Special Publication SJ89-SP5

FINAL REPORT

Development of a Socio-Economic Assessment Methodology with Applications to the Lake Apopka Basin

Report Prepared for

Saint Johns River Water Management District

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by

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May 30, 1989

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1.0 INTRODUCTION

The St. Johns River Water Management District (SJRWMD) has been divided into the 28 surface water basins shown in Figure 1-1. Basin management studies, being developed for each of these areas, consist of the following four parts:

1. Level I - Reconnaissance Study
2. Level II - Floodplain Study
3. Level II - Socio-Economic Study
4. Level III - Comprehensive Water Management Study

The specific purposes of this project are to:

1. develop an evaluation procedure for performing a socio-economic assessment on a water resource project;

2. incorporate the procedure into computer software to be used on water resource projects throughout the St. Johns River Water Management District (SJRWMD); and

3. to develop a socioeconomic assessment model and perform a socio-economic assessment of the Lake Apopka Basin, number VI-2 in Figure 1-1.

A thorough review of the literature on decision-aiding techniques including benefit-cost analysis is presented in Chapter 2. Then, a more detailed description of specific methods of defining damage events and assessing benefits is presented in Chapter 3. This chapter includes a description of a spreadsheet model to extract events of interest from a time series. Methods for evaluating the benefits associated with floods and droughts are presented in Chapter 4. Spreadsheet models are presented for doing daily water budgets for the muck farm areas and for estimating the monthly and annual farm revenue with and without damaging events. The effects of water management on general public values, recreation, and property are presented in Chapter 5. Finally, the application of these methods to Lake Apopka is presented in Chapter 6. The summary, conclusions, and recommendations are presented in Chapter 7. A diskette with the software and databases is presented as an appendix.

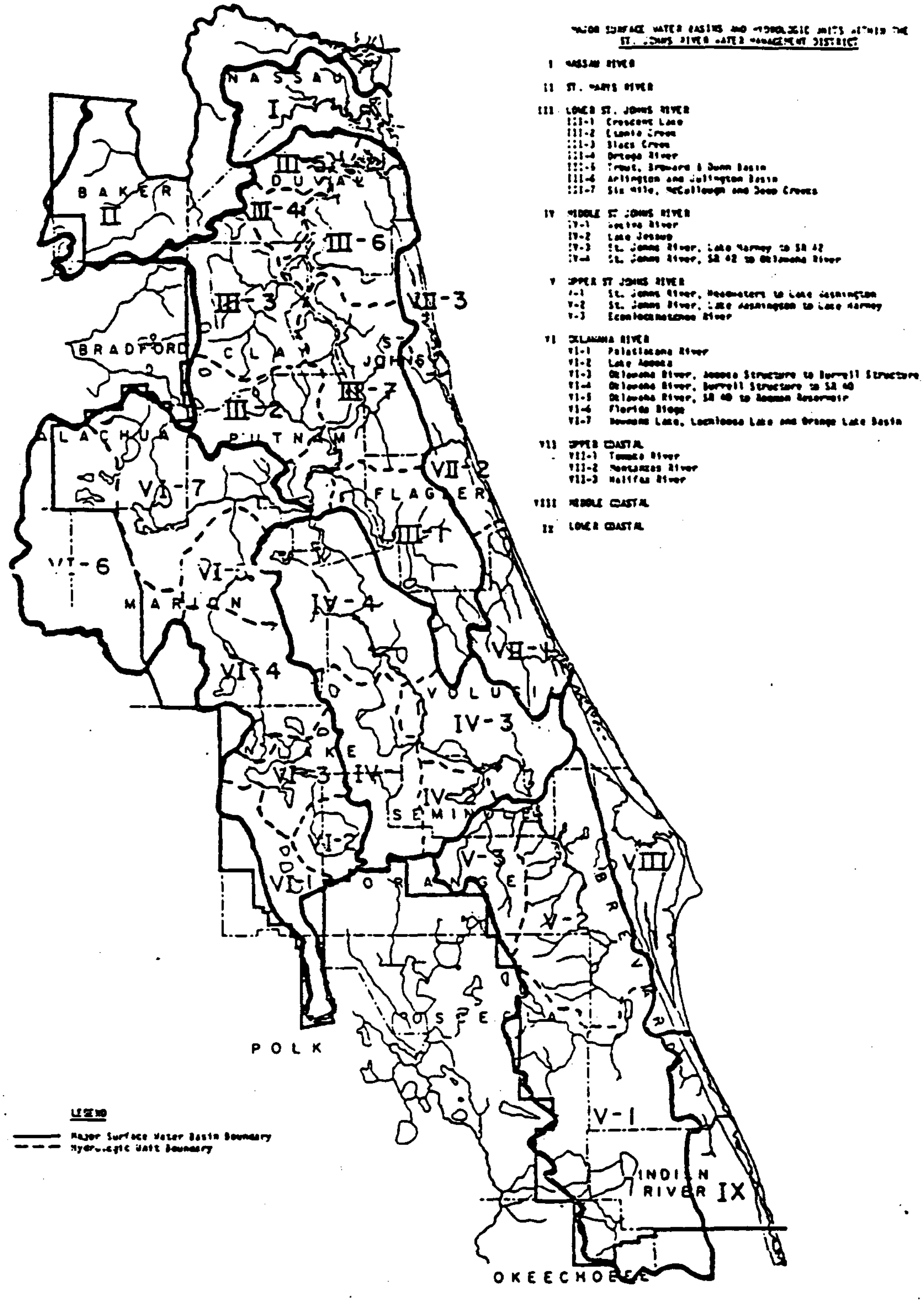


Figure 1-1. Surface Water Basins within the St. Johns River Water Management District.

2.0 GENERAL PRINCIPLES OF SOCIO-ECONOMIC ANALYSIS

2.1 Introduction

The purpose of this chapter is to present the general concepts related to developing conceptually sound and operational methods for evaluating the socio-economic and environmental aspects of proposed water programs and projects.

2.2 History of Use of Decision-Aiding Techniques

A brief chronology of the perspectives and uses of decision-aiding techniques in environmental engineering and water resources is shown in Table 2-1. Prior to 1970, perspectives on management in environmental engineering alternated between a focus on prevention which reflected the posture of public health professionals, and a focus on cost-effectiveness which reflected the posture of environmental engineers. While the perspectives differed, there was agreement that the primary objective was protection of public health. The environmental movement of the 1970's brought a new dimension to the public policy arena with a strong anti-degradation posture but also the attempt to express values for the natural system and to argue that all forms of life need to be protected. This change in posture greatly complicated the decision problem. Concern over the very high cost of environmental protection programs and renewed interest in protecting public health signaled a return to the use of cost-effectiveness and the introduction of risk analysis techniques in the 1980's.

The use of benefit-cost analysis techniques for evaluating federal water projects began in 1936. The first interagency guidelines were published in 1950 and have been updated several times. In the 1970's, environmental and social impacts, multiple objective analysis, and risk analysis were added as other components of the evaluation process. The 1983 Principles and Guidelines (P & G) revised the procedure to again focus on National Economic Development (NED) as the primary objective. As these newer considerations were added to the evaluation procedure, research was underway to determine appropriate methods for doing this analysis. A wide variety of procedures were developed for doing environmental impact analysis (EIA) including the development of numerous subjective ranking procedures. A major limitation with the EIA procedures was the lack of a clearly stated policy goal. In recent years, the use of risk analysis techniques in conjunction with EIA has provided a more useful policy framework since the emphasis has shifted from determination of whether impacts are either "safe" or "unsafe" to asking for estimates of the risk levels associated with each alternative. The risk-based information is much more useful for decision making.

A wide variety of normative and descriptive methods for doing multi-objective analysis are available (Cohon, 1978). Similarly, major advances have been made in using a variety of

Table 2-1. Evolution of Decision Making Perspectives in Environmental and Water Resources Engineering.

a. Environmental engineering

Period	Activity
1900-70	Balancing of posture of prevention (public health) and sanitary engineering (cost-effectiveness).
1970's	Strong anti-degradation posture. New focus on protection of the natural system.
1980's	Cost effectiveness returns. Risk analysis techniques are used.

b. Water resources engineering

Period	Activity
1936	Beginning of benefit-cost analysis.
1950's	First principles & standards.
1970	Include environmental impacts.
1970's	Include multiple objectives and social effects.
1980's	Include risk analysis.
1983	Return to single objective in Principles and Guidelines.

optimization methods such as linear and dynamic programming for water policy analysis. Thus, an abundance of techniques and associated software for doing normative analysis are available. These normative techniques prescribe what **should** be done if the assumptions of the model are realistic. Unfortunately, the real world does not usually conform to these highly simplified models. Thus, the normative models may not provide realistic policy guidance. During the past few years, interest has shifted to descriptive techniques such as expert systems because of their focus on simulating the way decisions are actually made.

2.3 Comparison of Analytical Methods

2.3.1 Introduction

Decision-aiding techniques used in water resources can be classified in several different ways. For example, Smith and Desvouges (1986) present a taxonomy of six frequently used decision making frameworks in water resources as shown in Table 2-2.

2.3.2 Benefit-Cost Analysis

2.3.2.1 Theory

The general theory and numerous applications of benefit-cost analysis are well documented in James and Lee (1971). The Federal government has developed several documents starting with the so-called "Green Book" in 1950 up to the Principles and Guidelines published in 1983. In addition, various federal agencies have prepared more detailed interpretations of how to conduct specific types of benefit-cost analyses. The most recent (1983) Principles and Guidelines presents specific instructions for the following categories of water resources:

No.	Category
1	Municipal and industrial water supply
2	Agricultural floods, erosion, and sedimentation
3	Agricultural drainage
4	Agricultural irrigation
5	Urban flood damage reduction
6	Hydropower
7	Navigation
8	Recreation
9	Commercial fishing

The Environmental Protection Agency is not required to follow the P & G. However, we suggest adding environmental quality as another purpose.

For this study, which focuses on Lake Apopka, the major benefit categories are listed below.

Table 2-2. Alternative Decision Frameworks for Water Resources Problems (Smith and Desvouges, 1986).

Conceptual basis/method	Description	Advantages	Disadvantages
A. Technical			
1. Technology-based standards	Defines "best" in terms of available or practicable technology	No explicit impact assessment is needed	No direct measure of benefits
2. Cost-risk analysis	Estimate cost to reduce risk to reasonable level	Relatively simple to use	Must select a single measure of risk
3. Cost-effectiveness analysis	Selects alternative that min. costs of meeting specified goal	No need to quantify benefits	Uses a single measure of effectiveness
B. Normative			
1. Benefit-cost analysis	Selects project that maximizes benefits minus costs	Considers all options on a common value scale for which data are available	Does not examine distribution of benefits and costs
2. Economic impact analysis	Evaluate effects of actions on economy	Ties to macro-economic models; identifies distribution of impacts	Of limited value for project selection because of aggregation
3. Multi-objective analysis	Quantifies how well project satisfies multiple objectives	Allows multiple objectives to be considered	Must tradeoff among incommensurate goals;large information needs for quantification

No.	Benefit Category
1	Agricultural irrigation, drainage, and flood damages
2	Environmental quality, recreation and property values

These two priority areas are discussed in detail in later chapters. The impacts of navigation are captured in the evaluation of boating activities in the section on recreation. The analysis of flooding, drainage, and irrigation problems in agricultural areas is more complicated than the corresponding analysis of urban areas because the farmers have such a wider choice of strategies available to them. Thus, the urban analysis can be viewed as a special case of the agricultural models. Hydropower is not a significant consideration in this area.

2.3.3. Multiple Objective Models

2.3.3.1 General Literature

Cohon and Marks (1973) first presented a comprehensive overview of multiobjective planning techniques in water resources. Cohon (1978) expanded on this original effort in presenting a much broader based evaluation of these techniques. Schilling, ReVelle, and Cohon (1983) describe how the results of a multiobjective analysis can be presented in an effective manner.

Goodman (1984) lists four approaches to multi-objective planning in water resources:

1. Maximization of one objective, with constraints (specified values or limits) on the other objectives.

2. Formulation of alternative plans, each emphasizing a different objective, and from this developing a mixed objective plan through a consensus or bargaining process among the participants in the planning process and the decision makers.

3. Use an explicit system of weights to make the several objectives commensurable, thus permitting the maximization of a utility or welfare function.

4. Use target values for all objectives, with functions to express penalties for failures to meet these targets.

Brown (1984) describes a successful application of a multiobjective planning problem, incorporating substantial public involvement, to a major water resources decision with intense conflicts. An iterative, open planning process was used. This project had a total cost of $1 billion. The public involvement cost $1 million and the technical studies cost $14 million. Shabman (1984) discusses two models of planning-- adaptive planning, and rational, analytic planning. Deason and White (1984) focus on clear specification of the objective set in multiobjective planning.

2.3.3.2 Applications of Multi-Objective Planning in Florida

Heaney et al. (1975) used a linear programming model to generate the transformation curve of the tradeoff between maximizing an economic objective and maximizing an environmental objective using an energy criterion. A major limitation of using such normative models to project future scenarios is that the projections may be unrealistic. Thus, the trade-off analysis may be quite misleading. Also, the multi-objective analysis did not evaluate the distribution of the impacts among the participants. The distributional factors were addressed in another part of this study.

Trimble and Marban (1988) present a recent example of using multi-objective analysis at the South Florida Water Management District to find an improved operating schedule for Lake Okeechobee. A list of the four competing objectives considered and the associated performance measures or target values used in the simulation model are presented in Table 2-3.

2.3.4. Methods of Risk Analysis

2.3.4.1 Introduction

Risk analysis became popular in the late 1970's and continues to be an attractive way to analyze alternatives. It is recognized in the Principles and Guidelines (1983) as an element in the analytical process. Recent applications to environmental and water resources problems are summarized in Ricci (1985) and Haimes and Stakhiv (1986). The theory and application to the related area of probabilistic approaches to engineering design are presented in Harr (1987).

Rowe (1977) classifies approaches to risk into four categories.

1. Risk aversion. Tolerate no risk, e.g., no carcinogens in food, or all waters shall be swimmable and fishable.

2. Cost-risk analysis. Reduce risk to a "reasonably" low level. Sometimes the use of best practicable or best available technology is specified.

3. Cost-effectiveness analysis. Similar to cost-risk analysis only some direct measure of performance is used.

4. Benefit-cost analysis. Select option that maximizes total benefits minus total costs.

Table 2-3. Multi-objective Analysis and Performance Measures Used in Recent Study of Operating Schedules for Lake Okeechobee Source: Trimble and Marban, 1988.

Four competing objectives	Performance measure
1. Provide adequate flood protection for the regions around the lake.	Maximum stage on Sept. 1
2. Meet the water use requirements of the agricultural and urban areas dependent on Lake Okeechobee for water supply.	% of demands not met
3. Preserve the biological integrity of the estuaries downstream from the lake.	Number of days of high discharge
4. Preserve and enhance the lake's littoral zone which provides a natural habitat for fish and wildlife.	% of days exceeding elev. of 15 ft.

2.3.4.2 Feasibility of Doing Risk Analysis

Risk analysis methods can be viewed as a more refined method that is appropriate when sufficient information regarding the probability distributions, or at least the second moment of the distribution, is known. Such information is readily available for the hydrologic aspects of the decision problem, e.g., the extreme value distributions for rainfall or streamflow. However, such information is usually not available for other aspects of the decision model, e.g., benefit data.

Computationally, it is easy to incorporate risk analysis concepts because of improvements in analytical solution methods. Also, the greatly enhanced power of computers and excellent software allows large-scale Monte Carlo simulations to be performed on microcomputers. Risk analysis methods have been used for years by engineers in evaluating the necessary safety of a design. In the engineering design case, benefits are replaced by the probability density function (pdf) of the capacity of the system and costs are replaced by the pdf of the load on the system. The probability of failure, i.e., of having negative net benefits can be found by determining the pdf of the net benefits. If the pdf's follow convenient distributions, e.g., normal or log normal, then the resultant pdf can be derived. However, it is usually necessary to use Monte Carlo simulations for problems of realistic size. In this case, a random number generator is used to select values of each of the input parameters of the model. Then, a simulation is run to obtain the value of the output for this set of conditions. This process is repeated a sufficient number of times to derive the pdf of the output.

2.3.5 Social Choice Models

2.3.5.1 Theory

Burke, Heaney, and Pyatt (1973), and Burke and Heaney (1975) summarize a wide variety of approaches to collective decision making in water resources. They define the overall problem as the aggregation of individual needs and preferences into a specific course of action that is feasible, desirable, and equitable. Within this context, analysis of the public interest can be categorized into three basic modes. The rationalist mode assumes that a substantive, discoverable public interest exists and can be deduced using normative decision models. The idealist mode similarly assumes that a substantive, discoverable public interest exists but that it can be best discovered by qualified experts such as engineers and public officials. Lastly, the pluralist mode assumes that no substantive, discoverable public interest exists. Instead, it is the residual of the group interaction process.

2.3.5.2 Models

Bulkley and McLaughlin (1966) developed a collective action simulation model to estimate the outcome of a public choice problem knowing the affected groups, the issues, the attitudes of the groups, and their political power. Heaney et al. (1973) applied this model to the Upper St. Johns River Basin. In retrospect, the most useful part of this model application was the effort that was made to define the issues, the affected groups, the attitudes of the affected groups toward the issues, and the relative power of each group. The model was able to identify one clearly unacceptable alternative. However, it was unable to discriminate very well among the remaining alternatives. This model did not track the incidence of benefits and costs among the affected groups.

2.3.5.3 Social Choices and Voting Rules

Some excellent research has been done on the impact of voting rules on social choices with regard to whether the selected rule is "fair". Arrow's impossibility theorem proves that no voting rule satisfies all of a set of reasonable fairness criteria. Burke and Heaney (1975) have done research on this problem and later worked with Straffin (1979) who prepared a monograph on the various rules. It is important to be aware of the implications of selecting a voting rule, especially in decision making by committees and other small groups.

2.3.6. Other Decision Aiding Methods

In addition to the descriptive and normative decision methods described above, other approaches and philosophies have been used. Virtually all of the proposed methods attempt to utilize the power of modern computers in some way. Manheim (1988) presents a forward-looking proposal for a general model for providing active computer support to design, planning and management. The focus of his framework is on "problem-working processes" instead of "problem-solving" or "decision-making" processes. He argues that problems are rarely "solved" nor are final "decisions" actually made. Rather, the goal is to move the process in the right direction over time.

Another highly touted new decision making tool is expert systems. Maher (1987) provides a nice summary of applications to civil engineering and water resources. In the taxonomy of decision tools, the expert systems approach may be viewed as a descriptive method that focuses on computerization of how decisions are presently made. Indeed, one of its most attractive features is that a significant effort is made to calibrate the decision model to see that it realistically depicts how the decision makers currently think. Knowles, Heaney, and Shafer (1988) developed an expert system for evaluating small quantity generators of hazardous wastes.

Decision support systems is another popular classification of decision making tools. Here, the focus is more on providing an efficient computer based work environment for professional analysts to perform all of their tasks including analytical methods, database manipulations, word processing, and graphics including GIS and CAD.

2.3.7 Conclusions on Analytical Methods in Water Resources

During the past 30 years, there has been a veritable explosion of new analytical methods for examining water resources problems. These techniques held promise of finding "optimal" solutions for complex water problems. The emphasis has been on developing efficient computational techniques.

The federal government has expanded the scope of decision making from traditional benefit-cost analysis to including environmental impacts, multiple objectives, and risks, and to having models that recognize that the decision making environment is an open process with relatively little structure and numerous decision makers.

Because of the focus on modeling , databases have not been developed on benefits, costs, risk levels, etc. Also, relatively little work has been done on quantifying the distributional aspects of water resources projects, i.e., how the benefits and costs are apportioned among the affected groups.

2.4 Current Federal Water Planning Guidelines

2.4.1 Introduction

The 1983 Principles and Guidelines list six major steps in the planning process:

1. Specification of the water and related land resources problems and opportunities.

2. Inventory, forecast, and analysis of water and related land resource conditions within the planning area relevant to the identified problems and opportunities.

3. Formulation of alternative plans.

4. Evaluation of the effects of the alternative plans. This evaluation of effects consists of assessment and appraisal. The assessment measures the physical, chemical, and biological effects of the various alternatives with and without the plan. The appraisal is the process of assigning social values to the technical information gathered as part of the assessment process. An economic valuation criterion is used in the appraisal of national benefits. Other valuation metrics are needed in the environmental, regional economic development, and other social effects evaluations.

5. Comparison of alternative plans.

6. Selection of a recommended plan based upon comparison of alternative plans.

This plan formulation and evaluation process is dynamic and may involve several iterations. A major effort is required to develop the four accounts and do a comprehensive evaluation. Goodman (1984) presents a nice summary of the details of this planning process.

2.5 Methods for Assessing Environmental Impacts

2.5.1 Benefit Assessment in an Impact Assessment Framework

The traditional approach of assessing the benefits of a water resources alternative can be viewed in a broader framework of impact assessment as a monetary valuation impact assessment approach. McAllister (1980) describes, evaluates, and compares several approaches including benefit-cost analysis, the planning balance sheet approach, the goals achievement matrix, land suitability analysis, and environmental evaluation. A wide variety of methods and approaches have been used to do environmental evaluations. Recent books on this subject include Jain and Hutchings (1978), Erickson (1979), McAllister (1980), Ortolano (1984), and Baldwin (1985).

An early question to be addressed is how many impacts are to be measured. As McAllister (1980) points out, the Leopold Matrix, one of the first proposed environmental evaluation procedures, contains 8,330 distinct impact items (Leopold et al. 1971). Also, it is important to assess the incidence of the impacts among affected groups. Lichfield, Kettle, and Whitehead (1975) have used this approach in several studies of urban planning in England. If only 12 affected groups are identified, then the simple Leopold Matrix now would contain about 100,000 entries. Thus, it is vital to be highly selective in which impacts are to be catalogued for a given project. It is impossible to list _a priori_ the most important indicators since they are site specific. Determination of the _magnitude_ of impacts is relatively easy, e.g., the dissolved oxygen will decrease by 1.5 mg/L during summer months. The more difficult task is to assign a measure of the _importance_ of this change.

Procedures for performing an economic valuation of the importance of the changes are well established. For those impacts for which it is not meaningful to ascribe a monetary measure of value, then some other valuation metric must be used. McAllister (1980) lists energy valuation as espoused by H.T. Odum as a possibility for energy related projects. Otherwise, he classifies the remaining techniques as point or voting measures.

2.5.1.1 Point Schemes

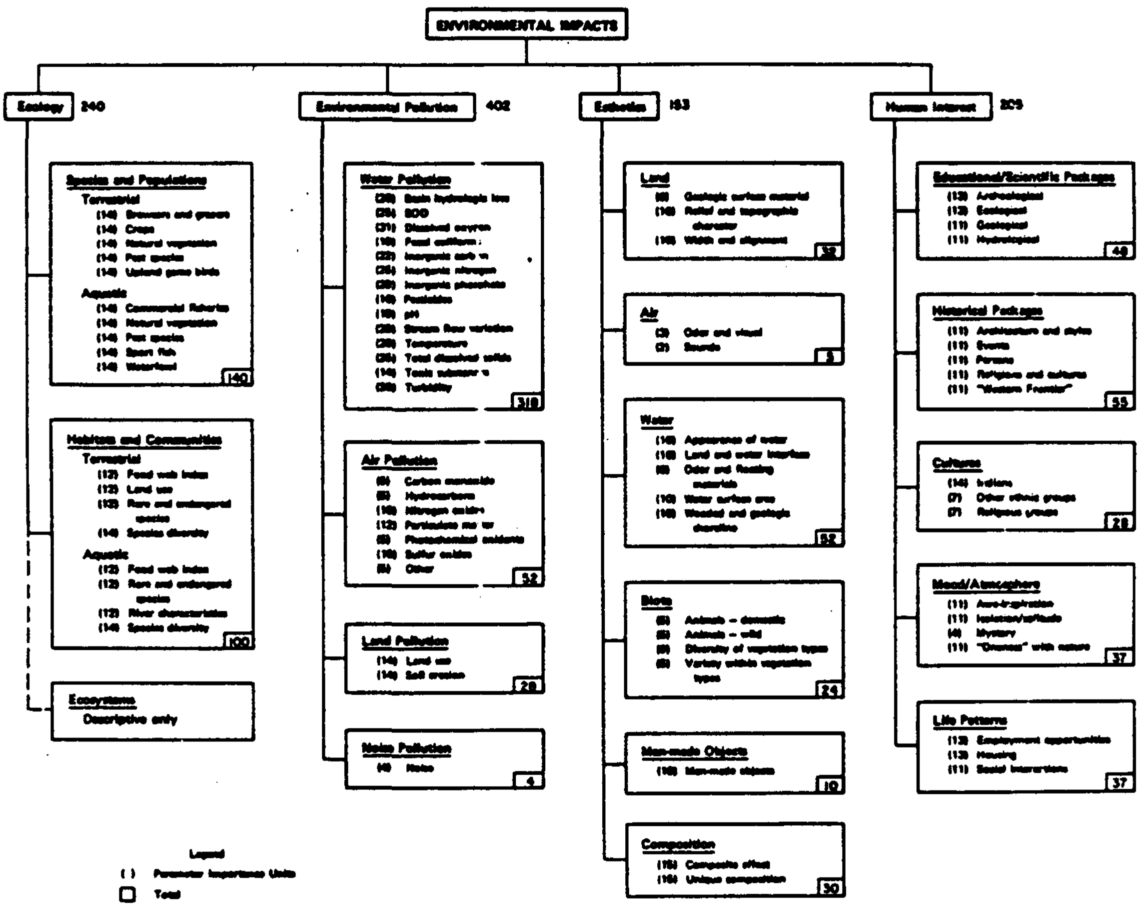
Dee et al. (1973) developed a fairly complete point scheme for 79 effects divided into the four major categories of ecology, environmental pollution, esthetics, and human interest as shown in Figure 2-1. For each of these 79 effects shown in Figure 2-1, a normalized valuation function was prepared. Eight of these valuation functions are shown in Figure 2-2. As you can see from examining these figures, this process is very subjective and requires a very large effort to collect and interpret the vast amount of required data. This evaluation is also complicated by the interdependencies among the assumed measures of impact,e.g., dissolved oxygen concentration and "appearance of water" would be expected to be correlated.

An alternative to a point system is to set up a review group of "appropriate" people to do the screening using one of the numerous available social choice screening devices. Selecting the appropriate mix of technical and nontechnical people and the voting rule is a nontrivial problem.

A general problem with environmental impact evaluation is the potential for multiple counting of impacts which were also addressed in the economic impact. For example, dissolved oxygen concentration may have been used as the key indicator of recreation potential in the NED studies. "Basin hydrologic loss" could have been reflected in the portion of benefit assessment dealing with water supply or navigation deficiencies.

The "importance" of many environmental impacts is specified in legislation and regulatory agency mandates and guidelines. Thus, a significant part of the environmental "valuation" is actually checking whether the estimated present and projected values of each environmental indicator fall within "acceptable" ranges. The Principles and Guidelines (1983) list numerous federal laws that must be satisfied for a project to be feasible. For the District, this checklist would include satisfaction of relevant environmental quality standards, e.g., dissolved oxygen not less than 5.0 mg/L, as well as satisfaction of other governmental restrictions on land use, e.g., the recent wetlands legislation in Florida. Indeed, the focus of contemporary environmental impact assessment is to project the impacts and then to go through a relatively complex list of criteria to be satisfied for the solution to be feasible. In addition to the institutionally specified performance criteria, other limits on impacts may be specified by recognition by the affected public, and/or by technical experts. These other ways in which criteria are specified are recognized in the 1983 P & G.

Heaney (1988) reviewed the results of 20 years of efforts to devise acceptable environmental indicators of the effectiveness of investments in dry-weather and wet-weather wastewater treatment. He concludes that no single indicator or set of indicators is satisfactory. What is needed is a more general indicator of



Sum of Points = 1000

Figure 2-1. Environmental Evaluation System.

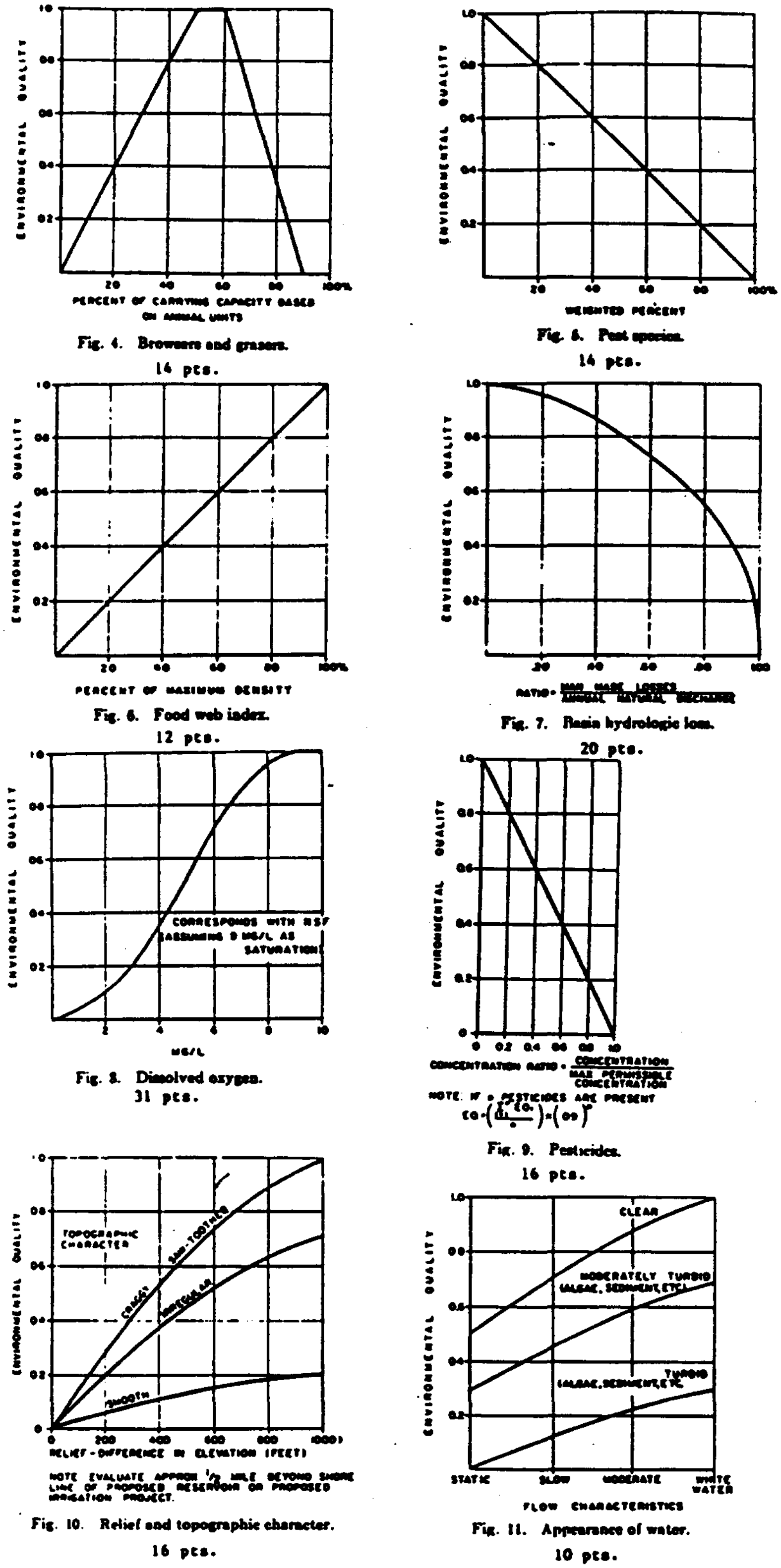


Figure 2-2. Environmental Valuation Functions Used by Dee et al. (1973).

value to the public in terms of improvements in the range of permissible beneficial uses, e.g., improve the water quality to open the beaches for swimming. Thus, for the purposes of this socio-economic assessment, the valuation of environmental impacts will be done through determination of their impact on man's direct use (e.g., fishing and swimming) and indirect use (e.g., paying to protect an area for posterity). As will be described later, economists have developed viable methods for evaluating these so-called non-user benefits.

2.6 Impact Assessment Methodology

The wide variety of procedures for evaluating the impacts associated with water resources projects can be classified into two basic approaches: frequency approach and continuous simulation. The frequency approach for flood damages is shown in Figure 2-3 . The three basic relationships are the stage-damage curve which is an output from the impact assessment, and the stage-flow and flow frequency curves come from the hydraulic and hydrologic studies. This same framework can be used to look at other water resources purposes such as water supply or water quality. The key assumption of the frequency analysis approach is that all of the events are independent. This is a reasonable assumption for rare events such as major floods or droughts. It is not a good assumption for more frequent events and situations where the behavior of the affected parties is more complicated. For example, if a farmer suffers flood damage during the early part of the planting season, he has several choices including replanting the same crop, replanting a different crop, and waiting until next year. If a second damaging event occurs shortly after the first one, then the damages from the second event depend upon the time since the previous events.

The alternative and more general approach is to do a continuous simulation of the operation of the water system over ten to one hundred years, and track the incidence of all categories of benefits over time. This method is much more robust than the frequency approach since realistic operating policies can be included and the effects of interdependencies of all kinds of events can be analyzed. This continuous simulation approach is used in this socio-economic study. The frequency approach is used only for rare events where the assumption of independent events is tenable. The details of this procedure will be described in the next chapter which examines present and proposed methods of assessing impacts.

2.7 Conclusions

The purpose of this chapter was to review and summarize decision-aiding techniques used in water resources management. A wide variety of techniques can be used. The appropriate technique in a given situation is heavily dependent upon the available database. The suggested approach is to start with benefit-cost analysis methods and then go to more refined approaches if the data are available.

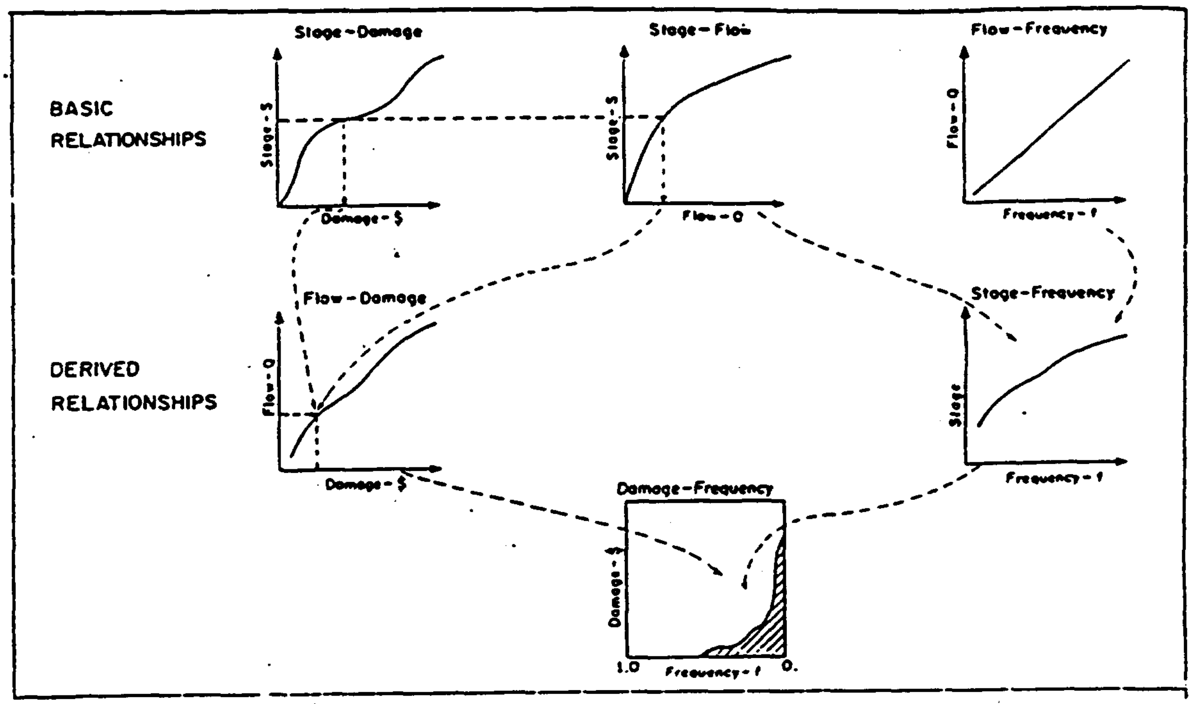


Figure 2-3. Basic and Derived Relationships for Flood Damage Analysis.

3.0 SYSTEM PERFORMANCE AND EVENT DEFINITION

3.1 Introduction

In order to quantify the magnitude and importance of a project's impact on its surroundings, it is necessary to adopt some measures of impact, acquire historical data that contain events of interest, determine the magnitude of the impacts, analyze the incidence of events causing impacts, and then quantify the importance of the impacts.

The choice of which impacts are considered affects not only the choice of what data are analyzed, but it can have an effect on the conclusions drawn from the analysis. Heaney et al. (1988) state that a general list of the most important indicators of impact is not possible since they are site specific. Some measures of impact for water resources objectives such as flood control, water supply, and recreation are shown in Table 3-1. Examples of corresponding data requirements for these three water resource objectives are shown in Table 3-2.

Specifying the magnitude of impacts is not difficult since many impacts can be physically measured or observed. For instance, the magnitude of a flood can be measured by the maximum stage during the event. A frequency analysis of the data will provide important information such as the return periods of the various impact magnitudes.

The impacts are ranked in order to identify their relative importance which can sometimes be specified as some benefit or damage measured in dollars. When all of the impacts cannot be measured in dollars, techniques such as point or voting schemes are used to rank the importance of the impacts. These techniques are very subjective since the decision makers knowingly or unknowingly express their personal preferences in the process of ranking a given set of impacts.

The most common way to evaluate impacts is to select a measure of performance such as flood stage and then to estimate the nature of flood events, i.e., the occurrence of stages in excess of the prespecified target. This same method is used in all areas of quality control wherein samples are analyzed over time. A sample is "defective" or "fails" if its value falls outside a selected range, e.g., beyond three standard deviations above or below the mean. The next section summarizes the ways in which performance is evaluated. Then, a spreadsheet model is presented that allows the events of interest to be extracted from the data file. This method is explained in more detail in Shafer (1989).

Table 3-1. Example Measures of Impact for Selected Water Resource Purposes.

Purpose	Measures of Impact
Flood Control	Heavy sediment load, bank erosion, structure damage, crop damage, restricted land use.
Water Supply	Sprinkling bans, mandatory cutbacks in water use, reduced economic development.
Recreation	Beach closings due to pollution, restrictions on white water rafting, fish catch limits.

Table 3-2. Examples of Data for Three Water Resource Purposes.

Purposes	Description of Data
Flood Control	Stage record of river, historical flood damage information.
Water Supply	Stage record of reservoir, historical pumpage and well data, per capita water use records.
Recreation	Available recreation sites, recreation demand, number of days in which the sites are closed.

3.2 Single Purpose System Performance

To analyze a time series it is necessary to first define what constitutes an event of interest, and then determine the frequency and nature of the events. Events can be defined as periods in which the system output fails to meet performance standards. System failure occurs when the load on the system at time t exceeds the resistance to failure at time t. This can be expressed mathematically as follows:

$$\text{Failure occurs at time } t \text{ if } l > b \qquad (3\text{-}1)$$

where l is the system load and b is the resistance of the system to failure. The load for a recreation facility such as a park would be the number of visitor days, while the resistance of the park would be the carrying capacity of the facility. A failure of the park would be caused by an exceedance of the carrying capacity of the facility by the number of users in one day.

The load carried by a flood levee is the flood stage, the flood duration, flood exposure, and wind effects. The resistance of a levee to a failure is the levee height and the hydraulic and soil resistance to boiling, sliding, and erosion (Duckstein and Bernier, 1985). A time series of the resistance and the load of system is shown in Figure 3-1. The system is shown to fail at time $t=t_f$ when the resistance, b, is less than the load, l. .pa

In water resources, a time series of discharge, Q, as shown in Figure 3-2, can be characterized by the mean (Q_{avg}) and the variance (Qv) of the discharge. Although these two parameters can describe this time series adequately for some hydrologic analysis, they cannot be used to characterize the reliability of the system to provide some required discharge Q_{req}. The inability of the mean and variance to characterize a system can be seen by comparing the time series in Figure 3-2 to the time series in Figure 3-3. Both of the series have the same Q_{avg} and the same variance Qv; however, the system that created the time series in Figure 3-3 would appear to be less reliable than the system that produced the time series in Figure 3-2 since it contains two incidents in which the required discharge (Q_{req}) is not met for some period of time t. Detailed time series analysis can be used to characterize system performance.

In order to characterize system performance, Hashimoto et al. (1982) put forth three criteria for evaluation, i.e., reliability, resiliency, and vulnerability. Reliability is defined as the likelihood of system failure. It can be described mathematically as:

$$R=1-r, \qquad (3\text{-}2)$$

where R is reliability, and r is risk. Risk is the probability of system failure.

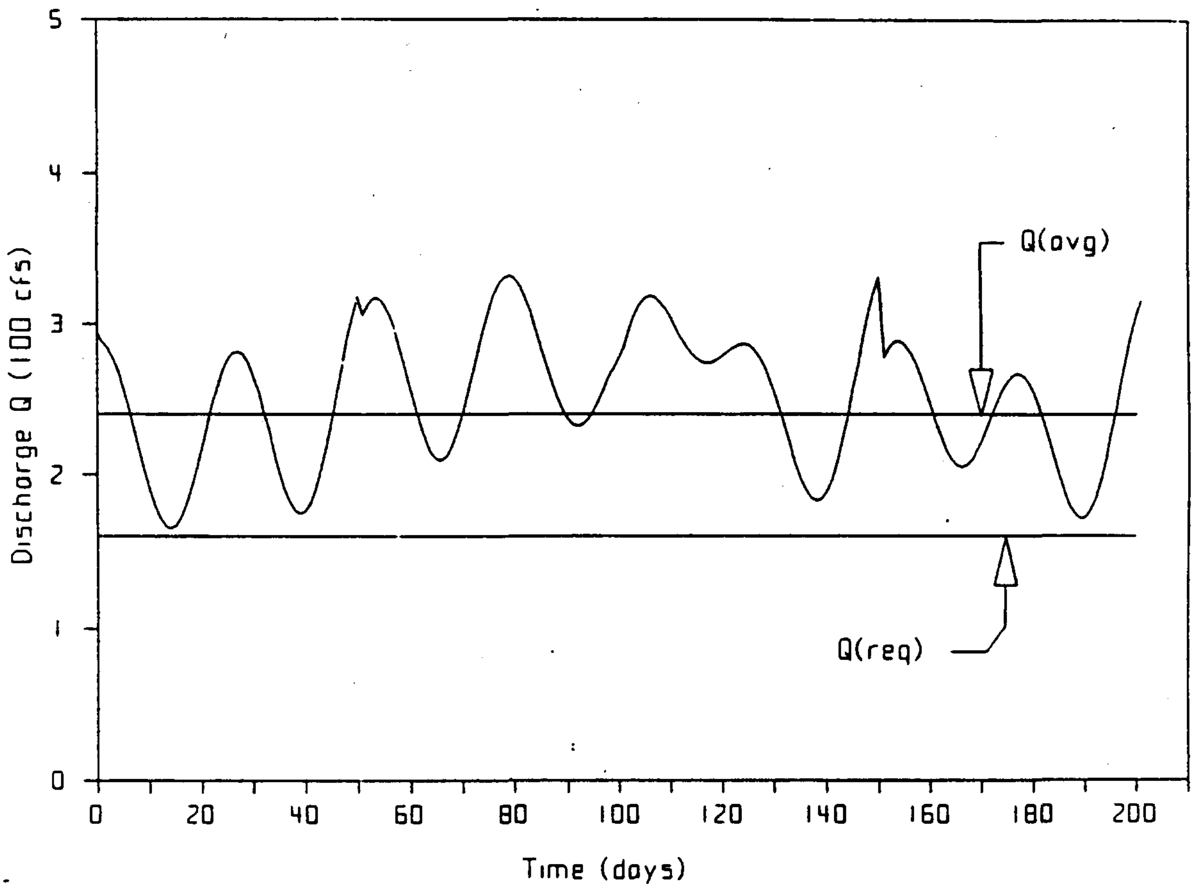


Figure 3-2. Stream Discharge -vs- Time - Case 1.

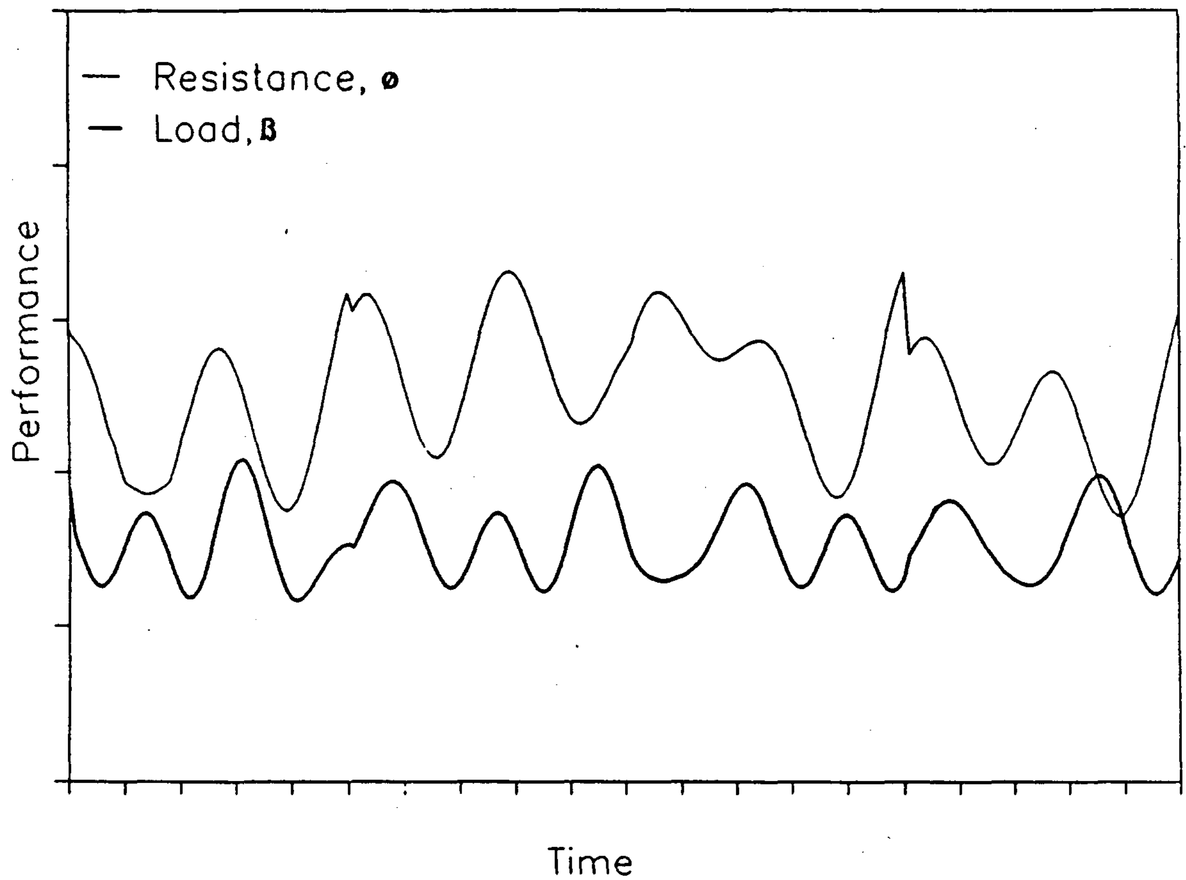


Figure 3-1. Time Series of System Load and Resistance.

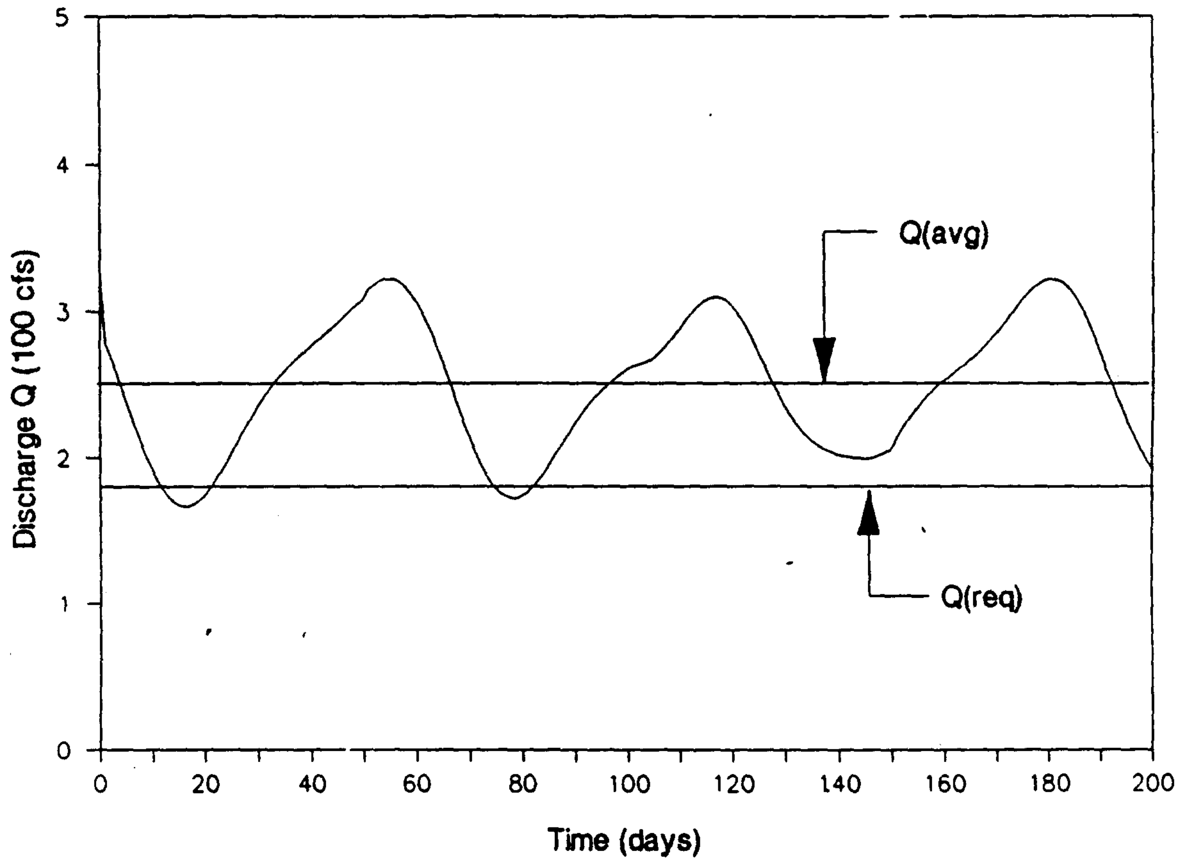


Figure 3-3. Stream Discharge -vs- Time - Case 2.

Reliability can be derived from a system which is described by the output variable Q which is measured at every interval t. The set of output measurements Q are either members of the set S which contains satisfactory output or the set U which contains unsatisfactory output (Hashimoto et al., 1982). Figure 3-4 shows the domain Q which contains the instances of q above Q_{req} that belong to the set of satisfactory outcomes, S, and the instances of q below Q_{req} that belong to the set of unsatisfactory outcomes, U. The reliability of this system is then described by the probability P that a measurement q belongs to the satisfactory set S.

Plate and Duckstein (1988) defined reliability as the probability of the first time that the system fails. Reliability in this case is defined as the probability density function of the first failure time rather than the probability of system failure.

Although designing systems with high reliability is desirable, this practice means that any system failure will be more catastrophic than the corresponding failure of a system designed at some lower level of reliability (Fiering, 1982a and b, Hashimoto et al., 1982). An example would be the construction of a flood protection device that allows the placement of houses within a flood plain. Although the flood control structure protects these houses during the high frequency events that previously precluded building within the flood plain, eventually the occurrence of a rare event will cause the device to fail. More property will be damaged than if a less reliable flood control option had been used; however, the probability of damage is less.

Resiliency has been defined by Fiering (1982a) as the ability of a system to accommodate surprise, recover, and possibly thrive while being subjected to unanticipated fluctuations in environmental conditions. Hashimoto et al. (1982) state that resiliency describes how quickly a system tends to recover once it has failed. A system with high resiliency would tend to recover faster than one with comparatively low resiliency. Since, in many cases the cost of a failure event is directly related to the duration of the event, designs that employ a high level of resilience would tend to be favored. Hashimoto et al. (1982) mathematically describe resiliency y as p, the probability of the system being in the satisfactory set S at time t and at time t+1 being in the unsatisfactory set U divided by the risk, r. This equation is:

$$y = \frac{p}{(1-R)} = \frac{\text{Prob}\{X_t = S \text{ and } X_{t+1} = U\}}{\text{Prob}\ \{X = U\}} \qquad (3\text{-}3)$$

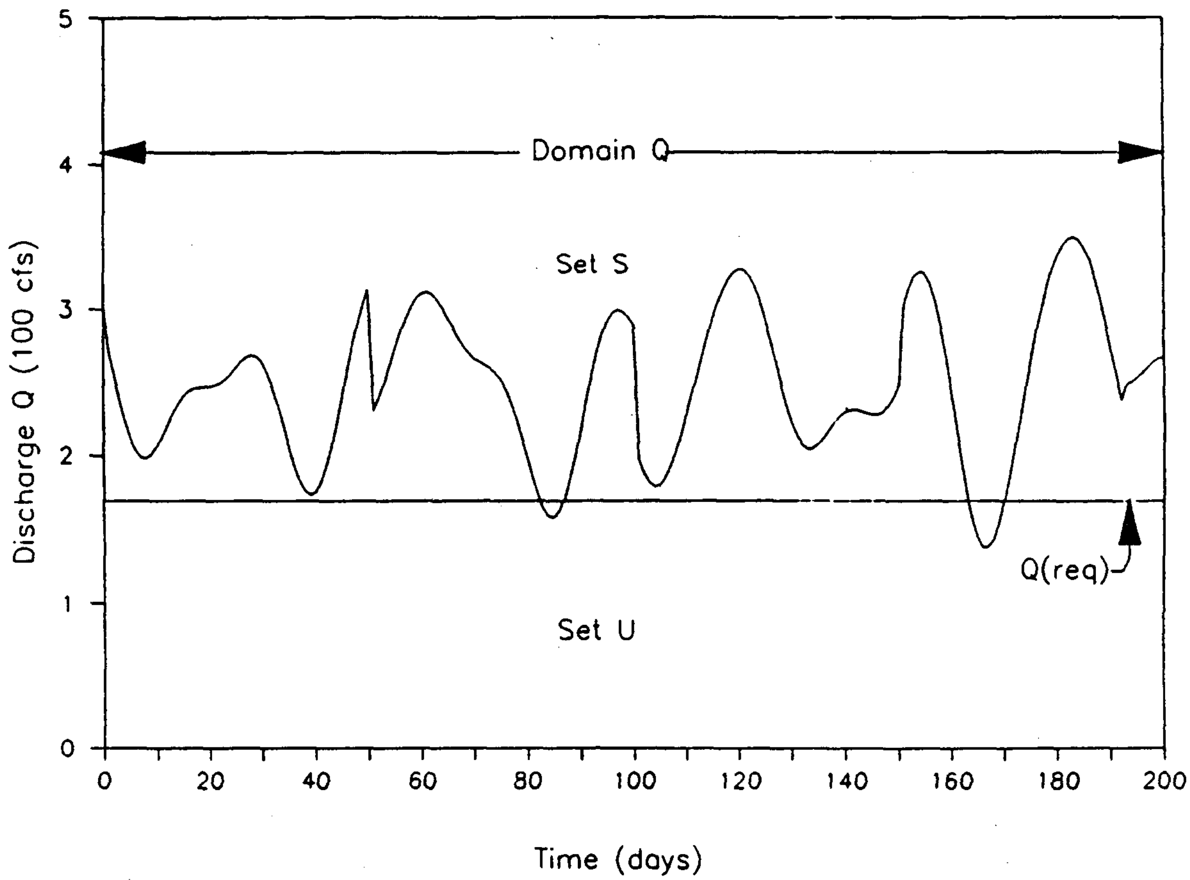


Figure 3-4. Stream Discharge -vs- Time. Satisfactory and Unsatisfactory Events are Shown.

Resiliency also has numerous other descriptions such as the residence time in the nonfailure state, the steady state probability of not being in the failure state, the mean first passage time to the failure state, and the mean passage time between successive failures (Fiering, 1982b). The extent to which a system can be controlled has a great impact on its inherent resiliency. Systems that are highly controlled tend to fail less often and recover from failure quicker. However, the more controlled a system becomes and the higher its level of resiliency the greater the chance that a failure will be of catastrophic proportions.

Hashimoto et al. (1982) define vulnerability as the expected severity of a failure event. They go on to state that the more reliable a system is, the more vulnerable it is to catastrophic failure. Since people tend to place greater trust in more reliable systems, the loss that occurs when a reliable system fails is greater than when a less reliable systems fails.

3.3 Multi-Purpose System Performance

The concept of determining performance can be extended to a multipurpose system such as a reservoir that is designed to provide multiple purposes such as flood protection and water supply. A time series of the reservoir stage in which it is desirable to maintain the elevation of the water surface between S_{max} and S_{min} is shown in Figure 3-5. The performance of the system can be described by the number of times the reservoir stage does not fall between the desired elevations (reliability), the average length of time in which the stage is not bounded by the minimum or the maximum desired stages (resiliency), and the expected cost of system failure (vulnerability).

Duckstein and Bernier (1985) applied performance indices to a study of the operation of a multi-purpose flood control and water supply reservoir in order to determine the preferred operation schedule. For each operating algorithm used in a simulation of the reservoir behavior they calculated five performance indices. The performance indices from each simulation were grouped into figures of merit that allowed the decision maker to see the trade-offs among the numerous performance indices.

3.4 Spreadsheet Model for Event Analysis

With the advent of personal computers and easy to use database software, it is much easier to analyze historical records by extracting events of interest from the complete record. The advantage is that a time series of system output no longer has to be characterized by the event return periods or exceedance probabilities. Grayman, Males, and Clark (1989), used Lotus 1-2-3 and R:Base 5000 DBMS software to aid in the analysis of water quality data. They used the system to summarize average concentrations and other statistics for each parameter at each sampling site.

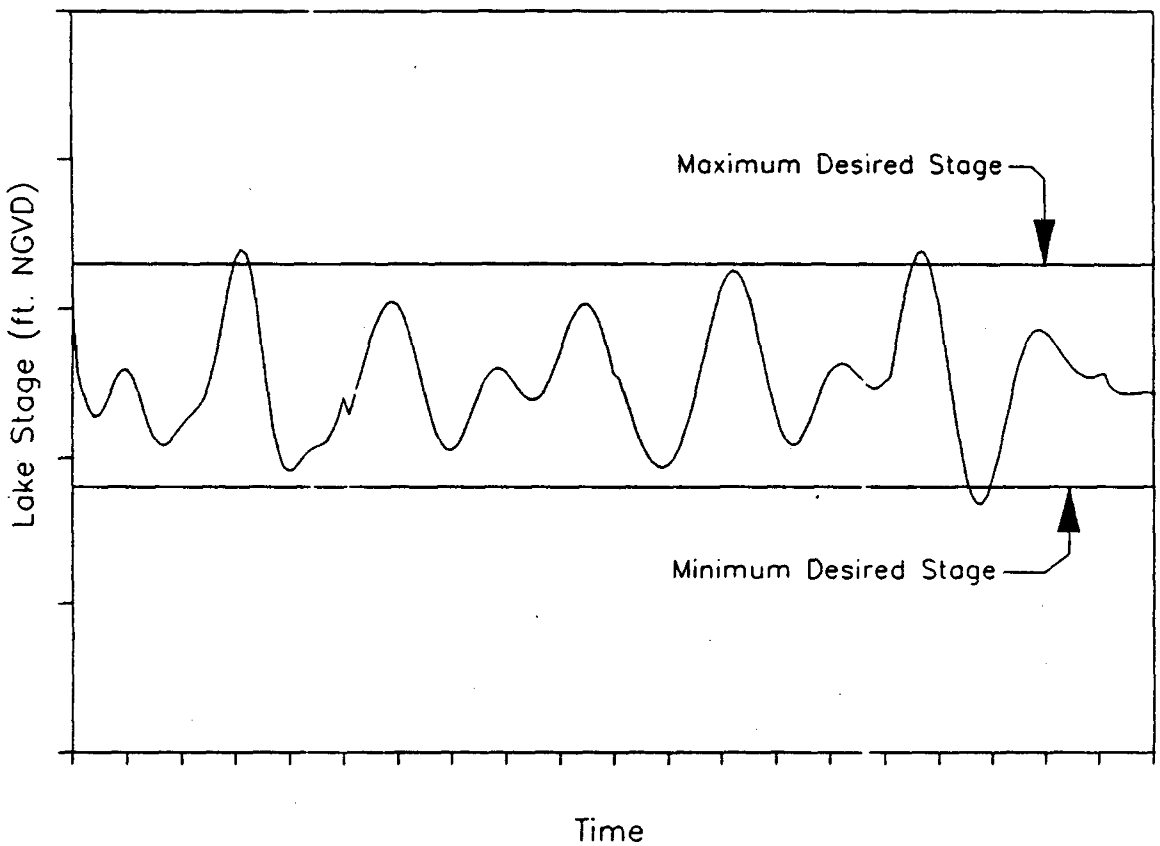


Figure 3-5. Example of Lake Stage -vs- Time With Maximum and Minimum Desired Stage.

A stage-exceedance probability relationship for a historic lake stage record is shown in Figure 3-6. All that can be surmised from the figure is that the stage is above 67 feet for some percentage of the time. It is impossible to tell from the figure whether the lake stage exceeded 67 feet during 10 separate events, or whether the lake stage exceeded 67 feet during one event lasting 20 percent of the time. One way of determining the event frequency and duration is to extract the events from the period of record so that they can be visually inspected. This can be done using a personal computer and database software.

The Lotus 1-2-3 spreadsheet, EVT_STS, was created to extract from a daily lake or stream stage record the value and corresponding date of occurrence for events of interest and compute the duration of each event by stage. The example input dataset contains daily measurements of the lake stage. With slight modification, the EVT_STS spreadsheet can handle any time step such as daily, hourly or weekly. The Lotus 1-2-3 add-in, @BASE (Personics, 1987), is used by this spreadsheet to perform the database queries. EVT_STS has four sections: the input screen, the imported records range, the summary table, and the macro code. The operations of EVT_STS are performed automatically by the macro Alt-J. The macro is activated once the @BASE add-in is attached to the F8 key and one @BASE file has been opened.

3.4.1 Input Screen

The input screen is shown in the top left portion of Figure 3-7. If a flood analysis is specified, then the database search criteria is for any days in which the stage exceeds the value placed in cell E13, shown in Figure 3-7. A drought analysis is performed using a search criterion of any days with stage less than the value in cell E12. The beginning date and the inter-event period of cells E15 and E16, respectively, are used in the imported records section of EVT_STS to compute the date of exceedance and separate them into events. The minimum inter-event period is entered into cell E16. The first month of the crop year is entered in this screen so that the output of EVT_STS can be used in the crop damage model discussed later in this report.

3.4.2 Imported Records Range

The imported records range of EVT_STS is shown at the bottom left of Figure 3-7. This is the portion of the spreadsheet in which records that meet the criteria specified in the input table are imported into the spreadsheet by the Lotus 1-2-3 add-in @BASE. After the desired records are placed in columns A and B, the four cell formulas above the column headings are copied to each row containing the imported records. The "Recno" in column A is the location of the record within the database file. Since the records are input into the database file chronologically, the date of occurrence of each extracted record can be computed by adding the record number of each of the extracted records to the

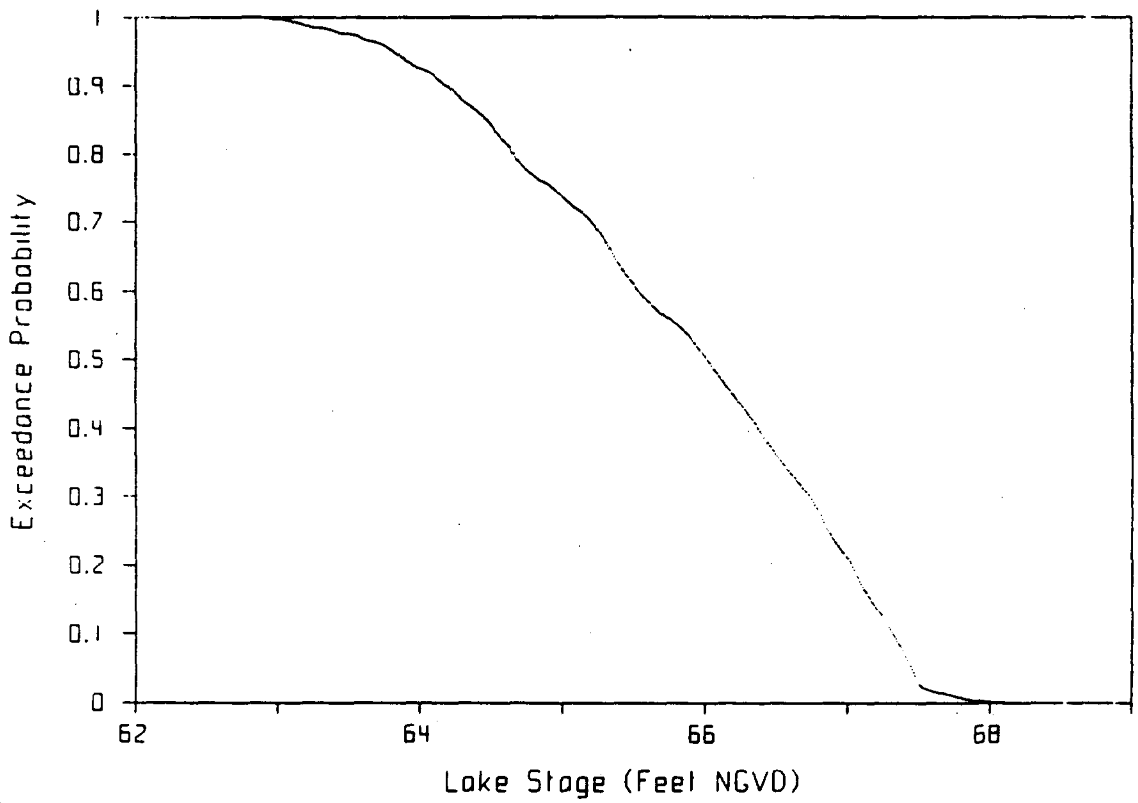


Figure 3-6. Example of Exceedance Probability Plot for Lake Stage.

	A	B	C	D	E	F
1	Input Parameters for Statistical Analysis using DBASE.					
2						
3	After specifying the type of analysis being performed, the					
4	macro Alt-J can be activated to perform the analysis.					
5						
6						
7						
8	1. Type of analysis (Place a "1" by the appropriate choice, and					
9	then enter the appropriate stage value)					
10	a. Flood analysis				1	
11	b. Drought analysis				0	
12	2. Search for days with stage <				62.5 feet NGVD	
13	2. Search for days with stage >				68.00 feet NGVD	
14	3. Beginning date (Lotus Serial #)			01-Jan-43		
15	4. First month of crop year				8	
16	4. Interevent period				15 days	
17						
18	--					
19	Imported Records				Min	0
20					Max	0
21			01-Jan-43	0	02-Jan-43	0
22				Duration	Beginning	Extreme
23	Recno	STAGE	Date	(days)	Date	Stage.
24	990	68.27	17-Sep-45	8	17-Sep-45	68.27
25	991	68.25	18-Sep-45	12	18-Mar-60	68.26
26	992	68.10	19-Sep-45	23	12-Sep-60	68.28
27	993	68.20	20-Sep-45			
28	994	68.14	21-Sep-45			

	H	I	J	K	L
3	SUMMARY STATISTICS OF TIME SERIES				
4	Type of Analysis				FLOOD
5	Date				09-Mar-89
7	Beginning Date of Simulation Reco 01-Jan-43				
9	Time to First Event				3 years
10	Number of Events				3
11	Number of Unsatisfactory Days				43 days
12	Stage of Extreme Event				68.28 feet NGVD
13	Average Duration of Event				14.33 days
14	Longest Event Duration				5296 days
15	Shortest Event Duration				8 days
16	Average Inter-Event Period				2155 days
17	Longest Inter-event Period				5296 days
18	Shortest Inter-event Period				178 days
20	Events with Stage >			68.00 ft.	
21		Crop	Event	Extreme	Inter-Event
22	Event	Year	Duration	Stage	Duration
23			(days)	(ft)	(days)
24	17-Sep	46	8	68.27	990
25	18-Mar	60	12	68.26	5296
26	12-Sep	61	23	68.28	178

Figure 3-7. Input, Records, and Summary Areas of EVT_STS.

Lotus serial number that represents the starting date of the period of record. This is done in column C of EVT_STS.

The durations of the events in column D are computed by the formula in column D that separates the events using a minimum inter-event period. If longer than the minimum inter-event period between the time of the previous exceedance and the time of the current exceedance has passed, then the current exceedance is the first day of the event. If the time between exceedances is less than the minimum inter-event period, then the current exceedance is part of the last event.

The formula in column E calculates the beginning date of each event. This formula calculates to a value other than zero only when it is the last exceedance of an event. Columns D, E, and F, are sorted according to the values in column E. Rows in which column E calculates to zero are placed at the bottom of the sorted data and then erased. The formula in column F keeps track of the minimum or maximum values for each event. The maximum value is tracked when flood analysis is specified, and the minimum value is tracked when drought analysis is specified.

3.4.3 Summary Table

The summary table of EVT-STS is the right hand portion of Figure 3-7. A synopsis of the events is listed at the top of the summary table. The statistics such as the number of events, number of unsatisfactory days, average duration of events, and average inter-event period are simple indices of a system's reliability and resiliency. All events extracted from the database file are listed at the bottom of the summary table. This portion of the summary table is used primarily to format the output from the data query so that it can be input easily into the agricultural damage assessment model to be presented later. The equations convert the date of the exceedance events into a Lotus 1-2-3 serial number for the day and month corresponding to the event date. This date is adjusted to reflect the first month of the crop year specified in the initial input screen.

The duration of each event by flood zone is computed by determining the number of days in which the stage is between the elevations shown at the top of Figure 3-7. Each event is divided into duration by elevation zone so that a more accurate estimate of the damage resulting from the event can be made. The results of the distribution of event duration by elevation zone is placed at the bottom of Figure 3-7.

3.4.4 Macro Code

The keystroke macro Alt-J is shown in Figure 3-8. This macro automatically sets the query criteria, accesses the database file, extracts the desired records, copies the analytical formulas to all rows with records, and sorts the events by date. Descriptions of each line of the programming code are also shown in Figure 3-8. The macro assumes that the @BASE add-in has

```
  BG        BH         BI         BJ        BK      BL   BM  B     BO          BP      BQ    BR    BS

Macro Alt-J
                PROGRAMMING CODE                                 CODE DESCRIPTION

\J        (goto)OPERATION-(wait @now+.00003)                     Goto opening screen.
          (goto)SUMMARY-(down)/re(end)(down)(right 13)-          Erase previous calculations.
          (branch FLD_ANAL)                                      Branch to FLD_ANAL.
\K        (goto)OUTPUT-(down)/re(end)(down)(right 5)-            Erase previously imported data.
          (up)(app2)cp--                                         Access @BASE Add-In Package.
          (if FLOOD>.1)(down 2)-→GRTER_THAN--(branch IMPORT)     If Flood Analysis, branch to IMPORT.
          (down 4)-→LSS_THAN--                                      Else, specify "<" criteria.
IMPORT    dti-a-q                                                Import records that meet criteria.
\R        (goto)EQUATIONS-/cEQUATIONS-(down 3).                  Go to EQUATIONS, and copy then
          (left)(end)(down)(right 3)-                               beside imported records.
          (down 2)/rv(end)(down)(right 3)--                      Convert formulas to values.
          (down)(left)/dsrd.(right 4)(end)(down)-                Specify sort range.
          p(right 3)-d-g                                         Sort according to date of events.
          (right 3)                                              Continue
                                                                   "  "
LST_EVT   (if @cellpointer("contents")<1)(branch \P)             Find last event by checking cells.
          (down)(branch LST_EVT)                                 If cell = 0, branch \P, else move
                                                                   down and try again.


\P        (Left)/re(end)(down)(right 2)-                         Erase non-event data.
          (up)(end)(up)(down 3)
          /dsrd.(right 2)(end)(down)(end)(down)                  Sort events by date.
          (end)(up)-p(right)-a-g                                 "  "  "  "  "
          (goto)EQN_2-/c(right 4)-                               Copy equations starting with EQTN_2.
          .(end)(down)(end)(down)(end)(up)-                      "    "    "    "    "
          (goto)SUM_PG-(calc)                                    Recalcute summary page.




FLD_ANAL  (if +FLOOD+DROUGHT>1.5)(branch RESTART)                Check for flood and drought analysis.
          (if FLOOD<.2)(branch DRGT_AN)                          Is flood analysis is specified.
          (goto)MAXX-/c-(down)-(branch \K)                       Copy maximum equation to formulas.


DRGT_AN   (if DROUGHT<.2)(branch RESTART)                        Check for drought analysis.
          (goto)MINN-/c-(down 2)-(branch \K)                     Copy minimum equation to formulas.


RESTART   (goto MSSG)-(wait @NOW+.000018)(home){quit)            Display message and goto HOME.
```

Figure 3-8. Macro Alt_J of EVT_STS.

previously been attached to the F8 key and that only one database file is currently open. It also assumes that the database field used in the criteria specification is the leftmost field in the database file. These assumptions can be modified in the macro program.

3.5 Ways to Measure Benefits

3.5.1 Direct Primary Benefits

Benefits are measured by comparing the benefits with the project vs. the benefits without the project (James and Lee, 1971). The with and without principle is important. Benefits should not be based on before and after comparisons because these changes occur independent of project activities. Direct primary benefits are measured in two ways: 1. through the market value of the output; or 2. through the cost of producing the same output in some alternative way. Examples of market values are the selling price for drinking water, or the market value of a fish. The alternative cost approach is used when no direct market exists. In this case, the gross benefits are the savings from selecting an alternative relative to the second best alternative, given that the second best alternative would actually be built. For example, the benefits of a hydropower plant can be estimated as the added savings from constructing the hydropower plant instead of a coal-fired plant, given that the coal-fired plant would have been built. The alternative cost approach must be used with care since it is open to abuse if the next best alternative is not actually economically feasible since the benefits increase in direct proportion to the lack of attractiveness of the next best alternative. In the context of valuing a natural system, its benefits would be the savings in wastewater treatment costs, flood control, etc.

3.5.2 Land Enhancement Benefits

Land enhancement benefits are the net gain in land value as a result of pursuing a selected alternative. Land drainage is a popular case where land enhancement benefits have been claimed as the drainage and flood protection facilities permit more intensive and higher valued agricultural and/or urban activities to occur. For example, 87 percent of the wetland loss in the United States in the period from the mid-1950's to the mid-1970's was caused by agricultural development (Tiner, 1984). As Bardecki (1989) points out, the reason that wetland development has been viewed as economically attractive is that only private values have been included in the benefit-cost calculations. As is now known, wetlands perform vital public functions such as wastewater treatment, flood control, erosion protection, enhanced fish and wildlife habitat, climatic and atmospheric values, education and research, recreation, and aesthetics. Based upon an evaluation of five wetland valuation studies, the private or capturable wetland benefits range from 1 percent to 28 percent of total (private + public) value. Since the land owner cannot capture the public benefits and since much of the cost of drainage development was subsidized by the government, it is not surprising that large-scale wetland drainage has occurred.

Fortunately, recent changes in attitudes towards wetlands has led to actual use of wetlands for functional purposes such as wastewater treatment and flood control. In addition, wetland restoration projects have been implemented showing that a real market exists for such activities. For example, the restoration of the Kissimmee River floodplain is being undertaken at a cost that may exceed $100 million. Wastewater treatment facilities are incorporating wetlands into their designs. Thus, it is possible to use the "alternative cost" approach since direct evidence exists that the next best alternative would have been pursued in the absence of the wetland.

3.5.3 Procedures to Estimate Alternative Costs

3.5.3.1 Federal Guidelines

The Federal NED Guidelines outline the categories of costs to be included in project evaluation as shown in Table 3-3. NED guidelines on cost estimating are vague and not very helpful. For example, they suggest including replacement costs in the cost estimates which is improper.

EPA has developed cost estimating guidelines in response to difficulties in evaluating the relative cost effectiveness of air, water, and land control programs. They found that they had no consistent guidelines for preparing these cost estimates. Uhl (1979) has developed a set of uniform guidelines for them.

3.5.3.2 Cost Estimating Models

Two coordinated cost estimating guides have been developed under sponsorship of the Corps of Engineers and EPA. MAPS (Corps of Engineers, 1980) can be used to do preliminary cost estimating for all water resource facilities except wastewater treatment plants. A list of the cost estimating elements in MAPS is shown in Table 3-4.

Wastewater treatment plant costs can be estimated using CAPDET (Harris et al. 1982). Each of these models is well-documented and includes an excellent user's manual. They represent several millions of dollars of effort. The primary problem with using them today is that they are somewhat obsolete. They would need to be updated and a database representing Florida conditions added.

Table 3-3. Categories of Costs to be Included in Federal P&G (1983).

Category	Cost Center Federal	Cost Center Non-federal
Direct costs		
Planning and design		
Construction		
Construction contingency		
Administrative services		
Fish and wildlife habitat mitigation		
Relocation		
Historical and archaeological salvage		
Land, water, and mineral rights		
Operation, maintenance, and replacement		
Other direct costs		
They compute as types of benefits or disbenefits, e.g., downstream flooding caused by the project.		

Table 3-4. Items Covered in MAPS Cost Estimating Manual.

Force mains	Storage tanks
Gravity mains	Tunnels
Open channels	Water treatment
Pipelines	Water distribution systems
Pump stations	Wellfields
Reservoirs	

3.5.4 Conclusions on Benefit-Cost Analysis

Benefit-cost analysis methods have been used by the federal government since 1936 and standardized guidelines have existed since 1950. These guidelines have continued to be refined with the latest version appearing in 1983. Also, the Institute of Water Resources of the Corps of Engineers has an active program of developing more detailed guidelines for each of the major functional areas in water resources. We have obtained all of the available information from IWR and have reviewed it and related computer models. In general, there seems to be agreement on the P&G methods for assessing benefits and that suitable models are available. The primary gap seems to be lack of suitable databases for conducting these studies. For example, if water withdrawals for irrigation are not measured, then our ability to do an accurate assessment of irrigation benefits is quite limited. Thus, it is vital to evaluate the extent to which available data will support the use of various analytical methods. On the cost side, the P&G is not very helpful but other federal guidance documents and cost estimating models are quite helpful. Some vexing issues related to cost allocation remain but these can be dealt with in later stages of the cost analysis.

We propose to accept the P&G Guidelines (1983) and supporting IWR reports on specific project purposes as being conceptually sound and providing general guidance on how to conduct similar studies in the SJRWMD. This approach has the added advantage of being consistent with federal procedures in the event that cooperative programs might be undertaken in the future.

In summary,the analytical approach being used in the current St. Johns socio-economic project is as follows:

1. Estimate benefits by purpose but keep accounts for all affected groups.

2. Place strong emphasis on developing a high quality database so that the estimates are creditable.

3. Develop and calibrate a continuous simulation model to perform this analysis.

3.6 Conclusion

System performance can be described by the reliability, resilience, and the vulnerability of the system. These parameters more accurately describe a system's output than just its mean and variance. The use of multi-objective analysis allows more informed decisions to be made since trade-offs among several impacts will be more apparent when all of these parameters are considered during project selection. Although exceedance probability plots can be helpful if applied correctly, they also can be misleading since the nature of the extreme events is not adequately represented.

Using database systems to extract from a time series the actual events of interest aids the characterization of the time series. The EVT_STS spreadsheet is designed to extract the events of interest from a time series and compute simple indices of reliability and resiliency. It can be modified to handle other types of data such as stream discharge records. Additionally, EVT_STS acts as a pre-processor of event information for the agricultural flood damage assessment model described in Chapter 4.

Different ways to quantify benefits in terms of direct measures or based on the cost of the next best economically feasible alternative were described. In addition, the proper way to assess land enhancement benefits both from the public and private viewpoints was described. It is essential to include these public benefits in the calculations.

4.0 FLOOD AND DROUGHT DAMAGES

4.1 Introduction

The federal guidelines for assessing flood damage reduction benefits are contained in the National Economic Development (NED) Benefit Evaluation Procedures Manual (U.S. Water Resources Council, 1983). In general, benefits accrue through the reduction in actual or potential damages associated with land use. The NED manual defines the three different benefit categories as inundation reduction, intensification, and location. Intensification benefits accrue when the type of flood plain use remains the same while the method of operation is modified. Location benefits accrue because of increased activity within the flood plain due to the flood control project. Not all types of benefits have to be evaluated for certain flood hazard reduction measures since many of them are not applicable to all of the reduction measures. The three types of flood damages recognized by the NED guidelines are physical damage, income loss, and emergency costs.

The evaluation procedure requires that the expected flood damages for present and future conditions be computed with and without (not before and after) the proposed flood control project. This requires, among other items, a determination of present floodplain characteristics, a forecast of activities in the affected area, and an estimate of potential land use. The NED manual outlines the assessment methodology and basic data requirements; however, other federal publications such as the Hydrologic Engineering Center's DAMCAL Users Manual (U.S. Army Corps of Engineers, 1979) provide examples of damage calculations in addition to a more detailed description of the procedures.

4.2 Urban Flood Damage Assessment

The calculation of expected flood damages incurred by a structure is done by estimating the stage-frequency, stage-depth of flooding, depth of flooding-damage relationships, and determining and integrating the frequency-damage relationship (Plazak, 1986). The expected flood damage for the area of interest is calculated by summing the damage incurred by each structure within the flood plain.

Flood damage is a function of more than just depth of flooding. Factors such as stream velocity, duration, water quality, debris, and construction techniques also affect the extent of damages. Plazak (1986) found that errors in the estimation of flood damages were caused by inaccurate estimates of the elevations of structures, failure to consider replacement of existing structures, and failure to consider that unemployed labor may be used to repair flood damage. Plazak also stated that the cost of additional accuracy probably would not exceed the benefits.

Johnson (1985) evaluated the significance of location on expected flood damage. By disaggregating the damages by location, he found that expected damages within the 25-year floodplain were ten times higher than damages outside of the 25-year floodplain. He concluded that the economic feasibility of a flood control project depends greatly upon the number of structures within the 25-year floodplain.

A large quantity of data is required for an urban flood damage assessment; nevertheless, it can usually be acquired. Land use data can be obtained from property assessment records. Structure elevations can be found either in the property assessment records or they can be surveyed. Hydrologic data are usually provided by a gauged stage record or from a simulated stage record. Historical flood damage records are also a very useful source of information.

The existence of a number of computer programs and the relative availability of the required input data make the computation of expected urban flood damages relatively straightforward. Thus, this topic will not be pursued in any greater detail. As mentioned above, the techniques for evaluating urban flood damages can be handled as a special case of the more complex agricultural damage assessment problem.

4.3 Agricultural Irrigation, and Flood Damage Assessment

Procedures for evaluating agricultural benefits are described in Section III of the NED Benefit Evaluation Manual (U.S. Water Resources Council, 1983). The agricultural benefits that are considered in this section of the manual include flood damage reduction, drainage, irrigation, erosion control, and sediment reduction. The manual states that benefits accrue when agricultural output is increased or when operating costs decrease for the same level of production.

The benefit categories considered are damage reduction benefits and intensification benefits. Damage reduction benefits, measured as a decrease in operating costs or an increase in crop yields, are determined using farm budget analysis. Intensification benefits arise when cropping patterns change. They are measured either by farm budget or land value analyses. The evaluation procedure for benefits to crop production identifies land uses and cropping patterns for with- and without- project conditions, determines damage reduction benefits, projects the net value of agricultural production with and without the project conditions, and computes intensification benefits.

Damage to farm-related property within the floodplain is evaluated in the same manner as property within an urban floodplain. The total agricultural benefits are the sum of the crop production benefits and the benefits from agriculturally related properties.

The Institute of Water Resources (IWR) Procedures Manual for estimating agricultural flood damage (Hansen, 1987) outlines the evaluation procedure as does the NED manual except that it gives a detailed explanation of the theory behind flood damage calculations. According to the IWR Agricultural Flood Damage Procedures Manual (Hansen, 1987), the factors affecting flood induced crop losses are seasonality, frequency, duration, interevent period, and price fluctuations. Unlike urban flood damages, crop damage from a particular flood event is a function of the season in which the flood occurs. For example, the damages suffered from a crop that is destroyed early in its life are greater than the damages suffered from a field that is inundated after the crop is harvested; however, the urban damages would be the same for both situations. The frequency of flooding has a direct impact on the land use or cropping pattern of a flood plain. Land that is frequently flooded is generally put to a use having a lower damage potential, and consequently has a lower income potential.

Damages in urban areas are related more to peak discharge or elevation rather than duration. However, crops may tolerate short periods of inundation with minimal impact on yield. The interevent period is important because additional crop losses can occur if fields are replanted between flood events. A delay in planting can reduce crop yields and hence net income.

4.4 Methodology of Computing Flood Damage

The frequency method and the continuous record are the alternative methodologies used to compute flood damage. Frequency based damage calculations are done by weighting the predicted damages from a number of hypothetical flood events of different magnitude and frequency to compute the expected annual damages (Hansen, 1987). Stage/frequency hydrographs are used to determine the quantity of land flooded. The Agricultural Flood Damage Analysis Model (AGDAM) developed by the U.S. Army Corps of Engineers (1985) uses the frequency based approach to calculate flood damages. Frequency based calculations generally do not handle multiple flood events occurring in the same season very well. The seasonality of flood events is also not handled as well by the frequency method as by the continuous method.

The continuous record approach to calculating expected annual flood damages is done by analyzing a record of historic flood elevations and estimating flood damages for events during the period of record. The general concept of the damage estimation procedure is shown in Figure 4-1. The sum of the event damages divided by the number of years of record is the expected annual flood damages. This method requires a gauged stage record of at least 25 years in length, preferably longer. At different reaches within the flood plain, the record has to be adjusted to reflect elevation and cross-sectional differences. If the length of stage record is insufficient, the record can be synthesized using a rainfall/run-off simulation. Flood frequency analysis does not have to be performed since the stage record reflects flooding potential (Hansen, 1987).

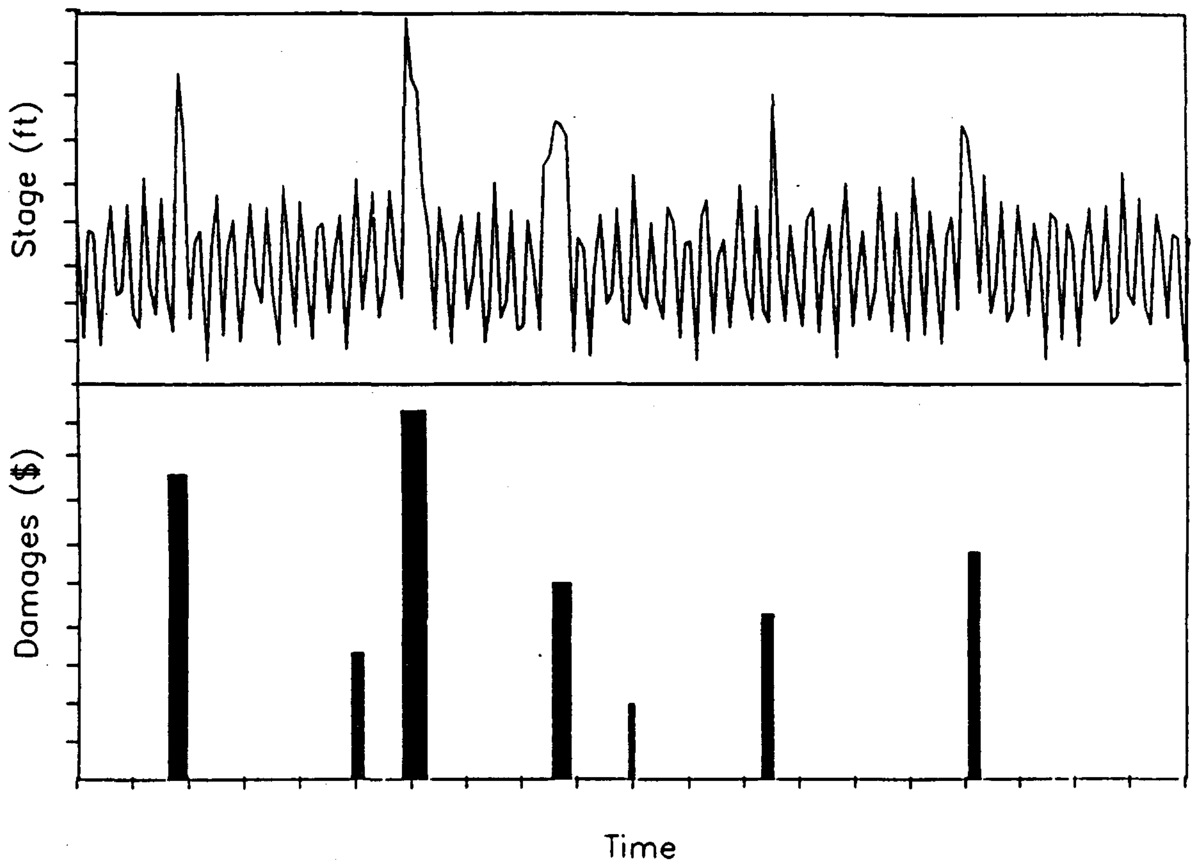


Figure 4-1. General Concept of Flood Damage Assessment.

The advantage of the continuous record method is that it handles multiple events within one season easily. This is important for crop damage analysis since replanting may occur between two flood events during one season. One disadvantage of the continuous record approach is the probable lack of a sufficiently long gauged stage record for the area of interest. The use of a gauged stage record of less than 10 years in length causes unreliable estimates of damages since either large flood events may be over or under represented.

The frequency based methods work best when damage events are unlikely to occur more than once during a single crop year. Alternatively, the events are independent. If multiple events occur in a single crop year then the continuous record approach should be used since it handles interdependent events better than the frequency approach.

4.5 Available Computer Models

Agricultural and urban benefits resulting from water resource projects such as flood mitigation can be analyzed by computer simulation. A number of pre-packaged computer programs that perform benefit assessment are available from the U.S. Army Corps of Engineers (Hydrologic Engineering Center, 1986).

4.5.1 Urban Flood Damage Models

Although urban flood damage estimates were not the primary focus of this study the basic theory and the available models were reviewed since agricultural damage analysis is based upon urban flood damage analysis. An example is the analysis of flood damage to agricultural structures which is done using the same techniques as urban flood damage estimation. Two computer programs used to compute urban flood damages are DAMCAL (U.S. Army Corps of Engineers, 1979) and DAPROG 2 (Applebaum, 1985). Both of these programs use a frequency based simulation rather than a continuous simulation to estimate flood damages. They also employ depth of flooding-percent damage tables instead of depth of flooding-damage tables since they are more site specific. The DAMCAL program, developed by the Hydrologic Engineering Center (HEC) in Davis, California, evaluates the economic impact of a broad range of alternative flood damage reduction measures. The program uses a grid representation of geographical information such as topographic elevation, reference flood elevation, existing land use classification, and alternative future land use patterns to evaluate the economic impact of alternative flood damage reduction measures. DAMCAL creates a stage-damage relationship for each cell within the grid. This gives accurate damage estimates for individual structures.

The Baltimore District of the Corps of Engineers developed the computer program called DAPROG 2 to compute stage-damage relationships for residential and commercial structures (Applebaum, 1985). This program estimates average stage-damage relationships for each reach. The stage-damage equations used by

DAPROG 2 were not intended to predict damages to individual structures very accurately. Additionally, the stage-damage relationships used by the program were developed for the Wyoming Valley of Pennsylvania and may not be applicable to other regions.

4.5.2 Agricultural Damage Models

Two available agricultural flood damage models are AGDAM (U.S. Army Corps of Engineers, 1985) and CACFDAS (Killcreas, 1981). Both were developed by the U.S. Army Corps of Engineers. AGDAM uses frequency hydrographs as its hydrologic input and economic data such as crop distributions, crop loss functions, and elevation-area relationships. Seasonal differences in event frequencies are handled using weighting factors; however, multiple events in one season are not handled very well by this model.

The Corps of Engineers in Vicksburg, Mississippi, has developed a computer program for the continuous record method of agricultural flood damage estimation. The program, "The Computerized Agricultural Crop Flood Damage Assessment System" CACFDAS, (Killcreas, 1981), performs the damage calculations based on a time history of the number of acres flooded. The time history of flooded acreage is converted into a time series showing the amount of acres flooded and the length of the flood. From this time series, the flood damage to individual crops is calculated using crop budget, inundation tolerance, and cropping pattern information. Given a sufficiently long period of record, the CACFDAS program would compute a more reliable estimate of damages than DAMCAL; however, it requires more detailed information on crop budgets and planting patterns.

4.5.3 Spreadsheet Modeling

Recently, spreadsheets have been used in the analysis of a number of water resource problems. Miles and Heaney (1988) developed a spreadsheet template for the design of stormwater drainage systems that gives a better result than a dynamic programming model intended to provide the optimal drainage design. Miles and Heaney were able to obtain better results because the spreadsheet modelled the hydraulics more realistically than the optimization program. Although a similar program was developed in FORTRAN by the Florida Department of Transportation (FDOT), it was not used by the FDOT engineers. Because this spreadsheet template is very similar in appearance to a drainage design table, it is easy to familiarize oneself with its operation.

A hazardous waste database system was developed by Knowles, Heaney and Shafer (1989) within a Lotus 1-2-3 worksheet. This model employs elements of expert systems and geographical information systems for the evaluation and notification of small quantity hazardous waste generators. Heaney et al. (1989) developed a stormwater permitting review system for the South Florida Water Management District. This system is designed to integrate all aspects of permit reviewing such as engineering analysis and report generation.

Spreadsheet templates can be created to ease the effort of formatting input so it can be used by a Fortran program. For example, Miles et al. (1986) developed an input preprocessor for the EPA Storm Water Management Model (SWMM). Fortran is certainly a proven programming environment for water resources modelling; however, relatively new spreadsheet technology offers a number of advantages over Fortran that can aid in the development of models. Much of the programming code of a typical model written in Fortran or Basic is devoted to input and output statements. Correspondingly, a large percentage of the time spent programming a model is used writing input and output statements. Since there are no input and output statements in a spreadsheet model, more time can be spent developing the model algorithm and less time formatting the input or output.

Spreadsheet models are easier to develop and debug since this environment is interactive and does not require that programs developed within it be compiled before use. The graphical capabilities of spreadsheets allow the user to easily plot model output. The on-line graphics facilitate model calibration.

4.5.4 Conclusions on Models

Assessing water resource benefits resulting from urban and agricultural flood damage reduction or agricultural irrigation enhancement is relatively straight forward since the methods have been around for more than 50 years. Agricultural flood damage is more difficult to assess than urban flood damage since flood seasonality, duration, and frequency must be considered. The continuous simulation approach to assessing benefits is inherently more accurate than the frequency approach and should be used if conditions warrant.

Available flood damage assessment models can be used to accurately evaluate current or projected conditions if no model assumptions are violated. Spreadsheet models can be developed to analyze water resource problems as long as the model is no more than moderately complex. Complex models can be prototyped within the spreadsheet and then converted to Fortran or Basic code.

4.6 Agricultural Flood and Drought Damage Models

4.6.1 Introduction

Rather than use the available agricultural flood damage assessment models such as AGDAM and CACFDAS, a spreadsheet-based agricultural flood and drought damage assessment system was developed that can handle multiple cropping and multiple damage events in a single crop year. The microcomputer models use the continuous simulation method to handle event seasonality. Data from the agricultural area bordering the northern shore of Lake Apopka located in Orange County, Florida, is used to illustrate the methodology. The Lake Apopka study area is described in detail in Chapter 6. Because of the unique hydrologic conditions and farming practices of this region, it also serves as a good test of the capabilities of these models.

A flood or drought damage assessment for the muck farm area is difficult due to the extent to which the farmers have control over the local hydrology. An illustration of the differences between hydrologic conditions of typical agricultural areas and the hydrologic conditions of the Lake Apopka muck farm region is shown at the bottom of Figure 4-2. This figure shows that flood damage can result from two conditions: rainfall in excess of the farmer's ability to discharge the runoff to the lake, and/or levee over-topping during periods of high lake stage.

A prototype soil moisture simulation model is developed to handle the internal drainage and irrigation activities of the muck farms. The purpose of this model is to determine flood or drought events based on a daily tracking of the soil moisture. Flood events caused by levee overtopping are determined by using the EVT_STS spreadsheet, discussed in Chapter 3, to analyze a simulated lake stage record provided by the Saint Johns River Water Management District (SJRWMD).

Monetary damages are determined by the farm budget simulator, Agricultural Damage Assessment Model (ADAM) that uses available crop information in conjunction with event information provided by either the EVT_STS program or the soil moisture simulation. All of the models are programmed within the Lotus 1-2-3 spreadsheet environment because of the speed and ease of model development and debugging.

4.6.2 Simulation of Soil Moisture

4.6.2.1 Lynne's Model

Lynne (1984) created an agricultural water demand projection model that also projects the financial impact of changes in irrigation/ drainage strategies, price and cost conditions, and rainfall quantity. Lynne's model was designed and calibrated to assess the impact of a drought on the agricultural interests in the Lake Okeechobee drainage basin. The model simulates the water table by attempting to maintain a goal water table depth (GWT) given maximum irrigation and drainage rates for each sub-basin. The GWT is specified for individual crop types. The irrigation capacity is assumed to be 1.0 inch per day with each tract irrigated every seven days. The "trigger" for irrigation or drainage is input into the model as inches from the GWT.

Lynne's model simulated the hydrologic parameters such as evapotranspiration and drainage quantities fairly accurately; however, the economic impact projections could not be adequately validated due to the lack of actual economic returns for the

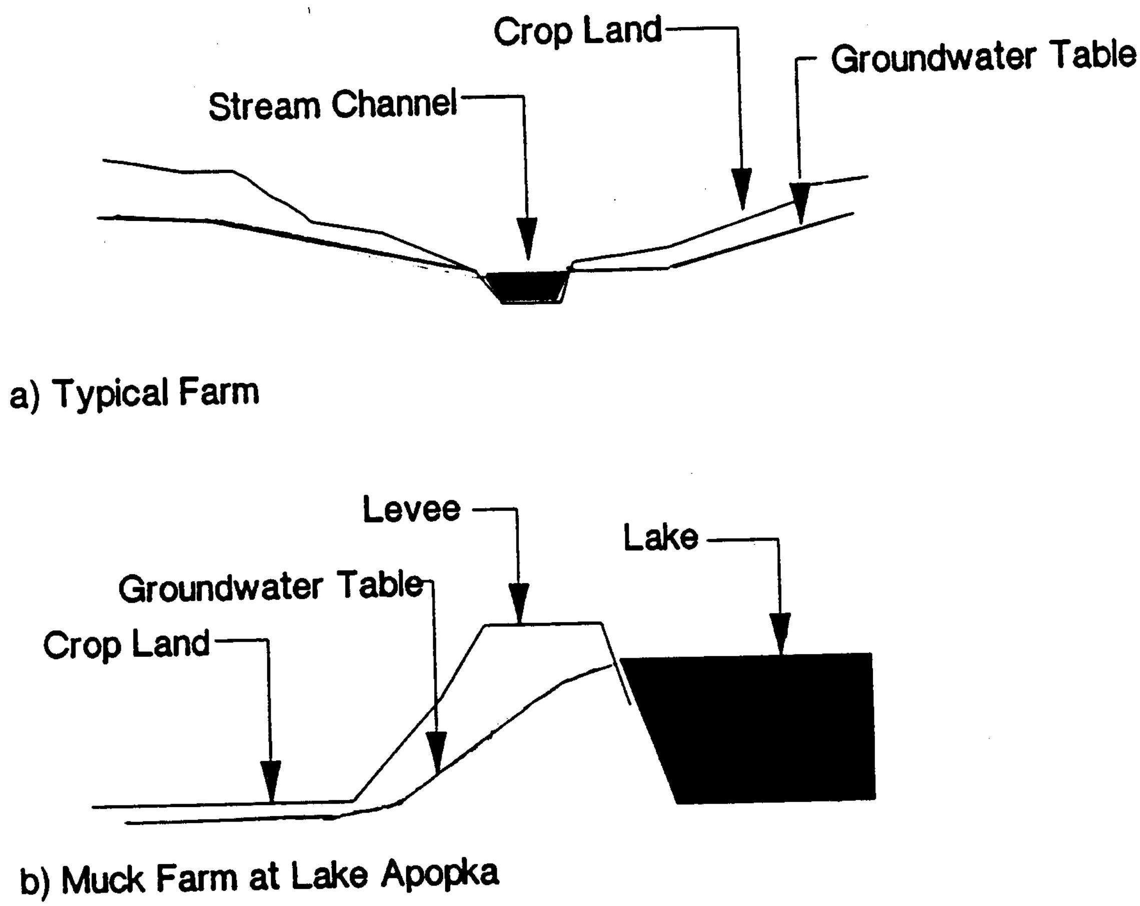


Figure 4-2. Illustration of Hydrologic Conditions at Lake Apopka Muck Farms, and Typical Farming Area.

study region. Although he did not address flood damages, Lynne demonstrated that a combined crop/water table simulation can be performed on a agricultural area that has both water supply and drainage requirements.

4.6.2.2 Spreadsheet Simulation of Soil Moisture

High water table events within the muck farm area occur whenever the rainfall quantity exceeds the farmer's ability to discharge excess runoff to the lake. Excess water that seeps through the levee is periodically discharged in order to maintain the water table below some desired maximum. The farmer's ability to anticipate heavy rainfall and subsequently draw the water table down below the desired minimum elevation prior to rainfall events helps to mitigate crop damage caused by inundation.

In order to predict when rainfall events will cause crop damage it is necessary to simultaneously model the rainfall pattern and the farmer's manipulation of the water table. A simple spreadsheet model was used to simulate the water table by tracking the soil moisture. The model is driven by rainfall and evapotranspiration data from Lisbon, Florida. The summary statistics, calibration parameters, and the equations that drive the model are shown in Table 4-1. The irrigation and drainage triggers are entered into the model as the distance from the soil surface to the water table. These parameters are then converted into a volume measurement using the depth of the soil, the field capacity, and the total acreage. The difference between the lake stage and the internal canal stage was used to estimate the seepage through the levee into the farm area.

The daily irrigation and drainage demands were determined by the current soil moisture condition. Irrigation water is also applied to the farm if no precipitation was recorded during the previous three days. The model does contain simplifications of the evapotranspiration calculation and the quantity of seepage that would flow through the lake levee; however, this was necessary due to the poor quality of the available data.

After adjusting the input parameters so that the total, mean, and standard deviation of the simulated and actual pumpage or irrigation are close, the periods of excessive or deficient soil moisture are determined. Since this soil moisture model is programmed within the spreadsheet environment the results of each calibration effort can be quickly seen using the graphics capability of the spreadsheet. An estimate of the economic damages can be computed by inputting the event dates and durations into the crop budget simulator described later in this chapter.

The model was calibrated against 1967 to 1970 pumpage data for the Zellwood Drainage District which comprises approximately one half of the muck farm acreage. After adjusting the model parameters so that the total, mean, and standard deviation of the

Table 4-1. Calibration Parameters, Summary Statistics, and Governing Equations for the Spreadsheet Soil Moisture Simulation Model.

Model Parameters

Acreage		8500 acres	
Field Capacity		0.125	
Irrigation Capacity	(IC)	2 inches	2495 acre-feet
Drainage Capacity	(DC)	1.5 inches	1372 " " "
Soil Depth		4 feet	4250 " " "
Drain Trigger	(DT)	18 inches	2656 " " "
Irrigation Trigger	(IT)	18 " "	2656 " " "
Optimum Storage	(OS)	18 " "	2656 " " "
E-T Coefficient		0.8	
Initial Soil Storage		2656 acre-feet	
Lake Elevation		66.7 feet	
Canal Elevation		62.5 feet	
Hydraulic Conductivity		13.8 feet/day	
Estimated Daily Seepage Through Lake Levee		26.5 acre-feet/day	

Summary Statistics

	Actual	Simulated Soil Moisture Model
Quantity Pumped (acre-feet/year)	73256	69348
(inches/year)	103.4	97.9
Average Daily Pumpage (acre-feet)	201	206
Standard Deviation (acre-feet)	259	317

Model Equations:

Initial Soil Moisture (Mi) $M_{i(t)} = M_{(t-1)} + (PPt_{(t)} + Seepage_{(t)} - ET_{(t)}.$

Irrigation (I) IF $Mi_{(t)} > IT$ or $PPt_{(t)} + PPt_{(t-1)} + PPt_{(t-2)} = 0.$

then $I_{(t)} = \text{Min.}\ (OS - M_{(t)}, IC)$, else $I_{(t)} = 0.$

Drainage (D) IF $Mi_{(t)} < DT$ then $D_{(t)} = \text{Max.}\ (M_{(t)} - OS, DC)$,

else $D_{(t)} = 0.$

Final Soil Moisture (M) $M_{(t)} = Mi_{(t)} + I_{(t)} - I_{(t)}.$

simulated and actual pumpage were close, the flood events were determined. A time history of the simulated and the actual pumpage is shown in Figures 4-3 and 4-4. The simulated pumpage, shown in Figure 4-4, contains too many high pumping days and not enough days with a moderate amount of pumping. The calibration of the model could be improved by changing the assumptions used to simulate the behavior of the farmers. One assumption that could be tried is to attempt to simulate the farmer's ability to anticipate rainfall and draw the soil moisture down prior to the rainfall event.

The four year simulation period produced two floods, one during May and the second at the end of August. The model was run again after eliminating the seepage quantity from the water balance. No reduction in the number of flood events was observed. This is not surprising since seepage water accounts for less than the 25 percent of the water discharged to the lake annually (Applied Technology and Management, 1988). Most of the water that is discharged to the lake is runoff from open channel irrigation activity.

Given additional data such as pump records and crop information for each subbasin, a simulation could be performed for each of the subbasins within the area. The reliability of the results obtained from this model would depend upon how well the operating policies of the muck farms are simulated.

4.6.3 Simulation of the Annual Farm Budget

The seasonal variations in crop production investments are estimated in order to accurately predict the potential crop damage caused by flood or drought conditions that may occur any time throughout the crop growing season. This is particularly true for agricultural areas that undergo intensive year-round farming activity such as the muck farms near Lake Apopka. The agricultural damage models AGDAM and CACFDAS may not adequately track the crop production investments for a region such as the Lake Apopka muck farms since they were not designed to handle areas undergoing extremely intensive farming.

Because of this limitation a spreadsheet model was created to simulate the seasonal cash flow of an agricultural region given the occurrence of crop damage events such as floods or droughts. The model is referred to as ADAM, for agricultural damage assessment model.

4.6.3.1 Farm Budget Simulator

The programming logic used in ADAM is outlined in Figure 4-5. Each of the eight boxes in the top of Figure 4-5 represents tables within ADAM. With the exception of "Production Costs" and the "Monthly Acreage Plantings" these boxes represent input tables. The arrows indicate approximately where the input data are used in the summary calculations table. The description of

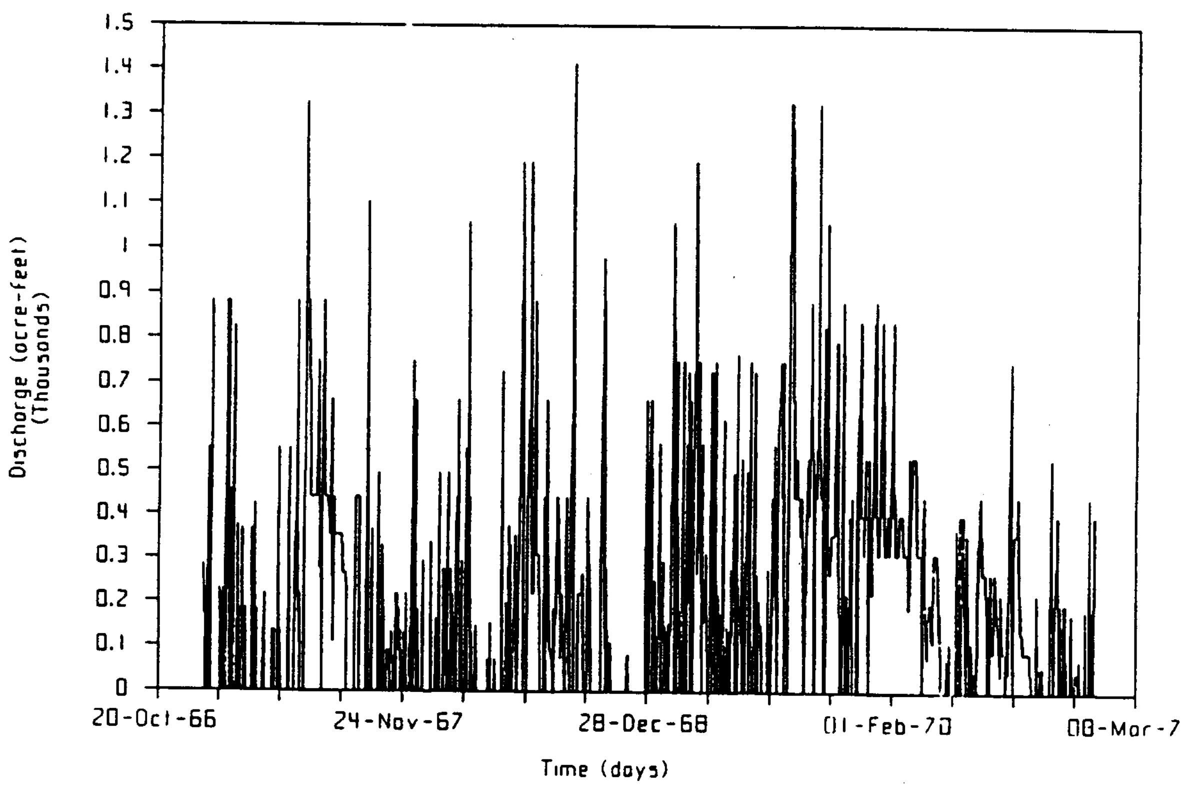


Figure 4-3. Actual Pumpage at Zellwood Drainage District 1967-1970.

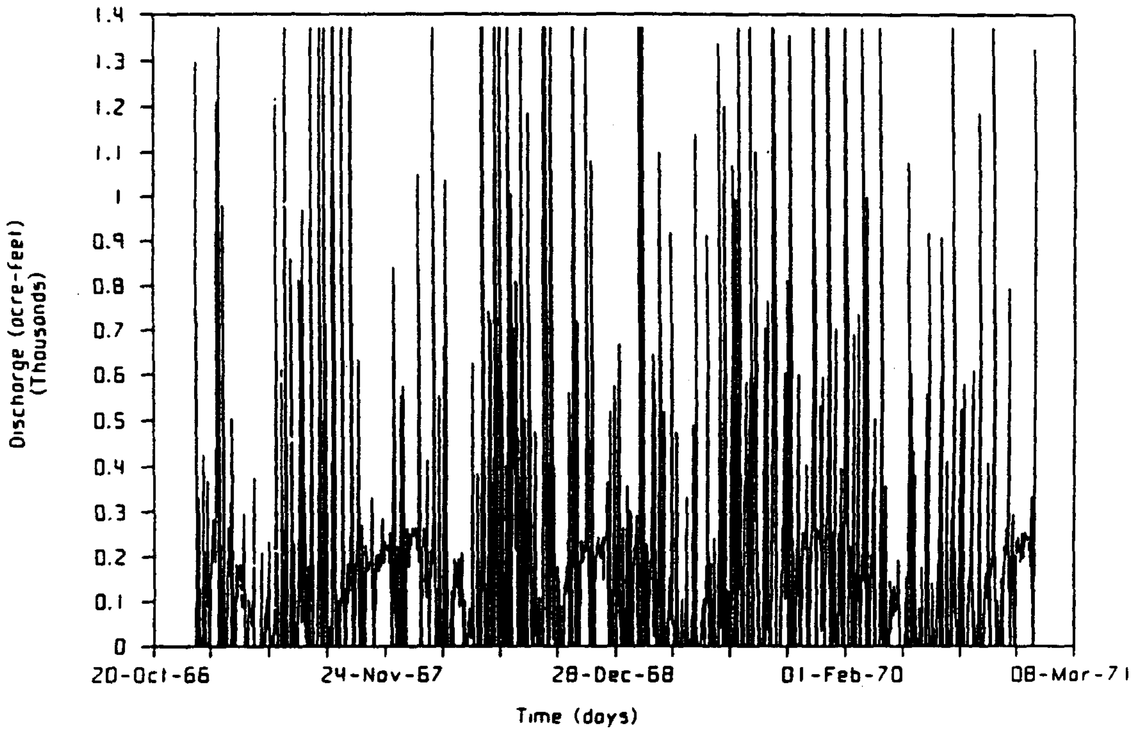


Figure 4-4. Simulated Pumpage at Zellwood Drainage District 1967-1970.

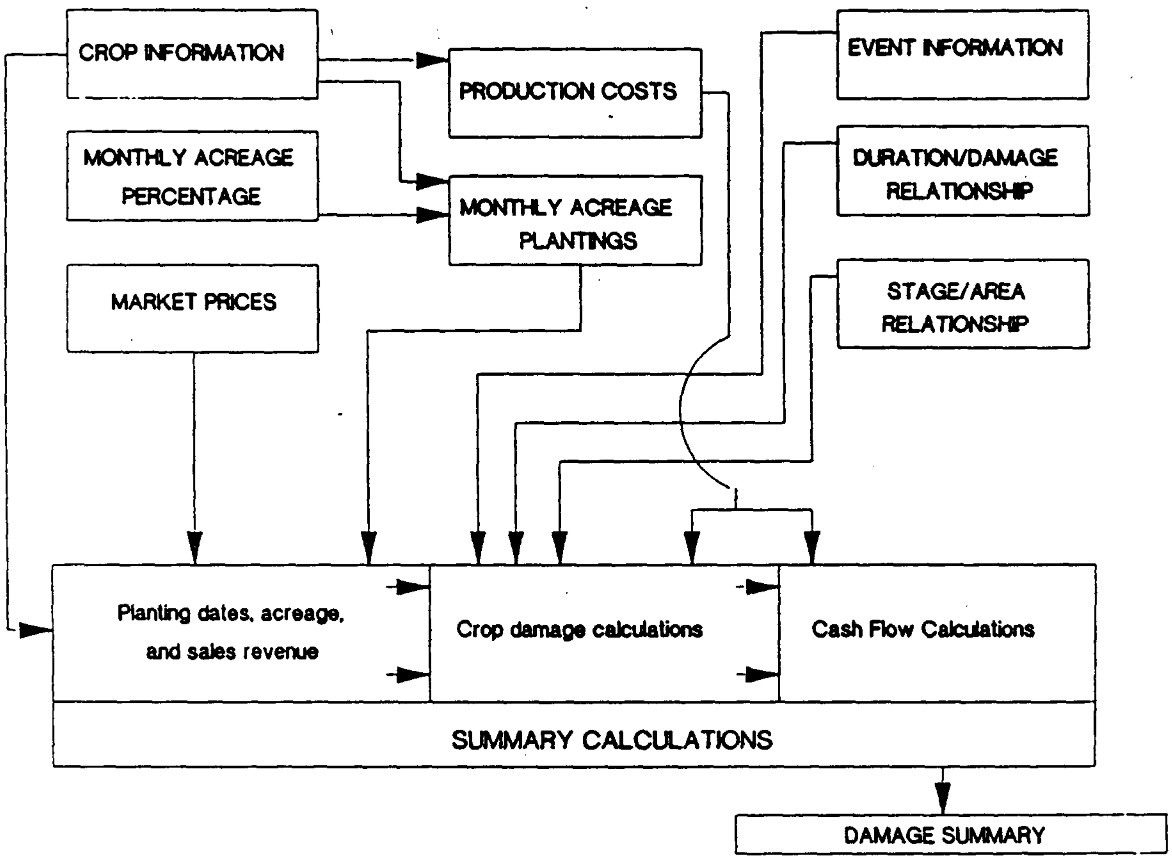


Figure 4-5. Programming Logic of Crop Budget Simulator ADAM.

the crop budget simulation model, ADAM, begins with a summary of the input data required and ends with a summary of output information.

4.6.3.1.1 Input Data

Data are entered into ADAM using six tables. The required input data for the model are planting and harvesting costs, crop yields, monthly crop acreages, crop prices, length of growing period, crop damage - event duration relationships, event information, and the stage/area relationship. For the first month of the crop year, the acreage, yield, growing period, harvest period, and the planting and harvesting costs are input to the crop information table shown in Figure 4-6. The number entered into the cell named FRST_MNTH (BJ4) is used throughout the spreadsheet to specify the first month of the crop year. The initial planting cost is the per acre production investment at the time of crop planting. The total planting cost is the sum of all of the production investments made prior to harvesting.

The monthly distribution of the yearly acreage devoted to each crop is input to the monthly acreage plantings shown in Figure 4-7. The cells in row eight of Figure 4-7 are calculated based on the first month of the crop year entered into the crop information table shown in Figure 4-5. The acreage distributions for this example were found in the Florida Agricultural Statistics-Vegetable Summary (Florida Department of Agriculture, 1988) and in a report by Applied Technology and Management (1988).

The average monthly market prices for each crop are input to the table shown in Figure 4-8. Monthly crop prices are used since they vary greatly depending upon the season. Average yearly prices would not accurately predict annual sales revenue given the variance in the monthly crop prices. The monthly market prices for this example were taken from the Florida Agricultural Statistics-Vegetable Summary (Florida Department of Agricultural Statistics, 1988).

Since the duration of an event plays a large part in the extent of the damage, the damage calculations should take this into consideration. The table in which the crop damage - event duration relationships are input is shown in Figure 4-9. This table can be set up so that different crops can be given different damage-duration relationships.

A stage-area relationship is used by ADAM to prorate the crop damage based on the event duration for each elevation zone, where an elevation zone is defined as the percentage of acreage between successive stages entered in the cells in column CS shown in Figure 4-10. The percent area for each elevation zone is entered next to the corresponding lower elevation of the zone. ADAM is currently set up to consider a maximum of six elevation zones.

	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP
1	INPUT TABLE FOR CROP INFORMATION									
2										
3										
4	First Month of Crop Year =			8						
5										
6		Average	Product	Estimated	Growing	Harvest	Initial	Total	Unit	Harvest
7	Crop	Yield	Units	Acreage	Period	Period	Planting	Planting	Harvest	Cost
8							Cost	Cost	Cost	
9				(acres)	(days)	(days)	($/acre)	($/acre)	($/unit)	($/acre)
10	Cabbage	435	crates	260	60	15	232	662	2.60	1131
11	Carrots	100	cwt	11600	90	20	279	1044	1.79	179
12	Celery	606	crates	1700	90	20	594	1523	2.91	1763
13	Sweet corn	227	crates	13300	90	20	155	592	2.27	515
14	Escarole	500	crates	2600	60	15	607	1214	2.43	1214
15	Lettuce	170	cwt	1950	60	15	232	662	2.60	1131
16	Radishes	225	cartons	6100	30	10	158	582	0.59	133
17	Other	323	crates	2055	60	15	322	897	2.60	841
18	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
19	Total			39565						
20										

Figure 4-6. Input Cells for Crop Information.

	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE
1	INPUT TABLE FOR MONTHLY ACREAGE PLANTINGS AS A PERCENTAGE OF TOTAL ANNUAL ACREAGE													
2														
3														
4														
5														
6														
7				Percent of crops planted in indicated month										
8	Crop	8	9	10	11	12	1	2	3	4	5	6	7	Sum
9	--------	----	----	----	----	----	----	----	----	----	----	----	----	----
10	Cabbage	0.0	0.7	10.6	13.0	16.1	20.8	22.6	14.8	1.4	0.0	0.0	0.0	100
11	Carrots	6.6	25.0	26.5	19.1	16.9	0.0	5.9	0.0	0.0	0.0	0.0	0.0	100
12	Celery	7.0	21.1	5.6	0.0	0.0	0.0	22.5	25.4	18.3	0.0	0.0	0.0	100
13	Sweet corn	7.8	18.4	0.0	0.0	0.0	0.0	0.0	6.4	48.2	19.1	0.0	0.0	100
14	Escarole	0.7	10.8	13.8	15.8	14.9	17.1	15.5	11.4	0.0	0.0	0.0	0.0	100
15	Lettuce	0.0	3.9	14.9	11.7	17.8	22.3	21.2	8.2	0.0	0.0	0.0	0.0	100
16	Radishes	0.0	9.6	13.3	12.3	10.3	11.9	12.6	15.0	13.5	1.5	0.0	0.0	100
17	Other	2.6	7.2	12.9	12.7	15.2	18.2	18.6	12.0	0.7	0.0	0.0	0.0	100
18														

Figure 4-7. Input Range for Monthly Acreage Planting.

	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE
21	INPUT TABLE FOR AVERAGE MONTHLY MARKET PRICES													
22														
23														
24		8	9	10	11	12	1	2	3	4	5	6	7	Avg
25	----------	----	----	----	----	----	----	----	----	----	----	----	----	----
26	Cabbage	5.1	5.1	5.6	5.6	4.6	5.1	3.8	4.1	4.7	5.6	6.7	5.1	5.1
27	Carrots	12.2	12.2	12.2	16.1	16.1	13.3	9.0	8.7	10.1	11.3	13.2	12.2	12.2
28	Celery	7.5	7.5	7.5	9.5	5.5	8.5	7.3	7.2	6.8	6.7	6.9	9.1	7.5
29	Sweet corn	7.0	7.0	8.1	5.7	5.2	8.2	11.5	8.3	6.8	5.9	5.5	4.4	7.0
30	Escarole	4.9	4.9	4.9	4.7	6.0	5.3	6.4	4.1	4.2	4.1	4.1	4.9	4.9
31	Lettuce	15.4	15.4	15.4	23.9	17.6	18.5	13.0	16.9	12.5	10.5	10.5	15.4	15.4
32	Radishes	3.2	3.2	4.5	3.0	3.3	3.8	2.6	2.5	3.0	3.0	2.9	3.2	3.2
33	Other	7.9	7.9	8.3	9.8	8.3	8.9	7.6	7.4	6.9	6.7	7.1	7.7	7.9
34														

Figure 4-8. Input Range for Average Monthly Market Prices.

INPUT TABLE FOR EVENT DURATION / PERCENT DAMAGE RELATIONSHIP

CG	CH	CI	CJ	CK	CL	CM	CN	CO
Event Duration (days)	Cabbage	Carrots	Celery	Sweet corn	Escarole	Lettuce	Radishes	Other
0	0	0	0	0	0	0	0	0
1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
9	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
12	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
15	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
18	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
20	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
25	1	1	1	1	1	1	1	1

Figure 4-9. Input Range for Event Duration/Percent Damage Relationship.

	CQ	CR	CS	CT	CU	CV
1	INPUT TABLE FOR STAGE-AREA RELATIONSHIP					
2						
3	Stage	Area	Area			
4	(ft.)	(acres)	(percent)			
5	62.5	13916	100%			
6	63	13916	100%			
7	64	13916	100%			
8	65	13916	100%			
9	66	13916	100%			
10	67	13916	100%			
11	68	13916	100%			
12	70	13916	100%			
13	71	13916	100%			
14	72	13916	100%			
15						
16	Total	13916	100%			
17						
18						

Cell	Formula
CS5	CR5/CR16

Figure 4-10. Input Range for Stage-Area Relationship.

Since flood damage by levee overtopping is being considered, the true stage-area curve was not used; rather the length of time in which the levee is overtopped was used as the primary means in determining the extent of damage. However, ADAM is designed to consider the typical hydrologic situation shown in Figure 4-2. The input cells for the day and year of the event are shown at the top of Figure 4-11. The model requires the following information for each event, the day and month, the year, and the duration of the event by elevation zone. The event information is entered in the summary table of crop damage shown in the bottom of Figure 4-11. During the operation of the model, the data for each event is automatically placed in the event input cells shown in the top of Figure 4-11.

A Lotus 1-2-3 serial number is used to represent the day of the year that the event began. Any event dates entered into this table of ADAM must be converted into a Lotus 1-2-3 serial number date for the period after the first month of the crop year. The date of the event must be represented this way or the damage calculations will be wrong. The year of the event is used by the model to separate the results of multiple event years from single event years. The duration of the events is used in conjunction with the damage duration table of ADAM to determine the extent of damage caused by the event. The event stage is used by the stage-area table, shown in Figure 4-10, to compute the percent of the total area that is inundated.

4.6.3.1.2 Intermediate Calculations

The table in which the monthly acreage plantings are computed is shown in Figure 4-12. Example formulas for the calculations are also shown in Figure 4-12. The cabbage acreage planted in month eight (cell DS8) is calculated by multiplying the total annual cabbage acreage planted, ACREAGE_1, entered in the crop information table shown in Figure 4-6, by the percentage of the total annual cabbage acreage planted in month eight found in Figure 4-7. The corresponding acreage for each month and crop is calculated in a similar manner. The ADAM table of the monthly active acreage is shown in Figure 4-13. The monthly active acreage for each crop type is calculated by adding the previous month's acreage plantings to the current month's plantings. The equations of this table depend upon the length of the growing season of each crop. If the length of the growing period of any of the crop types is changed, then the corresponding equations in this table have to be altered to ensure that the table is calculated correctly. This table checks that the planted acreage does not exceed the acreage available; however, the results of this table are not used in any subsequent calculations.

The calculation table of the time series of production costs and the corresponding formulas is shown in Figure 4-14. This table is used to estimate the production investment over the planting to pre-harvesting period. An example of the cumulative production investment for corn (Hansen, 1987) is shown in Figure 4-15. The cumulative investment curve shows that much of the

CW	CX	CY	CZ	DA	DB

INPUT CELLS FOR EVENT DATE, DURATION, AND STAGE.

	Event
Date	18-Mar-01
Duration	21
Stage	68

Year of Current Event 0
Year of Last Year 61

Annual Crop Losses ($1000) 3903

SUMMARY TABLE OF CROP DAMAGE CAUSED BY EACH EVENT

Length of Record = 42 years

Events with Stage > 68.00

Event	Year	Event Duration	Extreme Stage	Crop Damage
03-Aug	46	6	68	137
17-Sep	47	5	68	1816
19-Oct	52	7	68	4288
23-Sep	55	14	68	4116
18-Mar	61	21	68	3903

Avg. Annual Crop Damage ($1000) 340

Figure 4-11. Input Cells for Event Data, and Summary Table of Events and Damage.

	DR	DS	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED	EE
1	INTERMEDIATE CALCULATION OF MONTHLY ACREAGE PLANTINGS													
2														
3														
4					Acreage planted in indicated month									
5	Crop	8	9	10	11	12	1	2	3	4	5	6	7	Sum
6	------------	------	------	------	------	------	------	------	------	------	------	------	------	------
7														
8	Cabbage	0	2	28	34	42	54	59	38	4	0	0	0	260
9	Carrots	768	2900	3071	2218	1962	0	682	0	0	0	0	0	11600
10	Celery	120	359	96	0	0	0	383	431	311	0	0	0	1700
11	Sweet Corn	1038	2452	0	0	0	0	0	849	6414	2547	0	0	13300
12	Escarole	18	281	359	411	387	445	403	296	0	0	0	0	2600
13	Lettuce	0	76	291	228	347	435	413	160	0	0	0	0	1950
14	Radishes	0	586	811	750	628	726	769	915	824	92	0	0	6100
15	Other	53	147	265	261	312	374	382	246	15	0	0	0	2055
16	------------	------	------	------	------	------	------	------	------	------	------	------	------	------
17	SUM	1996	6803	4920	3902	3678	2033	3091	2936	7567	2638	0	0	39565
18														
19														
20														

Cell	Formula
DS8	+$ACREAGE_1*GX10/100

Figure 4-12. Calculation Range of Monthly Acreage Allotments.

	DR	DS	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED
1	INTERMEDIATE CALCULATION OF MONTHLY ACTIVE ACREAGE												
2													
3					Active acreage in indicated month								
4	Crop	8	9	10	11	12	1	2	3	4	5	6	7
5	------------	----	----	-----	-----	----	----	----	----	-----	-----	----	----
6	Cabbage	0	0	29	61	76	96	113	97	42	4	0	0
7	Carrots	768	3668	6738	8188	7250	4179	2644	682	682	0	0	0
8	Celery	120	479	575	455	96	0	383	814	1125	742	311	0
9	Sweet corn	1038	3490	3490	2452	0	0	0	849	7263	9810	8961	2547
10	Escarole	18	299	640	770	798	832	848	699	296	0	0	0
11	Lettuce	0	76	367	519	575	782	848	573	160	0	0	0
12	Radishes	0	586	811	750	628	726	769	915	824	92	0	0
13	Other	53	200	413	526	573	686	756	628	261	15	0	0
14	------------	----	----	-----	-----	----	----	----	----	-----	-----	----	----
15	SUM	1996	8799	13062	13722	9996	7301	6360	5258	10654	10662	9272	2547
16													
17													

Cell	Formula
DU6	DT6+DU6
DU9	DS9+DT9+DU9

Figure 4-13. Calculation of Incremental Production Investment.

	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
1	INTERMEDIATE CALCULATION TABLE OF PRODUCTION COSTS									
2										
3	Crop	Cabbage	Carrots	Celery	Sweet corn	Escarole	Lettuce	Radishes	Other	
4	Age	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	
5	(days)									
6	1	232	279	594	155	607	232	158	322	
7	15	496	626	914	355	911	497	466	673	
8	20	570	783	1142	444	1045	570	582	772	
9	30	607	835	1218	474	1113	607	582	822	
10	35	625	861	1256	488	1147	625		847	
11	40	643	887	1295	503	1180	644		872	
12	45	662	914	1333	518	1214	662		897	
13	50	662	940	1371	533	1214	662		897	
14	60	662	992	1447	562	1214	662		897	
15	70		1044	1523	592					
16	80		1044	1523	592					
17	90		1044	1523	592					
18										
19										

Cell	Formula
DH6	+INIT_CST_1
DH7	+TOT_PCST_1*.75
DH23	+TOT_PCST_1

Figure 4-14. Calculation of Incremental Production Investment.

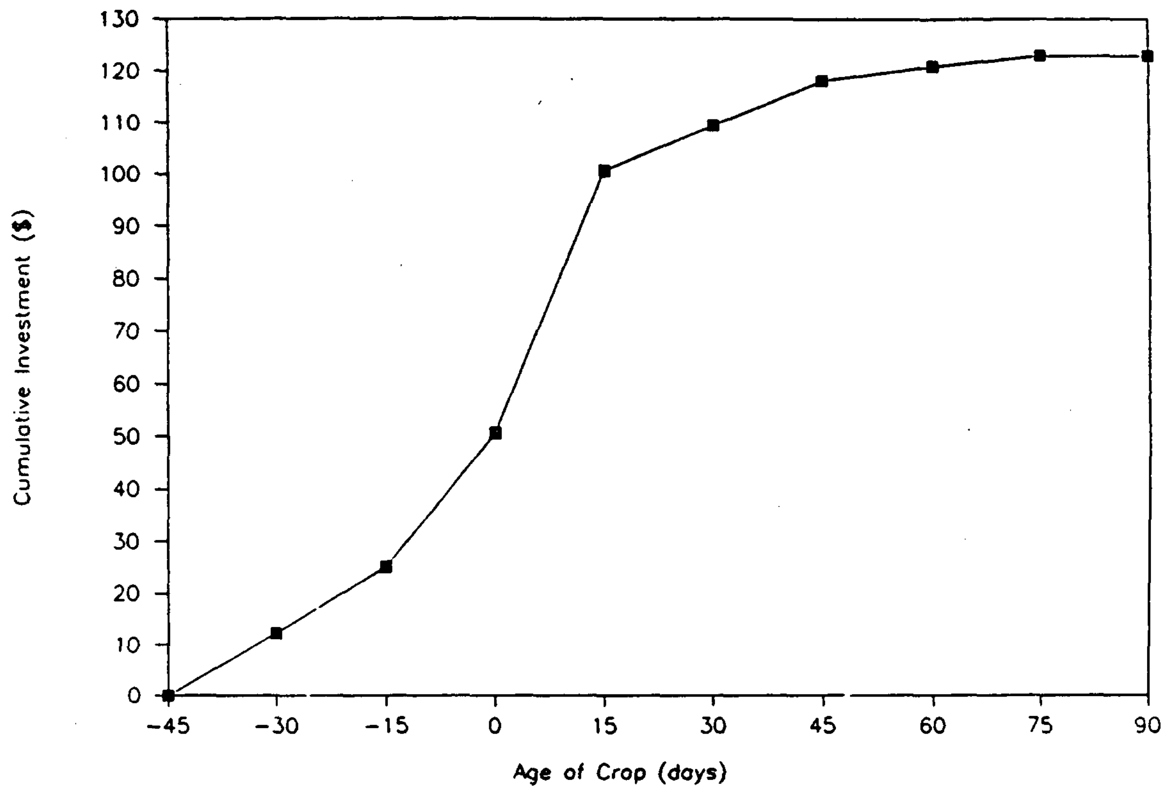


Figure 4-15. Estimated Cumulative Production Investment for Corn.

planting cost is actually invested before planting. More than 75% of the total production cost has already been invested by the time the corn crop is 15 days old. The general investment trend shown in the IWR example was used in the model except that the pre-planting investment was assumed to be zero. An example of the production investment curve used in the crop budget simulator is shown in Figure 4-16.

The production costs, shown in Figure 4-14, are prorated between the time of the planting and the start of harvest so that 75% of the investment is made during the first 15-20 days of the planting date. All of the crop investments are assumed to have been made once harvesting has commenced. The formulas for cells DH6 through DH14 calculate the prorated costs for nine points in time between planting and harvesting. The costs are prorated in a similar manner for crops that have longer or shorter growing periods. If the length of the growing season for any of the crops are changed, then the formulas in this table also have to be changed.

4.6.3.1.3 Summary Calculations

The calculations required to compute the annual crop budget are done in the summary calculation table of ADAM, shown in Figures 4-17 and 4-18. This table contains 18 columns. Each row of this table contains all of the necessary calculations for an individual crop planting. There are 96 rows representing twelve plantings each of eight crop types. Documentation of the formulas used to calculate each column of the table is also shown in Figures 4-17 and 4-18.

Potential crop loss results if a damage event occurs between the planting and harvesting dates for each planting event shown in the second column of Figure 4-17. The amount of crop damage depends upon the age of the crop at the time of the flood event. If a flood event occurs just after a crop is planted, then only the initial planting costs are lost. However, if the flood event occurs during the final days of harvesting, then the amount of crop damage is the difference between the expected net income from the fully harvested field and the net income from the partially harvested field.

In order to keep track of the effects of all of the events during a single year, the summary calculation table was divided into five sections: planting information, previous damage calculations, current damage calculations, cumulative damage calculations, and cash flow calculations. The planting information section begins with column A and ends with column D. The crop type is entered in column A. Each crop type uses 12 rows of the spreadsheet since planting can occur in any of twelve months. The planting dates entered in column "B", shown in Figure 4-17, are the Lotus 1-2-3 serial numbers assigned to the first day of each month between the first and last month of the crop year. These planting dates will automatically change if the first month of the crop year, shown in Figure 4-6, is changed. The planting

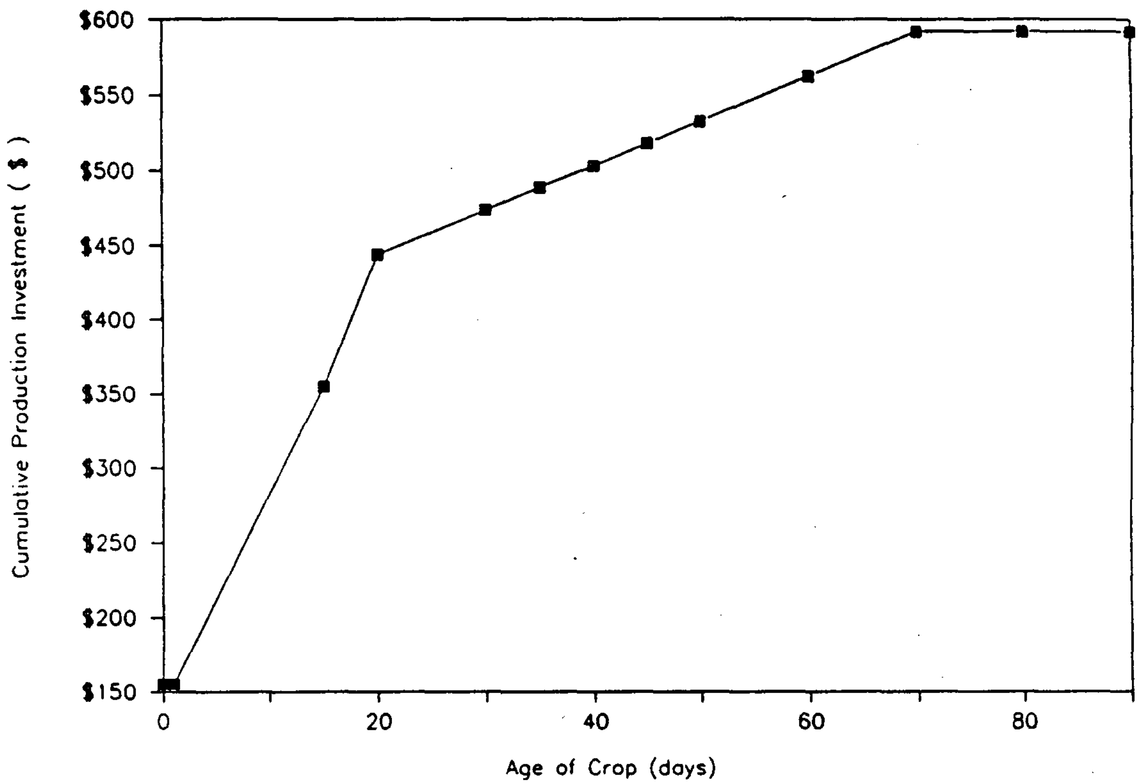


Figure 4-16. **Estimated Cumulative Production Investment for Sweet Corn.**

	A	B	C	D	E	F	G
1	SUMMARY CALCULATIONS OF FARM BUDGET CASH FLOW.						
2							
3							
4	Date	00-Jan		Year	0		
5	Duration	0		Last_Year	0		
6							
7							
8	-----Planting Information------				-----Previous Damage-----		
9	Crop	Planting	Amount	Sales	Cum.	Cum.	Last
10	Type	Dates	Planted	Revenue	Damage	Damage	Re_plt
11		(DD-MM)	(acres)	($/ac)	(%)	$ Loss	(%)
12							
13	Cabbage	01-Aug	0	2419	0	0	0
14	Cabbage	01-Sep	2	2419	0	0	0
15	"	"	"	"	"	"	"
16	"	"	"	"	"	"	"
17	"	"	"	"	"	"	"
18							

Cell	Formula	Description
A13	+CROP_1	Crop type of planting.
B13	EK6	Lotus serial number of planting date.
C13	+DS8	Monthly acreage planted.
D13	$YIELD_1*$BU$26	Crop yield multiplied by expected price.
E13	@IF(YEAR-LST_YEAR,L13,0)	Reset formula for cumulative damage (%).
F13	@IF(YEAR-LST_YEAR,+M13,0)	Reset formula for cumulative damage ($).
G13	@IF(YEAR-LST_YEAR,+K13,0)	Reset formula for last replant (%).

Figure 4-17. Summary Calculation Range Showing Planting Information and Previous Damage Computations.

	H	I	J	K	L	M	N	O	P	Q	R
8	-------Current Damage Calculations-----				---Cumulative Damage---			---------------Cash Flow-----------------			
9	Crop				Cum.	Cum.	Harvest	Harvest	Total	Sales	Net
10	Age	Damage	Damage	Re_plt	Damage	Damage	Amount	Costs	Planting	Revenue	Income
11	(days)	(%)	($)	(%)	(%)	($)	(%)	($)	Costs		
12											
13	60	0	0	0	0	0	0	0	0	0	0
14	"	"	"	"	"	"	"	"	"	"	"

Cell	Formula	Description
H13	@IF(FLD_DAY>B13#AND#FLD_DAY<B13+GROW_PER_1, FLD_DAY-B13,GROW_PER_1)	If event date is between planting and harvesting dates, then crop age = event date - planting date, else crop age = age at maturity.
I13	@IF(H13<(GROW_PER_1-HARV_PER_1),@VLOOKUP(DURTN_1,CRP_LSS,1), (1-(H13-(GROW_PER_1-HARV_PER_1) /HARV_PER_1))*@VLOOKUP(DURTN_1,CRP_LSS,1))	If crop age < age at start of harvest, then lookup percent damage based on duration of event, else the damage is equal to the fraction not harvested times the duration/damage amount.
J13	@VLOOKUP(H13,COSTS,1)*C13*I13 *(1-E13)	Current Damage $ = per acre investment for a crop that is H13 days old, times the number of acres planted, times the amount damaged.
K13	@IF(G13=0#AND#H13<GROW_PER_1/2, I13,0)	If there is no previous replant, and the crop age is less than 1/2 maturity, then replant percent = current damage, else replant percent = 0.
L13	+E13+(1-E13)*(I13-K13)	Cumulative damage % = previous cum. damage (%) + remaining crop multiplied by the current net damage.
M13	+F13+J13	Cum. damage $ = previous cum. damage $ + current damage ($).
N13	(1-L13)	Harvest percent (N13) = 1 - damage percent (L13).
O13	+C13*N13*HARV_CST_1	Harvest cost = acreage * percent harvest * harvest cost.
P13	+C13*N13*TOT_PCST_1+M13	Planting cost = harvested acreage * planting cost + crop losses.
Q13	+N13*C13*D13	Sales revenue = percent harvested * acreage * income/acre.
R13	+Q13-P13-O13	Net income = revenue - planting costs - harvesting costs.

Figure 4-18. Summary Calculation Range of Current Damage, Cumulative Damage, and Cash Flow.

dates are used to determine if an event occurs during the cultivation period of each planting. The acreage for each planting, column "C" in Figure 4-17, is calculated by referencing the appropriate cell of the the active acreage table shown in Figure 4-11. The sales revenue per acre for each planting is computed as the crop yield times the monthly average market price.

The next three sections of the summary calculation table determine and track crop conditions over the period of a crop year. The extent of crop damage caused by one event depends upon the damage caused by previous events within the same crop year. The order in which ADAM recalculates the spreadsheet is important, since the results from the columns in the cumulative damage section depend upon the results from the previous damage section which in turn are based upon the cumulative damage results.

The order in which spreadsheets calculate individual cells is usually based upon the formulas themselves. Those cells that depend upon the results from other cells are calculated after the other cells. When the result of a cell formula depends upon another cell that in turn depends upon the first cell, it is not really clear which cell should be calculated first. Within a spreadsheet, this dilemma can be resolved by specifying either column-wise or row-wise recalculation order. ADAM requires that column-wise recalculation order be specified.

The previous damage portion of the summary calculation table is shown in Figure 4-17. The cumulative damage percent, the cumulative monetary damage, and the last replant percentage, columns E, F, and G, respectively, keep track of the effects of previous events over the course of the simulation year. These columns reset to zero whenever the year of the current event is not the same as the year of the previous event. If the current year and the previous year are equal, then these columns store the results of the previous event. The formulas and descriptions of the previous damage section are shown in Figure 4-17.

The current and the cumulative damage calculations of the summary calculations are shown in Figure 4-18. The five columns of the current damage calculation are the current crop age, the damage percentage, stage/area damage, monetary damage, and replanting percentage. These calculations are found in columns H, I, J, K, and L, of the summary table. If the event date falls between the planting and harvesting dates of a planting, then the crop age, in column H, is calculated by subtracting the planting date from the event date. If the event date is after the crop has been harvested, then the crop age is the length of a successful cultivation period for that crop type.

The damage percent of column I determines whether or not the planting was exposed to the event based on the crop age in column H. If the event occurs during the harvesting period, then the formula in column I calculates the remaining crop that was exposed to the event. If the crop has already been harvested, then the cells in column I calculate to zero.

The percent damage in column J is found using the duration of the event by zone and the duration-damage relationship. The previous damage calculations keep track of the damage done to each elevation zone by previous events that have occurred earlier in the current simulation year. These equations reset to zero for the first event of every simulation year. The potential damage is the amount of damage if no previous events had occurred during the current year. The current damage is the difference between the potential damage and the previous damage. If the potential damage for a zone is less than the previous damage, then no damage would occur since that portion of the crop would have already been lost.

The monetary damage in column K of Figure 4-18 is based on the extent of damages from column I and J, the crop age of column H, and the number of acres in the planting. The crop age is used to determine how much money was invested in the crop when the event occurs. This information is found in the production cost table using a Lotus 1-2-3 @VLOOOKUP function.

The ability to replant crops is one way in which farmers lessen the impact of crop damage events. The formula to calculate replanting percentage in column K of ADAM is set up to allow only one replanting event during a crop year. Replanting was also not considered if the crop was older than one-half the age of maturity because this would drastically alter the harvest date of the planting which in turn would interfere with the availability of land for subsequent plantings. The rules specifying when replanting is simulated can be changed by altering the @IF statement in this column.

The cumulative damage section of Figure 4-18 has three columns of calculations, the cumulative damage percent, the cumulative monetary damage, and the percent harvestable. The cumulative damage percent in column L is calculated by adding current damage percentage from the current damage calculation section to the amount of damage calculated in the previous damage section. The cumulative monetary damage in column M is calculated by adding the current monetary damage to the previous monetary damage.

The cash flow section of Figure 4-18 has four columns of calculations: harvest cost, total planting cost, sales revenue, and net income. The harvest cost in column P is equal to the acreage, in column C, times the percent harvested, in column O, times the harvest costs. The planting cost, in column Q is the percent harvested times the acreage times the total planting cost plus the cumulative crop damage from column M. The sales revenue in column R is the percent harvested times the acreage times the income per acre from column D. Even though this section is recalculated for every event entered in summary table of crop damage, shown at the bottom of Figure 4-11, the results are only posted when the year of the next event differs from the previous event year.

4.6.3.1.4 Model Operation

This budget simulator can be used to estimate the monetary damages of crop failure caused by either flood or drought events. The simulator calculates the crop damages as the difference between the annual net income given no events during the crop year and the annual net income given damage events. In order to ensure that the yearly crop damage is calculated correctly, a spreadsheet macro ALT-J is invoked to input the event data in the appropriate cells, shown in Figure 4-11, and then calculate the spreadsheet. The macro and a description of its logic is shown in Figure 4-19. This macro records the end of year results of each simulation year in which events occurred by placing the net losses for the year in the crop damage column of the crop damage summary table, shown in Figure 4-11, before the results of the first event of the next simulation year are calculated. This macro ensures that the cumulative monetary damage and percent damage are reset when the current event is the first of its simulation year. After all of the events have been input into the simulator, the average annual damages are calculated and recorded below the row containing the last event in Figure 4-11.

The change in the monthly cash flow caused by damage events can be seen by comparing the cash flow for years with, and without, crop damage events. An example of the monthly farm cash flow for a crop year given no events and a crop year given some loss events is shown Figure 4-20. The cumulative monthly cash flow for a simulation year can be calculated in the table, shown in Figure 4-21, by using the macro Alt-F. This macro copies the results of the simulation year from the summary calculation table over to another portion of the spreadsheet and then uses the data table command to compute the results of the @DSUM formulas for each month of the year. To compute the monthly cash flow for a year with only one flood, the date, duration and simulation year (different than the value in the LST_YEAR cell) are entered into the appropriate cells. After the spreadsheet is recalculated once, the macro Alt-F is invoked. To simulate a year with more than one event, the spreadsheet is recalculated once between the manual entry of the data for each event and then the Macro Alt-F is invoked.

4.7 Conclusion

The methodology developed to assess flood and drought damages to crops is general enough to be applied to almost any agricultural area. The prototype model developed to simulate soil moisture conditions in agricultural areas that are artificially drained provided insight into the difficulties of tracking the soil moisture given farming activities that manipulate the local groundwater table. The spreadsheet model,

```
      FV    FW      FX        FY         FZ          GA        GB        GC        GD        GE      GF

  1   MACRO ALT-J
  2                                      Year              0
  3                                      Lst_year          0
  4
  5        COUNTER#1       5
  6        Row of Event #1          28
  7
  8
  9   \J   /reTOT_DAM~{let COUNTER#1,0}{let LST_YEAR,-2}  Erase old results, reset COUNTER#1, YEAR.
 10        {let FLD_DAY,+CW26}                            Enter first event date.
 11        {let DURTN_1,+CY26}                            Enter first event duration.
 12        {let YEAR,+CX26}                               Let YEAR = year of first event.
 13        {let STAGE,+CZ26}                              Let STAGE = stage of first event.
 14        {calc}                                         Calculate spreadsheet.
 15   LOOP {let COUNTER#1,+COUNTER#1+1}{recalc MACRO}     Increment macro counter.
 16        {let LST_YEAR,+YEAR}                           Let LST_YEAR = YEAR.
 17        {let YEAR,+CX33}                               Let YEAR = current event year.
 18        {if LST_YEAR<>YEAR}{let DA32,DAMAGES}          If current event year <> last event year,
 19                                                            then record last year's damages.
 20        {if CW33=0}{branch SUM}                        If no more events, then branch to SUM.
 21        {let FLD_DAY,+CW33}                            Let FLD_DAY = current event date.
 22        {let DURTN_1,+CY33}                            Let DURTN_1 = current event duration.
 23        {let STAGE,+CZ33}                              Let STAGE = current stage.
 24        {calc}{branch LOOP}                            Calculate spreadsheet and branch to LOOP.
 25
 26   SUM  {goto}EVENT#1~{up}{end}{down 3}                Find location of last event.
 27        Annual Crop Damage ($1000)~{right 4}           Write text next to final answer.
 28        @sum({up 2}.{left}{end}{up}                    Direct cursor to highlight all damages.
 29        {down}{right}~)/RECRD_YRS~                     Compute average annual damages.
 30                                                       Quit macro.
```

Figure 4-19. Macro Alt-J of the Crop Budget Simulator.

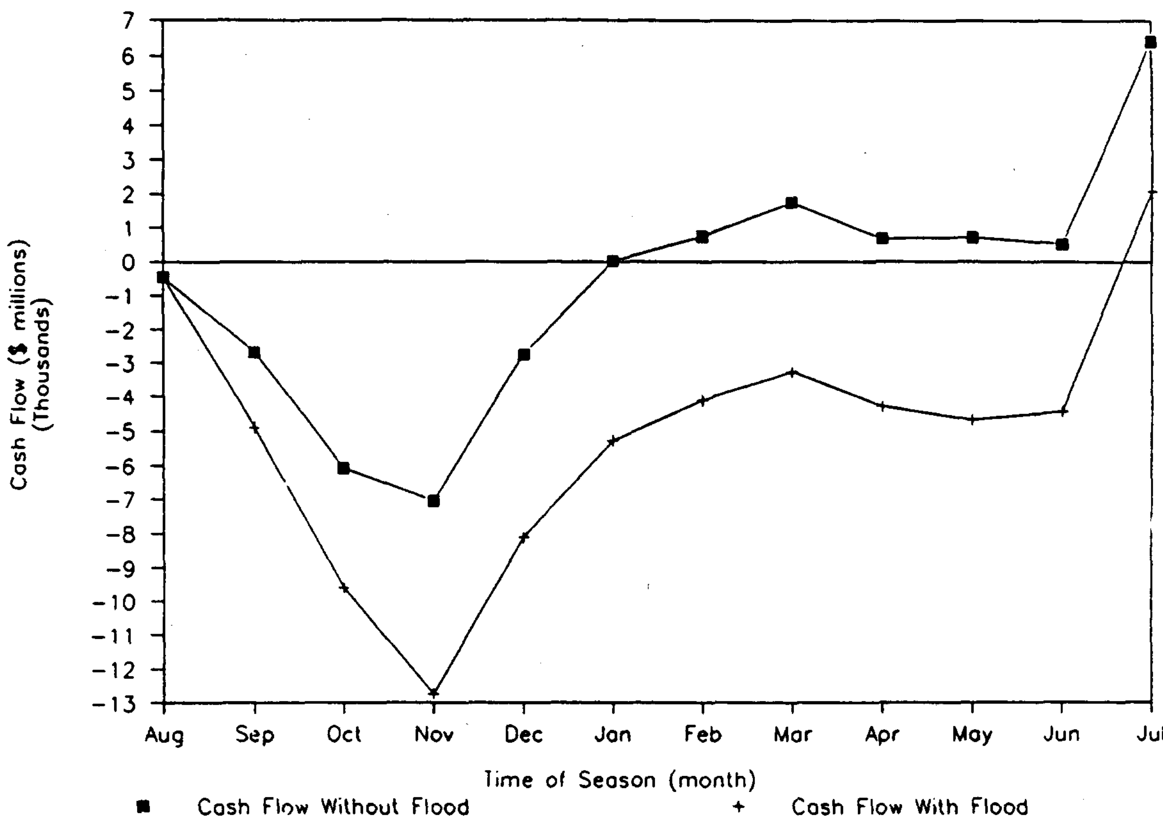


Figure 4-20. Example of Yearly Cash Flow for With and Without Crop Loss Events.

AG AH AI AJ AK AL AM

COMPARISON OF ANNUAL FARM CASH FLOW FOR WITH AND WITHOUT CROP LOSS EVENTS. (USE ALT-M TO RECALCULATE).

Month		Planting Costs	Harvest Cost	Sales Revenue	With * Events Cash Flow	Without Events Cash Flow
Aug	1	1620	0	0	-1620	-1620
Sep	2	5892	0	0	-7512	-7512
Oct	3	4708	100	638	-11682	-11682
Nov	4	3658	1544	5239	-11646	-11646
Dec	5	3421	3533	12006	-6594	-6594
Jan	6	1621	1816	7740	-2291	-2291
Feb	7	2887	1665	5266	-1578	-1578
Mar	8	2403	1860	5291	-550	-550
Apr	9	4766	1466	3308	-3474	-3474
May	10	1561	1698	4410	-2324	-2324
Jun	11	0	1226	2974	-576	-576
Jul	12	0	5166	12168	6426	6426

Macro to Operate Monthly Cash Flow Table 9.

```
\F     /rvcsh_flw#1~csh_flw#2~/dtl~~
```

Criteria Range for Table 9.

Hrv_Cost	Plt_Cost	Sales_Rev
1	1	1

Cell	Formula
D8	@DSUM(FLOW,1,AI32..AI33)/1000

Figure 4-21. Calculation Range of Monthly Crop Investment.

ADAM, used in conjunction with the EVT_STS spreadsheet, simulates the response of farm budgets to drought or flood conditions and can be used to predict the monetary impact of these events on an agricultural region. This model was developed to handle multiple cropping and multiple events and the crop damage model can be applied in most agricultural regions with little modification. Since ADAM was programmed in a spreadsheet environment, it is relatively easy to use and can be readily changed without having to compile the programming code.

5.0 Environmental Quality, Recreation and Property Values

5.1 Environmental Quality

5.1.1 Introduction

Water quality change has an impact on man through human health, productivity, and recreation/aesthetics (Freeman 1979). The NED guidelines don't address water quality in terms of measurement methods, but the EPA has sponsored research projects on this topic during the past several years (e.g. See Smith and Desvouges, 1986 for a summary of studies related to recreation).

Contaminated water can affect morbidity or mortality rates. Renewed concern over hazardous wastes has prompted studies to estimate the risk levels. Such studies are difficult and expensive. Thus, current water quality standards have been relied upon to evaluate whether water is "safe". Public perceptions of the safety of a drinking water supply are reflected in the sales of bottled water, home water treatment devices, and other added safety precautions. Another way to value a water supply is based on the cost of the next best alternative. For example, if Lake Apopka is viewed as being an unsafe source of potable water, what is the cost of the next best alternative?

Using water of degraded quality can increase production costs, e.g., the impact of higher salinity on reducing crop yields, or the effect of hard water in reducing the service life of hot-water heaters. Water quality can affect the amount of recreational activity at a site. Some benefits of water quality can be identified through recreational activity/expenditures as discussed later in the section on recreational benefits. Local property values can be used to quantify the aesthetic value of water as discussed later. This method assumes that the value of the water resource at hand is capitalized in surrounding property values.

Heaney (1988) has reviewed alternative methods of evaluating the effectiveness of investments in water quality controls such as sewage treatment plants. He concludes that physical, chemical, and/or biological measures of effectiveness do not adequately measure the efficacy of the investment. Furthermore, even if a single parameter such as dissolved oxygen can be selected, it is still difficult to agree upon whether to use the minimum level, the duration of low values, or other measures of dissolved oxygen deficiencies. He states that it is essential to measure monetary benefits such as enhanced recreational opportunities since they represent the best available integrator of our collective concern about water quality. Researchers have devised methods for estimating direct recreation benefits and so-called non-user benefits. We prefer to use the phrase environmental quality to describe the "non-user" benefits because it more closely describes the desire to quantify the value to the general public of protecting or restoring an environmental resource. The literature on this subject is reviewed in the next section.

5.1.2 General Theory of Environmental Quality Valuation

The environmental quality benefits, popularly referred to in the literature as non-user or intrinsic value, are captured in the benefit received from a site even though direct participation does not occur. Environmental quality benefits are the sum of:

- option value - value placed on having the option of using an environmental resource;
- existence value - benefit of knowing an environmental resource exists; and
- bequest value - value of preserving a resource for future generations.

Theoretical and applied issues surrounding these environmental quality values are discussed by Brookshire and Smith (1987), Madariaga and McConnell (1987), and Boyle and Bishop (1987).

5.1.3 Contingent Valuation Method

The contingent valuation method directly asks households their willingness to pay for various levels of environmental quality opportunities. This is carried out through questionnaires and bidding games, and typically utilizes photographs and/or maps to aid the respondent. A survey question would be worded something like this: What is the most you would be willing to pay each year in higher taxes to raise the water quality of Lake Mendota from Level "B" to Level "A" as shown in the above photograph? A numerical example of contingent valuation can be found in Institute for Water Resources (1986b).

The premise of this method is that individuals will reveal their preferences for environmental goods and services; thus a demand curve can be estimated directly. The demand curve in conjunction with use estimates can be used to derive consumer surplus.

Contingent valuation techniques are used to derive the value of recreational user benefits as well as environmental quality benefits. The component of the environmental resource being measured is determined a priori by the survey design. Questionnaire development and implementation consumes much of the literature and research conducted in continent valuation application. Bias in questionnaire development often hampers accurate estimation of benefits. See Smith and Desvouges (1986) for a discussion of issues surrounding survey design.

Using contingent valuation techniques, Walsh (1986) interviewed 198 households and found that the user value of water-based recreation accounts for approximately 30% of the total value. The objective of the study was to derive preservation benefits of environmental programs in Colorado. User, option, existence, and bequest values are shown in Figure 5-1 for Colorado households. The non-use values range from $37 to $58 per year per household for maintenance of recreation facilities and water quality preservation, respectively. Dividing by an average household size of 2.8, the annual non-user value range is $13 to $21 per capita.

Other examples of empirical estimates of non-user values are given in Table 5-1. Sutherland and Walsh (1985) used the following question in a contingent valuation survey:

> Assume that the only way to protect water quality in Flathead Lake and River is for all people to pay into a special fund to be used exclusively for this purpose. What is the maximum amount of money your household would be willing to pay annually to protect water quality in Flathead River and Lake?

The respondents were then asked to estimate specifically their option, existence and bequest values for the water quality in the waterway. Greenley et al. (1981) also used contingent valuation, but used a payment medium of increased sales tax for preserving the South Platte River Basin.

One major difficulty with quantifying environmental quality value is that the citizenry are asked to estimate their willingness to pay but they know that they will not actually have to make these payments. The other major difficulty is to define the affected population. Is it the people within a fixed distance from the site, the entire state, or in the case of a major resource like the rain forests of the Amazon, the entire world?

Fortunately, heightened citizen concern for improving and restoring degraded environmental resources has led to the voluntary allocation of significant public monies to achieve these objectives. For example, the Lower Kissimmee River in Florida is being dechannelized at a cost that may exceed $100 million. Also, numerous wetland restoration projects are underway. In such cases, we have direct evidence of the general public's willingness to pay for improved environmental quality. The demonstrated willingness to spend public funds to restore Lake Apopka will be used to estimate these environmental quality benefits in Chapter 6.

5.2 Direct Recreation Benefits

5.2.1 History

In 1962, the federal government sponsored 27 studies via the Outdoor Recreation Resources Commission (Walsh 1986). This marked the federal government's first budgetary support for

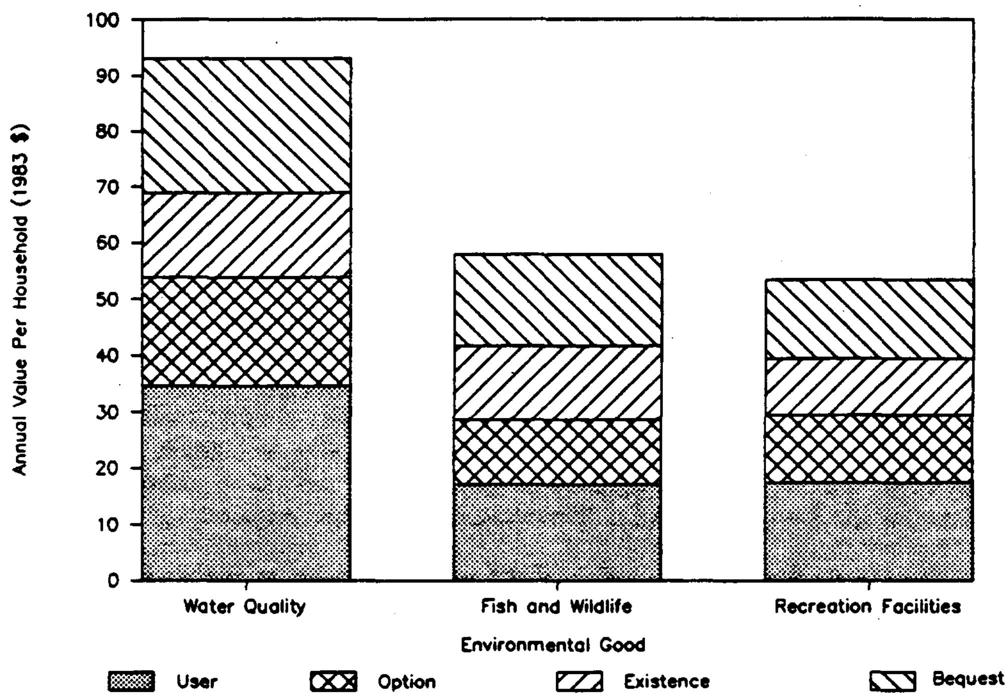


Figure 5-1. Analysis of Value Categories in Colorado (Walsh, 1986).

Table 5-1. Empirical Estimates of Non-User Values Annual $/household/year.

Value Measured	1987 Value $/household	Region	Reference
Option	14.99	Montana	Sutherland & Walsh (1985)
Option	46.88	Colorado	Greenley et al. (1981)
Option	30.85	Penn	Desvouges et al. (1983)
Option	45.88	Penn	Smith & Desvouges (1986)
Option	22.50	Colorado	Walsh (1986)
Option	14.00	Colorado	Walsh (1986)
Mean Option Value $29.18			
Existence	28.11	Montana	Sutherland & Walsh (1985)
Existence	17.42	Colorado	Walsh (1986)
Existence	34.59	Colorado	Greenley et al. (1981)
Existence	68.81	Penn	Desvouges et al. (1983)
Existence	11.62	Colorado	Walsh (1986)
Mean Existence Value .. $29.79			
Bequest	37.24	Montana	Sutherland & Walsh (1985)
Request	28.02	Colorado	Walsh (1986)
Bequest	50.91	Colorado	Greenley et al. (1981)
Bequest	16.33	Colorado	Walsh (1986)
Mean Bequest Value $33.13			
Total Non-User Value			
	48.00	Walsh (1986)	
	68.00	Walsh (1986)	
	125.00	Greenley et al. (1981)	
	80.00	Southerland & Walsh (1985)	

Mean Total Non-User Value $80.25

measurement of recreational benefits of water resource projects. Also, Senate Document 97 was passed in 1962, which established a set of guidelines for measurement of water resource recreational benefits. Although research on recreation benefit measurement had taken place in the 1950s (e.g. Knetsch 1959), the federal government's commitment of funds in 1962 stimulated significant research on the topic.

The 1964 Land and Water Conservation Act called for state plans requiring supply and demand measures of recreational activity. Use of the unit-day valuation of recreational benefits was mandated through a supplement to Senate Document 97. By the mid-1960s, research teams from Resources for the Future had put together several studies on economic valuation of recreation. Most cite Clawson and Knetsch (1966) as the major landmark contribution to the field of recreation valuation.

The guidelines of Senate Document 97 were revised in 1973 to include use of the travel-cost method, and again in 1979 to recommend use of the contingent valuation method. Presently, under the last revision made in 1983, all three methods are supported.

5.2.2 General Theory of User Values

Work on estimation of recreational benefits has been undertaken mainly by economists; therefore, its theoretical backing is economic in nature. The basic tenet is to estimate the consumer surplus, i.e., the difference between the price consumers would pay and the actual price paid for recreational goods and services. Household consumer surplus is similar to production-based profit except in a consumption setting. The main task is derivation of the demand curve which is the price consumers would pay for various levels or quantities of recreational goods.

Assume that the demand schedule and curve shown in Table 5-2 and Figure 5-2 represent the measure of willingness-to-pay by recreationists at a hypothetical site. As the price per trip increases, the annual number of trips demanded decreases. If the actual price paid was zero, which is the case with many environmental goods, the consumer surplus (or household profit) is the total area under the demand curve which is $245. If an entrance fee of $10 per trip was initiated, consumer surplus would be decreased by the amount under the price curve, $65, and the net amount of $180 would be the consumer surplus.

5.2.3 Regional Economic Impact of Recreation

Recreational activity stimulates the economy of a region. Recreationists travel to a site and spend money on recreation-related goods and services providing revenue for local businesses, employment for the local population, and tax dollars for local government. Bell (1987) carefully accounted for the economic impact of recreation fishing at Lake Okeechobee.

Table 5-2. Hypothetical Demand Schedule for Recreational Site.

Price $/visit	Quantity Demanded	Incremental Benefit	Paid Benefit	Consumer Surplus	Total Benefits	Given Price
$70	0	$5	$245	$0	$245	$10
60	1	15	240	5	245	10
50	2	25	225	20	245	10
40	3	35	200	45	245	10
30	4	45	165	80	245	10
20	5	55	120	125	245	10
10	6	65	65	180	245	10
0	7		0	245	245	10

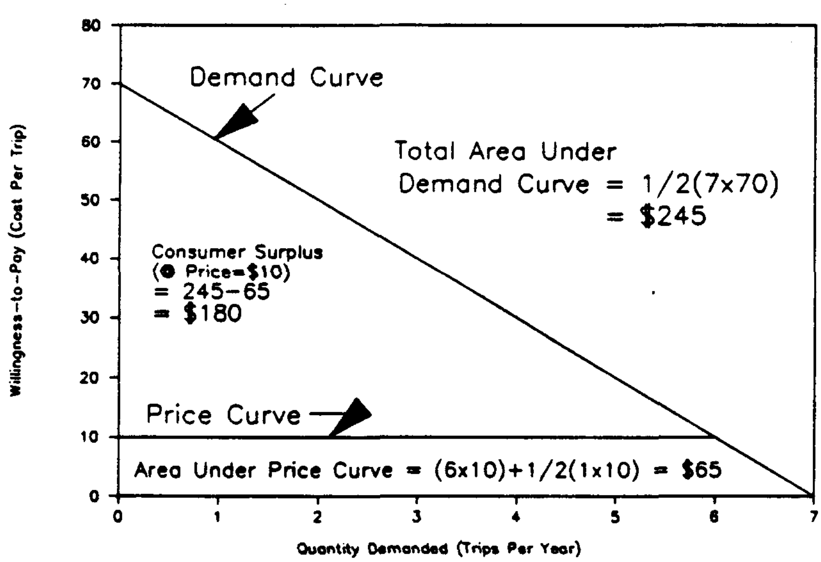


Figure 5-2. Derivation of Consumer Surplus-a Hypothetical Example.

Variable costs such as bait, tackle, food, lodging, fuel, boat rental, guides, and licenses were considered as were the costs of purchasing boats and motors. Regional employment support is calculated by dividing total sales in each expenditure category by the appropriate sales to employment coefficient (recorded in the U. S. Census of Business). Bell found that recreational fishing by tourists and residents generated over $22 million (1985 $) and supported 495 jobs in the region. Thus, the average annual revenue to generate a job is approximately $45,000. The impacts are shown in Table 5-3.

Economic impact measurement defines the importance of the recreation site to the regional economy, but in terms of national economic development only represents a shift of benefits and therefore should not be considered in benefit-cost related decisions. Bell and Leeworthy (1986) and Bell (1987) provide excellent discussions and applications of separate measures of economic impact and economic value of recreation in Florida.

5.2.4 Recent Benefit Estimation Overviews

Freeman (1979) provides an overview of how many types of environmental benefits, including recreational benefits, can be estimated. A similar text by Hufschmidt et al. (1983) provides examples from both the U.S. and abroad. Salient issues in benefit assessment are addressed by various authors in Bentkover et al. (1986). Walsh (1986) has written a comprehensive work dedicated solely to recreational decision-making.

5.2.5 Current Principles and Guidelines (P & G)

The 1983 version of the P & G dedicates a section to procedures for evaluating recreational benefits. The method of evaluation must conform to the following criteria:

1) Evaluation is based on an empirical estimate of demand applied to the particular project.

2) Estimates of demand reflect the socioeconomic characteristics of market area populations, qualitative characteristics of the recreational resources under study, and characteristics of alternative existing recreational opportunities.

3) Evaluating accounts for the value of losses or gains to existing sites in the study area affected by the project (without-project condition).

4) Willingness to pay projections over time are based on projected changes in underlying determinants of demand.

Table 5-3. Economic Impact of Recreational Fishing at Lake Okeechobee, 1985-86 (Bell, 1987).

Expenditures ($1000, 1985)	
Residents (Variable Cost)	$2,347
Residents (Boats & Motors)	7,212
Total Residential	9,589
Tourists (Variable Cost)	5,724
Tourists (Boats & Motors)	736
Tourists (Indirect)	6,053
Total Tourist	12,512
Total Expenditure Impact	$22,071
Employment	
Residents (Variable Cost)	51
Residents (Boats & Motors)	59
Total Residential	110
Tourists (Variable Cost)	193
Tourists (Boats & Motors)	6
Tourists (Indirect)	186
Total Tourist	385
Total Employment Impact (Number of Jobs)	495

These criteria require the evaluation procedure to include a thorough inventory of recreational activity in the area; an estimation of consumer willingness-to-pay; and an analysis of conditions with and without the project. These criteria fall directly in line with the inputs and outputs of the recommended methods.

Three methods of benefit measurement have been recommended in the guidelines: unit-day valuation, travel-cost valuation, and contingent valuation. All three methods require an inventory of recreational activity and have an end-product in dollars. They differ in the means used to estimate willingness to pay. Detailed procedures and examples are provided for each method by the Institute for Water Resources (1986a, 1986b). The unit-day valuation and travel-cost methods are discussed below; the contingent valuation method was presented in section 5.1.3.

Empirical estimates of consumer surplus via the three recommended methods are given in Table 5-4. The tabulated values are adjusted to 1987 dollars and come from a database which is a compilation of consumer surplus values and related information for freshwater-related recreation. The database is designed to allow extraction of consumer surplus values by region, recreational activity, author, or year of study.

The purpose of Table 5-4 is to provide a comparative overview. Unit-day value estimates account for 78% of the total number of estimates shown in Table 5-4. Travel cost and contingent valuation estimates make up the remainder with 20% and 2%, respectively. Particular details as to assumptions and methods of derivation have significant influence on the values, and should be thoroughly examined before citing or applying the value for an actual valuation.

The consumer surplus values are categorized by geographic region in the U.S. and shown in Figure 5-3. The dominance of unit-day value estimates is clear as they are indicated in Figure 5-3 by the solid dots. The ranges and median values in each geographic region are shown in Table 5-5. The minimum values in each category are assigned unit-day values because values for low quality sites (see footnote 2, Table 5-4) are tallied. Boating in the northeast has a much greater median value than in the southeast. Urban pressure on northeastern recreational land in conjunction with high land values limit boating opportunities; consequently a boating-day possesses higher value in the northeast. One other apparent trend is that value for non-motorized boating in the west is higher than motorized boating. Given the investment in motorized boats, value is expected to be comparatively higher than non-motorized boating. The higher values in the west could be attributed to white-water rafting in the waterways of western mountainous regions. Again, details of each empirical estimate should be considered if specific trends and conclusions are made.

Table 5-4. Consumer Surplus Estimates by Unit-Day Value, Travel-Cost and Contingent Valuation Methods, 1987 Dollars per User-Occasion.

Recreational Activity	Consumer Surplus $/visit	Method	Geographic Region	Reference	Notes
Fishing	37.27	TCM	Arizona	A	
Fishing	31.71	TCM	Florida	B	
Fishing	36.70	TCM	Georgia	C	
Fishing	22.50	TCM	U.S.	D	
Fishing	13.99	UDV	SE U.S.	E	
Fishing	11.84	UDV	Northern U.S.	E	
Fishing	11.84	UDV	Rocky Mt U.S.	E	
Fishing	13.99	UDV	SW U.S.	E	
Fishing	11.84	UDV	Inter Mt U.S.	E	
Fishing	12.92	UDV	Pacific SW U.S.	E	
Fishing	16.15	UDV	Pacific NW U.S.	E	
Fishing	13.99	UDV	NE U.S.	E	
Fishing	11.84	UDV	Alaska	E	
Fishing	2.88	UDV	U.S.	F	1,2
Fishing	5.53	UDV	U.S.	F	1,4
Fishing	13.58	UDV	U.S.	F	3,2
Fishing	20.30	UDV	U.S.	F	3,4
Fishing	38.75	CVM	U.S.	G	
Boating	16.59	CVM	Colorado	H	5,6
Boating	30.32	TCM	Arizona	I	5
Boating	29.64	TCM	Idaho	J	5
Boating	33.78	TCM	Utah	K	5
Boating	5.96	TCM	Wash-Oregon	L	5
Boating	3.23	UDV	SE U.S.	E	5,7
Boating	5.38	UDV	SE U.S.	E	5
Boating	20.25	TCM	New Mexico	M	
Boating	31.71	TCM	Florida	B	5
Boating	5.96	TCM	Wash-Oregon	L	
Boating	55.62	TCM	New York	N	
Boating	3.23	UDV	SE U.S.	E	
Boating	6.46	UDV	SE U.S.	E	
Boating	31.71	TCM	Florida	B	
Boating	6.46	UDV	Northern U.S.	E	5,7
Boating	11.84	UDV	Northern U.S.	E	5
Boating	5.38	UDV	Rocky Mt U.S.	E	5,7
Boating	10.76	UDV	Rocky Mt U.S.	E	5
Boating	6.46	UDV	SW U.S.	E	5,7
Boating	12.92	UDV	SW U.S.	E	5
Boating	8.61	UDV	Inter Mt U.S.	E	5,7
Boating	16.15	UDV	Inter Mt U.S.	E	5
Boating	5.38	UDV	Pacific SW U.S.	E	5,7
Boating	9.69	UDV	Pacific SW U.S.	E	5
Boating	3.23	UDV	Pacific NW U.S.	E	5,7
Boating	6.46	UDV	Pacific NW U.S.	E	5

(continued)

Table 5-4. Consumer Surplus Estimates by Unit-Day Value, Travel-Cost and Contingent Valuation Methods, 1987 Dollars per User-Occasion.

Recreational Activity	Consumer Surplus $/visit	Method	Geographic Region	Reference	Notes
Boating	5.38	UDV	NE U.S.	E	5,7
Boating	9.69	UDV	NE U.S.	E	5
Boating	3.23	UDV	Alaska	E	5,7
Boating	6.46	UDV	Alaska	E	5
Boating	3.23	UDV	Northern U.S.	E	7
Boating	6.46	UDV	Northern U.S.	E	
Boating	4.31	UDV	Rocky Mt U.S.	E	7
Boating	8.61	UDV	Rocky Mt U.S.	E	
Boating	5.38	UDV	SW U.S.	E	7
Boating	10.76	UDV	SW U.S.	E	
Boating	4.31	UDV	Inter Mt U.S.	E	7
Boating	7.53	UDV	Inter Mt U.S.	E	
Boating	3.23	UDV	Pacific SW U.S.	E	7
Boating	6.46	UDV	Pacific SW U.S.	E	
Boating	2.15	UDV	Pacific NW U.S.	E	7
Boating	4.31	UDV	Pacific NW U.S.	E	
Boating	6.46	UDV	NE U.S.	E	7
Boating	12.92	UDV	NE U.S.	E	
Boating	2.15	UDV	Alaska	E	7
Boating	4.31	UDV	Alaska	E	
Water Sports	3.23	UDV	N U.S.	E	7
Water Sports	6.46	UDV	N U.S.	E	
Water Sports	4.31	UDV	Rocky Mt U.S.	E	7
Water Sports	8.61	UDV	Rocky Mt U.S.	E	
Water Sports	5.38	UDV	SW U.S.	E	7
Water Sports	9.69	UDV	SW U.S.	E	
Water Sports	4.31	UDV	Inter Mt U.S.	E	7
Water Sports	8.61	UDV	Inter Mt U.S.	E	
Water Sports	5.38	UDV	Pacific SW U.S.	E	7
Water Sports	9.69	UDV	Pacific SW U.S.	E	
Water Sports	4.31	UDV	Pacific NW U.S.	E	7
Water Sports	8.61	UDV	Pacific NW U.S.	E	
Water Sports	6.46	UDV	NE U.S.	E	7
Water Sports	11.84	UDV	NE U.S.	E	
Water Sports	4.31	UDV	Alaska	E	7
Water Sports	8.61	UDV	Alaska	E	
Water Sports	41.69	TCM	Arizona	A	
Water Sports	20.25	TCM	New Mexico	M	
Water Sports	30.79	TCM	Florida	B	
Water Sports	34.79	TCM	New York	N	
Water Sports	13.96	TCM	Texas	O	
Water Sports	5.38	UDV	SE U.S.	E	7
Water Sports	9.69	UDV	SE U.S.	E	

(continued)

Table 5-4. Consumer Surplus Estimates by Unit-Day Value, Travel-Cost and Contingent Valuation Methods, 1987 Dollars per User-Occasion.

Recreational Activity	Consumer Surplus $/visit	Method	Geographic Region	Reference	Notes
Water Sports	2.76	UDV	U.S.	F	8,2
Water Sports	5.17	UDV	U.S.	F	8,4

References and Footnotes

A Martin et al. (1974)
B Gibbs (1973)
C Zeimer et al. (1980)
D Vaughan and Russell (1982)
E U.S. Forest Service (1985)
F U.S. Water Resources Council (1983)
G Charbonneau and Hay (1978)
H Walsh et al. (1980)
I Keith et al. (1982)
J Michaleson (1977)
K Bowes and Loomis (1980)
L Sutherland (1980)
M Ward (1982)
N Kalter and Grosse (1969)
O Grubb and Goodwin (1968)

1. "General" fishing
2. Low quality site, 30 of 100 points
3. "Specialized" fishing
4. High quality site, 90 of 100 points
5. Non-motorized boating
6. Midpoint value, actual range: $15.38 - $17.79
7. Below standard quality site
8. Actually reported as "general recreation"

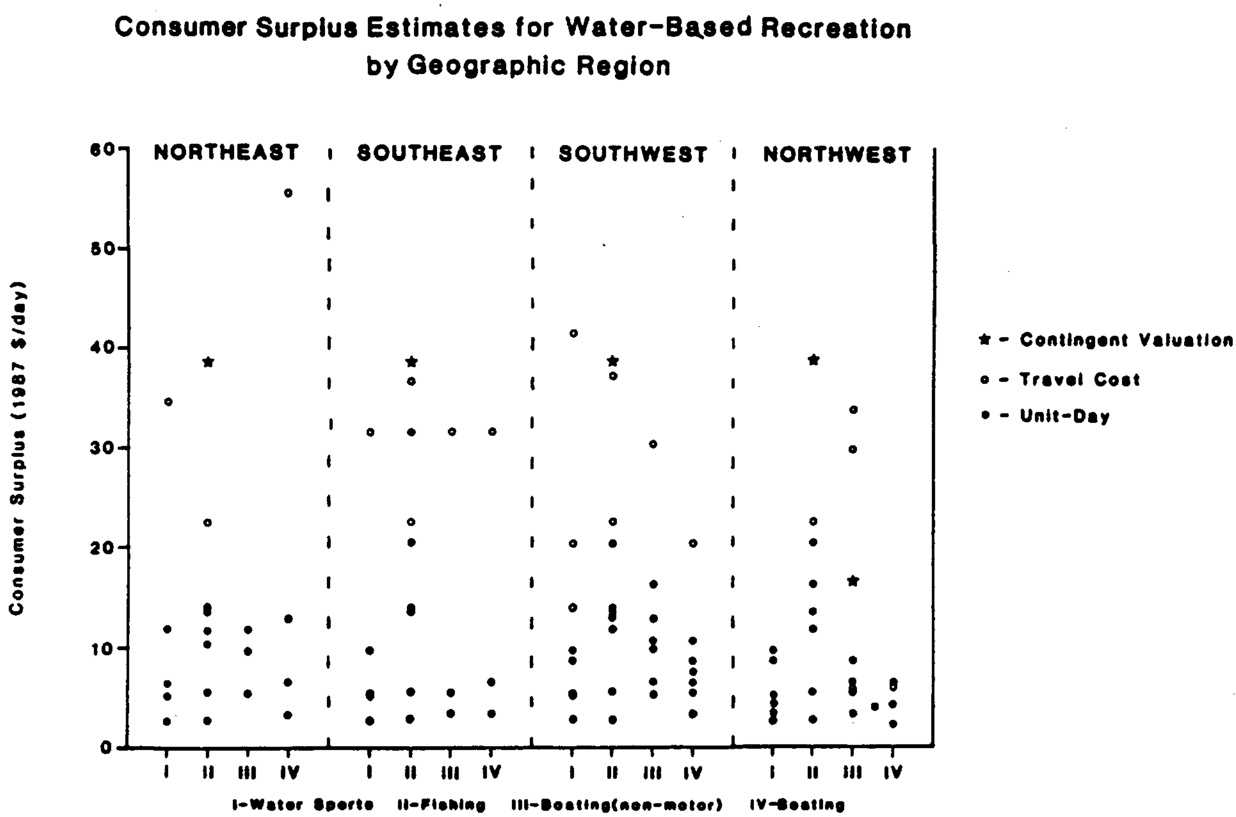


Figure 5-3. **Consumer Surplus Estimates for Water-Based Recreation by Geographic Region.**

Table 5-5. Geographical Breakdown of Summary Statistics for Empirical Estimates of Consumer Surplus, 1987 Dollars per User-Occasion.

	Southwest	Southeast	Northeast	Northwest
Water Sports				
Max	41.69	31.71	34.79	9.69
Median	8.61	5.38	6.46	4.31
Min	2.76	2.76	2.76	2.76
No. Samples	10	5	6	10
Fishing				
Max	38.75	38.75	38.75	38.75
Median	13.79	20.30	13.79	12.71
Min	2.88	2.88	2.88	2.88
No. Samples	10	9	8	10
Boating (non-motor)				
Max	30.32	31.71	11.84	33.78
Median	10.76	5.38	9.69	6.46
Min	5.38	3.23	5.38	3.23
No. Samples	7	3	3	11
Boating				
Max	20.25	31.71	55.62	6.46
Median	7.53	6.46	9.69	4.31
Min	3.23	3.23	3.23	2.15
No. Samples	7	3	4	8

5.2.6 Unit-Day Valuation Method

The unit-day value method utilizes expert judgment in approximating an average unit willingness-to-pay by consumers. Once the aggregate number of visitors is derived, benefits can be calculated using appropriate unit day values which are in dollars per visitor-day.

The first set of unit day values was derived by the U.S. Forest Service in 1962. Updates of the Forest Service values account for inflation and also reflect values from studies which use contingent valuation and travel-cost valuation methods. Values reflecting standard quality and less than standard quality sites assigned to nine regions in the U.S. for various recreational activities were published in 1985. The water-based recreation values adjusted to 1987 dollars were shown in Table 5-4. The values range from $2.15 per day in the Pacific Northwest for boating to $16.15 per day for sport fishing in the Pacific Northwest.

The P & G (1983) also publishes a set of unit-day values for general and specialized recreation, and general and specialized fishing and hunting. The values are based upon a point assignment system (0 to 100 points possible) which considers recreation experience, availability of substitutes, carrying capacity, accessibility, and environmental quality. Dollar values are assigned from the point total by a conversion table provided in the P & G (1983). The dollar values range from $1.80 for a day of general recreation to $21.50 for a day of special recreation. Fishing and hunting values range from $2.64 to $21.50 per day. Values representing low quality sites (30 of 100 points) and high quality sites (90 of 100 points) were shown in Table 5-4.

The present guidelines recommend using unit-day values when the contingent valuation or travel-cost methods would exceed project budget constraints or if the site at hand is expecting a visitor load of less than 750,000 recreation visitor days per year. The method is often used because the associated costs are much lower than the other methods which require primary data. The use of unit-day valuation, or average unit willingness-to-pay, is not highly regarded in the literature. Insensitivity to actual supply and demand is the main drawback. Dwyer et al. (1977) conclude that if more consideration was not given to distribution of preferences, quality of other sites, and geography of the population in the region that the "...unit-day value approach is an unsatisfactory method for evaluating benefits due to its arbitrary nature." They go on to say that some important variables required to accurately assess benefits cannot be considered by analyzing averages.

5.2.7 Travel-Cost Valuation Method

The travel-cost method assumes that cost of travel can be used as a surrogate for value of the recreation site. Per capita use of the recreation site decreases as out of pocket expenses (or distance from the site) increase. This method involves empirical estimation of use patterns in the area, calculation of the demand curve by converting distances to dollars, and estimation of benefits. An example of the travel-cost procedure is given in Institute for Water Resources (1986a) and Dwyer et al. (1977).

A site which is very close to the user-population is defined as a user-located site. On the other hand, a distant site is defined as a resource-located site. The P & G (1983) do not recommend the travel-cost method for resource-located or user-located recreation sites -- the most successful applications have been for sites located 100 to 150 miles away from the user, referred to as intermediate range sites.

In light of the theoretical drawbacks of the unit-day valuation method, travel-cost methods were the first empirical response by researchers; thus numerous applications have been undertaken. Examples of consumer surplus estimates from travel cost studies for freshwater related recreation were given in Table 5-4. The values range from $13.69 for water sports in Texas (Grubb and Goodwin, 1968) to $41.69 for water sports in Arizona (Martin, et al., 1974).

One of the major difficulties in using the travel cost method arises when accounting for multi-purpose trips (Bentkover et al., 1986). Total expenditures incurred on a multi-purpose trip cannot be considered the value of a single purpose. Data requirements for the necessary statistical control are sometimes extensive. Another drawback and often an error in interpretation is the analysis of gross expenditures versus net expenditures (Sorg and Loomis, 1984). Valuation of the site should be based upon expenditures in excess of those associated with "staying at home".

5.2.8 Final Comments on the Valuation Methods

Each of these methods - unit-day valuation, travel-cost valuation, and contingent valuation - have been used successfully, and are recommended by the federal government. Given that contingent valuation directly estimates demand for environmental goods, a more precise valuation is attainable as compared to the travel-cost and unit-day methods. Properly designed contingent valuation approaches can account for user, as well as, non-user benefits. Costs associated with contingent valuation are higher, and when only secondary data are available (or affordable), unit-day values provide acceptable estimates of recreational user-value. Selection of the appropriate method to implement can be aided by the flow chart in Figure 5-4 which is taken from the

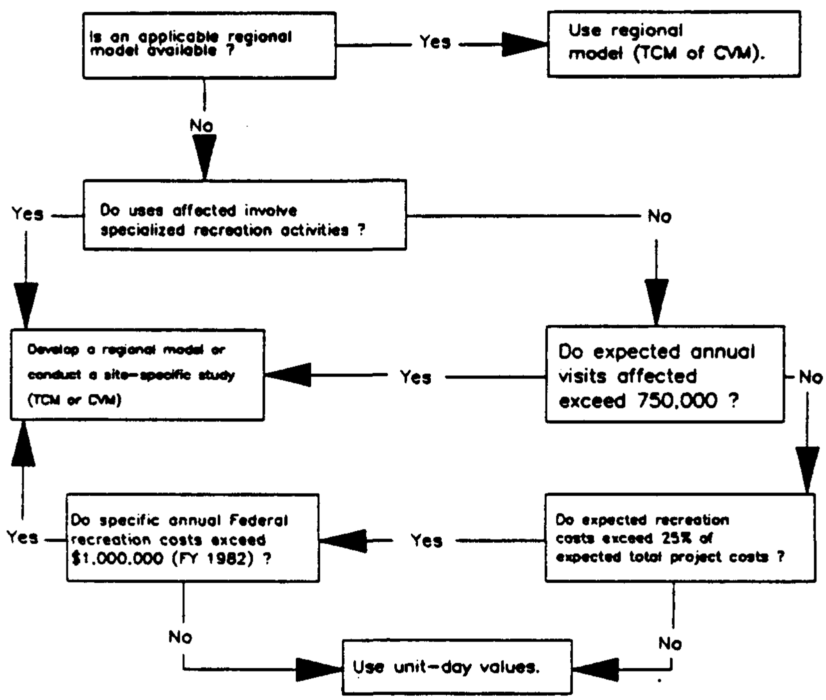


Figure 5-4. Evaluation Method Decision Scheme (P & G, 1983).

P & G (1983). For a more complete critical examination of these methods see Bentkover et al. (1986), Dwyer et al. (1977), and Smith and Desvouges (1986).

5.2.9 Freshwater Recreation Valuation in Florida

Several empirical estimates of recreational benefits have been carried out in Florida. Gibbs used a variation of the travel-cost technique to estimate benefits associated with the Kissimmee River in the early and mid-1970s (1973, 1975). On-site costs, travel costs, income, site characteristics, group size, and season were regressed on length of trip. Using this function, on-site costs were plotted against length of trip by substituting in the mean values of the other independent variables. Consumer surplus was derived as $59.91 per recreationist per trip. Factoring by the mean length of trip, 5.64 days, and adjusting for inflation, the daily consumer surplus value is $31.71. Using recreation usage data the recreational usage value of the entire river was calculated as approximately $91 million (1987 $).

In a study undertaken for the Suwannee River Water Management District, Bell (1986) assessed the recreational value and economic impact of the Suwannee River. Utilizing unit-day values (freshwater-based values from Charbonneau and Hay, 1978), a total recreational asset value of $623 million was calculated. Gross annual recreational expenditures for the eight county area totaled approximately 1.3 billion dollars and supported over 33,000 jobs.

In a study for the Florida Game and Fresh Water Fish Commission, Bell (1987) provided estimates of the value recreational fishing in Lake Okeechobee. Again, using Charbonneau and Hay (1978) results as unit-day values he calculated the asset value of recreational bass fishing to be $41 million.

Milon's work has given extensive consideration to methodological issues. Milon's (1986) examination of Orange and Lochloosa Lakes revealed total expenditures in the region attributed to sport fishing to be approximately $10,700,000. Benefits of an aquatic weed control program designed to allow year-long access for recreational fishing and boating were valued at $383,100.

Recreation valuation and economic impact assessment of saltwater-based activities have been undertaken by Bell and Leeworthy (1986), Milon (forthcoming), and Curtis and Shows (1982, 1984).

5.2.10 Conclusions on Recreation

With the help of resource economists, the federal government has provided guidelines to properly assess the value of recreational goods and services. Given the detailed recommendations of the Principles and Guidelines (1983) for undertaking recreation studies, the availability of solid supporting manuals with specific guidelines, the large amount of recent literature on the subject and availability of good previous studies in Florida which provide methodological and database guidance, it is relatively straightforward for the St. Johns River Water Management District to conduct recreation valuation in the District.

5.3 Property Evaluation in Water Resource Analysis

The recreational value associated with esthetic attributes of water resources has often been classified as intangible or non-monetary; consequently analytical consideration of aesthetic value has traditionally been conducted in an environmental impact statement (EIS) setting. A discussion of how a portion of aesthetic value can be considered through property values is presented in this section. Measurement of property values not only has important implications in terms of comparing benefits and costs, but implications of methodological advancement as well. If parcel level data are collected (which is very possible given contemporary relational database capabilities), it is possible to trace the incidence of benefits and costs throughout the study area. This level of data collection/management is the first step in dealing with distributional effects which has limited benefit-cost analysis in the past.

5.3.1 Theory

Many elements of residential land are explicitly purchased. For instance, the buyer knowingly pays for municipal water/wastewater service for a parcel of land, or pays for land that is cleared, or buys land which is located in a particular zone. Other features of land exist which are not explicitly purchased. These qualities are distinguished by effects external to the parcel of land, referred to as externalities. Water resources act as externalities and are the concern here.

Given that land is a consumer good and the presence of water resources modifies the demand for land, the value of water resources is reflected in land values. Environmental economists refer to this as the hedonic price of the water resource. The magnitude of influence which water resources has on land values depends upon the level of demand for such a good. Demand is contingent upon the parcel's proximity to the water resource as well as the quality of the water resource. To illustrate, assume a lake alters surrounding land rents in the manner shown in Figure 5-5 (Thrall 1982). The lake is located at S_0; the effect of the lake is completely diminished at sn. The quality of the water resource has a bearing on the level of land rents at S_0, the magnitude of the rent gradient, and the location of S_n. If the utility from the lake were enhanced, the rent gradient is expected to shift to R'.

Derivation of the hedonic price of water resources is an econometric technique which carries with it several rules and assumptions. Falcke (1982) and Freeman (1979) provide a good overview of these issues. Two assumptions about the housing

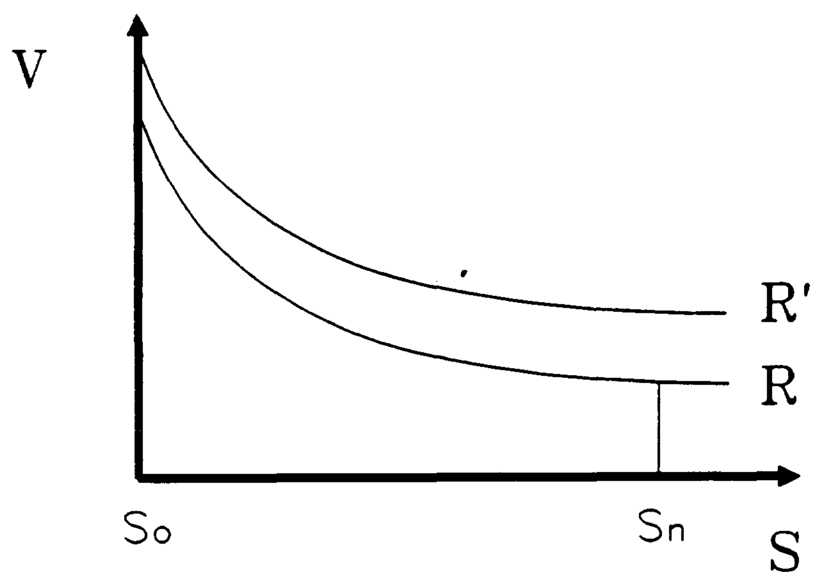


Figure 5-5. Land Values Surrounding a Lake Water Resource.

market are made: 1) a single housing market dictates housing choice in the study area; and 2) the housing market is in equilibrium (buyers and sellers are optimally satisfied with each transition they are involved in). Given these assumptions, the technique involves two steps. First a marginal implicit price function of the lake characteristic at hand is derived. Second, a willingness to pay function, or inverse demand curve, is derived.

The hedonic (implicit) price function can be shown mathematically as ...

$$V_i = V(S_i, L_i, W) \qquad (5\text{-}1)$$

where:
V_i = land value at site i,
V = land value function,
S_i = site characteristics at site i,
L_i = location characteristics at site i, and
W = level of lake characteristics.

The form of this function varies, but is generally multivariate. The curve typically increases at a decreasing rate reflecting a diminishing value of (in the case of clean water for example) utilizing pristine water rather than nearly pristine water. Halvorson and Pollawkowski (1981) offer a good application of the Box and Cox (1964) procedures of functional form determination.

Differentiating the hedonic price function with respect to the lake characteristics defines the marginal implicit price.

$$\delta P / \delta W = V_m(W) \qquad (5\text{-}2)$$

where: $V_m(W)$ = marginal implicit price

Figures 5-6 and 5-7 respectively show the hedonic (implicit) price and marginal implicit price curves with respect to lake characteristics.

The marginal implicit price denotes the aggregate market value assigned to an additional unit of W; it does not directly account for individual household demand for W. Therefore, the second step in the hedonic price technique is derivation of willingness to pay curves or inverse demand curves for lake characteristics.

A variety of possibilities exist as to the shape and empirical nature of willingness-to-pay curves (Freeman 1974, 1979). Harrison and Rubinfeld (1978) illustrate the importance of accurate willingness-to-pay representation in an analysis of the distribution of air quality benefits among income groups. It is assumed here that the lake characteristics are independent of a household's willingness to pay. This means that lake characteristics are considered exogenous to their implicit price and can be estimated without regard to a supply side function (as assumed by Harrison and Rubinfeld 1978). Thus the willingness to pay curve can be estimated by the function below.

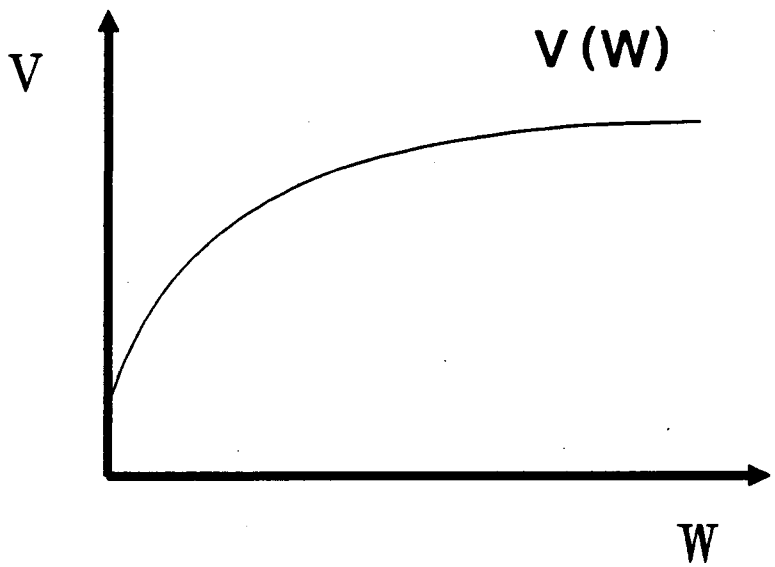


Figure 5-6. Hedonic Price Function.

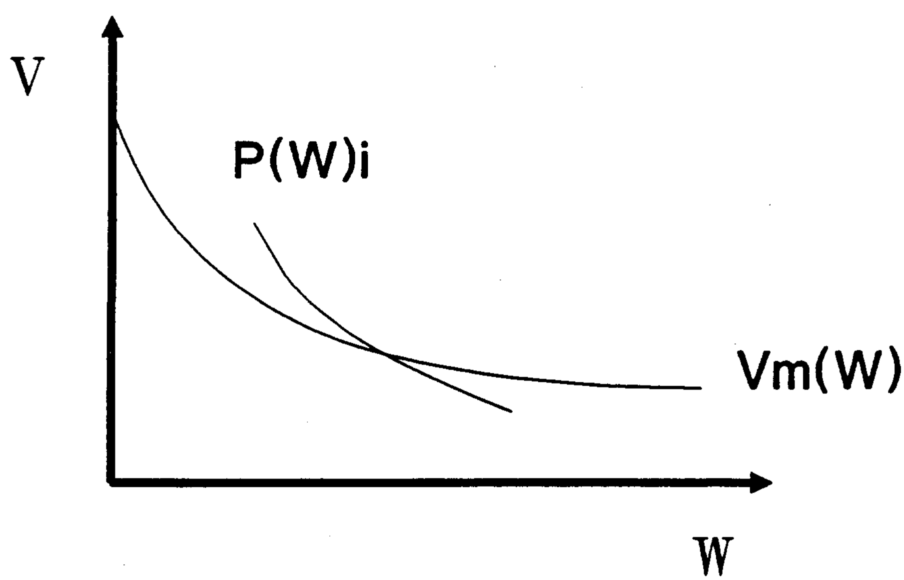


Figure 5-7. Marginal Implicit Price and Willingness-to-Pay Functions.

$$P_i = P(S_i, L_i, W_i, HH_i) \qquad (5\text{-}3)$$

where:
P_i = willingness to pay for household i,
P = willingness to pay function,
S_i = site characteristics at site i,
L_i = location characteristics at site i,
W_i = observed marginal implicit expenditure on W, and
HH_i = set of household characteristics.

Household willingness to pay functions are fitted in a manner similar to the fitting of implicit price functions. The intersection of a household's willingness to pay function and the marginal implicit price function defines the equilibrium state for the household in terms of lake characteristics (Figure 5-7). Households will buy quantities of W at the aggregate marginal implicit price, moving along their willingness to pay curve to the point where the two curves intersect. This is the level of lake resource the household will choose to obtain.

The benefits received by a household through a non-marginal change in lake characteristics, say from W to W', is the integral of the willingness to pay function from W to W'. The aggregate benefits are the sum of this integral for each household.

$$B = \sum_{i=1}^{n} \int_{W}^{W'} P_i(W)\,dW \qquad (5\text{-}4)$$

where:
B = the aggregate benefits due to the change in lake characteristics,
W = initial lake characteristic level,
W' = lake characteristic level after change,
P_i = willingness to pay for household i, and
n = total number of sites.

5.3.2 <u>Applications of Hedonic Pricing</u>

Many attempts to price environmental goods through property values have been undertaken. The majority of these studies examined the value of air quality. Freeman (1979) gives an excellent review of these studies which had been reported through 1979. The general conclusion of nearly all the studies was that air quality is capitalized in property values -- but empirical relationships varied greatly as did the actual variables included in the studies.

Another application has been in the field of natural hazards. In this case, the presence of a natural hazard is assigned value through capitalization in proximate property values. Tobin and Newton (1986) examined flooding and found the hazard to adversely affect land values. Magnitude and frequency of flooding along with socio-economic characteristics of the residents in the floodplain were found to affect the rate of recovery of land values following a flood event. Natural disasters (in general) were examined by Rubin and Yezer (1987). They found the magnitude of land value response to a natural disaster was significantly less in the case of an expected disaster versus an unexpected disaster.

Falcke (1982) put forth an enterprising effort of closely following econometric rules of hedonic theory in measuring water resource benefits. Following an excellent theoretical presentation of the technique, Falcke follows the work of Dornbush and Barranger (1973) in their derivation of a perceived water quality index. Survey data showed that laypersons and technical experts often have differing perceptions of the conditions of a water body, e.g., in an extreme case, residents felt the water quality of lake improved while the experts felt quality had deteriorated. A statistical relationship is found between the expert's and lay person's perceptions and is adopted into the analysis.

A time-series investigation of 17 estuaries, rivers, and lakes which have undergone significant water quality change is conducted. Site specific equations for each are calibrated with percent property price change as the dependent variable. Each equation used distance from the water body and perceived water quality change as independent variables, as well as a subset of the following variables: distance to school, distance to shopping, location on busy street, location on corner lot, previous property value, lot size, distance to new highway, distance to nearest highway access, distance to environmental nuisance, distance to other new facilities like a bridge, boat-launching area, country club, etc. The distance to waterbody parameter estimate for each site was regressed against perceived water quality change, waterbody type, public access, and region indicator. This statistically meshed the site specific equations into a single function.

5.4 Conclusions

This chapter discussed three categories of benefits received from an improved water resource system: environmental quality improvement benefits that accrue to the general public in the affected area, direct recreation benefits, and property benefits. Correspondingly, if a site has been degraded, then these same groups have incurred damages that can be partially or even wholly ameliorated by restoring the water resources system. The next chapter applies these techniques to the Lake Apopka area.

6.0 SOCIO-ECONOMIC ASSESSMENT OF LAKE APOPKA

6.1 Description of the Study Area

Lake Apopka is a 12,545 hectare lake located in Orange and Lake counties of central Florida (see Figure 6-1). It is the headwater lake in a chain which also consists of Lakes Beauclair, Dora, Eustis, Griffin, and Harris. Although Apopka is Florida's fourth largest lake, it is shallow with an average depth of less than two meters.

6.2 History

This section draws heavily on a 1982 book by Jerrell Shofner titled History of Apopka: 1882-1982.

The first modification of Lake Apopka occurred as a result of attempts, beginning in 1878, to construct canals between Lake Apopka and the downstream lakes and eventually into the St. Johns River. Such a canal system would permit movement from Lake Apopka all the way to the Atlantic Ocean at Jacksonville (Shofner, 1982). The Apopka Canal Company, chartered in 1878, was granted several thousand acres of sawgrass lands north of Lake Apopka if it could complete a canal and drain the lands by January 1, 1881. While the canal company struggled for several years trying to complete the canal, railroads were built on both sides of Lake Apopka (Shofner, 1982). The original canal company gave up its effort to drain the lands after more than ten years of effort. A new group continued the canal effort and completed it in 1893. According to Shofner (1982), the canal was able to lower the water level of Lake Apopka by four feet, leaving an estimated 20,000 acres of the sawgrass dry enough for cultivation.

In the late 1800's, there were strong incentives to drain the muck lands as Shofner cites local newspaper articles describing the land as "...over 30,000 acres of rich lands that have a depth of from three to four feet of the best and most fertile humus soil that will produce enormous crops" and "...the muck was ten feet and 'raises careless weeds twenty-five feet high and a foot in diameter". It was later shown that the muck was actually from three to nine feet in depth.

Early efforts to farm the land met with limited success due to it being difficult to work, having widely varying water table levels, and due to cold waves in 1894, 1895, 1898, and 1899. In 1910, 14,500 acres of the muckland were purchased for $20 per acre. In 1915, the Zellwood Produce Company obtained permission to do additional canal work aimed at further lowering the level of Lake Apopka in order to solve the high water problems plaguing the muck farm areas. This permit caused a bitter protest from 135 vegetable farmers on the south end of the lake who farmed 7,331 acres valued at $2,190,160. They argued that lowering the lake by two feet would "expose vegetable matter that may cause typhoid and other malignant fevers".

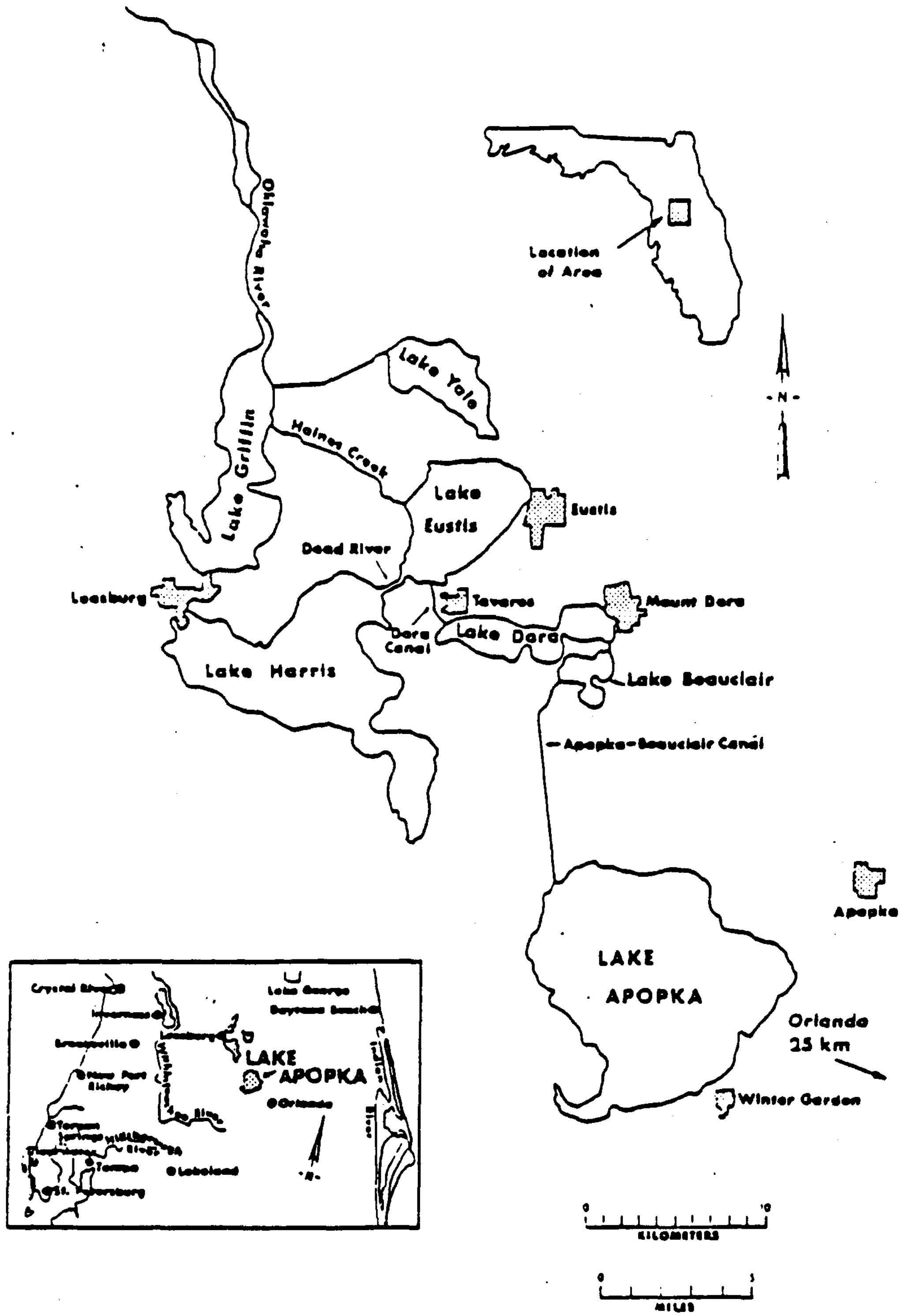


Figure 6-1. Map of Lake Apopka (EPA 1978).

They also argued, more plausibly, that the drainage project "... would interrupt the flow of water and damage irrigation systems, reduce the area of the lake which served as a protection against frost, and adversely affect navigation on the lake." The claims of the farmers at the south end of the lake were based on an assumed low water mark for Lake Apopka of 65 feet. However, after lengthy investigation, the low water mark was established at 62 feet. This finding permitted the muck farm interests to lower the lake level to 63 feet. While they were able to lower the lake level, attempts to grow potatoes failed and the development company went bankrupt. Lake Apopka recaptured the muck that had been drained in September 1926 when a huge hurricane placed the muck farm land under six to eight feet of water. With the exception of attempts to mine the peat for fertilizer, efforts to farm it did not resume until the early 1940's.

The Zellwood Drainage and Water Control District was created in 1941. A network of canals was built so that water levels could be maintained independently in each tract. Lake Apopka was dammed so that its elevation was two feet above the muck land. Water could be brought in by gravity, but excess water had to be pumped into the lake. A loan of $142,000 was used to develop about 2,600 acres, and another loan of $257,000 was used to develop about 6,000 acres. An additional $87,500 was required to complete these projects. The appraised value of the muck farm land was $150 per acre. Initial acreages of winter vegetables planted during the war included Zellwood Farms,Inc.-640 acres of celery, beans, carrots, spinach, and cabbage; Oviedo-Zellwood Growers-360 acres; and A. Duda and Sons-3000 acres.

Mr. Arch Hodges, who had extensive experience with drainage problems in the Everglades, became supervisor of the Zellwood Drainage and Water Control District in 1946. He was able to avert damage due to floods. However, the remaining problem was to reduce the possibility of frost damages since the low muck lands are several degrees colder than surrounding areas. Planting and operating schedules were modified to minimize frost hazards.

Principal crops have been celery, carrots, and sweet corn, but turnips, cabbage, mustard, collards, escarole and other vegetables are also grown. In 1975, there were 13 major vegetable farms in the Zellwood area growing about $18 million of crops on 14,000 acres of muck land.

In the 20th century, Lake Apopka became known as a world renowned lake for sport fishing with thriving fish camps including Paradise Cove, Fisherman's Paradise, Wells' Gap, Johnson's Fish Camp, Orange Fishing Lodge, Red Rose Lodge, and Sunshine Manner. The number of fish camps at Lake Apopka for the period from 1950 to the present is shown in Table 6-1. The decline in the number of fish camps is a good indicator of the decreased desirability of Lake Apopka after the mid-1950's.

Table 6-1. Number of Fish Camps at Lake Apopka.

Year	Number
1950	13
1956	21
1965	9
1976	4
1983	1

Sources: Battoe, Walker, and Modica (1988), U.S. Environmental Protection Agency, 1978.

According to an state-wide water quality assessment prepared by the Florida Department of Environmental Regulation, Lake Apopka and the lakes in its chain are the largest group of lakes in the state in which the water quality is poor as shown in Figure 6-2 (Hand, Tauxe, and Friedemann, 1988). Indeed, a considerable improvement in Lake Apopka's water quality will be needed for it to be upgraded to fair. Thus, the discharges to Lake Apopka have had a serious detrimental effect, not only on the lake itself, but also the downstream lakes and the Upper Oklawaha River.

The chronology of events affecting Lake Apopka, as summarized by the US EPA (1978), Fonyo (1987), and Battoe, Walker, and Modica (1988) is presented in Table 6-2.

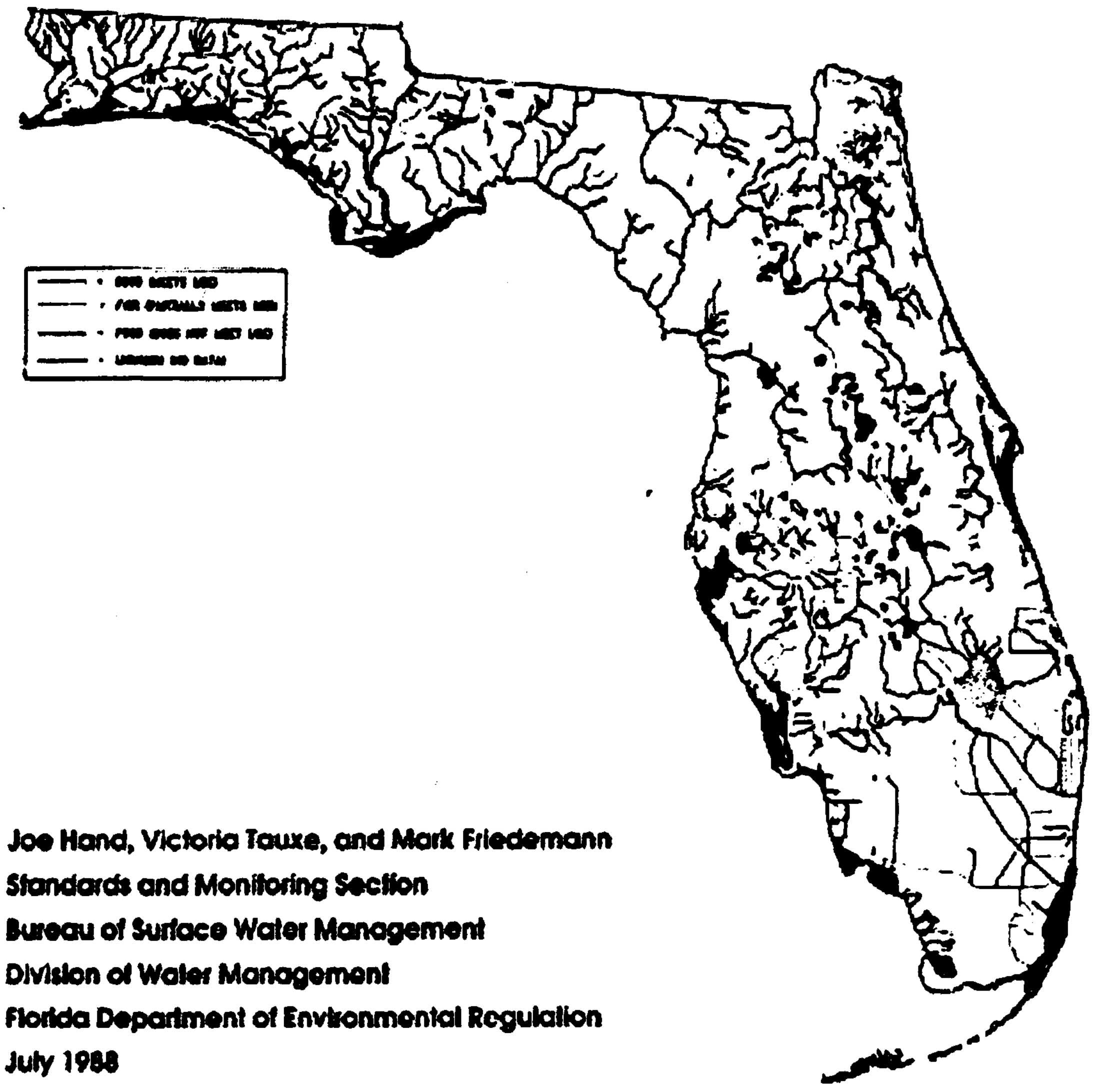
6.3 Population Trends and Interest in Environmental Control

6.3.1 Population Trends

The decadal population from 1910 to present, shown in Table 6-3, indicates that Orange and Lake counties have experienced rapid growth during the past 30 years. Orange and Lake counties account for 6.15 % of the population of the State of Florida. With regard to the concern regarding Lake Apopka, in 1950, only 151,000 people lived in these two counties. However, by 1990, the two county population will grown to 816,000, over five times its 1950 level. Thus, many more people are affected by the degraded condition of the lake chain. In addition, the Orlando area has become a worldwide mecca for tourism. The degraded condition of the lake also affects this group.

A continued rapid growth of population for Lake and Orange counties is expected and they should have over one million people by the turn of the century and reach a population of nearly two million by the year 2020.

1988 FLORIDA WATER QUALITY ASSESSMENT
305(b) TECHNICAL APPENDIX



Joe Hand, Victoria Tauxe, and Mark Friedemann
Standards and Monitoring Section
Bureau of Surface Water Management
Division of Water Management
Florida Department of Environmental Regulation
July 1988

Figure 6-2. 1988 Florida Water Quality Assessment.

Table 6-2. Chronology of Significant Events in the Lake Apopka Study Area.

1870's	The Apopka Canal Company is organized by J.S. Speer to drain the organic soil on the north side of Lake Apopka for farming, and to dredge a waterborne transportation route connecting lakes Apopka, Beauclair, Dora, and Eustis to ship vegetables and citrus.
1880's	The Apopka Canal Company flounders and the Delta Canal Company continues work.
1893	Canal connecting lakes Apopka and Beauclair is excavated by the Delta Canal Company.
1922-27	Sewage effluent from Winter Garden first discharged into lake.
1924	Fresh-fruit preparation plants begin discharge of effluent into lake.
1941	Zellwood Drainage and Water Control District(ZD&WCD) is created by a special legislative act to oversee the irrigation and drainage of approximately 8,700 acres of farmland north of the lake, They begin construction of a flood control dike to separate their farms from Lake Apopka.
1942	The dike is partially completed and muck farms start pumping stormwater and seepage water into the lake.
1947	The ZD&FCD completes construction of the dike along the north end of the lake.
1947	September hurricane destroys large amounts of bottom vegetation. First algal bloom reported in October.
1948	Citrus concentrate processing plants begin discharging into the lake.
1948	Chemical control of water hyacinths attempted.
1948	Apopka-Beauclair Canal opened.
1948-50	Rooted aquatic vegetation disappeared. Frequent algal blooms reported.
1949-50	Drought results in massive fish kill in Lake Apopka.
1950-55	Game fishing peaks with over 15 fishing camps located on the lake.

1950 Lake water stabilized by control structure placed in Apopka-Beauclair Canal by local interests to stabilize water levels in Lake Apopka to provide optimal levels for agricultural water supply and improved navigation.

1951 Regional drought of 1949-50 prompts study of the Oklawaha Basin.

1953 The Lake Apopka Water Control Authority (LAWCA) and the Lake County Water Control Authority (LCWCA) are created to plan construction of works to stabilize water levels in the Oklawaha Chain-of-Lakes.

1954 LAWCA and LCWCA adopt lake regulation schedules for the Oklawaha Chain-of-Lakes.

1957 Rough fish estimated as 82 percent of fish population (by number).

1957-59 Three separate selective fish poisonings killed a total of 20 million pounds of shad.

1958 LAWCA completes construction of Apopka-Beauclair Lock and Dam.

1959 Heavy rains from March through October cause ZD&WCD to sustain damages of $140,000 to capital improvements and considerable crop losses. The estimated frequency of occurrence for the flood was one in ten years. Following this flood, the perimeter dike protecting the 9,000 acres of ZD&WCD was raised to 70 ft. NGVD.

1960 In four days of mid-March, rainfall amounts exceeding 10 inches fell on the Oklawaha River Basin resulting in over $4,000,000 in damages to truck crops in the Oklawaha River Basin--particularly Lake Apopka. Flood durations were two months or more. The estimated return period was 25 years.

Due to excessive rainfall, LAWCA opened the gates in the Apopka-Beauclair Structure flooding an area around lakes Dora and Eustis; LCWCA secures an injunction to restrain them and they were forced to close the gates to the recommended openings.

1961 Legislature creates the Southwest Florida Water Management District which assumed responsibility for operation and maintenance of the control works.

1962 The Four River Basins Project is approved by Congress to provide for flood protection, navigation, drainage, water conservation, and pollution abatement. The plan includes a levee along the north and northwest shore of Lake Apopka.

1963 In May, a gas embolism kills 10 million to 20 million pounds of rough fish, and .4 million pounds of game fish.

1963 SWFWMD assumes responsibility for operation and maintenance of the Apopka-Beauclair Structure.

1965 The LAWCA disbands and becomes inactive.

1967 The Lake County Pollution Control Agency is established.

1971 Experimental gravity drawdown results in death of alligators, turtles, and fish attributed to Aeromonas bacteria.

1972 Florida's five water management districts are established.

1977 St. Johns River Water Management District assumes responsibility for the Lake Apopka area.

1977 Discharge of citrus concentrate processing plant ends.

1978 All point-source discharges to the lake are stopped.

1987 Heavy rains in March increase the stage at Lake Apopka to 68.25 ft. which overtops the levee north of the lake and causes flood damages to adjacent farms.

1987 The Surface Water Improvement and Management Act (SWIM) becomes law.

Sources: EPA, 1978; Fonyo, 1987, Battoe, Walker, and Modica (1988), U.S. Army Corps of Engineers, 1965.

Table 6-3. Population Trends in Lake and Orange Counties and Florida.

	Population in Counties All values in 1000's					
Year	Lake	Orange	Orange & Lake	Florida	O&L as % of Florida	Reference
1910	9.5	19.1	28.6	753	3.80%	Dietrich
1920	12.7	19.9	32.6	968	3.37%	"
1930	23.2	49.7	72.9	1468	4.97%	"
1940	27.3	70.1	97.3	1897	5.13%	"
1950	36.3	115	151	2771	5.46%	"
1960	57.4	264	321	4952	6.48%	"
1970	69.3	344	414	6789	6.09%	"
1980	105	471	576	9747	5.91%	BEBR-a
1990	150	666	816	12418	6.15%	BEBR-b
2000	187	822	1009	15899	6.35%	"
2010	216	919	1135	17998	6.31%	"
2020	240	1019	1259	19942	6.31%	"

References:
Dietrich, T.S. 1978.
Bureau of Business and Economic Research, 1989a.
Bureau of Business and Economic Research, 1989b. Median estimate.

6.3.2 Commitment to Environmental Quality Enhancement

The Surface Water Improvement and Management (SWIM) Act of July 1987 states that many of the surface waters of the State of Florida have been degraded and need to be restored and/ or protected. Lake Apopka is specifically identified as a priority area. The extent of the commitment to clean up Lake Apopka can be estimated by the amount of money that the public is willing to spend voluntarily to achieve these objectives. These expenditures are voluntary in the sense that the state is not required to do this restoration under any specific federal mandate.

For example, the South Florida Water Management District has embarked on a major effort to restore the Lower Kissimmee River by dechannelizing it. This effort could cost more than 100 million dollars. In the case of Lake Apopka, the State of Florida and the St. Johns River Water Management District have made significant financial commitments to this effort as shown in Table 6-4 which is based upon data from Battoe, Walker, and Modica (1988).

Table 6-4. Funding for the Restoration of Lake Apopka.

Year	Amount, $
1985	$2,165,000
1986	500,000
1987	2,750,000
1988	6,346,000
1989	7,271,000
1990	9,067,000
Total	$28,099,000

Reference: Battoe, Walker, and Modica, 1988.

Of this total of over $28 million, $15 million is being used for acquisition of muck lands. The purchase price of this land acquisition was about $2,700 per acre. At this rate, the entire 15,000 acres of muck land could be purchased for about $40 million. The projected total cleanup cost for Lake Apopka could easily exceed $50 million. This willingness to invest public funds to restore a common resource can be used as a lower bound on the public benefits. The present citizens of the state are making this investment in the hope of an enhanced long-term benefit. For Lake Apopka and other areas undergoing restoration or protection, the overwhelming majority of the funding comes from non-users as described in the section on environmental quality benefits. These non-users represent people from the nearby region, the rest of the state, and elsewhere. Let us assume that the primary target group of non-users is the 800,000 people who presently reside in Lake and Orange counties. This group has committed to spend about $40 million in 1989 dollars to restore Lake Apopka. This amounts to a one time commitment of $50 per capita. If this investment is amortized over 25 or 50 years or even infinity at a discount rate of 10 %, then the equivalent annual expenditure would be at least $5 per capita per year as shown in Table 6-5. By comparison, the per capita per year contingent valuations reported in the previous chapter were about $25. Thus, this estimate for Lake Apopka is on the low side.

Table 6-5. Amortized Value of Current Investment of $50 at an Interest Rate of 10 %.

Amortization period years	Equivalent Annual Cost $/year
5	$13.19
10	8.14
25	5.51
50	5.04
infinity	5.00

The situation can be described as saying this large non-user group has desired to restore Lake Apopka and the downstream areas affected by its pollution for the past twenty five years as documented earlier in this chapter. However, these earlier attempts were unsuccessful because of an insufficient number of people who felt that they were detrimentally impacted by continuing pollution of Lake Apopka and its downstream lakes and the Upper Oklawaha River. Given enough people impacted by this problem, then at some point the pendulum will swing in favor of remediation instead of continuing to accept the degradation. The estimated annual environmental quality damages to the public of a degraded Lake Apopka based on the present demonstrated willingness to spend significant public funds is shown in Table 6-6 for the populations of Lake and Orange counties for the period from 1960 to 2020. All of these values are in 1989 dollars. These damages have increased from about $802,000 per year in 1960 to a current value of over $4 million per year, and are expected to be nearly $6.3 million per year by 2020.

Table 6-6. Losses to General Population Due to Degraded Lake Apopka, 1960 - 2020.

(1) Year	(2) Population Orange & Lake Counties 1000's	(3) Annual Loss $/capita	(4) Annual Loss $/capita
1960	321	$2.50	$ 802
1970	414	$5.00	$2,068
1980	576	$5.00	$2,879
1990	816	$5.00	$4,080
2000	1009	$5.00	$5,045
2010	1135	$5.00	$5,675
2020	1259	$5.00	$6,295

Column Explanation

(1) Census year.

(2) Census and median projected populations for Lake and Orange counties.

(3) No loss in 1950. Annual loss is annualized value of current expenditure of $40 million on behalf of current population of 800,000 or $50/capita. Annualization of $50 over an infinite planning horizon gives an equivalent annual loss of $5.00/capita/yr.

(4) Col. (2)*Col. (3).

6.4 GIS Analysis of Land Use and Land Value

6.4.1 Present and Future Land Use

Present and future land use patterns in a region can be analyzed by using a geographical information system (GIS) such as the ARC-INFO system operated by SJRWMD. A true GIS can display geographical information in map or textual form. Since GIS software is still in its infancy, it is expensive and requires skilled operators due to its complexity. Additionally, most of the map information must still be manually digitized from hard-copy maps.

In light of these difficulties, the land use analysis for this project was done using Lotus 1-2-3 spreadsheets and land use information provide by SJRWMD and Orange County. The water management district provided a GIS map showing the present land uses patterns around the basin and a PC file containing the land use classifications and acreages for 1600 cells outlined on the map.

Land use information provided by Orange County was a map titled "The Future Land Use Policy Guide for Orange County". Unfortunately, no electronic version of this map was available. The Lake County version of a future land use guide is not available.

A sample of the present land use information is shown in database format in Table 6-7. The first column in Table 6-7 contains the cell number corresponding to the location of that cell on the land use map provided by SJRWMD. Each cell on the SJRWMD map contains 160 acres. The land use classifications in Table 6-7 are the same as those used by SJRWMD except for forestry and wetlands which are aggregations of similar land uses.

Using the database capabilities within the spreadsheet, simple queries such as total acreage for each land use, or total acreage of a specific land use within a given area can be determined. Simple maps showing the lake and the acreages of different land uses can also be created within the spreadsheet.

For this study, the present land use database was used to determine the total citrus acreage applicable for each crop insurance rate and a spreadsheet map of the crop insurance rates in the basin was created.

A summary of the present land uses and corresponding acreages is presented in Table 6-8. As expected, agricultural land uses make up a large portion of the total basin acreage. Muck farms and citrus acreage presently account for nearly 50% of the total basin acreage (excluding Lake Apopka and basin land south of the turnpike).

Table 6-7. Sample of Present Land Use Database for the Apopka Basin (SJRWMD 1988).

Cell Number 0	Low Density 110	Medium Density 120	High Density 130	Commercial 140	Industrial 150	Mining 160	Parks & Recreation 180	Open Land 190	Crop Land 210	Improved Pasture 211	Muck Farm 214	Citrus 221
227	0	0.42	0	0	0	0	0	0	0	0	0	0
264	10.01	0	0	0	11.54	0	0	0	0	0	0	20.3
265	0	0.7	0	0	20.97	0	0	0	7.55	0	0	20.63
266	0	33.49	0	0	0	0	0	0	0	0	0	63.30
267	0	121.41	0	0	16.72	0	0	0	0	0	0	0
268	0	86.09	0	10.85	24.32	0	0	0	0	0	0	21.63
269	0	25.32	0	0	24.6	0	0	0	0	0	0	25.97
270	0	13.3	0	0	12.28	0	0	0	0	0	0	0
271	0	0	0	0	41.7	0	0	0	0	0	0	1.77
272	0	0	0	0	12.6	0	0	0	0	25.76	0	0
273	4.10	0	0	0	5.75	0	0	0	0	11.14	0	0
274	0	0	0	0	26.93	0	0	0	0	29.05	0	0
296	0	0	0.31	0	0	0	0	0	0	0	0	0
297		0	1.95	0	0	0	0	0	0	0	0	0
301	0	0	0	5.44	0	0	0	0	0	0	0	14.36
302	8.32	0	0	0	0	0	0	0	0	0	0	33.67
303	19.35	0	0	0	0	0	0	0	0	0	0	34.05
304	32.24	0	0	0	26.76	0	0	0	0	0	0	60.27
305	9.57	0	0	0	53.14	0	0	0	0.09	0	0	56.25
306	0	0.22	0	0	19.05	0	0	0	0	0	0	111.06
307	0	20.53	0	0	21.7	0	0	0	0	0	0	58.59
308	0	9.02	0	1.06	52.72	0	0	0	0	0	0	60.10
309	0	5.46	0	0	64.04	0	0	0	0	0	0	51.79
310	0	11.65	0	0	63.16	0	0	0	0	0	0	61.42
311	0	0	0	0	9.03	0	0	0	0	0	0	124.40
312	43.35	0	0	0	24.07	0	0	0	0	0	0	6.75
313	61.01	0	0	0	0	0	0	0	0	0	0	0
314	26.73	0	0	17.81	7.69	0	0	0	2.24	46.56	0	15.59
315	0	0	0	0	0	0	0	0	3.37	0	0	0
332	0	0	0	0	3.23	0	0	0	0	0	0	0
336	0	0	52.72	0	0	0	0	0	0	0	0	0
337	0	0	94.92	0	0	0	0	0	0	0	0	0
338	0	14.15	1.37	0	0	0	0	0	0	0	0	0
339	12.75	1.00	0	0	0	0	0	0.90	0	0	0	9.91

Cell Number 0	Confined Feeding 230	Nursery 240	Scrub 329	Forestry 400	Lakes & Ponds 520	Wetlands 600	Borrow Pit 742	Transportation 810	Peat Mining 1612	X-Coord	Y-Coord	Citrus Insurance
227	0	0	0	0	0	0	0	0	0	336769	1573023	0
264	0	0	0	0	0	0	0	0	0	334129	1565103	0
265	0	0	0	0	0	0	0	0	0	334129	1567743	0
266	0	0	0	0	0.44	0	0	0	0	334129	1570383	0
267	0	0	0	0	0.05	0.26	0	0	0	334129	1573023	0
268	0	0	0	0	0	0	0	0	0	334129	1575663	0
269	0	0	0	0	0	0	0	6.83	0	334129	1578303	0
270	0	0	0	0	0.07	0	0	1.03	0	334129	1580943	0
271	0	0	0	0	0	0	0	0	0	334129	1583583	0
272	0.54	0	0	1.96	0	0	0	0	0	334129	1586223	0
273	0.15	0	0	42.14	0	4.05	0	0	0	334129	1588863	0
274	0	0	0	0	0	2.63	0	0	0	334129	1591503	0
296	0	0	0	0	0	0	0	0	0	331489	1543983	0
297	0	0	0	0	0	0	0	0	0	331489	1546623	0
301	0	0	0	0	0	0	0	0	0	331489	1557183	0
302	0	0	0	0	0	10.35	0	0	0	331489	1559823	0
303	0	0	0	0	0	29.23	0	0	0	331489	1562463	0
304	0	0	0	0	0	0.57	0	0	0	331489	1565103	0
305	0	0	0	0	0	30.92	0	0	0	331489	1567743	0
306	0	0	0	25.77	0	0	0	0	0	331489	1570383	0
307	0	0	0	36.15	7.19	24.52	0	0	0	331489	1573023	0
308	13.56	0	0	20.09	0	3.52	0	0	0	331489	1575663	0
309	0	0	0	27.70	0.2	2.06	0	0.60	0	331489	1578303	0
310	0	0	0	0	1.74	5.61	0	16.23	0	331489	1580943	0
311	0	0	0	0	9.57	17.17	0	0	0	331489	1583583	0
312	15.27	0	0	57.73	0	12.03	0	0	0	331489	1586223	0
313	6.1	0	0	16.32	10.69	57.00	0	0	0	331489	1588863	0
314	0	0	0	7.50	2.34	30.84	0	0	0	331489	1591503	0
315	0	0	0	0	0	0	0	0	0	331489	1594143	0
332	0	0	0	0	0	3.50	0	0	0	328849	1533423	0
336	0	0	0	0	21.17	0	0	0	0	328849	1543983	0
337	0	0	0	0	3.37	0	0	0	0	328849	1546623	0
338	0	0	0	0	0	0	0	0	0	328849	1549263	0
339	0	0	0	44.33	0	0	0	0	0	328849	1551903	0

Table 6-8. Summary of Present Land Use Classifications and Corresponding Acreage (SJRWMD 1988).

Land Use	Classification Code	Acres	Percentage
Low Density Residential	110	2748	3.0%
Medium Density Residential	120	3492	3.8%
High Density Residential	130	500	0.5%
Commercial	140	417	0.5%
Industrial	150	1832	2.0%
Mining	160	37	0.0%
Parks & Recreation	180	25	0.0%
Open Land	190	662	0.7%
Crop Land	210	3310	3.6%
Improved Pasture	211	3244	3.5%
Muck Farm	214	15241	16.6%
Citrus	221	15215	16.6%
Confined Feeding	230	104	0.1%
Nursery	240	202	0.2%
Scrub	329	549	0.6%
Forestry	400	2248	2.5%
Wetlands	600	8462	9.2%
Borrow Pit	742	3	0.0%
Transportation	810	918	1.0%
Peat Mining	1612	424	0.5%
Lake Apopka	520	30671	33.5%
Lakes and Ponds	520	1387	1.5%
Total Area of Lake Apopka Basin *		91690	100.0%

* Most of the land south of Florida Turnpike was excluded from the basin because it is thought that this land is not truely within the Lake Apopka drainage basin.

The future land use policy guide for Orange County was used to predict future land use trends for the entire basin. A grid was overlaid on the Orange County Future Land Use Guide so that the acreages for each land use could be manually estimated. The grid system was placed so that the location of each cell was roughly the same for the Orange County map and the SJRWMD map. The land use classification system used by Orange County is shown in Table 6-9. The future land use for most of Orange county portion of the Apopka basin is shown in Table 6-10. The corresponding present land use for the same portion of the basin is shown in Table 6-11.

A correlation matrix was created to rectify the differences between the classification systems used by Orange County and SJRWMD. The unification of the residential land use classifications was based on the number of dwelling units per acre. Since the total area devoted to muck farming and lakes generally would not change over time, these land uses were not included in the unified classification system.

A comparison of the present and future land use patterns for approximately 16,000 acres of land located in the Orange County portion of the basin is presented in Table 6-12. An attempt was made to compare the present and future land use on a cell by cell basis. This analysis proved erroneous because of the accuracy of the manually recorded information in the future land use database as compared with the data provided by SJRWMD. An accurate cell by cell analysis could be performed if the present and future land use databases were of the same quality and used the same land use classification system.

Using normalized future land use percentages in Table 6-12, the acreage for each land use was calculated for the entire basin in Table 6-13. Because the urbanization pressure is greater for the Orange County portion of basin as opposed to the Lake County portion these estimates of future land use for the basin may be somewhat high. Nevertheless, certain trends can be observed. The amount of land devoted to residential development is shown to increase dramatically. This increase is expected to come mostly at the expense of agricultural land such as citrus groves. Since many of the citrus groves are currently unproductive due to recent freezes, the rate of development may increase. Less land devoted to citrus production means that the concern regarding the freeze protection provided by the lake should lessen. One effect on the lake will be the change from predominantly agricultural runoff to predominantly urban runoff in most of basin except the north end of the lake. However, the water quality impacts of urban runoff should be greatly reduced by the current regulations that require the installation of on-site storage and control facilities.

Table 6-9. Correlation Matrix for the SJRWMD and the Orange County Land Use Classification System.

Unified Classification	Orange County Classification	SJRWMD Classification
Low Density Residential	Rural Residential Urban Estate	Low Density Residential
Medium Density Residential	Low Density	Medium Density Residential
High Density Residential	Low-Medium Density Residential Medium Density Residential High Density Residential	High Density Residential
Commercial	Commercial	Commercial
Industrial	Industrial	Industrial
Conservation	Conservation	Forestry
Agriculture	Agriculture Rural Estate	Cropland Improved Pasture Citrus Confined Feeding Nursery & Special Crops Mining Open Land Grassy Scrub

Table 6-10. Future Land Use Database for Part of the Orange County Portion of Lake Apopka Basin.

Cell #	Low Density	Medium Density	High Density	Commer-cial	Indus-trial	Parks & Rec.	Agri-cultural	Conser-vation
307	0	0	6	0	0	0	134	0
308	32	0	16	0	0	0	112	0
309	38	90	0	13	0	0	0	0
310	0	96	0	51	0	0	0	0
311	0	115	6	0	0	0	0	0
313	19	6	26	0	0	0	0	96
314	115	0	26	0	0	0	0	19
340	0	0	0	0	0	0	141	0
341	0	0	0	0	0	0	160	0
342	0	0	0	0	0	0	160	0
343	0	0	0	0	0	0	147	0
347	0	0	0	0	0	0	134	0
348	6	0	0	0	0	0	147	0
349	83	26	0	0	0	0	6	0
350	0	112	3	38	0	0	0	0
351	0	134	13	0	0	0	0	0
352	0	19	6	0	0	0	0	83
353	0	45	6	0	0	0	0	102
354	70	32	0	0	0	0	0	58
377	13	147	0	0	0	0	0	0
378	134	26	0	0	0	0	0	0
379	16	0	0	0	0	0	144	0
380	0	0	0	0	0	0	160	0
381	0	26	0	0	0	0	134	0
382	45	32	0	0	0	0	83	0
383	0	19	0	0	0	0	141	0
387	0	0	0	0	0	0	147	0
388	0	0	0	0	0	0	160	0
389	109	19	0	0	0	0	13	0
390	19	128	0	0	0	0	0	0
391	0	96	58	0	0	0	0	0
392	0	38	96	0	0	0	0	13
393	0	45	77	0	0	0	0	13
394	77	13	45	0	0	0	0	26
416	0	80	0	3	0	0	0	77
417	51	109	0	0	0	0	0	0
418	160	0	0	0	0	0	0	0
419	51	0	0	0	0	0	109	0
420	0	0	0	0	0	0	141	19
421	0	32	0	0	0	0	90	19
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

Table 6-11. Sample of Present Land Use for Part of Orange County Portion of Lake Apopka Basin (SJRWMD).

Cell Number	Low Density	Medium Density	High Density	Commer-cial	Indus-trial	Parks & Recre.	Agri-cultural	Conser-vation
307	0	21	0	0	22	0	54	61
308	0	1	0	1	53	0	82	24
309	0	6	0	0	64	0	52	30
310	0	12	0	0	63	0	61	6
311	0	0	0	0	9	0	125	17
313	61	0	0	0	0	0	6	74
314	27	0	0	17	8	0	64	38
340	0	0	0	0	0	0	16	113
341	0	0	0	4	0	0	133	18
342	71	0	0	5	0	0	70	15
343	11	0	0	8	0	0	97	44
347	0	0	0	0	0	0	105	50
348	0	0	0	0	4	0	120	37
349	0	1	0	0	11	0	75	30
350	0	0	0	0	13	0	57	52
351	0	0	0	0	25	0	120	5
352	38	9	0	0	0	0	37	15
353	124	13	0	0	0	0	0	3
354	102	0	0	0	0	0	50	7
377	24	100	31	0	0	0	4	2
378	34	70	2	0	0	0	48	6
379	18	3	0	0	24	0	111	3
380	0	0	0	0	4	0	39	115
381	0	3	0	0	0	0	12	142
382	13	108	0	0	0	0	13	15
383	0	3	0	0	0	0	110	40
387	9	0	0	0	0	0	94	57
388	19	0	0	0	11	0	35	95
389	0	0	0	0	0	0	101	49
390	0	0	0	0	8	0	63	61
391	18	4	0	0	44	0	70	0
392	18	61	0	0	0	0	23	41
393	10	93	0	0	0	0	0	21
394	37	54	0	0	0	0	56	13
416	88	1	1	4	0	0	0	54
417	44	0	0	0	0	0	65	42
418	12	0	0	0	0	0	88	52
419	34	0	0	0	0	0	99	17
420	0	0	0	0	0	0	81	69
421	7	2	0	0	0	0	51	71

Table 6-12. Comparison of Present and Future Land Use Trends Using Most of the Orange County Portion of the Lake Apopka Basin.

Use Classification	Present Land Use (acres)	Present Land Use (percent)	Future Land Use (acres)	Future Land Use (percent)
Low Density Residential	1638	10.20%	3968	23.63%
Medium Density Residential	2792	17.39%	4454	26.52%
High Density Residential	242	1.51%	1075	6.40%
Commercial	257	1.60%	351	2.09%
Industrial	1113	6.93%	861	5.13%
Parks and Recreation	5	0.03%	74	0.44%
Agr cultural	6648	41.40%	4646	27.67%
Conservation	3361	20.93%	1363	8.12%
Total (1),(2)	16056	100%	16792	100%

(1). Total acreage for the present and future land use are not equal due to errors caused by the manual estimation of future land uses of the Orange County Land Use Policy Guide.

(2). Total excludes land classified as muck farming, transportation, peat mining, borrow pits, and lakes and ponds, since these land uses are not expected to change significantly.

Table 6-13. Extrapolation of Predicted Land Use Acreages in the Entire Lake Apopka Basin.

Use Classification	Present Land Use (acres)	Present Land Use (percent)	Future Land Use (percent)	Future Land Use (acres)
Low Density Residential	2748	6.38%	23.63%	10172
Medium Density Residential	3492	8.11%	26.52%	11418
High Density Residential	500	1.16%	6.40%	2756
Commercial	417	0.97%	2.09%	899
Industrial	1832	4.26%	5.13%	2207
Parks and Recreation	25	0.06%	0.44%	189
Agricultural	23323	54.18%	27.67%	11911
Conservation	10709	24.88%	8.12%	3495
Subtotal (1)	43046	100%	100%	43046
Lake Apopka				30671
Other Lakes & Ponds				1387
Transportation				918.3
Borrow Pit				2.54
Peat Mining				424
Muck Farming				15241
Total Basin Acreage				91690

(1). Subtotal excludes land classified as muck farming, transportation, peat mining, borrow pits, and lakes and ponds, since these land uses are not expected to change significantly.

6.4.2 Influence on Property Value

The value of water resources can be capitalized in surrounding property values. Gibbs (1973) found the lakes in the Kissimmee River Basin to add approximately $7 million to the aggregate value of lakefront properties. Variations of water quality and depth can also be reflected in property values. The influence of a given lake management scenario on property values could be significant, and should be considered when evaluating potential benefits and costs of the management scheme.

A preliminary estimate of the potential for land value enhancement at Lake Apopka was derived. As discussed in the previous section, a significant proportion of the basin is assumed undevelopable because of wetlands. In fact, of the approximate 129,000 feet of lake circumference, about 20,300 feet is presently residential and/or orange groves. The remaining 109,300 front-feet are either wetlands or muck farm (converted wetlands).

6.4.3 Summary of GIS Analysis

The general land use trend in the basin is expected to continue the conversion from rural to urban activities. Development around the expanding city of Orlando is the primary factor of change. Given this conversion, residential land development, some around the region's lakes, will take place. Lake Apopka will experience a portion of this type of development, but because of existing wetlands in the basin, the development will be relatively limited.

Table 6-14 shows the aggregate effect a degraded Lake Apopka is estimated to have on existing land values. The loss per front-foot is estimated to be $100 for the 20,300 acres or a total of $2,030,000. Using a 10 % interest rate and an infinite planning horizon, the equivalent annual loss is The aggregate loss per year in 1989 dollars is estimated as $203,000.

6.4.4 Potential Value of Tax Assessor's Databases

An improved estimate of the relation between lake quality and property values can be obtained using information from the county property assessors' tax databases. For example, the Orange County Property Appraiser has found that their database is a valuable resource not only for land value analysis, but other components of water resource analysis as well. Creation of such a database strengthens the methodological emphasis of the study developing a good database and tracking the incidence of benefits realized by users for each water resource purpose.

Table 6-14. Estimated Loss of Property Value Due to Degraded Lake Apopka.

(1) Year	(2) Front Footage	(3) Amortized Loss $/front ft./yr.	(4) Total Loss $1000/yr.
1960	20328	$10	$203
1970	20328	$10	$203
1980	20328	$10	$203
1990	20328	$10	$203
2000	20328	$10	$203
2010	20328	$10	$203
2020	20328	$10	$203

Column Explanation
- (1) Census year
- (2) Based on measured developable front footage. Excludes shoreline in wetlands and perimeter bordering muck farms.
- (3) Amortized annual value of decrease in present land value of $100/front foot at an interest rate of .10 over an infinite planning period.
- (4) Col. (2)*Col. (3).

The appraiser's database provides locational data which are essential in developing urban flood damage estimates. In this particular study, urban flood damage estimation was not considered crucial, but the methodological utility stands. Parcel code, address, type of structure, number of bedrooms, number of bathrooms, miscellaneous building characteristics, external features, and structural value are recorded for each parcel of land on the appraisers' tapes. Each of these variables would be beneficial in a flood damage analysis.

Urban water supply models, such as the IWR Main, require inputs such as locational variables, property value, number of bathrooms, external features, and lot size. These data are all provided in the property appraiser's database.

Utilization of the database would also provide support in land acquisition decisions. Land use, historical sales, appraised value, and parcel size and location, and owner are all available. The recovery of these data in a computer form would most certainly make land acquisition investigations more efficient. This would allow the District to expediently evaluate various "what-if" and "how-much" land acquisition plans.

6.5 Crop Budget Model for the Muck Farms

Tracking the seasonal variations in crop production investments is necessary in order to accurately predict the potential crop value and to assess the impacts of floods, droughts, restrictions on pumping, and other events. This is particularly true for an agricultural area that undergoes intensive year-round farming activity such as the Lake Apopka muck farms.

Seasonal variations in crop investments can be simulated using cropping patterns, length of growing season, and production costs. Once the crop budget model can simulate the expected annual cash flow for the muck farms, it can be modified so that the economic damage caused by natural disasters and/or regulatory controls can be reflected in the annual cash flow. This model and its application to the Lake Apopka muck farms were described in Chapter 4.

The estimates of annual revenue and net income for the Lake Apopka Muck Farms are shown in Table 6-15. The total of 39,565 acres planted is much larger than the actual size of the muck farm area because of multiple cropping within the area. The estimated annual net income per acre of land is $462 per year. This figure would be lower if land rent costs were considered. The total annual revenue is estimated to be about $60 million per year. The net revenue or profit is estimated to be about $6.4 million per year. Hebert and Llewellyn(1988), IFAS extension agents, estimated the total value of the 1987 vegetable production on the muck farms in Orange County to be $72.3 million, about 20 percent higher than the estimate produced by our more detailed model. Naturally, total revenue and profits vary from year to year due to changing climatic and market conditions. The monthly distribution of active acreage, shown in Figure 6-3, indicates that the most intensive farming activities occur in the spring and fall of the year with the summer months being the relatively dormant period.

Table 6-15. Estimate of the 1986-87 Annual Revenue and Net Income for the Lake Apopka Muck Farm Operations.

Annual Revenue	$59,040,000
Net Annual Income	$ 6,426,000
Net Annual Income as a Percentage of Revenue	10.9%
Annual Acreage Planted (acres/year)	39,565
Total Plantable Land (acres)	13,916
Average Number of Crops Per Acre	2.84
Annual Revenue per Acre ($/acre/year)	$4,243
Revenue per Planted Acre ($/planted acre)	$1,492
Net Annual Income per Acre ($/acre)	$162
Net Annual Income per Planted Acre ($/planted acre)	$462

The muck farm operations have been operating at a steady state level. Thus, our best estimate of the the annual value of this activity is $6.4 million per year. This value will be compared to the losses incurred by other groups as a result of the degraded condition of the lake.

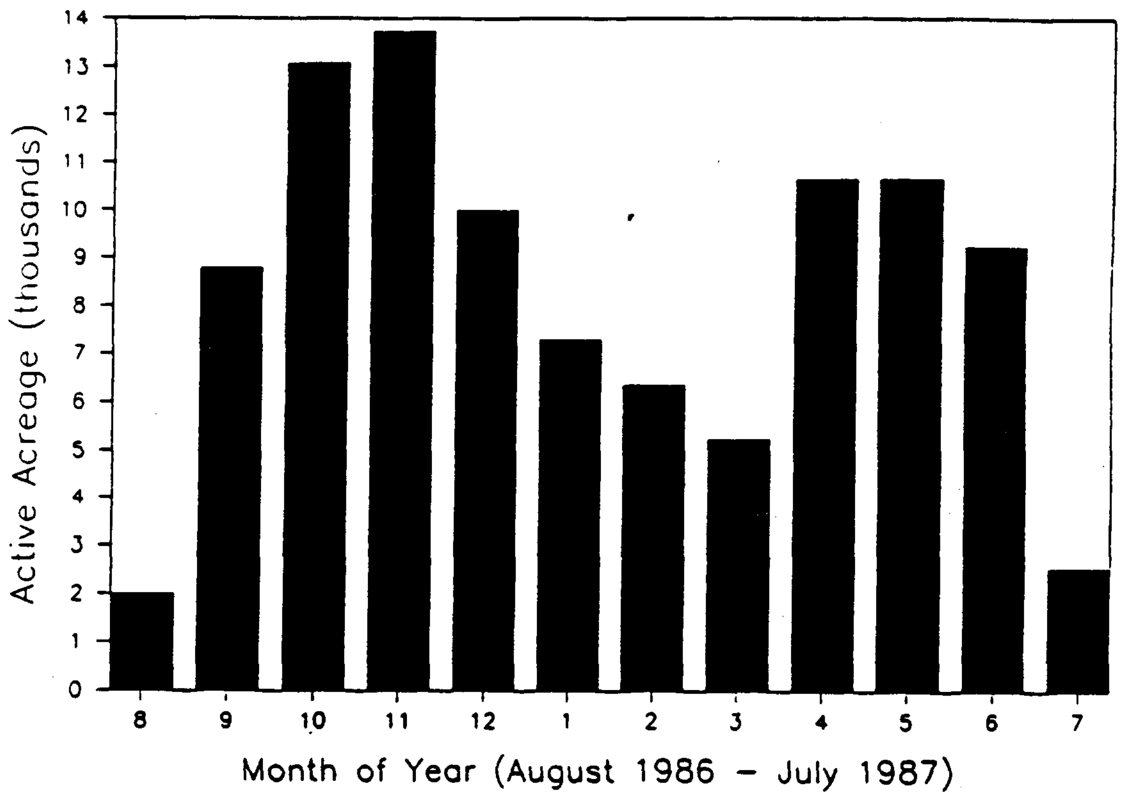


Figure 6-3. Estimated Active Acreage at Apopka Muck Farms, 1986-87.

6.6 Flood Damages at Lake Apopka Muck Farms

Overtopping of the levee bordering the farms on the north end of the lake can happen by two mechanisms: a lake stage greater than the minimum elevation of the levee, or wind setup and wave action added to a lower lake stage to cause levee overtopping. Crop losses caused by heavy rainfall events were not considered in this portion of the analysis since any changes in the levee structure or the lake regulation schedule would have a minor effect on these damages. No significant flood damages have been reported since the current control system was installed over forty years ago. Thus, this system has provided a high level of protection for the farming activities. Flood control protection levels for agricultural activities are usually designed to provide protection for floods with a recurrence interval of two to twenty years. Given the high value of the muck farm crops, a higher level of control was installed and has been successful.

6.7 Effect of Land Use Restrictions on Muck Farms

The recent purchase of 1850 acres of muck farm land by SJRWMD will reduce the cultivatable land from approximately 13,916 acres of land to 12,251 acres. This loss of 1,665 acres of cultivated land will cost the agricultural sector of the region approximately $7,000,000/year in total revenue and $770,000/year in net income. Of course, the loss in income is offset by the gain in potential earnings from the sale of the land.

If 10 percent of the remaining farm land was set aside for internal water storage, this would only affect the number of acres planted in November and December, as shown in Table 6-15 and Figure 6-3. The net resulting loss of income would be $162/acre multiplied by the 1225 acres set aside, or $200,000 per year for all of the muck farm operations. This estimate would tend to be on the high side for two reasons; the set aside land would be taken from the production of crops which are less profitable than average (less than $162/planted acre), and a simple rescheduling of some planting dates would more evenly distribute the total planted acreage so that the peak active acreage in November and December would not exceed the 11,025 available acres. However, the costs probably would not be shared equitably by the individual farmers since each operation has a different planting schedule and therefore would be more or less affected by the required land use restriction.

Another estimate of the cost of setting aside 10 percent of the land for internal water storage can be made by multiplying the average annual income per acre of land ($462) by the number of acres set aside (1,225). This estimate comes out to be $566,000 per year. This estimate is high since most of the year the set aside land would not have been in production anyhow, and the marginal loss in income per acre would be less than the average since the farmers would tend to minimize their losses by not planting the least profitable crops.

Currently, the farmers practice seasonal flooding of the farm land to arrest the oxidation of the muck soils. It may be possible to couple internal water storage with land flooding to achieve the multiple objectives of soil conservation and reduced discharge to the lake.

The above estimates of impacts are first approximations. A much improved estimate could be obtained using the crop simulation models described in Chapter 4. The water budget prepared for A. Duda & Sons by Applied Technology and Management in April, 1988 contains recent monthly pumping and crop/land use data. The report states that 256 acres of retention pond on the property will reduce the amount of water discharged to the lake by 69 percent. This figure was based on a simulation of the farm water budget using a monthly time step. The simulation assumes that the daily irrigation demand will be met by available pond storage before water is drawn from the lake and that no seepage into or out of the pond occurs.

Using a modified version of the soil moisture model, a rough daily simulation of the Duda farm was performed that showed that discharge to the lake could be reduced by 40 percent just by transferring water from plots being drained to plots being irrigated. However, it may not be possible to operate the farm in this manner. With a 256 acre pond, the daily simulation showed a reduction of 75 percent in water discharged to the lake. The 75 percent reduction for the daily simulation is very close to the 69 percent reduction shown in the consultant's report considering that the daily simulation did not take into account the July and August field flooding.

In addition to the cost of reducing productive acreage due to the pond construction, pumpage costs may increase because the farm will now be bordered on two sides by elevated reservoirs instead on just the lake side of the farm. The amount of the additional seepage caused by the ponds will be dependent upon the difference between the current piezometric head of the acreage farthest from Lake Apopka and the piezometric head of the acreage closest to the lake. Lining the retention ponds will eliminate the problem of seepage into or out of the ponds.

6.8 Freeze Susceptibility of Lake Apopka Citrus Groves

Because of its large size, it is commonly thought that Lake Apopka provides freeze protection for citrus trees nearby. This claim is partially substantiated by the crop insurance rate map provided by the Federal Crop Insurance Corporation (FCIC, 1987). The FCIC citrus crop insurance does not cover any losses due to damages to the citrus trees; however, crop damage caused by freezes, hail, or fires is covered. It is assumed that the rate maps reflect historical freeze patterns in the basin.

Bartholic and Bills(1978) found that the lake provides significant freeze protection for those areas downwind of Lake

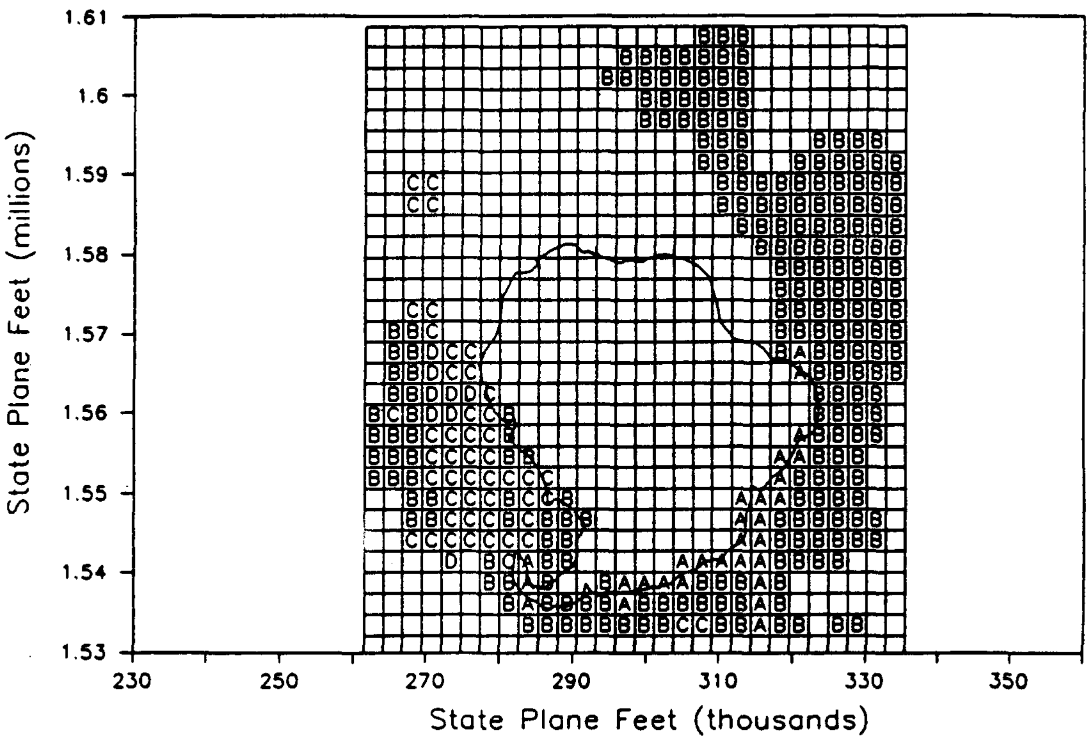
Apopka under high wind conditions. They determined that, even with an average depth of one meter, the surface area of the lake would be relatively unaltered and therefore protect the same amount of citrus acreage. They found that the heat capacity of the lake, given a one meter average depth, would be great enough to maintain surface temperatures almost unchanged from current lake conditions.

A simplified version of a crop insurance rate zone map for Lake Apopka, created by a spreadsheet geographical information system, is shown in Figure 6-4. This map shows a region along the south shore of Lake Apopka that has the most favorable crop insurance rate, which is type "A". In general, most of the citrus areas around the lake are rated type "B" with the less favorable "C" and "D" ratings found in an area characterized by high elevations located west of the lake.

It would be very difficult to accurately determine the cost of additional freeze damage caused by lowering the lake to a average depth of less than one meter due to factors such as variable wind direction and localized surface temperatures. Because crop insurance rates should reflect the cost of freeze damage, they were used in this study as a substitute for the actual damages.

If the lake was lowered to an average depth of less than one meter, during the critical period from November 30 to February 28 (USEPA 1978), then the citrus acreage on the south shore of the lake might have its crop insurance rate adjusted from category "A" to "B". Other acreage currently rated "B" would most likely would not have its insurance rate changed since the "B" rating is applied to most citrus acreage in the region. Table 6-16 shows that the expected additional cost of crop insurance would be $16,000/year if the present amount of "A" acreage was shifted to "B" acreage. The maximum cost of $82,000/year would come about if some of the citrus growers in the category "A" zone currently do not purchase crop insurance, and would be compelled to purchase crop insurance because of a drawdown of the lake. Using projected land use patterns in the basin, the expected increase in crop insurance premiums was calculated to be $7,900/year. The lower expected increase in crop insurance premiums reflects the future urbanization of the Apopka Basin.

It is not exactly clear whether the lake provides additional protection against freeze damage to the trees. Chen and Gerber (1986) state that December freezes often inflict more damage to citrus trees than January or February freezes since, in December, citrus trees have not had enough time to acclimate and are thus more vulnerable to low temperatures. The extent of the damage resulting from the December 1983 freeze is partially blamed on the high daily minimum temperatures of the ten days preceding the freeze. An average daily minimum temperature of 13 degrees Celsius is cited as the temperature at which citrus trees begin to lose accumulated hardiness and thus become more prone to



Legend

Zone	Risk	Insurance Rate @
A	Low	7.2
B	Moderately Low	8.9
C	Moderately High	11.1
D	High	12.7

@ (% of insured value)

Figure 6-4. Map of Rate Zones for Citrus Crop Insurance in the Lake Apopka Basin.

Table 6-16. Summary of Crop Insurance Costs by Rate Classification and Acreage. The Citrus Crop is Insured for $750/acre.

A. Annual Crop Insurance Costs for Present Citrus Acreage.

Classification Type	Acreages	Insurance Rates	Insurance Premium ($/acre)	Total Insurance Cost ($)
A	1233	7.18%	53.83	66,381
B	10194	8.90%	66.74	680,370
C	3211	11.14%	83.56	268,277
D	578	12.70%	95.22	55,012
Total	15215			$1,070,040

B. Increase in the Annual Insurance Premium for Present Citrus Acreage.

	Total Land (acres)	Additional Cost ($/acre)	Additional Cost ($/year)
Expected	1233	12.91	$15,923
Maximum	1233	66.74	$82,304

C. Annual Crop Insurance Costs for Future Citrus Acreage. *

Classification Type	Acreages	Insurance Rates	Insurance Premium ($)
A	617	7.18%	33,191
B	5097	8.90%	340,185
C	1605	11.14%	134,139
D	289	12.70%	27,506
Total	7608		$535,020

B. Increase in the Annual Insurance Premium for Estimated Future Citrus Acreage.

	Total Land (acres)	Additional Cost ($/acre)	Additional Cost ($/year)
Expected	617	12.91	$7,962
Maximum	617	66.74	$41,152

* The future citrus acreage is estimated using the 50% reduction of agricultural acreage over time shown in Table 6-13.

freeze damage. For certain weather patterns, proximity to Lake Apopka could be more detrimental than beneficial to citrus trees if the lake causes localized high daily minimum temperatures prior to hard freeze events.

A study needs to be performed that compares the pre- and post- freeze condition of the citrus groves situated next to Lake Apopka. A survey of the grove conditions before and after the December 1985 freeze would be ideal since many of the groves in the region were severely damaged. This study would at least partially determine the effect the lake has on tree damage caused by freeze events, and it could be used to assess the marginal impact of a reduction in the lake stage.

The cost of additional freeze damage to trees caused by lowering the lake stage can be assessed from the information found in studies by Muraro (1982,1985). An example of the cost of rehabilitating an acre of Hamlin Orange trees that have been cut back to the main trunk is presented in Table 6-17. Muraro has also calculated the ten year cash flow patterns for groves with interest and solidset replanting scenarios.

6.9 Recreational Benefits

6.9.1 The Central Florida Setting

The Florida Department of Natural Resources (1987) estimated statewide freshwater-based recreation to be approximately 47 million user-occasions in 1985. By 1995 this value is expected to exceed 55 million, an increase of nearly 20 percent. Freshwater recreational activity for 1985 and 1995 (projected) for Florida's 11 planning regions is shown in Table 6-18 and Figure 6-5. Region 6 is responsible for the largest percentage of the state's freshwater recreation and is expected to experience the largest increase by 1995. Lake Apopka is located in Orange and Lake Counties which are a subset of Region 6. These two counties combined account for over half of the recreational activity of Region 6.

Recently, the areas in geographic proximity to Lake Apopka are growing nearly as fast or faster than the state. Orlando and Ocala, urban areas on either side of Lake Apopka, are two of Florida's major growth centers. With the continued intensive population growth, the region between Ocala and Orlando is expected to become increasingly urbanized.

As regional population increases, pressure on local recreational facilities is heightened. Given Lake Apopka's size and location, coupled with Florida's thriving recreation industry and central Florida's intensive population growth and land use change, its potential role as a recreational resource is quite significant. This section estimates Lake Apopka's present and potential recreational value. The rationale behind the choice of method, data utilized, and the model for the estimates are presented.

Table 6-17. Cost of Rehabilitating Orange Grove Over Ten-Years (Muraro 1985).

"BUCKHORN" HAMLIN ORANGE GROVE — IRRIGATED

SCHEDULE OF CASH BUDGET ANALYSIS

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
ADJUSTED GROSS REVENUE	0	486	788	1200	1496	1535	1639	1605	1576	1553
OPERATING EXPENSES:										
COST TO "BUCKHORN" DAMAGED TREES	193	0	0	0	0	0	0	0	0	0
COST TO REMOVE TREES OR BRUSH	102	13	13	14	15	15	24	25	27	28
GROVE CARE COSTS	276	357	485	509	535	562	590	619	650	683
YOUNG TREE CARE - RESETS	0	13	20	28	38	40	42	44	47	49
- INTER-SOLIDSET	0	0	0	0	0	0	0	0	0	0
PLANT RESET/INTER-SOLIDSET TREES	0	14	14	15	16	17	17	18	19	20
PROPERTY TAXES	13	19	25	31	38	39	41	43	46	48
TOTAL OPERATING EXPENSE	390	415	557	598	641	673	715	751	788	828
NET OPERATING INCOME	-390	71	231	602	855	861	924	854	788	725
LESS: INSTALL IRRIGATION SYSTEM	800	0	0	0	0	0	0	0	0	0
ANNUAL NET CASH FLOW	-1190	71	231	602	855	861	924	854	788	725
ACCUMULATIVE NET CASH FLOW	-1190	-1118	-887	-286	569	1431	2355	3209	3996	4721

SCHEDULE OF GROVE DESCRIPTION, ACREAGE AND FRUIT PRODUCTION

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
TOTAL GROVE ACRES	1	1	1	1	1	1	1	1	1	1
TOTAL PLANTED ACRES	1	1	1	1	1	1	1	1	1	1
"BUCKHORN" TREES PER ACRE	70	68	66	64	62	60	58	56	54	52
INTERSET/SOLIDSET TREES PER ACRE	0	0	0	0	0	0	0	0	0	0
TREES LOST (REMOVED) PER YEAR	2	2	2	2	2	2	2	2	2	2
TOTAL BOXES FROM "BUCKHORN" TREES	0	68	116	192	264	300	319	308	297	286
TOTAL BOXES FROM INTERSET/SOLIDSET	0	0	0	0	0	0	0	0	0	0
TOTAL BOXES FROM RESET TREES	0	0	0	1	3	6	11	18	26	36
TOTAL BOXES PER ACRE	0	68	116	193	267	306	330	326	323	322

AVERAGE YIELD PER TREE:	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
"BUCKHORN" TREES	0.00	1.00	1.75	3.00	4.25	5.00	5.50	5.50	5.50	5.5
RESET AND INTERSET/SOLIDSET TREES	0.00	0.00	0.50	1.00	1.60	2.50	3.30	4.25	4.75	5.5

Table 6-18. Freshwater Recreational Activity in Florida Planning Regions, 1985 and 1995 Projections.

Planning Region	1000's of User-Occasions 1985	1995
1	2658	3016
2	1119	1285
3	2651	2939
4	3423	3854
5	2110	2746
6	8604	10587
7	4430	5223
8	6323	7513
9	3293	4325
10	4116	5283
11	7833	8618
State Total	46560	55389
Region 6 % of Total	18%	19%
Orange and Lake Counties		
% of Region 6 Total	52%	52%
Total user occasions	4474	5505
Total population	669	900
Visits/capita	6.69	6.12

Sources: Florida Department of Natural Resources (1987)
Bureau of Business and Economic Research (1989)

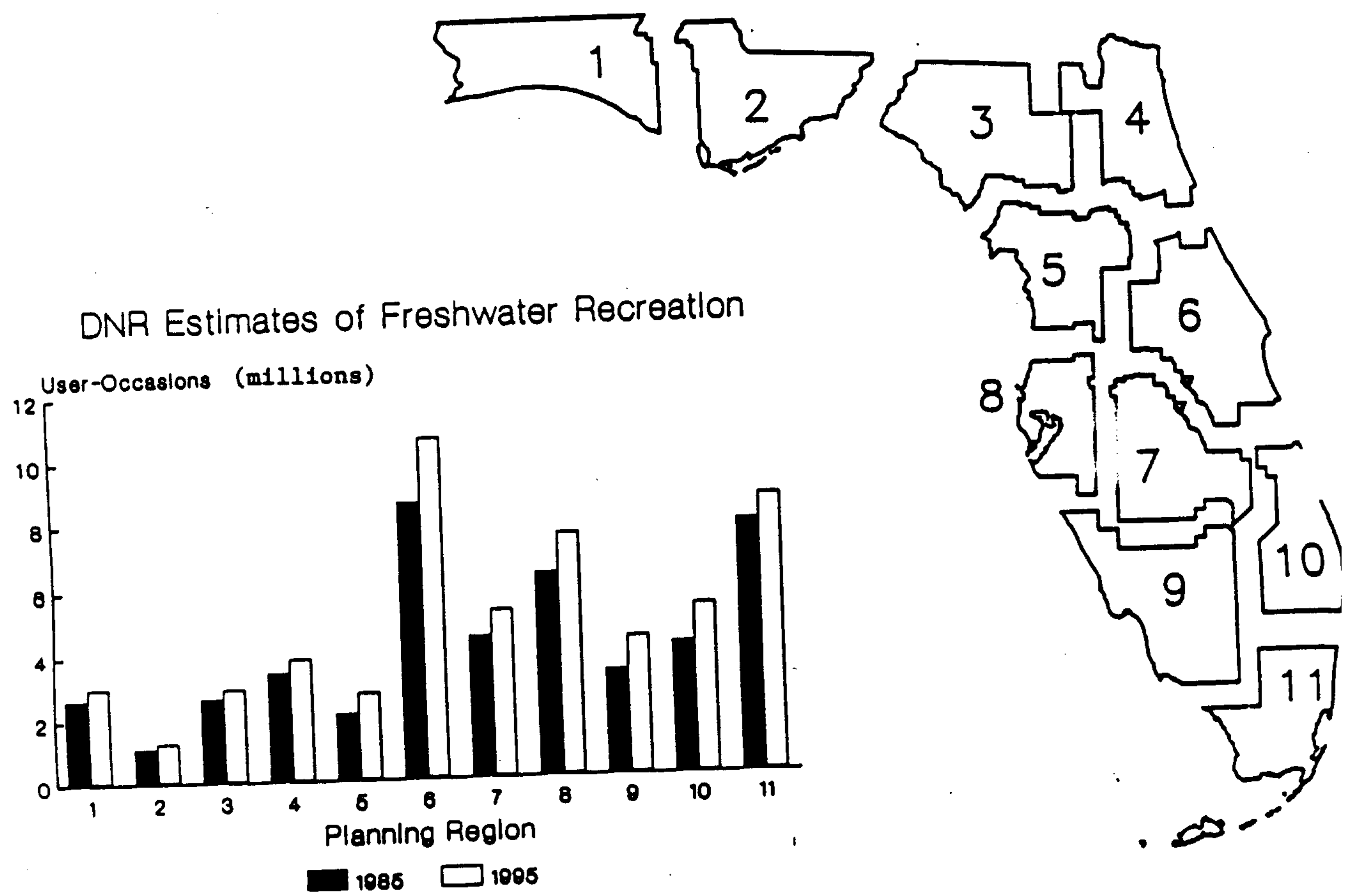


Figure 6-5. Florida Planning Districts.

6.9.2 Choice of Valuation Method

Considerable effort has been placed on development of methodologies and models to estimate recreational benefits. The literature has been searched, reviewing the contemporary works on benefit assessment methodology and applications with emphasis on Florida. Theoretical and methodological issues were presented in Chapter 5.

The federal government's recommended methodological decision-making scheme illustrates why the unit-day value method was selected for this study. A regional recreation model is not available, nor is specialized recreation being considered. Total annual visits are estimated to be below 750,000 (this will be discussed in more detail later). Finally, though precise cost information is not known, recreation costs are not expected to exceed 25 percent of the total project cost. Given the above set of decisions, unit-day valuation was chosen as the method employed in this study.

6.9.3 Estimation of Recreational Activity at Lake Apopka

The following equation is used to calculate the total recreational value of Lake Apopka by unit-day valuation:

$$TV_t = \sum_{i=1}^{n} a_{it} v_i \qquad (6\text{-}1)$$

where:

TV_t = total recreational value at site in dollars for time period t,

a_{it} = participation of activity i in user-days during time period t,

v_i = unit-value of activity i in dollars per user-day, and

n = number of recreational activities at site.

Actual present usage is based upon direct measurement of the number of boats entering Lake Apopka from Magnolia Park by Orange County Parks and Recreation Department, and the Apopka-Beauclair Canal Lock by the St. Johns River Water Management District. The estimated present potential use if the lake was not degraded is based upon proration of water-based recreation activity to facilities in the two-county region. This method employs data from the Florida Department of Natural Resources.

6.9.3.1 Present Usage

The Lake Apopka region was visited in order to secure information regarding recreational activity associated with the lake. Informal, open-ended interviews, spot recreation counts, boat traffic count data, and lock and dam passage data were obtained.

City officials from Winter Garden offered general concern because Lake Apopka "used to be" such a great recreational resource during the 1950s. A very crude estimate of 100 recreationists per day was given, but there used to be a level of activity where one could "barely find room to fish on the lake." The Winter Garden City Park adjacent to Lake Apopka is well maintained and is a popular recreational resource. The city's Fourth of July celebration attracts 15-20 thousand people to the park, but "no one goes in the water." The park used to house a marina with about 25 covered boat slips which were leased out. Boat rentals and repair services, and a concession stand were located at the park when activity on the lake was significant, but have since then closed.

A commercial fisherman who has been fishing in Lake Apopka since the 1950's asserted that his fish catch has not suffered in the least. He maintains that the "negative PR" associated with the lake is the "big problem." He catches 2-10 thousand pounds of catfish each week, serving customers in South Carolina, Jacksonville, Orlando, and other areas in Florida. Two years ago he generated over $800,000 in revenue. He gave a crude estimate of about 100 people on the lake per day during the week and 150 during the weekend. He also estimated that about 50 commercial fisherman use the lake at some stage during the year.

The Orange County Parks and Recreation Department maintains Magnolia Park which is located on the eastern edge of Lake Apopka. The park offers camping, fishing, boating, playground equipment, grills, and hiking trails. The park ranger makes daily counts on the number of trailers at the boat dock. Counts are made at about 9:00 a.m. and 3:00 p.m. Special attention is put forth to avoid double counting of trailers present for both counts. The boat ramp is open 24 hours; consequently, the counts are likely to be biased downward because of early morning and evening fishing. This speculative bias was supported by the county park ranger who lives on site.

The count data for Magnolia Park are shown in the top graph in Figure 6-6. Days of no usage occur on several occasions, while one day in 1981, over 80 boats used the ramp. The variance is fairly small and constant, though some dispersed counts occurred in 1981, 1987 and 1988. The daily average for the years 1981 to 1988 is shown in Figure 6-7. It has remained fairly constant ranging between 10 and just over 15 boats per day. The averages by day of week shown in Figure 6-8 are unexpectedly constant as well, ranging between 12 and 15 boats per day. Though Sunday and Saturday are the days with the highest levels of activity, the difference between weekends and weekdays was anticipated to be more pronounced. Monthly usage is shown in Figure 6-9. More activity occurs in the spring and fall, while lower levels exist in the winter and summer. The range is still only 9 to 15 boats per day.

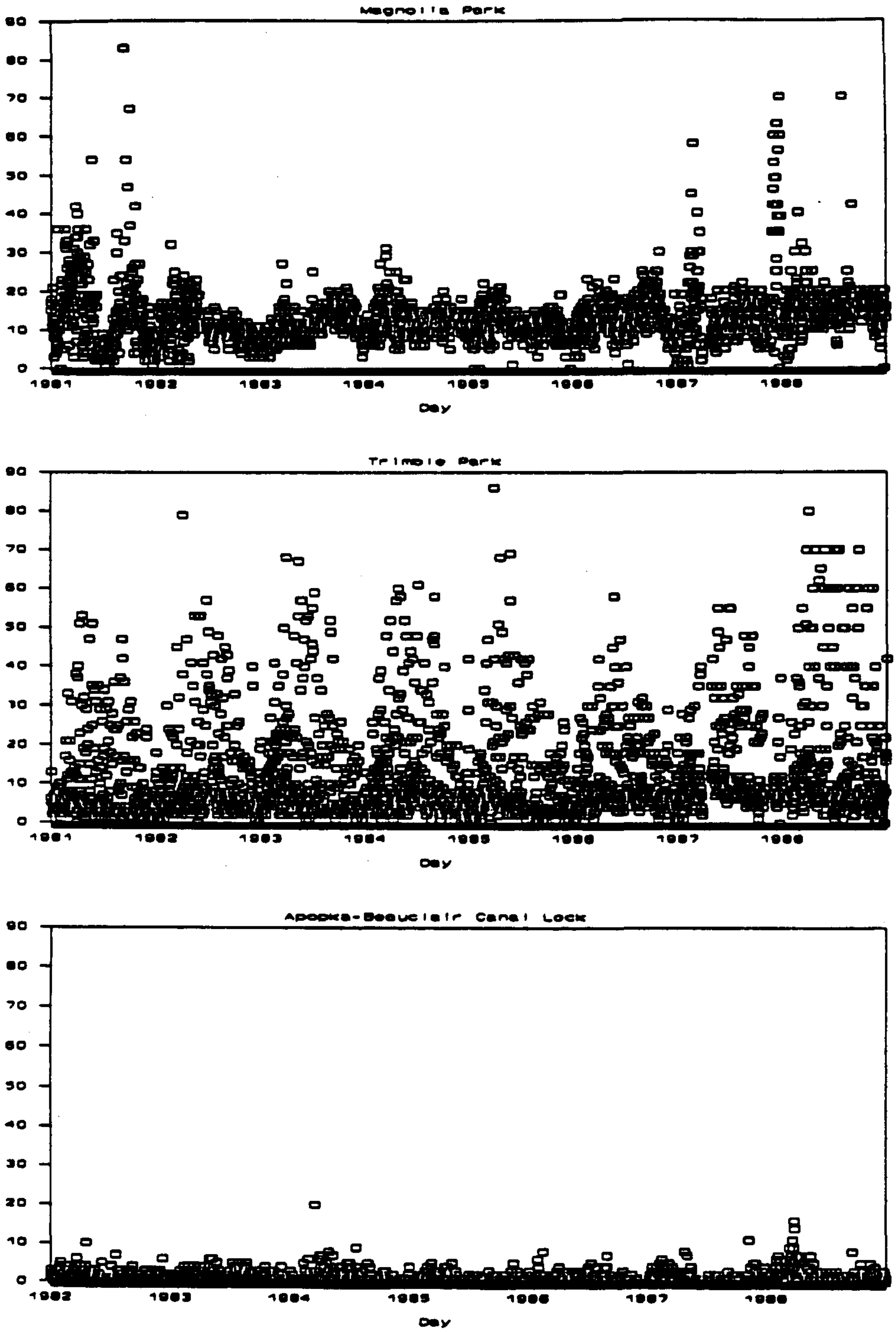


Figure 6-6. Daily Boat Count, Number of Boats Per Day.

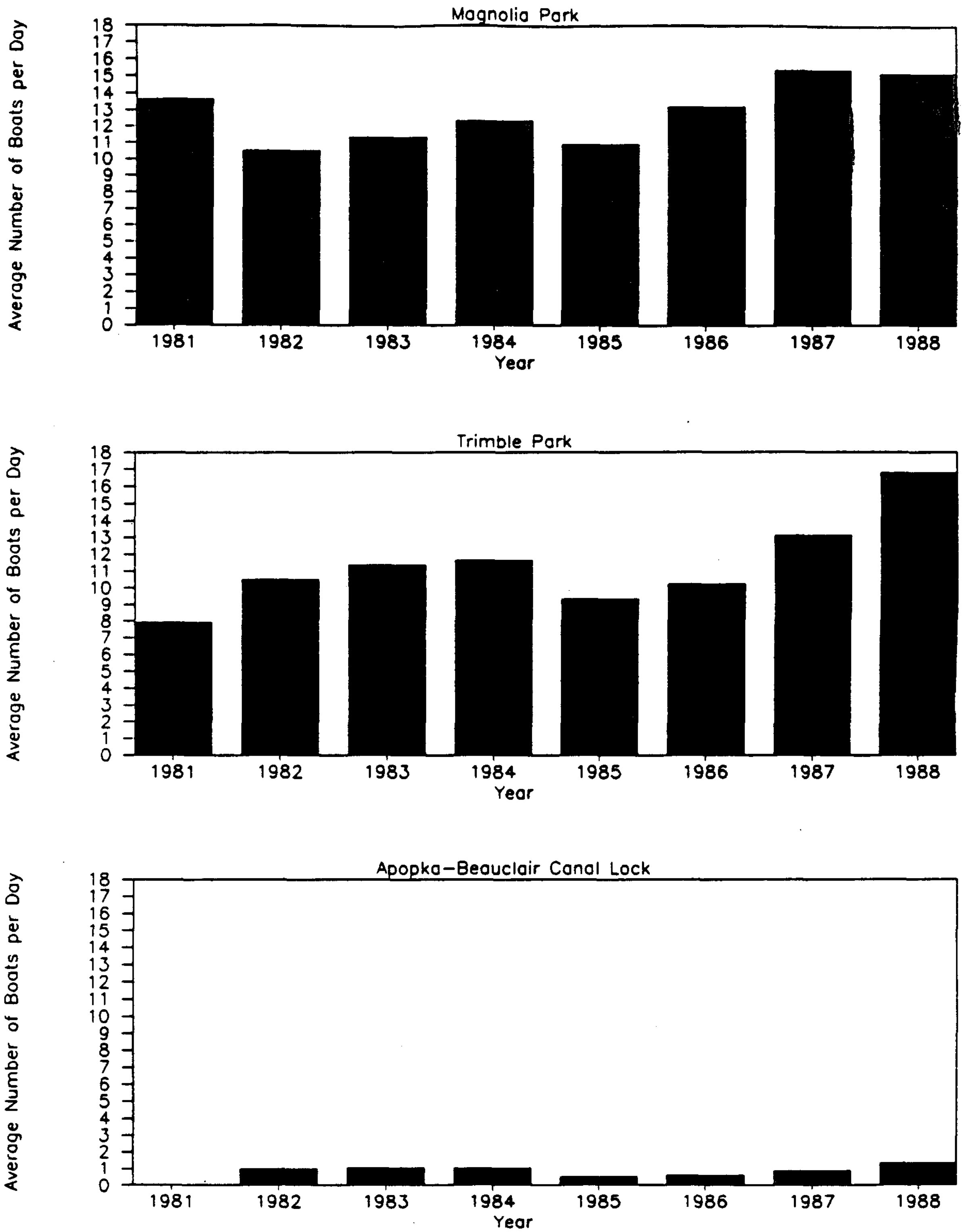


Figure 6-7. Average Daily Boat Count by Year.

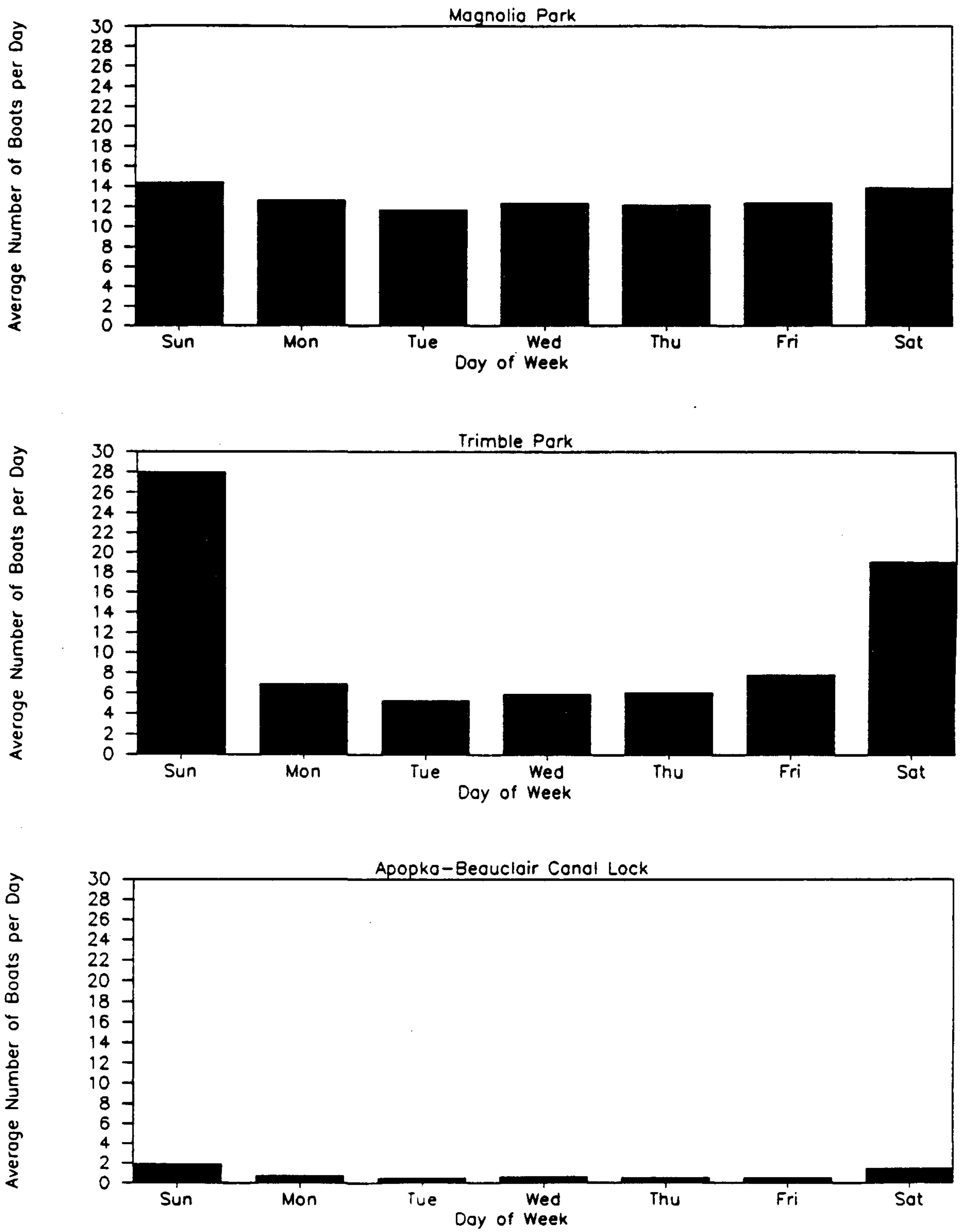


Figure 6-8. Average Daily Boat Count by Day of Week.

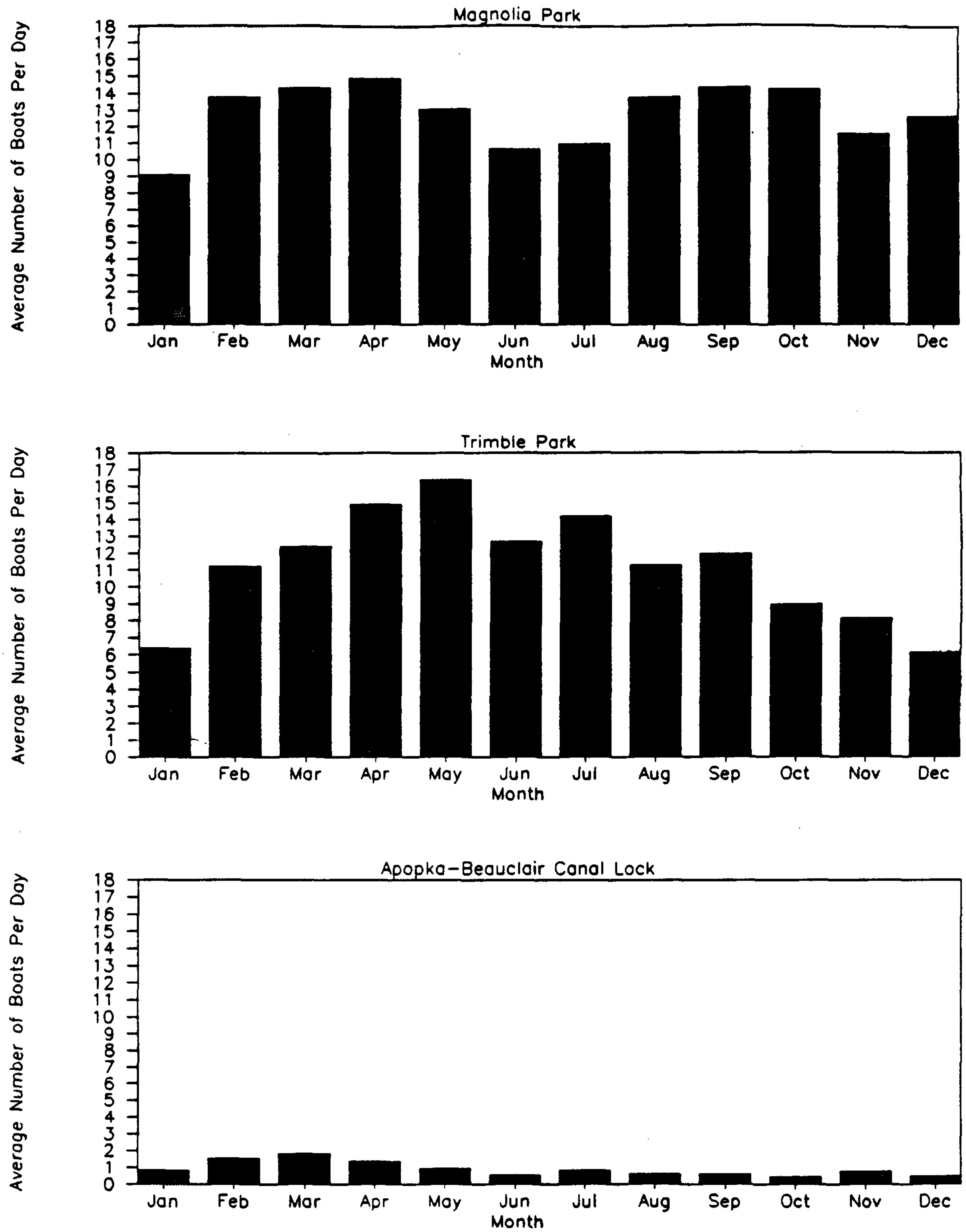


Figure 6-9. Average Daily Boat Count by Month.

Trimble Park, also maintained by the Orange County Parks and Recreation Department, is located directly downstream of Lake Apopka. The park is situated between Lakes Beauclair and Carlton, and offers camping, fishing, boating, playground equipment, grills, and hiking trails. Daily boat counts are also made at this park. The ramp is only accessible during the park hours of 8 a.m. to 6 p.m. in the winter and 8 a.m. to 8 p.m. in the summer. Thus, the bias which is expected in the Magnolia Park counts is likely to be absent. Though Trimble Park is not located on Lake Apopka, analysis of activity at this park provides useful comparative information regarding recreation in the region.

The count data for Trimble Park are shown in the center graph in Figure 6-6. Days of no usage occur on several occasions, while nearly 80 boats per day used the ramp on some days in 1982, 1985 and 1988. The variance is much larger as compared to Magnolia Park. The daily average for the years 1981 to 1988 is shown in Figure 6-7. Except for small decreases in 1984 and 1985, the average daily usage has been increasing. In fact, since 1981 usage has doubled to the 1988 average daily rate of approximately 16 boats per day. The averages by day of week shown in Figure 6-8,indicate a very significant increase weekend usage as compared to the weekday. The average on Sunday is nearly 28 boats per day while the highest weekday usage rate is 8 boats per day. Daily counts by month are shown in Figure 6-9. The winter is the slow season, gradually picking up in February to t e annual peak in May of 16 boats per day. The second highest eak occurs in July at about 15 boats per day. A slight rise is experienced in September apparently mimicking the fall season increase as found at Magnolia.

The lock at the Apopka-Beauclair Canal is operated by the St. Johns River Water Management District. The following data are collected for each boat passing through the lock: date, time, type of boat, origin, destination, number of passengers, and boat license number.

The number of boats passing the lock is insignificant compared to the boat counts at Trimble and Magnolia Parks. Many days there are no passages. The daily peak value of 20 occurred in 1984. The daily passages for 1982 to 1988 are shown in the bottom graph in Figure 6-6. The mean daily averages for those years are shown in Figure 6-7. Mean passages have stayed between 0.5 and 1.3 per day. A weekend day gets approximately double that of the weekday as shown in Figure 6-8. The daily means by month shown in Figure 6-9 reveal March as the busiest month with an average of 2 passages per day.

Though the dataset collected at the lock may not be highly significant to this particular study, these types of data need to be collected to evaluate the recreational value of Lake Apopka. Knowing the origin of the recreationists, the duration of their stay, and the time of day are very important variables for an accurate recreation valuation study. It is interesting that 3 of 4 boats passing through the locks are coming from some other lake or waterway to visit Lake Apopka. Just over half of those boats visiting Lake Apopka come from the ramp at Route 448. Boaters from Lakes Dora, Eustis, Harris, and Griffin consist of 15%, 8%, 7%, and 1%, respectively, of those visiting Lake Apopka. The average number of persons per boat is 2.63.

The number of boats is assumed to encompass all recreational activity at Lake Apopka. Three main points of entry exist at Lake Apopka: Magnolia Park, City Park at Winter Garden, and the city boat ramp at MonteVerde. Based upon field observations the City Park at Winter Garden is assumed to get the same level of activity as Magnolia Park, which in 1988 was an average of 15.2 boats per day. It is further assumed that the MonteVerde boat ramp receives about half that of Magnolia Park. These assumptions are based upon very limited exposure to the actual activity in the area, but represent the most realistic estimate that can be made at this time. Present usage is estimated as the sum of the average daily count at the three ramps and the average daily passage through the lock, or 15.2 + 15.2 + 7.1 + 1.3 = 38.8 boats per day. Multiplying the boats per day value by the average number of persons per boat (2.63) gives 102 recreationists per day. This value compares favorably with the estimates made by the Winter Garden city official and the commercial fisherman. Thus, the annual activity estimate based upon direct counts is 37,230 user-occasions.

6.9.3.1 <u>Present Potential Usage</u>

The purpose of this section is to estimate the present direct recreational use if the lake was not degraded. Earlier in this chapter, information was presented on how the number of fish camps in the area increased to a peak of 21 in 1956 and then declined rapidly as the lake quality deteriorated to the point where only one fish camp remains in spite of the fact that the population of Lake and Orange counties has increased from about 240,000 in 1955 to approximately 800,000 at present, an increase of about 330 %. Using this criterion, the lake's fishing value is less than 10 percent of its potential. Unfortunately, statistics are not available on the amount of activity at fish camps. Thus, this measure gives only a very rough approximation of the impact of the degraded lake on fishing.

The method of estimating potential present recreational activity is based upon Florida Department of Natural Resources supply and demand data. Referring to equation 6-1, annual values will be examined making $t = 1$ represent year 1. For freshwater-based recreation, $n = 5$, and the recreation types, $i = 1$ to 5, are represented as follows:

1 = freshwater beach
2 = freshwater boat fishing
3 = freshwater non-boat fishing
4 = other freshwater boating
5 = canoeing

These five recreation types were selected from the 26 types included in the Department of Natural Resources (DNR), Division of Parks and Recreation annual recreation survey (DNR 1987).

Following Bell (1986), the method employed assumes that a given subregion receives an equal percentage of recreational activity as it provides in terms of percentage of recreational facilities to the region as a whole. So, if a subregion provides 10 percent of the regional recreational facilities, then it is assumed to receive 10 percent of the regional recreational activity. In this case, Lake and Orange Counties are the region and Lake Apopka is the subregion.

Activity data are available at the county level; thus recreational activity in Orange and Lake Counties is analyzed. Tourist and resident participation data for each of the five activities for both counties are shown in Table 6-19. The grand total for the two counties is 4,467,000 user-occasions.

The DNR also surveys the supply of recreation facilities in these two counties. Their survey includes facilities maintained by federal and state governments, county and municipal governments, private-commercial, private- nonprofit, and private-club. Thousands of acres of privately-owned land and water which provide recreational opportunities in an "unofficial" manner are not included in the survey because of the difficulty in identifying them with a proper degree of specificity. Such facilities include private swimming pools, private boat docks, apartment complex tennis courts, etc. The water-related recreational supply measures for Orange and Lake Counties are shown in Table 6-20. Lake Apopka's share of recreation supply for each measure is given.

The supply table lists site area count and size which include all types of recreation areas. Though Lake Apopka comprises a subset of these aggregate values, its percentage is not representative of actual recreation supply. Lake acreage is also given. Lake Apopka is 18% of the total lake area of Orange and Lake Counties. It is unrealistic to assume 18% of the recreational activity in the area takes place at Lake Apopka. Consequently, boat ramp count is selected as the most accurate supply measure for Lake Apopka.

Table 6-19. Water-Based Recreational User Occasions in Orange and Lake Counties of Florida, 1000s of User-Occasions, 1985.

Activity	Lake County Res.	Lake County Tour't	Lake County Total	Orange County Res.	Orange County Tour't	Orange County Total	Two-County Total
Beach	103	92	195	482	740	1,222	1,416
Boat Fishing	403	228	631	351	201	552	1,183
Shore Fishing	294	88	382	147	74	221	603
Boat Ramp	291	262	553	208	250	458	1,011
Canoeing	109	9	118	44	92	136	254
				Grand Total ====>			4,467

Source: Florida Department of Natural Resources (1987)

Table 6-20. Water-Based Recreation Supply for Lake Apopka, 1985*.

Recreational Supply Measure	Orange County	Lake County	Two-Cnty Total	Lake Apopka	Percent L. Apopka
Site Areas[1] (count)	305	219	524	5	0.95
Site Area[1] (acres)	3414	23393	26807	67.[illegible]	0.25
Beach Areas (count)	36	28	64	0	0.00
Beach Area (sq ft)	303900	858855	1162755	0	0.00
Beach Length (miles)	1.5	2.3	3.8	0	0.00
Boat Ramps (count)	43	83	126	5	3.97
Marinas (count)	7	53	60	0	0.00
Canoe Trails (miles)	13.5	16.4	29.9	0	0.00
Lake Area[2] (acres)	77735	91508	169243	30671	18.12

Source: Florida Department of Natural Resources (1987)

1/includes areas of all types of recreational activity
2/source: Shafer et al. (1986)

* Excludes recreation in privately owned areas.

The method employed in this analysis does not allow quantification of demand shifts to accurately derive potential recreation value. Therefore, the potential value of Lake Apopka is based upon a comparative analysis of a site considered to provide above average freshwater recreational opportunities.

Lake Harris, located approximately 10 miles northwest of Lake Apopka in Lake County, is considered an excellent freshwater recreational resource and is used as the benchmark site. It is also a likely choice because its size and proximity allow the assumption of a similar recreation market.

The number of boat ramps is assumed to be an indicator of site usage. The average length of shoreline between each boat ramp is 7560 feet at Lake Harris. Based upon this boat ramp occurrence rate, the potential number of boat ramps for Lake Apopka is 11 (this considers only the 82,680 feet of non-muck farm perimeter of Lake Apopka) which is more than twice the actual number of boat ramps at Lake Apopka. This is 8.7 percent of the boat ramp supply which is assumed to service 8.7 percent of the shore fishing, boat fishing and boat ramp activity in the two-county region. Thus, the potential present fishing activity in lake Apopka is 242,600 user-occasions per year, or 665 users per day, over six times its present use.

In Lake Apopka's present state; swimming is not considered to be a recreational option. Its potential though as a freshwater swimming site can be calculated as was recreational fishing. There are 64 freshwater beach areas in Orange and Lake Counties (see Table 6-21). One beach area of the 64, or 1.6% of the total, is located at Lake Harris. Annually, 1.41 million freshwater beach user-occasions take place in the two counties (see Table 6-19). Assuming 1.6% of the user-occasions occur at Lake Harris, the potential annual beach usage for Lake Apopka is 22,700 user-occasions. The sum of beach usage and fishing activity, 265,300 annual user-occasions, is the estimated potential recreational activity value for Lake Apopka.

Dividing through by days in a year and potential number of ramps reveals a daily ramp usage value of 66 user-occasions per day. This appears to be a reasonable value given that Magnolia Park services about 40 persons per day in its present state (see section 6.9.3.1). DNR (1987) recommends an upper limit of 108 user-occasions per day. The potential value of 66 user-occasions per day is about 60% of the recommended peak which is within a plausible range of accuracy.

6.9.4 Unit-Day Value Estimation Model.

The unit-day value (v_i) is assumed to be equal for all pertinent recreational activities. This assumption follows the discussion in the P and G (1983) of unit-day valuation for "general recreation".

The point system recommended in the P and G to generate the unit-day value is used. By nature, a point system introduces subjectivity; consequently, it is necessary to carefully track and account for how the point-generated unit-day value is derived. A computer model was developed which provides a summary of each valuation session, thus allowing for subsequent comparison and adjustment. The model allows the analyst to select the most appropriate condition for the following criteria: recreation experience, availability of opportunity, carrying capacity, accessibility, and environmental quality. Each condition is associated with a range of points as shown in Table 6-21. Input to the model is the set of conditions chosen, high and low points for each component are tallied. Then corresponding 1987 dollar values are assigned to the sum of the high and low points for all the components. The mean of the high and low estimates is the final estimate of unit-day value. An output summary table and graph displaying conditions selected is produced.

Once logged-on to Lotus 1-2-3, retrieve the file in which the model named "REC_MOD.WK1" is stored. The title banner should be the first screen. If not, hit the home key to begin the model. Continue through the model by following the provided instructions, placing an "x" by the selection which best describes the site conditions for each criteria.

The first criterion evaluated represents the recreation experience provided by the site. It is a measure of the number of its recreational opportunities. If a wide variety of recreation is available at the site, a high score is assigned, and vice-versa. The choices for this component are shown in Figure 6-10.

The second criterion, availability of opportunity, is a measure of the supply of recreational activity in the area. If many recreational sites are located in the region, then a low score is given. If relatively few are available, then a higher score is given. The choices for this component are shown in Figure 6-11. The temporal indicators referred to in the choice range are driving times to the site.

Choices for the criterion which assesses carrying capacity for a site are shown in Figure 6-12. This measure accounts for the recreational facility development at the site. A site equipped with the optimal quantity of facilities to suit the demand for the site is assigned high points, and sites with facilities marginally satisfactory in meeting public health and safety standards receive low points.

The accessibility component measures ease of travel to, from and within the site. Low access sites receive low points and sites which have high access and good roads receive high points. The judgment choices are shown in Figure 6-13.

Table 6-21. Point System for Unit-Day Value Assignment.

Criteria	Judgment factors				
(a) Recreation experience [1]	Two general activities [2]	Several general activities	Several general activities; one high quality value activity [3]	Several general activities; more than one high quality high activity	Numerous high quality value activities; some general activities
Total points: 30 Point value:	0–4	5–10	11–16	17–23	24–30
(b) Availability of opportunity [4]	Several within 1 hr. travel time; a few within 30 min. travel time	Several within 1 hr. travel time; none within 30 min. travel time	One or two within 1 hr. travel time; none within 45 min. travel time	None within 1 hr. travel time	None within 2 hr. travel time
Total points: 18 Point value:	0–3	4–6	7–10	11–14	15–18
(c) Carrying capacity [5]	Minimum facility development for public health and safety	Basic facilities to conduct activity(ies)	Adequate facilities to conduct without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site potential	Ultimate facilities to achieve intent of selected alternative
Total points: 14 Point value:	0–2	3–5	6–8	9–11	12–14
(d) Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good roads to site; fair access, good roads within site	Good access, high standard road to site; good access within site
Total points: 18 Point value:	0–3	4–6	7–10	11–14	15–18
(e) Environmental quality	Low esthetic factors [6] exist that significantly lower quality [7]	Average esthetic quality; factors exist that lower quality to minor degree	Above average esthetic quality; any limiting factors can be reasonably rectified	High esthetic quality; no factors exist that lower quality	Outstanding esthetic quality; no factors exist that lower quality
Total points: 20 Point value:	0–2	3–6	7–10	11–15	16–20

[1] Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.
[2] General activities include those that are common to the region and that are usually of normal quality. This includes picnicking, camping, hiking, riding, cycling, and fishing and hunting of normal quality.
[3] High quality value activities include those that are not common to the region and/or Nation and that are usually of high quality.
[4] Likelihood of success at fishing and hunting.
[5] Value should be adjusted for overuse.
[6] Major esthetic qualities to be considered include geology and topography, water, and vegetation.
[7] Factors to be considered to lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.

Figure 6-10. Recreation Experience Component for Unit-Day Value Assignment as Displayed in Model.

A) RECREATION EXPERIENCE

x<=== Two general activities.
General activities include those that are common to the region and that are usually of normal quality. This includes camping, hiking, riding, cycling, and fishing and hunting of normal quality.

<=== Several general activities.

<=== Several general and one high quality activity.
High quality activities include those which are not common to the region and/or Nation and that are usually of high quality.

<=== Several general and more than one high quality activities.

<=== Numerous high quality activities; some general activities.

Figure 6-11. Availability of Opportunity Component for Unit-Day Value Assignment as Displayed in Model.

B) AVAILABILITY OF OPPORTUNITY

x<=== Several within 1 hour travel time; a few within 1/2 hour.

<=== Several within 1 hour travel time; none within 1/2 hour.

<=== One or two with 1 hour travel time; none within 45 minutes.

<=== None within 1 hour travel time.

<=== None within 2 hours travel time.

Figure 6-12. Carrying Capacity Component for Unit-Day Value Assignment as Displayed in Model.

C) CARRYING CAPACITY
(overuse adjustments should be considered)

<=== Minimum facility development for public health & safety.

x<=== Basic facilities to conduct activity(ies).

<=== Adequate facilities to conduct without deterioration of resource or activity experience.

<=== Optimum facilities to conduct activity at site potential.

<=== Ultimate facilities to achieve intent of selected alternative.

Figure 6-13. Accessibility Component for Unit-Day Value Assignment as Displayed in Model.

D) ACCESSIBILITY

<=== Limited access by any means to site or within site.

x<=== Fair access, poor quality roads to site; limited access within site.

<=== Fair access, fair roads to site; fair access, good roads within site.

<=== Good access, good quality to site; fair access, good roads within site.

<=== Good access, high standard road to site; good access within site.

The final criterion considers the environmental quality of the site. Selections are shown in Figure 6-14. Again, a site of outstanding environmental quality will receive high points, and vice-versa.

Each of the criteria are a named range and can be accessed through the Lotus 1-2-3 "GO TO" option. A summary table of selections and corresponding unit-day values is a range named "SUMMARY". After selections are made for all the criteria, "GO TO" "SUMMARY" to view the results. A graph of the analysis can be viewed by hitting the F10 key.

6.9.5 Present User-Value for Lake Apopka.

Baseline unit-day values are derived based upon the P and G (1983), and the U.S. Forest Service estimates. The P and G unit-day value estimate for Lake Apopka is $2.33. The summary of this value assignment is shown in Table 6-22, and Figure 6-15. Explanation for the choices is as follows. Presently, two general recreational activities take place at Lake Apopka, fishing and boating. Opportunities for these activities are very high in the two-county area; therefore a low point value is issued for the availability of opportunity component. A few nice boat ramps and parks exist around the lake, which is considered "adequate" carrying capacity. There is little public access to the lake (in terms of roads or boat ramps), especially from the Lake County side. Therefore the second accessibility choice was selected. Finally, the environmental quality of the lake is low based on several criteria, e.g. the water has very low clarity, and has a history of algal blooms and fish kills.

The U.S Forest Service publishes a set of unit-day values for various recreational activities for regions throughout the U.S. (see Chapter 5). A majority of the estimates differentiate between standard quality, and less than standard quality sites. Unfortunately, only one unit-day value for fishing is provided (which is assumed for a standard quality site). Since Lake Apopka is a less than standard quality site, the percent difference in standard and less than standard quality sites for "water sports" is assumed to reflect the lower quality value for fishing. Thus, the unit-day value estimate for fishing based upon the U.S. Forest Service is $7.77 per user- occasion.

Given the present annual user-occasion estimate presented above (section 6.9.3) of 37,230, and the unit-day value estimates of $2.33 and $7.77 per user-occasion, the present annual recreational user-value estimates for Lake Apopka based upon the P & G and U.S. Forest Service are $86,700 and $289,000 respectively.

Figure 6-14. Environmental Quality Component for Unit-Day Value Assignment as Displayed in Model.

E) ENVIRONMENTAL QUALITY
(major aesthetic qualities to be considered include geology and topography, water, and vegetation)

x<=== Low aesthetic factors exist that significantly lower quality.

<=== Average aesthetic quality; factors exist that lower quality to minor degree.

<=== Above average aesthetic quality; any limiting factors can be reasonably rectified.

<=== High aesthetic quality; no factors exist that lower quality.

<=== Outstanding aesthetic quality; no factors exist that lower quality.

Table 6-22. Lake Apopka User-Value Analysis Results from P and G Based Estimate as Summarized in Model Output.

SUMMARY TABLE

Criteria Component	Possible Points	Points Assigned Based Upon Selection Made: Lower	Upper
A) Recreation Experience	30	0	4
B) Availability of Opportunity	18	0	3
C) Carrying Capacity	14	6	8
D) Accessibility	18	4	6
E) Environmental Quality	20	0	2
Unit-Day Value Estimate		$2.16	$2.49
Average of Lower and Upper Estimates			$2.33

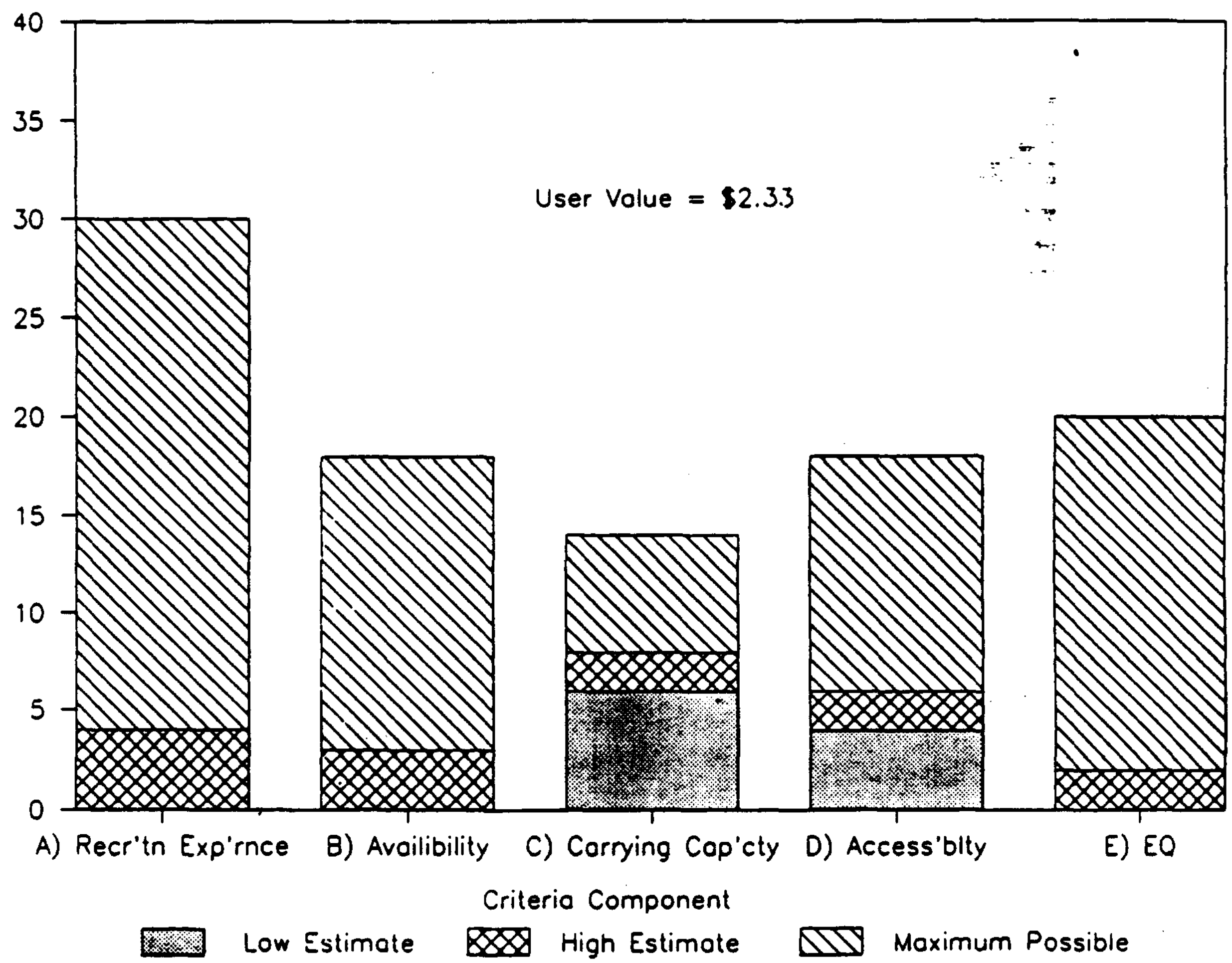


Figure 6-15. Baseline User-Value for Lake Apopka.

6.9.6 Potential Present User-Value for Lake Apopka.

Using the unit-day value estimation model, the unit-day value for Lake Harris based upon the P and G (1983) is $3.99 per user-occasion. The output summary table and graph from the model are shown in Table 6-23 and Figure 6-16. The product of the potential unit-day value and the sum of the annual usage provides an estimate of potential user-value at Lake Apopka, and is $1,061,800 per year.

The potential user-value estimate from the U.S. Forest Service values uses the standard quality value for fishing, $13.99 per user-occasion. Since beach activity is a potential use, the correct unit-value to be applied is $9.69 (see Chapter 5). Valuation for beach activity is the product of the unit-day value, $9.69, and potential beach user-occasions, 22,700, or $220,000 per year. Valuation for fishing and boating is the product of the unit-day value, $13.99, and potential fishing and boating user- occasions, 243,400, or $3,405,200 per year. The sum of the annual valuations for beach activity and fishing and boating activity, $3,625,200, is the potential recreational value for Lake Apopka.

Table 6-23. Lake Harris User-Value Analysis Results from P and G Based Estimate as Summarized in Model Output.

SUMMARY TABLE

Criteria Component	Possible Points	Points Assigned Based Upon Selection Made: Lower	Upper
A) Recreation Experience	30	11	16
B) Availability of Opportunity	18	0	3
C) Carrying Capacity	14	9	11
D) Accessibility	18	15	18
E) Environmental Quality	20	11	15
Unit-Day Value Estimate		$3.69	$4.28
Average of Lower and Upper Estimates			$3.99

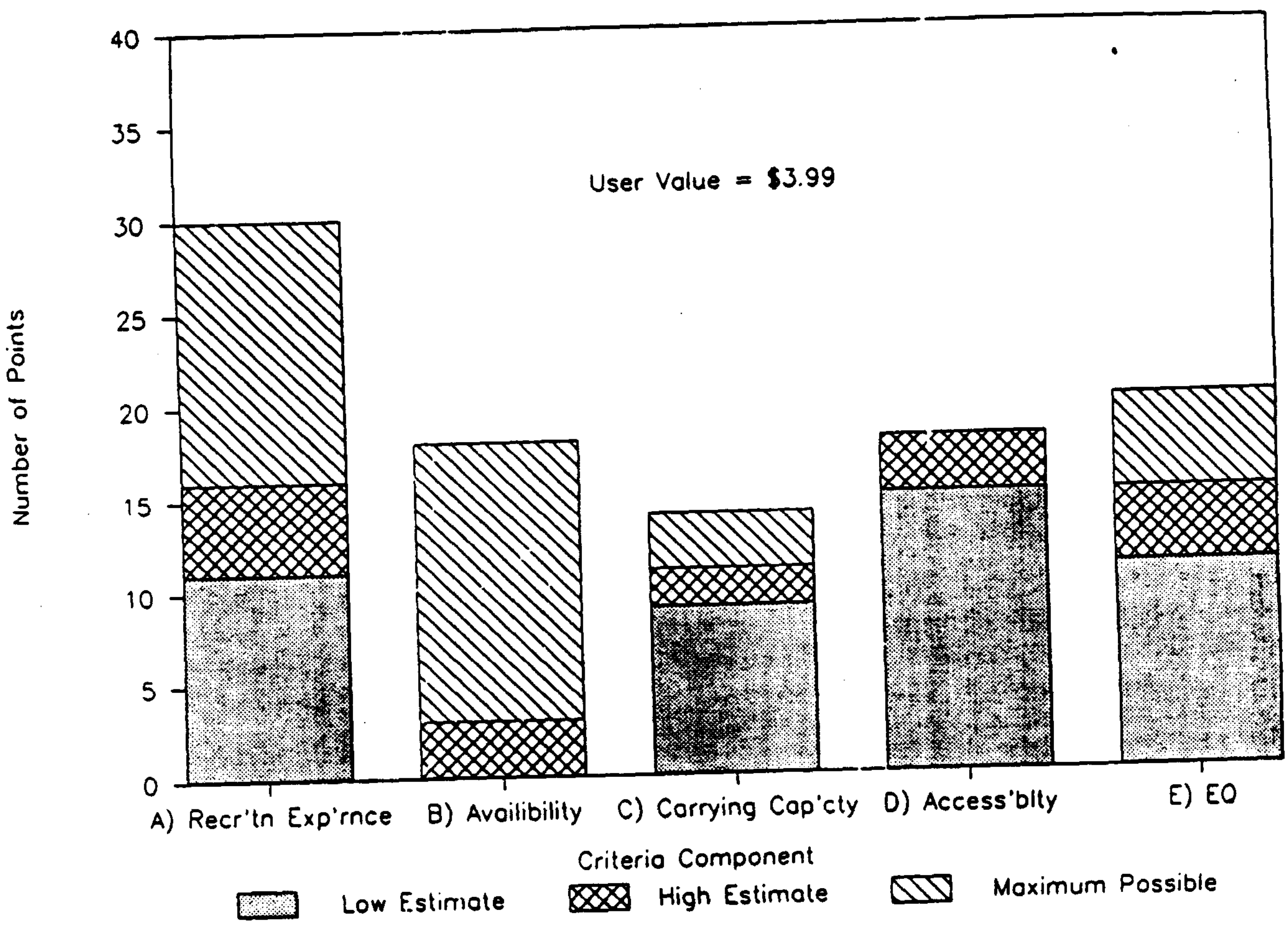


Figure 6-16. Potential User-Value for Lake Apopka

6.9.7 Summary of Present and Potential Recreational Benefits

The present and potential estimates of recreation benefits are given in Table 6-24. Present values for P and G and U.S. Forest Service based estimates are tallied in the top half of the table, and potential value derivations are shown in the bottom half. A graphical summary of all the recreation value estimates are given in Figure 6-17. Comparing the two unit-day value sources, the U.S. Forest Service estimate is more in line with some other empirically derived estimates, and is considered to be a more realistic estimate.

The baseline activity estimate based upon direct counts is 37,200 recreationists per year. The product of the P & G unit-day value of $2.33 and present usage provides an estimate of $86,676 per year. An annual value of 862,500 is derived using the U.S. Forest Service unit-day value of $7.77.

The potential value estimate is based upon Lake Apopka's share of the total freshwater-based recreation in Orange and Lake Counties if the lake were not degraded. Summation of the activity value across all activity gives a total value (see equation 6-1). Using the appropriate unit-day values for the potential activity in a undegraded Lake Apopka provides annual value of $1,061,000 for the P & G and 3,625,000 from the U.S. Forest Service.

Examining recreation over the period of 1960 to 2020 reveals that the total recreational losses (in 1989 dollars) due to impaired lake conditions was just over $1 million in 1960 but is expected to reach over $5 million by 2020. These derivations are shown in Tables 6-25 and 6-26. The values for each year were derived using the unit-day valuation method as presented in section 6.9.7 and shown in Table 6-24. Actual measurements of recreation user-occasions are given for 1980 and 1990, the remaining years are derived as a proportion of population and follow the assumptions given in the notes in Table 6-25.

Table 6-24. Summary of Present and Potential Recreational Value Estimates for Lake Apopka.

PRESENT ESTIMATE

	Direct Measure (users-occasions/year)	Unit-Day Value ($/user-occasion)	Annual Value ($)
P & G	37,200	2.33	86,800
Forest Service	37,200	7.77	289,000

POTENTIAL ESTIMATE

	Beach	Boat Fishing	Shore Fishing	Boating	Canoeing
Potential Recreational Value					
Apopkas % Activity	1.60	8.70	8.70	8.70	0
Activity (1000 User-Occasions)	22.7	102.9	52.5	88.0	0
P & G Unit-Day Value ($/User-Occasion)	3.99	3.99	3.99	3.99	3.99
P & G Activity Value ($1000/yr)	90.6	410.6	209.5	351.1	0.0
Forest Service Unit-Day Value ($/User-Occasion)	9.69	13.99	13.99	13.99	9.69
Forest Service Activity Value ($1000/yr)	220.0	1439.6	734.5	1231.1	0.0

Total Potential Recreational Value

P & G Estimate **$1,061,800**

Forest Service Estimate **$3,625,200**

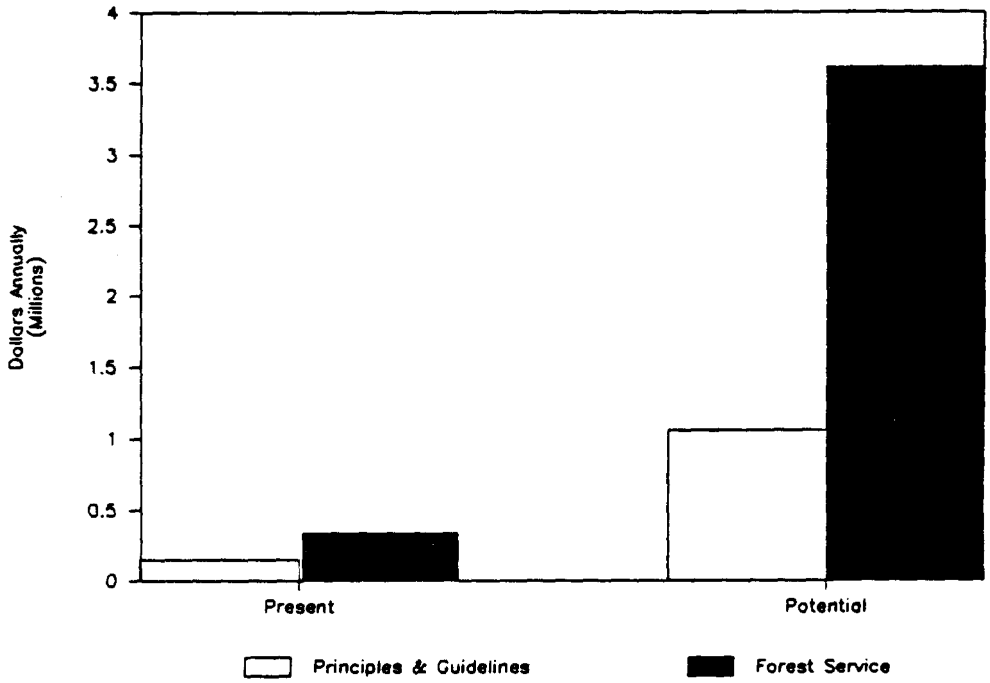


Figure 6-17. **Present and Potential Recreation Valuation for Lake Apopka.**

Table 6-25. Losses in Direct Recreation Value Due to Degraded Lake Apopka.

(1) Year	(2) Popul. 1000's	(3) Fishing & Boating Users/day Impaired Lake	(4) Fishing & Boating Users/day Clean Lake	(5) User-Value $/user Impaired Lake	(6) User-Value $/user Clean Lake	(7) Recreation value $1000 per Year Impaired Lake	(8) Recreation value $1000 per Year Clean Lake
1960	321	56	262	$7.77	$13.99	$158	$1,335
1970	414	72	337	$7.77	$13.99	$204	$1,721
1980	576	100	469	$7.77	$13.99	$284	$2,396
1990	816	100	665	$7.77	$13.99	$284	$3,396
2000	1009	124	822	$7.77	$13.99	$351	$4,199
2010	1135	139	925	$7.77	$13.99	$394	$4,723
2020	1259	154	1026	$7.77	$13.99	$438	$5,239

Year	Popul. 1000's	Swimming Users/day Impaired Lake	Swimming Users/day Clean Lake	User-Value $/user Impaired Lake	User-Value $/user Clean Lake	Recreation value $1000 per Year Impaired Lake	Recreation value $1000 per Year Clean Lake
1960	321	5	24	$5.38	$9.69	$10	$86
1970	414	0	31	$5.38	$9.69	$0	$111
1980	576	0	44	$5.38	$9.69	$0	$155
1990	816	0	62	$5.38	$9.69	$0	$219
2000	1009	0	77	$5.38	$9.69	$0	$271
2010	1135	0	86	$5.38	$9.69	$0	$305
2020	1259	0	96	$5.38	$9.69	$0	$338

(1) Census year.
(2) Census and median projected population of Lake and Orange counties in 1000's.
(3) Based on estimated activity levels for 1980 and 1990. Values for other years prorated based upon population.
(4) Based on estimated activity level for 1990. Values for other years prorated based upon population.
(5) Based on U.S. Forest Service estimate for low quality recreation.
(6) Based on U.S. Forest Service estimate for high quality recreation.
(7) Column (3)*Column (5).
(8) Column (4)*Column (6).

Table 6-26. Summary of Losses in Direct Recreation Value Due to Degraded Lake Apopka.

Year	Pop 1000's	Fishing & Boating $1000/ year Impaired Lake	Clean Lake	Swimming $1000/ year Impaired Lake	Clean Lake	Total Recreation Value, $1000/yr Impaired Lake	Clean Lake	Total Losses $1000/yr
1960	321	$158	$1,335	$10	$86	$168	$1,422	$1,253
1970	414	$204	$1,721	$0	$111	$204	$1,832	$1,629
1980	576	$284	$2,396	$0	$155	$284	$2,551	$2,267
1990	816	$284	$3,396	$0	$219	$284	$3,615	$3,331
2000	1009	$351	$4,199	$0	$271	$351	$4,470	$4,119
2010	1135	$394	$4,723	$0	$305	$394	$5,028	$4,634
2020	1259	$438	$5,239	$0	$338	$438	$5,578	$5,140

Estimates of present and potential recreational user-value of Lake Apopka were derived using unit-day values from the P and G (1983) and U.S. Forest Service (1985) (see Figure 6-17). Both estimates reveal an increase of approximately 300 percent if the quality of recreational experience at Lake Apopka were enhanced to a "standard" or "good" level. Physical characteristics associated with "standard" quality are beyond the scope of this study. Suggested recreation guidelines are provided by DNR (1987).

Also, unit-day values of consumer surplus to be lower than those values derived by the contingent valuation and travel-cost methods. An example is Gibbs (1973) estimated $31.71 (1987 $) for a day of recreation on the Kissimmee River in Florida which is more than double the highest daily value used in this analysis.

Another reason these estimates should be considered conservative is that the benefits to downstream lakes were not analyzed. The poor water quality of Lake Apopka adversely affects the quality of downstream lakes (Florida Department of Environmental Regulation, 1977). Subsequent enhanced recreational values provided by improvement of water quality at Lake Apopka should provide similar enhancement for Lakes Beauclaire, Dora, and Eustis. The added recreational value to these downstream lakes could be added to the baseline and potential benefit totals.

The present and potential estimates have been derived using the simplest method recommended by the federal government. Application of the results should be undertaken only with the full understanding of the assumptions of the model as discussed in Chapter 5.

The provided recreation valuation of Lake Apopka is a best estimate. Given the resource constraints of study, use of secondary data was required. Compilation of results, and analysis of other recreation studies provided data for the recreational database, which was drawn upon for this analysis. The DNR is the best secondary source of recreational data in the state, and the method employed is recommended by the federal government.

Given the enormous recreational potential of the central Florida region, a detailed analysis of recreation valuation is recommended.

6.9.8 <u>Recreational Benefits of Lake Management Alternatives</u>.

6.9.8.1 <u>Effectiveness of Other Lake Restoration Efforts</u>.

Dierberg, Williams, and Schneider (1988) have evaluated 43 Florida lakes to determine the impacts on water quality following one or more restoration practices. Of the 43 lakes, only 7 had enough data to draw conclusions. Three of the lakes - Griffin, Kissimmee, and Tohopekaliga - were treated by drawdown. Lake Howell benefited from sewage diversion. Megginnis Arm of Lake Jackson used a detention-filtration wetland treatment system to control urban runoff. Lakes Wildmere and Sybelia were stocked with grass carp. Lake Tohopekaliga also benefited from reduced sewage discharges over the period from 1980 to 1985.

6.9.8.2 Present Value of Future Benefits.

In order to have statistical evidence of the effectiveness of one or more controls, it is necessary to have sufficient data both before and after the control(s) are implemented. For example, the average Trophic State Index (TSI) for the Meginnis Arm of Lake Jackson for the period from 1978 to 1987 is shown in Figure 6-18. The control system was installed in 1982-1983. The primary improvement was in Secchi depth. However, chlorophyll or nutrient concentrations did not improve significantly.

Because of the relatively long detention times in lakes, i.e., months to years, these systems will respond slowly to improvements. This is particularly the case for Lake Apopka with its significant benthal deposits. While it is impossible to forecast accurately the rate of recovery of Lake Apopka, it is possible to show the effect on the benefit stream of various scenarios. Assume that the per capita annualized benefits for a complete restoration are $10/year. Table 6-27 shows the present value of these benefits, at a discount rate of 10 %/yr., over the next 30 years, for the following five cases:

Case 1: Constant full benefits. The net present value is $94.27.

Case 2: Benefits increase at a uniform rate from $0/yr. to $10/yr. The net present value is $28.83.

Case 3: Benefits decrease at a uniform rate from $10/yr. to $0/yr. The net present value is $68.58.

Case 4. No benefits for 15 years. Then full benefits of $10/yr. for the next 15 years. The net present value is $18.21.

Case 5. Full benefits of $10/yr. for 15 years. Then, no benefits. The net present value is $76.06.

The present value of future benefits decreases as the discount rate increases. Also, as is clearly shown by the results of Table 6-27, benefits achieved earlier are more valuable than those that come later. Of course, the benefits of a permanent lake restoration go on for many years. However, their present value tends to 0 because of the discounting formula, i.e.,

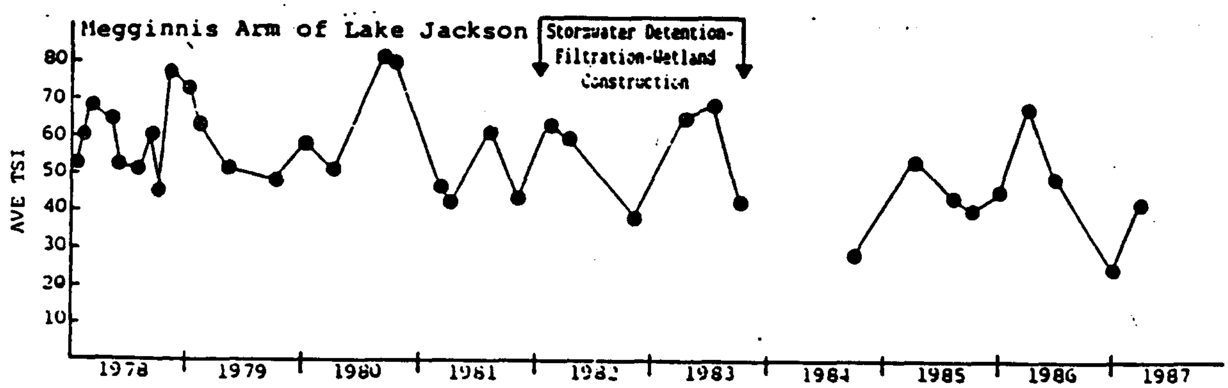


Figure 6-18. Average Trophic State Index for the Megginnis Arms of Lake Jackson during 1978-1987 (Dierberg et al., 1988)

Table 6-27. Present Value of a $10/yr. Benefit Over the Next 30 Years for Various Benefit Streams.

Present Value, $	$94.27	$28.83	$68.58	$18.21	$76.06
(1)	(2)	(3)	(4)	(5)	(6)
	Constant Benefit	Linearly Increasing Benefit	Linearly Increasing Benefit	Delayed Benefits	Short-Lived Benefits
Year	$/yr	$/yr	$/yr	$/yr	$/yr
1990		0			
1991	$10.00	$0.33	$10.00	$0.00	$10.00
1992	$10.00	$0.67	$9.67	$0.00	$10.00
1993	$10.00	$1.00	$9.33	$0.00	$10.00
1994	$10.00	$1.33	$9.00	$0.00	$10.00
1995	$10.00	$1.67	$8.67	$0.00	$10.00
1996	$10.00	$2.00	$8.33	$0.00	$10.00
1997	$10.00	$2.33	$8.00	$0.00	$10.00
1998	$10.00	$2.67	$7.67	$0.00	$10.00
1999	$10.00	$3.00	$7.33	$0.00	$10.00
2000	$10.00	$3.33	$7.00	$0.00	$10.00
2001	$10.00	$3.67	$6.67	$0.00	$10.00
2002	$10.00	$4.00	$6.33	$0.00	$10.00
2003	$10.00	$4.33	$6.00	$0.00	$10.00
2004	$10.00	$4.67	$5.67	$0.00	$10.00
2005	$10.00	$5.00	$5.33	$0.00	$10.00
2006	$10.00	$5.33	$5.00	$10.00	$0.00
2007	$10.00	$5.67	$4.67	$10.00	$0.00
2008	$10.00	$6.00	$4.33	$10.00	$0.00
2009	$10.00	$6.33	$4.00	$10.00	$0.00
2010	$10.00	$6.67	$3.67	$10.00	$0.00
2011	$10.00	$7.00	$3.33	$10.00	$0.00
2012	$10.00	$7.33	$3.00	$10.00	$0.00
2013	$10.00	$7.67	$2.67	$10.00	$0.00
2014	$10.00	$8.00	$2.33	$10.00	$0.00
2015	$10.00	$8.33	$2.00	$10.00	$0.00
2016	$10.00	$8.67	$1.67	$10.00	$0.00
2017	$10.00	$9.00	$1.33	$10.00	$0.00
2018	$10.00	$9.33	$1.00	$10.00	$0.00
2019	$10.00	$9.67	$0.67	$10.00	$0.00
2020	$10.00	$10.00	$0.33	$10.00	$0.00

Column	Explanation
(1)	Year
(2)	Annual benefit for constant benefits over next thirty years
(3)	Annual benefit for constantly increasing benefits over next thirty years.
(4)	Annual benefit for constantly decreasing benefits over next thirty years.
(5)	Annual benefits: none for first 15 years; $10/yr for last 15 years.
(6)	Annual benefits: $10/yr.for first 15 years; $0/yr. for last 15 years.

Note: The net present value is the sum of $A_j/(1+i)^n$ where A_j is the value in year j, i is the discount rate, and n is the number of years.

$$P = F/(1+i)^n \quad (6\text{-}2)$$

where
P = present value, \$,
F = future value, \$,
i = interest rate, and
n = number of years.

If i is 0, then the future benefit equals the present benefit. However, for a positive i such as i= .10, the present value of a future benefit of $10 is $2.59 for n = 10, $0.92 for n = 25, and $0.09 for n = 50. Offsetting the reduced future values is the growing number of people who will be able to enjoy the restored lake.

6.10 Summary of Socio-Economic Impact

6.10.1 Introduction

The purpose of the socio-economic analysis is to estimate the benefits and disbenefits associated with the past and projected use of Lake Apopka. This lake has been impacted by man's activities for more than a century. The initial impacts on the lake were the result of attempts to provide a navigation link among the Upper Oklawaha chain of lakes so that it would be possible to go from Lake Apopka all the way to the Atlantic Ocean. The initial canal, completed in 1893, also lowered the lake level by four feet, leaving an estimated 20,000 acres of lake bottom dry enough for cultivation. However, it was not until the early 1940's when the Zellwood Drainage and Water Control District succeeded in developing a diking, canal, and pumping system that provided adequate water management to bring this land under cultivation.

In its natural state and through the 1950's, Lake Apopka was world renowned for its sport fishing. However, the fishing declined rapidly as the water quality of the lake continued to degrade due to continued back pumping of nutrient rich drainage waters from the muck farms back into the lake. At present, the lake is one of the most polluted in the State of Florida and is the subject of major activities attempting to restore it to significantly improve its quality so that it can support a variety of recreational activities including fishing, boating, swimming, and passive recreation.

The area around Lake Apopka has experienced very rapid population growth during the past thirty years with the population of Lake and Orange counties increasing over fivefold from 151,000 in 1950 to 816,000. Thus, the number of people affected directly by the poor quality of Lake Apopka has grown substantially. Land use trends in the area indicate that the Lake Apopka area will experience a transition from agricultural to urban activities.

The socio-economic analysis is directed to estimating the benefits and dis-benefits associated with man's past, present, and projected uses of Lake Apopka. Benefits have resulted from the water management activities such as lowering the lake level and installing protective works to permit intense farming activity on the muck lands at the north end of the lake. Disbenefits accrue when man's activities degrade the quality of the lake's water and/or modify the lake levels in such a way that other beneficial uses such as recreation are impaired. These disbenefits fall upon the people who would use the lake for a variety of recreational activities, the riparian property owners whose property values are reduced, and to the general public who derive value knowing that: 1. the lake could be used if they so desired; The lake is of high quality thereby helping to maintain safe and desirable water for all uses; and 3. the lake is being preserved in a high quality state for posterity. The remainder of this section summarizes our estimates of these impacts over the past thirty years and the projected impacts over the next thirty years.

6.10.2 Time History of Socio-Economic Impacts

The earlier sections of this chapter on Lake Apopka have described the procedures used to quantify the socio-economic impacts of historical water management practices affecting Lake Apopka. Table 6-28 and Figure 6-19 summarize these impacts for the period from 1960 to 2020 for the case where the lake is not restored to its pre- 1950s condition. All of the values in Table 6-28 and Figure 6-19 are measured in current (1989) dollars including the historical and projected values.

The primary beneficiary of the diking and pumping system at the north end of the lake has been the muck farms which produce high valued vegetable crops which generate an estimated net revenue of $6.4 million per year. This estimate was derived from the Agricultural Damage and Assessment Model (ADAM) which was presented in Chapter 4 of this report.

The disbenefits due to degraded water quality are the sum of the losses in direct recreation value, the losses to the general public, and the losses in property values to the riparian property owners. The sum of these losses has increased from $2.1 million in 1960 to $7.3 million at present, and are projected to increase to $11.1 million by the year 2020. The losses in recreation and to the general public increase as population increases.

The net effect of the gains enjoyed by agricultural activities in the muck farms vs. the losses in recreation, property, and general environmental value is that the muck farm gains exceeded the societal losses in the earlier years from 1960 to 1980. However, the net effect became negative during the 1980's and will continue to be increasingly negative as we move into the future. These numbers represent our best estimates

Table 6-28. Summaries of Socio-Economic Gains and Losses Associated with Lake Apopka, 1960-2020.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		BENEFIT	<<<<<<<<<<<DISBENEFITS>>>>>>>>>>>>>>				
		*********All values in $1000/yr. in 1989 $******					
Year	Popul. 1000's	Muck Farms	Direct Recreation	General Public	Riparian Property	Total Losses	Net Benefit
1960	321	$6,400	$1,136	$ 802	$203	$ 2,142	$4,258
1970	414	$6,400	$1,464	$2,068	$203	$ 3,736	$2,665
1980	576	$6,400	$2,038	$2,879	$203	$ 5,120	$1,280
1990	816	$6,400	$3,003	$4,080	$203	$ 7,286	($886)
2000	1009	$6,400	$3,713	$5,045	$203	$ 8,962	($2,562)
2010	1135	$6,400	$4,177	$5,675	$203	$10,055	($3,655)
2020	1259	$6,400	$4,633	$6,295	$203	$11,132	($4,732)

(1) Census year.
(2) Census and median projected population for Lake and Orange counties.
(3) Estimated net revenue from farming based on ADAM model analysis.
(4) Net loss in boating and swimming recreation based on actual and potential use rates.
(5) Net loss in value to general public based on their willingness to pay to restore Lake Apopka.
(6) Net loss in waterfront property values due to degraded lake.
(7) Sum of Cols. (4) + (5) + (6).
(8) Col. (3) - Col. (7).

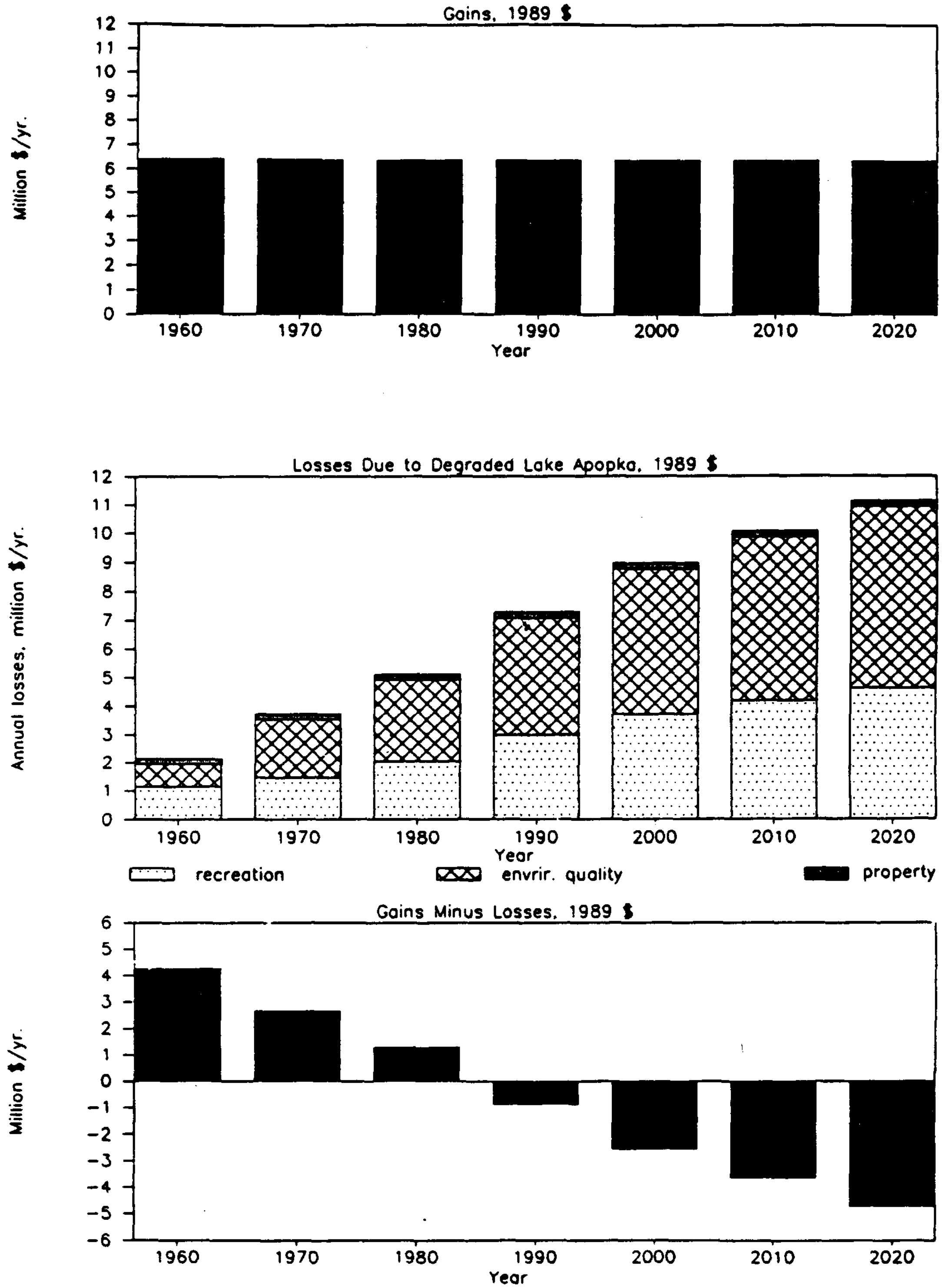


Figure 6-19. **Summary of Gains and Losses of Activities Affecting Lake Apopka.**

given the available data. Additional information is needed in all aspects of the socio-economic assessment of Lake Apopka itself. Also, information is needed on the downstream damages caused by the Lake Apopka discharges. Some of these impacts are captured in the the estimate of the damages to the general public as evidenced by their willingness to pay for the cleanup. Nevertheless, it has not been possible to quantify these direct downstream effects on recreation and property values.

7.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

7.1 Summary

The purposes of this study were to develop an evaluation procedure and associated software for performing a socio-economic assessment on a water project, and to apply this methodology to the Lake Apopka Basin in central Florida.

The socio-economic analysis provides decision makers with valuable information on the benefits and disbenefits of each of the alternatives under consideration. A wide variety of techniques have been developed over the years to do these evaluations ranging from simple benefit-cost analyses to complex multi-objective optimization models. The federal government has sponsored development of standardized procedures for doing these analyses. The most recent summary of these methods is contained in the Principles and Guidelines (1983). These guidelines cover the following areas of water resources: municipal and industrial water supply; agricultural floods, erosion, sedimentation, irrigation, and drainage; urban floods, hydropower, navigation, recreation, and commercial fishing. Conspicuously absent from this list is environmental quality which is not covered in the National Economic Development portion of the federal guidelines. Environmental quality is treated as a separate objective which is not quantified in monetary terms. Thus, additional effort was expended in incorporating this important purpose.

The literature review of analysis techniques covered conventional benefit-cost analysis, multi-objective analysis, risk analysis, social choice modeling, expert systems, decision support systems, and environmental impact analyses..

For the application to Lake Apopka, emphasis was given to the following two general categories of benefits:

1. agricultural irrigation, drainage, and flood damages; and
2. environmental quality, recreation, and property values.

The performance of a system can be described by its reliability, resiliency, and vulnerability. In order to analyze the full suite of benefits and disbenefits, it is essential to do a continuous simulation of how the system performs on a day to day basis. Also, it is essential to define threshold values outside (e.g., above or below) of which the system has "failed" and an "event" has occurred. The spreadsheet model presented in Chapter 3 allows these events of interest to be extracted from the database and input to the benefit estimation model(s).

Flood and drought damages to agricultural areas can be estimated using a spreadsheet model called ADAM (Agricultural Damage Assessment Model) that does a detailed continuous month to month tracking of farm operations. Flood and/or drought events interrupt the planned activity and the farmer adjusts as best he can to reduce his losses. The model application to the muck farm areas north of Lake Apopka was presented in Chapter 4.

The benefits of environmental quality enhancement include improved health, productivity, and recreation/aesthetics. Techniques exist for measuring the direct recreation benefits. Recently, techniques have also been developed to estimate the so-called non-user benefits. We prefer to use the name environmental quality (EQ) benefits, i.e., benefits that accrue to the general public from an improvement in environmental quality. These EQ benefits are the sum of:

- option value - value placed on having the option of using an environmental resource;
- existence value - benefit of knowing an environmental resource exists; and
- bequest value - value of preserving a resource for future generations.

These EQ benefits have been shown to represent a significant part of total benefits because a strong general concern exists for protecting the environment, and a willingness to pay for such programs in order to protect not only nearby water supply or recreational facilities but also to support programs far removed from their locale, e.g., the Amazon. One reason that these EQ benefits are significant is the large number of people who derive these benefits. While survey techniques have been used to estimate EQ benefits, a more direct measure is available in Florida thanks to recent environmental restoration programs that have committed large funds to support these activities. Such commitments represent a direct measure of voluntary willingness to pay to clean up and/or protect vital areas such as Lake Apopka, Lake Okeechobee, the Indian River, Tampa Bay, and the Everglades.

Procedures for evaluating recreation benefits using the unit day value method, the travel cost method, and the contingent value method are described in the literature. The results of these studies were summarized for various use categories.

The socio-economic methodology was used to estimate the benefits and disbenefits associated with the past and projected activities associated with Lake Apopka. This lake has been impacted by man's activities for more than a century. The initial impacts on the lake were the result of a navigation canal, completed in 1893. This canal also lowered the lake level by four feet, leaving an estimated 20,000 acres of lake bottom dry enough for cultivation. However, it was not until the early 1940's when the Zellwood Drainage and Water Control District succeeded in developing a dike, canal, and pump system that provided adequate water management to bring this land under cultivation.

In its natural state and through the 1950's, Lake Apopka was world renowned for its sport fishing. However, the fishing declined rapidly as the water quality of the lake continued to degrade due to continued back pumping of nutrient rich drainage waters from the muck farms into the lake. At present, the lake is one of the most polluted in the State of Florida and is the subject of major activities attempting to significantly improve its quality so that it can support a variety of recreational activities including fishing, boating, swimming, and passive recreation.

The area around Lake Apopka has experienced very rapid population growth during the past thirty years with the population of Lake and Orange counties increasing over fivefold from 151,000 in 1950 to 816,000. Land use trends in the area indicate that the Lake Apopka area will experience a transition from agricultural to urban activities.

The socio-economic analysis is directed to estimating the benefits and dis-benefits associated with man's past, present, and projected uses of Lake Apopka. Benefits accrue due to uses of the lake that result in an enhanced profitability of activities due to water management activities such as lowering the lake level and installing protective works to permit intense farming activity on the muck lands at the north end of the lake. Disbenefits accrue when man's activities degrade the quality of the lake's water and/or modify the lake levels in such a way that other beneficial uses such as recreation are impaired or precluded.

7.2 Conclusions

With regard to socio-economic analysis techniques, a wide variety of methods have been developed in the past thirty years. The emphasis has been on normative optimization models that can prescribe the optimal solution. Unfortunately, it is necessary to greatly simplify the description of the actual problem to satisfy the rigid strictures of the optimization models, e.g., linear functions, normal distributions, simple production functions. Thus, the results may not be a realistic appraisal of the actual situation. Because of this focus on modeling, databases have not been developed on benefits, costs, risk levels, etc., or how these impacts are distributed among the affected groups. Thus, our approach was to use standard benefit-cost analysis procedures with an emphasis on developing reliable databases for conditions that exist in the St. Johns River Water Management District and related areas.

It is essential to develop quantifiable measures of system performance, then to actually measure these quantities and see how well they perform against pre-specified criteria such as keeping the lake stage above a pre-set elevation. Given such a system, it is possible to directly evaluate performance and suggest improved operating policies. However, in the absence of actual and not just estimated values, it is difficult to develop cogent control strategies.

A continuous simulation model is essential to evaluate the socio-economic impacts of various water management strategies on farming activities and vice versa. The lake regulation schedules affect the rate at which water seeps into the muck farms. The farmers' activities affect the lake levels and its quality through their significant pumping activities during and following storm events. The farmer has a relatively wide variety of choices available including the selection and timing of crops, the design and operation of the water management system, and the method of response to high or low water stress conditions. Ideally, the simulation model could incorporate these decision rules into the analysis. This would require close cooperation with the farmers since they best know their operation.

For Lake Apopka, the public has committed about $40 million to help restore this lake. Averaging this commitment over the 800,000 people living in Orange and Lake Counties, we obtain a current cost of $50/capita. Amortizing this expenditure over an infinite planning horizon at an interest rate of 10 % yields an equivalent benefit or willingness to pay of $5.00/capita/year. Equivalently, the damages to these people from the present state of Lake Apopka are at least $5.00/capita/year.

The primary gap in recreation benefit assessments is lack of site-specific data. The methodology is straightforward.

The results of the application of the socio-economic procedures to Lake Apopka were summarized in Figure 6-19. The diking and pumping activities have allowed a high valued agricultural activity to thrive in the muck farm area north of Lake Apopka. Based on a detailed modeling of monthly agricultural activities, the estimated present net revenue from the muck farm activities is $6.4 million per year. This value is assumed to be constant (as measured in 1989 $) over the sixty year period from 1960 to 2020. This gain represents a private gain in that the farmers are able to capture all of these net revenues. Offsetting this gain are three categories of losses: decreased direct recreation values, lowered environmental quality to the general public, and decline in property values to the riparian owners. The losses in direct recreational value range from a low of $1.14 million in 1960 to a high of $4.6 million by the year 2020. The primary recreation value affected is boating activities. The largest loss is the loss in environmental quality suffered by the general public. The equivalent annual per capita loss is $5.00 per capita per year. This loss ranges from $0.8 million in 1960 to $6.93 million by the year 2020. The reason that this loss increases so substantially is that the population in the year 2020 is expected to be nearly four times greater in 2020 than it was in 1960, or an increase from 321,000 to

1,259,000. The last loss category is the loss in value of waterfront property along Lake Apopka. This loss is estimated to be a constant $0.2 million per year based on a decrease in water front property value of $100 per front foot.

The net effect of these gains and losses is that a positive net benefit accrued during the early years of muck farming. However, by the 1980's, the net value became negative and it is projected to become increasingly negative in the future if restoration is not done. The projected annual loss by the year 2020 is $4.73 million per year.

The citrus groves at the southern end of the lake have had a long-term concern regarding the effect of lowered lake levels on their freeze protection. While this technical question is not fully resolved, it is possible to estimate the economic consequences using crop insurance rates. The expected increase in crop insurance would be $7,900 per year. This issue is expected to become less critical as the citrus lands shift to urban uses.

The flood and drought damages to the muck farms with the existing water control system were investigated. The results indicate that the current system provides a high level of protection to the farmers and so they have not suffered any substantial crop damages due to water problems.

A preliminary analysis of the impact of restrictions on muck farm backpumping indicate that the farmers would suffer losses but not in direct proportion to the reduction in available land since they only use all of the available land during a few months of the year, and they could reschedule their farming activities to minimize these impacts. Unfortunately, due to lack of data, it was not possible to do a detailed analysis of this alternative.

Overall, the situation facing the Lake Apopka Basin is similar to problems throughout the country and around the world. In the United States, agricultural policies for many years have encouraged the development of wetland areas. During the period from the mid-1950's to the mid-1970's, 87 % of the wetland losses in the United States were attributable to agricultural development. Florida is a leader in trying to reverse these trends by making major efforts to reverse this trend and to restore these systems.

7.3 Recommendations

A major missing link in conducting socio-economic studies is lack of good databases. The most important long-term investment is to acquire such data. This study brought together the existing data and put it in datasets. However, site-specific information is critical. For example, without knowledge of the actual pumpage from the farms to the lakes, it is difficult to do an accurate assessment of the economic response of the farmers to storm events.

In order to improve the accuracy of the agricultural damage model, it should be linked directly with a hydrologic model that estimates water movement through the agricultural area. These systems are interdependent in the muck farm areas.

Further research is needed on developing estimates of general environmental quality benefits. These studies should gather information on the cost of environmental restoration programs in Florida and elsewhere and develop accurate benefit-cost models that include the values of natural systems in protecting the population. For example, existing benefit-cost methods do not correctly include the flood control, water quality, fish and wildlife habitat and other functions provided by wetlands that are primarily public benefits. These calculations can be done with a properly integrated socio-economic and hydrologic/water quality model that permits an accurate appraisal of the public as well as the private values. The output from such models coupled with good information on property values and taxes could provide strong public guidance on land acquisition and taxing policies.

Direct measurements of recreation activities at important lakes in the SJRWMD are needed in order to develop functional relationships between lake attributes and desirability for recreation. A significant database exists of lake characteristics. Also, it is possible to access tax assessors records for water front properties. However, these data sources must be supplemented by direct counts of recreation activities.

Lake Apopka is a vivid example that these relatively short-term gains in agricultural productivity will exact a much higher price in terms of loss of other values and the high cost of cleaning up these systems at public expense. Future policies need to recognize the functions performed by the natural systems and to incorporate these values in taxing and incentive systems that allow private property owners to justify deferring or refraining from developing their lands to the detriment of others.

The results of the socio-economic studies can be expressed in terms of a monetary equivalent for some of the damages, say flooding. However, it is difficult to convert all damages to a monetary equivalent. The multiple objective nature of water resources problems is well recognized. In the absence of complete conversion to a monetary equivalent, decision makers establish targets or goals for various purposes and/or minimum control levels. The purpose of the socio-economic analysis in this case is to evaluate the extent of compliance with this goal. Alternatively, one may wish to quantify the cost of attaining various levels of the selected goal(s).

The estimates of impacts presented in this report do not include the impacts of the discharges of polluted water from Lake Apopka on the downstream areas of the Upper Oklawaha River Basin. These impacts should be quantified in future studies.

8.0 ACKNOWLEDGEMENTS

This study has relied on data collected by other groups. We are indebted to them for their cooperation. Dr. C. Charles Tai, Dr. Larry Battoe, Mr. Gary Bethune, and Mr. David Still and other personnel of the St. Johns River Water Management District (SJRWMD) provided excellent technical guidance and suggestions. Mr. Armando Calabello of SJRWMD provided the output from the Arc/Info land use file for the Lake Apopka Basin.

Mr. Noble Enge, Dan Peck, and Marion Ritter from the Jacksonville District of the Corps of Engineers provided background information regarding their activities in the Lake Apopka area. Mr. Randy Ferris of the Orange County Parks and Recreation Department provided copies of the boat ramp data for Lake Apopka. Dr. Wally Milon of the University of Florida made several helpful suggestions on the recreation valuation aspects of the study.

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