593	7
8	0.2842 592 389	0.2922 932 018	0.3003 985 063	0.3085 728 187	8
9	0.2722 494 441	0.2804 654 313	0.2887 562 013	0.2971 189 268	9
10	0.2632 084 594	0.2716 021 271	0.2800 725 624	0.2886 164 407	10
11	0.2562 889 780	0.2648 522 131	0.2734 928 576	0.2822 071 051	11
12	0.2509 259 004	0.2596 483 138	0.2684 475 770	0.2773 194 369	12
13	0.2467 283 293	0.2555 982 535	0.2645 434 288	0.2735 592 056	13
14	0.2434 177 823	0.2524 229 653	0.2615 009 326	0.2706 467 022	14
15	0.2407 910 491	0.2499 191 452	0.2591 168 642	0.2683 789 634	15
16	0.2386 969 108	0.2479 358 295	0.2572 406 815	0.2666 060 410	16
17	0.2370 210 160	0.2463 591 647	0.2557 591 848	0.2652 155 451	17
18	0.2356 757 451	0.2451 021 928	0.2545 862 176	0.2641 222 582	18
19	0.2345 932 318	0.2440 978 105	0.2536 555 619	0.2632 609 648	19
20	0.2337 204 414	0.2432 938 009	0.2529 159 221	0.2625 813 865	20
21	0.2330 156 276	0.2426 492 538	0.2523 273 086	0.2620 445 308	21
22	0.2324 457 335	0.2421 319 401	0.2518 583 869	0.2616 200 148	22
23	0.2319 844 553	0.2417 163 556	0.2514 845 025	0.2612 840 750	23
24	0.2316 107 795	0.2413 822 445	0.2511 861 933	0.2610 180 696	24
25	0.2313 078 641	0.2411 134 721	0.2509 480 549	0.2608 073 395	25
26	0.2310 621 747	0.2408 971 558	0.2507 578 692	0.2606 403 353	26
27	0.2308 628 116	0.2407 229 896	0.2506 059 280	0.2605 079 445	27
28	0.2307 009 811	0.2405 827 164	0.2504 845 075	0.2604 029 681	28
29	0.2305 695 787	0.2404 697 118	0.2503 874 558	0.2603 197 137	29
30	0.2304 628 578	0.2403 786 564	0.2503 098 686	0.2602 536 767	30
31	0.2303 761 656	0.2403 052 749	0.2502 478 335	0.2602 012 902	31
32	0.2303 057 322	0.2402 461 288	0.2501 982 275	0.2601 597 286	32
33	0.2302 485 010	0.2401 984 516	0.2501 585 568	0.2601 267 526	33
34	0.2302 019 925	0.2401 600 160	0.2501 268 294	0.2601 005 872	34
35	0.2301 641 946	0.2401 290 285	0.2501 014 532	0.2600 798 248	35
36	0.2301 334 737	0.2401 040 444	0.2500 811 560	0.2600 633 490	36
37	0.2301 085 034	0.2400 838 998	0.2500 649 206	0.2600 502 744	37
38	0.2300 882 064	0.2400 676 565	0.2500 519 338	0.2600 398 987	38
39	0.2300 717 074	0.2400 545 587	0.2500 415 453	0.2600 316 647	39
40	0.2300 582 953	0.2400 439 970	0.2500 332 351	0.2600 251 301	40
41	0.2300 473 923	0.2400 354 802	0.2500 265 874	0.2600 199 441	41
42	0.2300 385 288	0.2400 286 123	0.2500 212 695	0.2600 158 284	42
43	0.2300 313 233	0.2400 230 739	0.2500 170 153	0.2600 125 621	43
44	0.2300 254 654	0.2400 186 076	0.2500 136 120	0.2600 099 698	44
45	0.2300 207 032	0.2400 150 059	0.2500 108 895	0.2600 079 125	45
46	0.2300 168 316	0.2400 121 014	0.2500 087 115	0.2600 062 797	46
47	0.2300 136 840	0.2400 097 591	0.2500 069 692	0.2600 049 839	47
48	0.2300 111 251	0.2400 078 702	0.2500 055 753	0.2600 039 554	48
49	0.2300 090 447	0.2400 063 469	0.2500 044 602	0.2600 031 392	49
50	0.2300 073 534	0.2400 051 184	0.2500 035 682	0.2600 024 914	50
51	0.2300 059 783	0.2400 041 277	0.2500 028 545	0.2600 019 773	51
52	0.2300 048 604	0.2400 033 288	0.2500 022 836	0.2600 015 693	52
53	0.2300 039 515	0.2400 026 845	0.2500 018 269	0.2600 012 455	53
54	0.2300 032 126	0.2400 021 649	0.2500 014 615	0.2600 009 885	54
55	0.2300 026 119	0.2400 017 459	0.2500 011 692	0.2600 007 845	55
56	0.2300 021 235	0.2400 014 080	0.2500 009 354	0.2600 006 226	56
57	0.2300 017 264	0.2400 011 355	0.2500 007 483	0.2600 004 941	57
58	0.2300 014 036	0.2400 009 157	0.2500 005 986	0.2600 003 922	58
59	0.2300 011 411	0.2400 007 385	0.2500 004 789	0.2600 003 113	59
60	0.2300 009 277	0.2400 005 955	0.2500 003 831	0.2600 002 470	60

PARTIAL PAYMENT TO AMORTIZE 1
PAYABLE AT END OF EACH PERIOD

ANNUAL
COMPOUNDING

YEARS	27% NOMINAL ANNUAL RATE	28% NOMINAL ANNUAL RATE	29% NOMINAL ANNUAL RATE	30% NOMINAL ANNUAL RATE	YEARS
1	1.2700 000 000	1.2800 000 000	1.2900 000 000	1.3000 000 000	1
2	0.7105 286 344	0.7185 964 912	0.7266 812 227	0.7347 826 087	2
3	0.5275 394 679	0.5352 062 066	0.5429 020 510	0.5506 265 664	3
4	0.4385 975 867	0.4462 357 835	0.4539 132 250	0.4616 292 226	4
5	0.3871 957 942	0.3949 437 633	0.4027 393 452	0.4105 815 484	5
6	0.3544 839 602	0.3624 002 847	0.3703 708 441	0.3783 942 967	6
7	0.3323 735 405	0.3404 816 996	0.3486 489 741	0.3568 736 368	7
8	0.3168 138 541	0.3251 193 773	0.3334 872 047	0.3419 152 051	8
9	0.3055 508 517	0.3140 492 925	0.3226 116 401	0.3312 353 605	9
10	0.2972 305 377	0.3059 117 316	0.3146 570 037	0.3234 634 396	10
11	0.2909 912 864	0.2998 418 706	0.3087 554 652	0.3177 288 158	11
12	0.2862 598 204	0.2952 648 341	0.3043 307 636	0.3134 540 701	12
13	0.2826 411 632	0.2917 851 066	0.3009 870 625	0.3102 432 741	13
14	0.2798 555 727	0.2891 231 170	0.2984 451 743	0.3078 178 414	14
15	0.2777 005 351	0.2870 769 943	0.2965 040 669	0.3059 777 755	15
16	0.2760 268 700	0.2854 985 011	0.2950 166 190	0.3045 772 413	16
17	0.2747 231 529	0.2842 773 299	0.2938 737 873	0.3035 086 013	17
18	0.2737 052 382	0.2833 305 344	0.2929 939 453	0.3026 916 595	18
19	0.2729 090 233	0.2825 952 273	0.2923 155 138	0.3020 662 291	19
20	0.2722 853 348	0.2820 234 188	0.2917 917 558	0.3015 868 848	20
21	0.2717 962 439	0.2815 783 010	0.2913 870 314	0.3012 191 924	21
22	0.2714 123 677	0.2812 315 291	0.2910 740 633	0.3009 369 616	22
23	0.2711 108 651	0.2809 612 073	0.2908 319 146	0.3007 202 206	23
24	0.2708 739 325	0.2807 503 797	0.2906 444 794	0.3005 537 091	24
25	0.2706 876 627	0.2805 858 907	0.2904 993 470	0.3004 257 487	25
26	0.2705 411 736	0.2804 575 177	0.2903 869 409	0.3003 273 918	26
27	0.2704 259 395	0.2803 573 080	0.2902 998 642	0.3002 517 764	27
28	0.2703 352 730	0.2802 790 689	0.2902 323 989	0.3001 936 367	28
29	0.2702 639 248	0.2802 179 751	0.2901 801 217	0.3001 489 291	29
30	0.2702 077 716	0.2801 702 640	0.2901 396 097	0.3001 145 477	30
31	0.2701 635 729	0.2801 330 011	0.2901 082 129	0.3000 881 059	31
32	0.2701 287 810	0.2801 038 963	0.2900 838 789	0.3000 677 692	32
33	0.2701 013 921	0.2800 811 624	0.2900 650 182	0.3000 521 274	33
34	0.2700 798 299	0.2800 634 041	0.2900 503 992	0.3000 400 964	34
35	0.2700 628 542	0.2800 495 320	0.2900 390 676	0.3000 308 424	35
36	0.2700 494 891	0.2800 386 954	0.2900 302 840	0.3000 237 244	36
37	0.2700 389 663	0.2800 302 299	0.2900 234 754	0.3000 182 492	37
38	0.2700 306 812	0.2800 236 165	0.2900 181 977	0.3000 140 376	38
39	0.2700 241 578	0.2800 184 501	0.2900 141 065	0.3000 107 981	39
40	0.2700 190 215	0.2800 144 139	0.2900 109 352	0.3000 083 061	40
41	0.2700 149 774	0.2800 112 607	0.2900 084 768	0.3000 063 893	41
42	0.2700 117 931	0.2800 087 974	0.2900 065 711	0.3000 049 148	42
43	0.2700 092 858	0.2800 068 729	0.2900 050 939	0.3000 037 806	43
44	0.2700 073 116	0.2800 053 694	0.2900 039 487	0.3000 029 082	44
45	0.2700 057 571	0.2800 041 948	0.2900 030 610	0.3000 022 370	45
46	0.2700 045 331	0.2800 032 772	0.2900 023 729	0.3000 017 208	46
47	0.2700 035 694	0.2800 025 603	0.2900 018 394	0.3000 013 237	47
48	0.2700 028 105	0.2800 020 002	0.2900 014 259	0.3000 010 182	48
49	0.2700 022 130	0.2800 015 627	0.2900 011 054	0.3000 007 832	49
50	0.2700 017 425	0.2800 012 208	0.2900 008 569	0.3000 006 025	50
51	0.2700 013 721	0.2800 009 538	0.2900 006 642	0.3000 004 635	51
52	0.2700 010 804	0.2800 007 451	0.2900 005 149	0.3000 003 565	52
53	0.2700 008 507	0.2800 005 821	0.2900 003 992	0.3000 002 742	53
54	0.2700 006 698	0.2800 004 548	0.2900 003 094	0.3000 002 110	54
55	0.2700 005 274	0.2800 003 553	0.2900 002 399	0.3000 001 623	55
56	0.2700 004 153	0.2800 002 776	0.2900 001 859	0.3000 001 248	56
57	0.2700 003 270	0.2800 002 169	0.2900 001 441	0.3000 000 960	57
58	0.2700 002 575	0.2800 001 694	0.2900 001 117	0.3000 000 739	58
59	0.2700 002 027	0.2800 001 324	0.2900 000 866	0.3000 000 568	59
60	0.2700 001 596	0.2800 001 034	0.2900 000 671	0.3000 000 437	60

Appendix C

KANDIYOHI COUNTY RESORT QUESTIONAIRE

NAME OF RESORT ______________________________
ADDRESS ______________________________
____
OWNER ______________________________
PERSON FILLING OUT SURVEY ______________________________

1. How long have you owned/managed your business?

2. How long has the business been in operation (prior to your ownership)?

3. Please circle the services your resort offers.

Housekeeping Units ____
Campground Units ____
Snack Bar
Rec. Room
Groceries
Fishing Boats
Pontoon Boat
Partial Hookups
Disposal Station
Central Showers
Tenting, RV's
Tennis
Swimming Beach
Launching Ramp
Motors/Gas
Playground
Bait & Tackle
Ice
Childcare
Canoe
Horseshoe
Volleyball
Waterskiing

4. Is your resort open year around? If not, please circle the months during which it is open.

January
February
March
April
May
June
July
August
September
October
November
December

5. Please specify what percent occupancy you had during your operating season in 1985. (ie. June = 100%, July = 95% etc.)

January ______	July ______
February ______	August ______
March ______	September ______
April ______	October ______
May ______	November ______
June ______	December ______

6. Was 1985 a typical year for you in terms of occupancy? If not, please explain how it was different.

7. Did you experience any specific problems in your resort operations during 1985 because of high water? If so, please describe.

8. Did you have to spend any money to remedy the problems incurred by high water? If so, please specify the amount spent on each item.

9. Were any of your resort operations affected by poor water quality in 1985? (i.e. algae and weed problems in swimming area, complaints from guests about smell, etc.)

10. Did you spend any money in 1985 to remedy water quality problems?
(i.e. mechanical removal of weeds, etc.), If so how much did you spend on each item?

11. Did you experience any problems due to sediment in the lake? (i.e. the development of sand bars, filling in of shoreline areas , bank erosion etc.)

12. Did you spend any money in 1985 to remedy problems related to sediment? If so, how much did you spend for each item?

13. Are there any services that your resort offers that were particularly affected by sediment problems in 1985?

14. Do you feel that sediment of poor water quality had an affect on the number of guests staying at your resort in 1985?

15. If the answer to question #14 is yes, please approximate how many visitors you lost because of water quality problems.

16. If you lost visitors in 1985 because of water quality problems, what do you feel this cost you in terms of gross dollars to your business?

17. If possible please specify the gross and net value of the business you did in 1985.

18. Was this a typical financial year? If not explain.

19. What percent of your visitors are from:

The local area (within 30 miles)? ______________________

Other areas of Minnesota? ______________________

Outside of Minnesota? ______________________

20. How do you feel water quality will influence your business in the future (from both a mainentance standpoint and financial standpoint)?

Please include a rate schedule or brochure about your resort when you return this form.

Thank you for your cooperation in this survey.