AN ECONOMIC EVALUATION OF THE NUYAKA CREEK FLOOD PLAIN UTILIZING A GENERAL MODEL TO ESTIMATE THE INCIDENCE OF AGRICULTURAL FLOOD DAMAGES

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PREFACE

This dissertation is concerned with developing and testing methodology for estimating the incidence of agricultural flood damages. The simulation model resulting from the study estimates flood damages at sample points which are uniformly distributed throughout a flood plain. Damage estimates are based upon the characteristics of a sample point; i.e., land use, productivity and location. An optimizing routine was also incorporated into the simulation model. The optimizing routine, in conjunction with the simulator, designates the land use at each sample point which maximizes returns net of production costs and average annual flood damages and specifies associated costs and returns.

I would like to take this opportunity to express my appreciation to my major adviser, Dr. Vernon R. Eidman, whose assistance and counsel regarding this study and other professional involvements proved to be both inspiring and enlightening. Also, to the other members of my committee, Dr. Richard Schermerhorn, Dr. Lyle D. Broemeling, Dr. Dean Schreiner, and Dr. Daniel D. Badger, special recognition for the consultation and direction provided in preparation of this thesis. Others especially helpful in various aspects of the study include Dr. Neil Cook, who was instrumental in initiating the research, Mr. Gordon Sloggett, Mr. Jim Tomlinson, Mr. Bill McGee, and Mr. Milton Boydston. I acknowledge my indebtedness to Mr. Fred Legrande, Mr. Elmo Bauman, Mr. Fred Dreis, and Mr. Jim Basler who gave so generously of their time in developing specific details concerning the study. I would like to thank the personnel of the Soil Conservation Service of the USDA and Agronomy Department, Agricultural Economics Department, and Computer Science Department of Oklahoma State University for the courtesy shown me and assistance provided.

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CHAPTER I

INTRODUCTION

There are substantial flood damages in both the agricultural and nonagricultural sectors of the United States economy.[1] The annual flood damages estimated by the Weather Bureau (adjusted to 1957 to 1959 prices) for the period 1943-1963 range from about $70 million to greater than one billion dollars with the average above $275 million. These estimates, shown in Figure 1 for 1903-1963, exclude most upstream losses.[2] Current estimates of annual upstream and downstream loss from flooding exceed one billion dollars.[3]

Federal flood control measures in the form of protection and prevention were initiated in 1936. Since adoption of the national flood control policy, more than seven billion dollars has been invested through the Corps of

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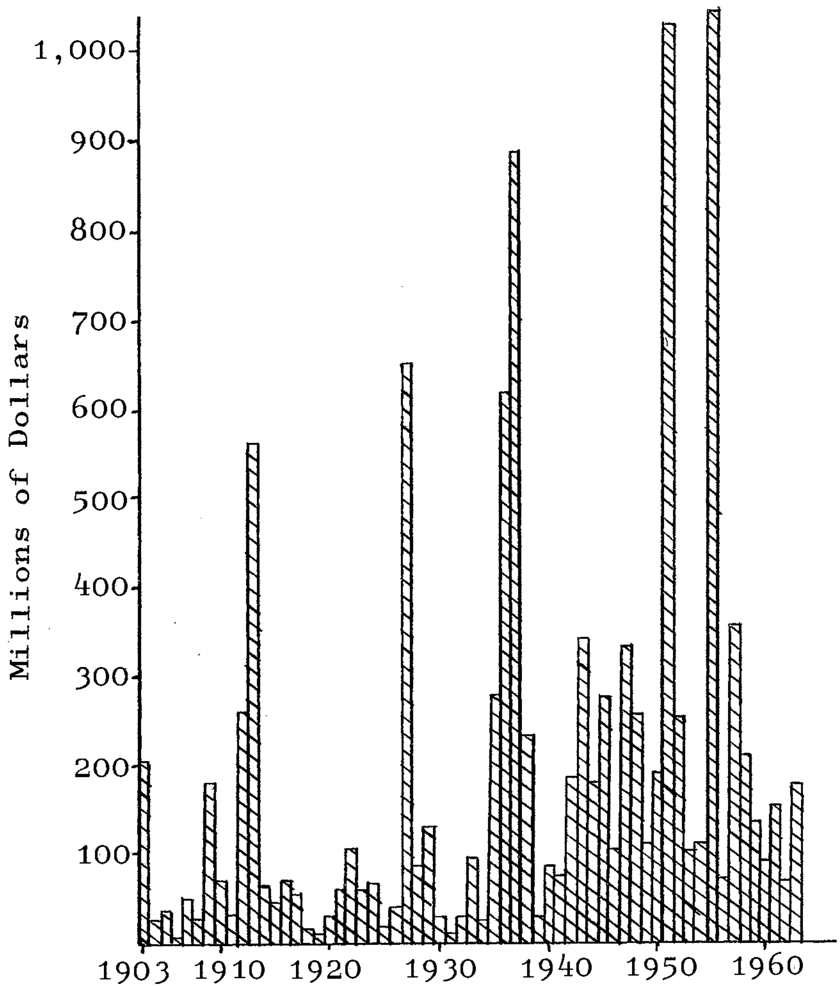
[1]U. S., Congress, House, Task Force on Federal Flood Control Policy, A Unified National Program for Managing Flood Losses, House Document No. 465, 89th Cong., 2d Sess., August 10, 1966, p. 3.

[2]U. S., Congress, Senate, Committee on Banking and Currency, Insurance and Other Programs for Financial Assistance to Flood Victims, Committee Print, 89th Cong., 2d Sess., September, 1966, p. 27, Figure 6.

[3]U. S., Congress, House, p. 3.



Source: U.S., Congress, House, Task Force on Federal Flood Control Policy, <u>A Unified National Program for Managing Flood Losses</u>, House Document No. 465, 89th Congress, 2d Session, August 10, 1966, p. 3.

Figure 1. United States Estimated Annual Flood Damages Excluding Most Upstream Losses: 1903-1963

Engineers and Soil Conservation Service. Annual federal expenditures for flood protection and prevention are currently $500 million and increasing.[4] Despite the federal flood control investments, flood losses have been increasing at an average annual rate of five and one-half percent.[5]

Flood records indicate there has not been a significant change in the frequency of natural overbank flows since flood losses became so large as to justify federal effort to control them.[6] Therefore, increases in flood damages are not due to an increase in intensity and frequency of rainfall, but are the result of a more intensive utilization of flood plain acreage.[7] Studies indicate that flood plain encroachment occurs because of (1) ignorance of the flood hazard, (2) anticipation of further federal protection, and (3) profitability to the private owner. Flood plain enchroachment because of reasons (2) and (3) above often involves a heavy social burden due to individuals anticipating federal relief in the event of a disastrous flood.[8]

Alarm over the extent of flood damages and interest in flood protection programs is increasing as the flood plain

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[4]U. S., Congress, House, p. 3.

[5]U. S., Congress, Senate, p. 27.

[6]U. S., Congress, House, p. 13.

[7]Flood plain refers to all land adjacent to a channel which is subject to flooding due to channel overflow.

[8]U. S., Congress, House, p. 11.

becomes more intensively utilized. The practice of more intensive use of flood plain land can be expected to continue in agriculture since the flood plain is among the most productive land in an area. Generally, as flood plain is converted to more intensive uses, vulnerability to flooding increases. This is explained through land use characterized by low per acre returns and a high degree of tolerance to floodwater (native pasture, woodland, etc.) being replaced by a cropping enterprise which has higher per acre returns but a low degree of tolerance to floodwater (row crops, alfalfa, etc.). Therefore, with more intensive use of flood plain, damages from flooding will continue to increase.

Increases in agricultural flood losses call for two distinct but related types of flood plain evaluation. There is flood protection to curb or reduce the increasing losses attributable to flooding. This type of evaluation involves an economic appraisal of the reduction in flood damage resulting from alternative flood protection measures formulated for a particular watershed.

In addition to flood protection proposals, a thorough flood plain evaluation considers land use organization and the effect of alternative adjustments. Flood damage estimates for alternative land uses throughout a flood plain facilitate such an evaluation and aid entrepreneurs in their effort to develop a satisfactory farm firm organization. Knowledge of the incidence of flood damages permits calculating returns net of average annual flood damages and production costs by land use and flood plain location.[9] By utilizing this data, flood plain land use and farm organization can be directed toward increasing profits or reducing the risk associated with flooding or some combination of both.

It is useful to identify both average annual flood damages and expected profit by land use throughout the flood plain since efforts to minimize or reduce flood damages will not necessarily yield a profit maximizing situation. For example, flood plain land use adjustments to attain large profit increases may be associated with increasing flood damages because an allocation of flood plain to higher value land uses may also result in greater flood losses. Conversely, increased flood damages could represent a reduced profit or inefficient flood plain encroachment.

Both types of flood plain evaluation discussed above require procedures for estimating flood damages. Governmental agencies working with flood losses and involved in watershed evaluation have formulated procedures for estimating losses resulting from floodwater. These procedures estimate flood damages with either a historical or frequency method.[10] The historical method computes damages based on

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[9]Average annual flood damages refers to the damages that would be expected in any given year considering alternative flood sizes and their probability of occurrence.

[10]A modification of the frequency method was utilized in this study and is discussed in detail as applied to the study in Chapter III.

the record of actual floods in the watershed and considers up to 150 separate storms. The frequency method calculates flood damages for as many as six flood sizes with the flood sizes selected to represent the distribution of floods in the watershed; i.e., once a year flood, flood occurring every two years, five years, etc., up to a 50 or 100 year flood.

Flood damage estimates are computed for an evaluation reach. The elevation of the flood plain within an evaluation reach is represented by measured points on one or more cross sections.[11] The distance between cross sections frequently exceed 3,000 feet. Evaluation reach data from which damage estimates evolve include cross section elevations, composite acre or percent distribution of each crop, crop yield, crop price, crop damage factors, and flood data.[12, 13] Computer programs designed to carry out the estimating procedure consider up to 10 crops, 12 seasons, and 4 inundation depth increments. Damages are computed by applying appropriate damage factors to the composite acre and expanding to

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[11] An evaluation reach is the area for which a flood damage value applies with a cross section being the elevation profile of a flood plain at one point on the channel; i.e., elevations at points or stations across a flood plain at one channel location.

[12] Percent distribution of each crop in an evaluation reach is analogous to a composite acre which is a hypothetical acre of flood plain composed of the same percentage of each land use as in an evaluation reach.

[13] Crop damage factors are the percentage reduction in gross value for a given depth of inundation increment and season.

the acres inundated. Evaluation reach data made available by present estimation procedures include acres inundated by flood size, damages by flood size, and average annual flood damages.

Applicability of present procedures with respect to a complete flood plain evaluation is severely restricted due to an inability to accurately predict flood damages for individual tracts of land. With present procedures, the incidence of flood damages cannot be specified for areas smaller than the evaluation reach because the land use pattern within an evaluation reach is unspecified; i.e., the percentage distribution of crops is defined but land use by field or individual tracts of land is not identified. More accurate estimates of the incidence of flood damages should result from a procedure using the elevation and land use of individual tracts of land.

The purpose of this study is to develop a method whereby flood damages can be estimated for a specific field with respect to the particular characteristics of that field; i.e., land use, productivity, depth of inundation, and location. More accurate estimates of the incidence of average annual flood losses can help establish: (1) more equitable assessments of the local costs of flood protection, (2) annual premiums for flood insurance, and (3) optimum cropping patterns. Benefits received by individual landowners from flood protection can be tied directly to reductions in depth of flooding on individual fields. Annual insurance premiums for specific fields can be related to the particular crop grown on the field. And the land use maximizing returns net of production costs and average annual flood damages can be identified for any flood plain location.

Objectives

The principal objective of this study is to develop a general model to estimate values associated with flooding on any specific area within a Soil Conservation Service project size watershed.[14] The values associated with flooding that the general model is developed to estimate are:

1. Acreage inundated by specific flood sizes with alternative systems of structures.
2. Flood damages for specific storms and average annual flood damages on any selected area within the flood plain of the watershed.
3. Average annual benefits from proposed systems of structures for specific fields and to land owners.
4. Flood damages with alternative land use patterns.

A second objective of this study is to convert the general model to an optimizing routine. The purpose of the modification is to develop a decision model for selecting

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[14] A Soil Conservation Service project size watershed applies to a drainage area of 250,000 acres or less.

that land use at each flood plain location which maximizes returns net of average annual flood damages and production costs. Additional data forthcoming from the modification are estimates of the optimum flood plain cropping patterns, associated net returns and flood damages for alternative systems of structures as well as with no structures.

A final objective of this study is to illustrate the model and its modification by applying them to a study area watershed. Study area data are utilized in the model and from the resulting computations inferences drawn regarding study area flood damages and optimum cropping patterns.

Review of Literature

Studies conducted regarding the incidence of flood damage have been limited, especially with regard to utilization of a computer model. Studies have, however, been conducted and procedures developed for designating flood risk zones and flood damage to specific property or location.

The Department of Housing and Urban Development sponsored a comprehensive program in cooperation with the Soil Conservation Service (SCS) and Corps of Engineers to present information and data for use in developing flood risk as a basis for insuring against flood losses.[15] The primary

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[15]Department of the Army, Corps of Engineers, Technical Information on Average Annual Flood Damages for Classes of Porperties by Flood Risk Zones, prepared for Department of Housing and Urban Development, Washington, D.C., June, 1966. (This is a report made in accordance with the agreement of April 8, 1966, between the Secretary of the Department of Housing and Urban Development and the Chief of Engineers.)

concern was for urban property with flood risk zones designated by frequency of flooding. Different urban properties were classified as one or more stories, frame, masonary, residential, industrial, etc. Average annual flood damages were determined by property classification, city analyzed, and flood risk zone. The flood damage values were given as absolute damages, dollars damage per 1,000 square feet, and damages per 1,000 dollars of structure value.

Agricultural flood damages were also considered in the above project.[16] The agricultural study was conducted for an area along the Mississippi River and determined acres inundated for alternative flood sizes. Damage computations of particular flood sizes were based on damages to a study area flood plain composite acre in designated flood risk zones. Average annual flood damages were computed for the composite acre in each designated flood risk zone. The results of this study, therefore, do not present data on the incidence of flood damages; i.e., average annual flood damages to a particular field considering a specific land use. The flood damage values apply only to the composite

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[16]Department of the Army, Corps of Engineers, Flood Insurance Study, Agricultural Area Along Mississippi River Winfield Levee and Drainage District Missouri, prepared for Department of Housing and Urban Development, Washington, D.C., July, 1966. (This is a report submitted in compliance with a request by the Chief of Engineers to present information and data for use in determining flood risks as a basis for insuring agricultural development against flood losses.)

area which is a combination of all study area land uses.

The Soil Conservation Service also utilizes the composite acre approach in evaluating small watersheds. Therefore, SCS damage estimates are subject to the same criticism; an inability to accurately predict the incidence of flood damages. Estimates of flood damages for areas less than that represented by an evaluation reach require sending trained field personnel to the area who, by observation, derive damage values. Small area flood damage estimates require specific land uses, making the composite acre inapplicable. Criticisms of present estimating procedures are not directed toward the accuracy of the model for relatively large flood plains, but toward the inaccuracy and difficulty of obtaining flood damage estimates for relatively small areas, such as a particular field.

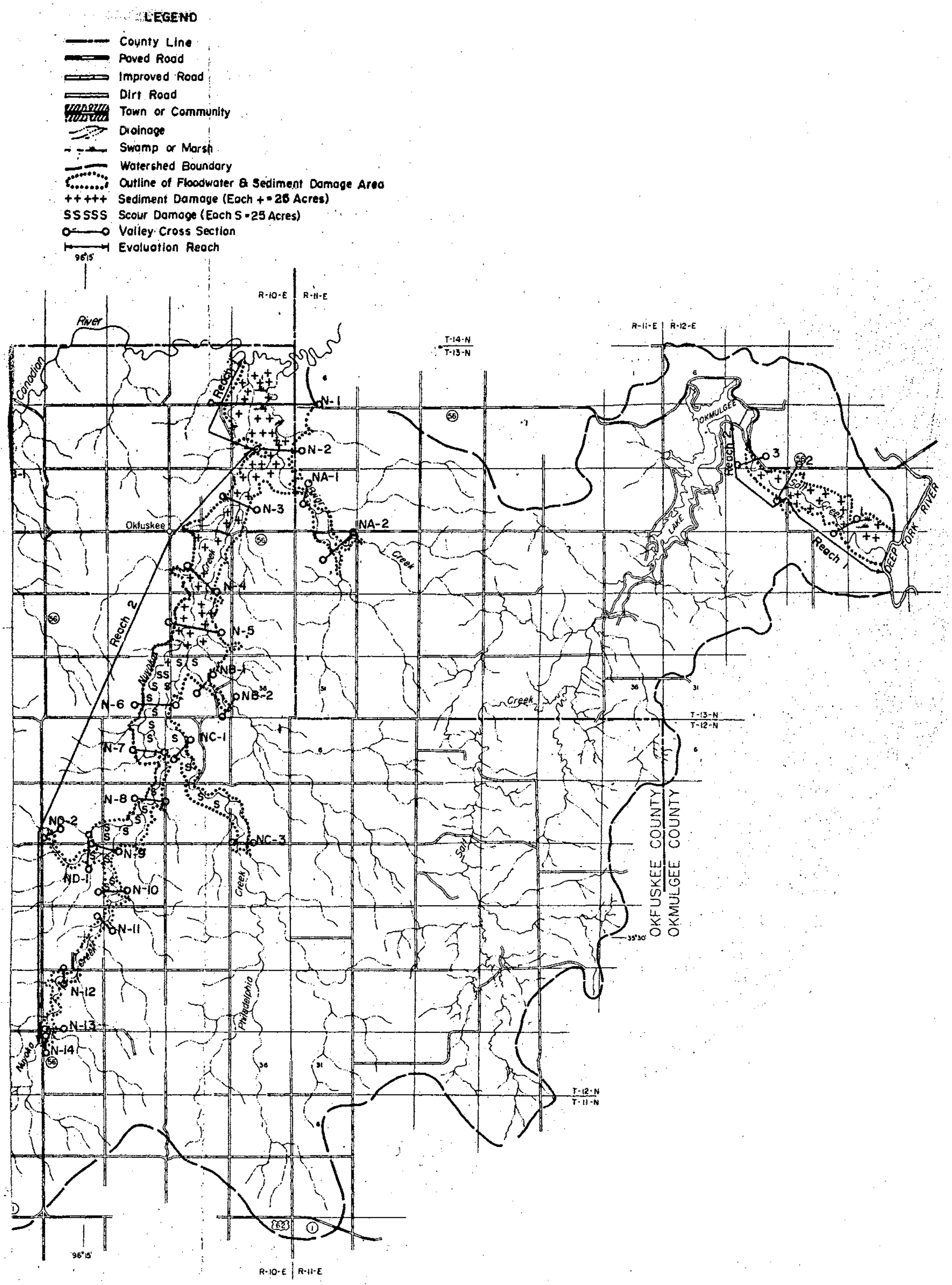
Previous procedures and models designed for estimating agricultural flood damages have been based on a study area composite acre and an evaluation reach. The present study proposes to extend the method of analysis such that flood damages can be estimated by a computer model for any specific area or field within the flood plain. With improved knowledge regarding the incidence of flood damages, the relationship between a crop's expected flood damages and net returns can be estimated for any flood plain location and in turn a profit maximizing as well as flood loss minimizing land used designated.

Study Area

Nuyaka Creek flood plain, a part of the Okfuskee Tributaries located in southeastern Oklahoma, was selected as the study area (see Figure 2). The study area served as a facility for developing and testing the general model designed to estimate the incidence of flood damages. The completed model, although developed for Nuyaka Creek, is constructed in a general form so as to be applicable to other SCS project size watersheds.

Nuyaka Creek watershed was selected as the study area after consulting with watershed planning parties in Oklahoma. Selection was based on the availability of previous planning information and flood plain applicability for model development. An SCS flood control watershed project for the study area was planned and has been approved by Congress for construction. Hence, many of the data requirements of the proposed model are available. Data available from the SCS project include cross sections, hydrology and hydrolic data such as flood routings and elevations, crop damage factors and flood plain boundaries.

Another desirable characteristic of the study area for model building is the large number of crops that are adaptable to the area. This permits consideration of several alternative crops in establishing an optimum cropping system. Present land use in the Nuyaka Creek flood plain is composed primarily of pasture which, according to the SCS



Source: SCS Watershed Work Plan

Figure 2. Area of Study

work plan, is the result of the severe flood hazard faced on bottomland.[17]

Nuyaka Creek Watershed does not possess unique physical characteristics; i.e., levies, dikes, or erratic elevation changes across the flood plain which render a computer model unworkable. The watershed consists of 54,221 acres of which 3,740 acres are flood plain. The flood plain soils are mostly dark, medium textured, permeable, of recent alluviums and are very productive. The value of the productive capacity of bottomland ranges from $100 to $350 per acre under present conditions and estimates indicate it will be worth $200 to $400 per acre when adequate flood protection is provided.[18]

The climate is moist and subhumid. Average annual precipitation is 40 inches. The average frost-free period of 221 days extends from March 30 to November 7. The mean annual temperature is 61.5 degrees with the range 75.9 degrees in the summer to 45.5 degrees in the winter.[19]

The historical record of floods from 1941 through 1960 shows a total of 69 floods in Nuyaka Creek. Forty-one of the floods occurred in April, May, and June when row crops

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[17]U. S. Department of Agriculture, Soil Conservation Service, Work Plan for Watershed Protection, Flood Prevention, Agricultural Water Management and Non-Agricultural Water Management; Okfuskee Tributaries Watershed, tentative draft, November, 1966, p. 10.

[18]Ibid., pp. 6-8.

[19]Ibid., p. 7.

are immature and wheat is nearing harvest, months of low crop tolerance to flooding. In the months of September and October when row crops are nearing harvest stage, 11 floods were recorded. Therefore, 52 of the 69 floods have occurred at a time when substantial damage can be expected.

The remainder of this thesis discusses and illustrates a feasible method of estimating the incidence of agricultural flood damages. The discussion considers theoretical concepts applicable to the study and useful in problem solution. The model developed to estimate the incidence of agricultural flood damages and modified to select optimum land use is presented as a series of interdependent equations. With the model and applicable theory established, attention is directed to the study area (Nuyaka Creek flood plain). The discussion of the study area focuses on developing and ascertaining data required as input data in the model. Finally, data for the study area evolving from the model are illustrated in conjunction with possible uses and implications.

CHAPTER II

THEORETICAL CONCEPTS

In planning a watershed, the Soil Conservation Service (SCS) of the United States Department of Agricultural generally develops several alternative structural systems designed to reduce flooding. The reduction in expected flood damages (benefits) with each of the projects is estimated and compared to determine if a difference in benefits exists among the alternatives. By considering project benefits in conjunction with project costs, the best project of the group considered is selected for construction with the necessary condition that benefits exceed costs. A project that is constructed may have associated costs that are the responsibility of project beneficiaries. Watershed conservancy districts typically have as their objective assessing each person in the flood plain for these costs in relation to the percent of total project benefits received.

Watershed planning and development, as above, is based both explicitly and implicitly on theoretical concepts. The purpose of this chapter is to identify and discuss the role of theory in guiding watershed evaluations. Economic theory and principles have relevance and application with regard to flood damages on bottomland when (1) analyzing possible alternatives to flood loss, such as retention structures and insurance, (2) determining an optimum land-use cropping pattern, and (3) evaluating efficiency of flood plain use. Estimating the incidence of flood damages, which underlies much of the analysis and evaluation in small watersheds, requires a scientific model and logically consistent procedure.

The discussion of theoretical concepts applicable to this study begins with the general theory of watershed development. Welfare economics as applied to watershed projects and assessment procedures is investigated. Efficiency of flood plain use follows welfare economics with consideration given to possible methods of attaining efficient utilization of flood plain. The discussion turns to simulation as a tool in watershed evaluation and the chapter is concluded by indicating how the theoretical concepts are applied to a flood plain analysis.

Welfare Economics

The theory of welfare economics has been developed to deal with situations in which the market could not be expected to achieve an efficient result. Welfare economics can be considered a macro concept in that the utility of society as a whole is the primary focus of attention. The objective of the theory is to bring about an efficient use of resources by an economic system with maximization of social welfare in the long run.

Some characteristics or properties which make welfare economics especially applicable to water resource development include the inability to apply projects to particular properties. That is, effective flood protection measures must be planned on a community-wide scale and water resource developments have unusually significant spillover or external effects such as income and employment multipliers, electrical power source, irrigation and recreation facilities and reduction of down-stream water supplies.[1]

Generally, the application of welfare economics postulates to water resource development is in the form of benefit-cost analysis. Through benefit-cost analysis, the feasibility of water resource development is evaluated. The benefits of a project are the goods and services which the project yields to society. Conversely, costs are the losses attributable to the project as well as the planning, construction, operation, and maintenance outlays required by the project. The benefits and costs of a project are, for accounting purposes, expressed in terms of dollars since it is inconsistent and meaningless to add quantities of dissimilar goods expressed in terms of physical units.[2] By comparing the total social cost of a project with the total social benefits, the feasibility can be established. If

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[1]Irving K. Fox, New Horizons in Water Resources Administration, RFF Report, April, 1965, pp. 63-65.

[2]Federal Reserve Bank of Kansas City, "Economic Analysis of Water Resource Development Projects," Monthly Review (October, 1958), pp. 9-16.

benefits exceed costs, then the project is placed in an economically feasible set.[3]

Welfare economics expressed through benefit-cost analysis sets forth the criterion that benefits must exceed costs to attain economic justification for a watershed project. This indicates that the utility to a watershed from a project is greater than the disutility associated with installing and maintaining the project. The watershed as a whole is moved to a higher indifference curve with the project.

The Pareto criterion, associated with welfare economics, specifies that a policy is desirable if it makes some individuals better off while no one is made worse off.[4] In this sense, the Pareto criterion is inapplicable to watershed projects since some individuals are made worse off by a project; i.e., reservoir installation on productive land. However, the Kaldor criterion, which is the Pareto criterion with a compensations principle added, resolves the welfare economics issue concerning those individuals made worse off by a project. The Kaldor criterion states that a given policy is desirable if those who gain from it can

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[3]For a more comprehensive discussion of benefit-cost analysis, see S.V. Ciriacy-Wantrup, "Benefit-Cost Analysis and Public Resource Development," Journal of Farm Economics, XXXVIII (November, 1955), pp. 676-689.

[4]Luther Tweeten, Public Welfare and Economic Efficiency (unpublished manuscript), p. 10, based on earlier studies as Melvin W. Reder, Studies in the Theory of Welfare Economics (New York, 1947).

compensate the losers.[5] Applying the Kaldor criterion, land where flood retention structures are constructed is purchased by the watershed to compensate individuals that would be made worse off by the project. Costs of land purchase and watershed project maintenance are distributed among the beneficiaries of a project according to an assessment procedure.

Welfare economics can also be applied to the commutative justice principle of assessing beneficiaries of flood protection projects. The concept of commutative justice is that society owes to each individual the value of his contribution. In this case, each factor of production is paid its value of marginal product. Considering the definition in relation to construction of a watershed project, this implies that each of the beneficiaries of the project should pay for specified project costs in relation to the proportion of total project benefits received.

For a project to be economically feasible, benefit-cost analysis specifies that benefits of the project exceed costs. Therefore, beneficiaries of economically feasible projects are placed on a higher indifference curve. Assessments based on the commutative justice principle prevent an assessment that would violate the Pareto criterion; that is, assessing an individual to the point where he is placed on

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[5]Luther Tweeten, Public Welfare and Economic Efficiency (unpublished manuscript), p. 11, also discussed in James M. Henderson and Richard E. Quandt, Microeconomic Theory (New York, 1958), p. 219.

a lower indifference curve than before the watershed project. By assessing each beneficiary in relation to total benefits received, the individuals made worse off by a project are compensated and all beneficiaries will remain on a higher indifference curve than applicable before the project.[6]

Assessments are typically calculated based on the reduction in flood damages assuming present land use. That is, land use, before project installation, is projected into the future and benefits derived. Assessments based on the reduction in flood damages assuming present land use may not satisfy the commutative justice principle. Commutative justice calls for assessing each beneficiary in relation to benefits received. Benefits based on pasture production are much less than those based on higher value crops such as alfalfa, cotton, or peanuts. Due to the lower dollar value in benefits, assessments on pasture will be small compared to higher value crop assessments. Therefore, the farm operator with an assessment based on benefits to pasture that adjusts land use to the higher value crops after flood protection will receive benefits greater than that reflected in the assessment. This indicates that the farmer above pays

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[6]There are extranalities not included in this discussion which are difficult to quantify. For example, increased production in flood plain resulting from flood protection may affect upland farmers through a lower relative income position or even a lower absolute income if the increased bottomland production reduces product price.

less than the proportion of specified costs commutative justice calls for. It follows that farm operators that do not adjust land use after flood protection are paying more of the specified costs than commutative justice would allocate.

Commutative justice provides the norm or objective for distributing assessments but care must be exercised in selecting the method of calculation in order to realize the goal. Assessments based on present land use with no allowance for future adjustments can be expected to violate the commutative justice principle. Land use in a flood plain and adjustments that occur have implications beyond influencing flood protection benefits and in turn assessments. In addition to distorting assessments, land use adjustments affect the efficiency of flood plain use.

Efficiency of Flood Plain Use

Watershed development and evaluation encompasses more than consideration of systems of structures to reduce flooding. Analysis is called for regarding changes in flood plain use and implications of increasing flood damages. Often there are new development and land use changes that constitute an inefficient and uneconomical utilization of flood plain. Theoretical economic incentives can be used to adjust flood plain use optimally while taking into account the hazards imposed by nature. A procedure to attain optimum flood plain use is compulsory flood plain occupancy charges with indemnification for flood losses. The objectives of such a program should be to achieve an efficient use of flood plain, provide financial relief at times of flooding, and avoid excessive flood damages with respect to the expected net returns. If flood plain occupants were required to pay an annual charge in proportion to the flood hazard, the expected results over the long run would be: (1) assurance to society that occupants were assuming appropriate responsibility for locational decisions, (2) more intensive utilization of flood plain would be precluded unless advantages exceeded the total cost, and (3) there would be an incentive to provide flood protection to reduce damage potential and, consequently, reduce the occupancy charges.[7]

Considering efficiency of flood plain use in terms of expected net returns, the objective is adherence to the marginal conditions of production so as to maximize profit. Any flood plain use other than that which maximizes profit would be an inefficient allocation of flood plain since the resource (bottomland) is not being utilized to produce its net potential. Efficiency, in this case, can be viewed as an optimization process. The optimum or most efficient flood plain land use will occur naturally with adequate knowledge of the conditions of production (flood hazard,

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[7]U. S., Congress, House, Task Force on Federal Flood Control Policy, A Unified National Program for Managing Flood Losses, House Document No. 465, 89th Cong., 2d Sess., August 10, 1966, p. 38.

production costs and expected returns) assuming rationality and the objective of profit maximization on the part of the flood plain operator. A simulation model is used in this study to improve knowledge of the flood hazard, determine efficient land use, and compute land owner assessments consistent with theoretical postulates.

Simulation

The concept of simulation, utilized in this study to estimate flood damages, is applicable to innumerable areas of analysis and can be developed into almost any conceivable model. Simulation is typically the building of an operating model which is largely mathematical in nature. Simulation provides a means of dividing the model-building job into smaller component parts and then combining these parts in their natural order and allowing a computer to present the effect of their interaction on each other. The simulation model describes the operation of a system in terms of individual events of the individual components of the system.[8]

A concise and appropriate definition of simulation by Shubik states:

> A simulation of a system or organism is the operation of a model which is a representation of the system or organism. The model is amenable to manipulations which would be impossible, too expensive or impractical to perform on the entity it portrays. The operation of the model can be

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[8] Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research (San Francisco, 1968), pp. 439-440.

> studied and, from it, properties concerning the behavior of the actual system or its subsystem can be inferred.[9]

Simulation is, therefore, construction of a model of a real life situation and then performing experiments on the model. A scientific model is an abstraction of some real system that can be used for purposes of prediction and control; i.e., determine how one or more changes in aspects of a modeled system may effect other aspects of the system or the system as a whole. A model is composed of four distinct elements which include (1) components, (2) variables, (3) parameters, and (4) functional relationships. The components of a system refers to such things as firms in an industry. Variables that appear in economic models are used to relate one component to another and are classified as exogeneous or endogeneous. Exogeneous variables are independent of the model and assumed to have been predetermined by either the environment or the decision makers. Endogeneous variables are dependent and determined by exogeneous variable interaction upon the system. The functional relationships describing the interactions of the variables and components of a model are in the form of identities or operating characteristics. Identities are synonomous with definitions while operating characteristics are usually mathematical equations establishing some relationship.[10]

[9]Martin Shubik, "Simulation of the Industry and the Firm," American Economic Review, L, No. 5 (1960), p. 909.

[10]Thomas H. Naylor et. al., Computer Simulation Techniques (New York, 1968), pp. 2-12.

Simulation is an attempt to incorporate into a model the parameters and variables that portray the real life situation. One of the most significant advantages of a model of this type is that it permits analysis of a problem under different values for the parameters. Also, simulation techniques make it possible to compress time. With the use of a computer, a system extending over a number of years can be simulated in a matter of minutes.

Application of Theory

The simulation technique provides a vehicle for estimating the incidence of flood damages under a given set of conditions. Flood damage estimates are based upon the routing of a specific distribution of flood sizes or storms through the flood plain. Flood damages are determined by the relationship between storm characteristics (severity and season) and alternative flood plain locational characteristics (elevation, land use, and productivity). Exogeneous variables or parameters frequently manipulated to simulate alternative conditions include: (1) the set of preventative measures and resulting flood elevations, (2) commodity prices, (3) flood plain land-use patterns, and (4) flood plain productivity.

Using the model in providing information for benefit-cost analysis results in improved methodology for aiding in calculation of project benefits for agriculture. Flood damages throughout a flood plain can be simulated with and without the project. The difference in the two flood damage estimates is the reduction of flood losses or benefits attributable to flood protection projects.

If a project is approved for construction, the data developed by the model can be directly applied to meet the assessing norm (assessment of beneficiaries of flood protection in proportion to total benefits received). Flood damages, with and without flood protection, are estimated for each flood plain location; thus, benefits of flood protection are available for each flood plain location. The proportion of total benefits received is determined by dividing the project benefits of a flood plain farmer by total flood plain benefits. However, assessments based on present land use do violate the commutative justice criterion if there are changes in flood plain land use.

Use of the simulation model can be extended beyond benefit-cost analysis and assessment procedures; i.e., employed as a guide in flood plain land use organization. With knowledge of the incidence of flood damages, the farm firm has the opportunity of organizing production for profit maximization. A farm, including bottomland, is an individual business concern and as a rational, independent, decision-making managerial unit, presumably has as its primary objective maximization of net revenue to its limiting resources.

Since profit maximization is the assumed objective of flood plain farm operators, expected land use changes can be identified. With improved knowledge of the flood hazard, farm operators can be expected to adjust land use to increase profit. With knowledge of the flood hazard, farm operators will approximate a profit maximizing cropping pattern under present flood plain conditions, and after flood protection is provided make appropriate adjustments to retain a profit maximizing operation.

Assuming rational farm operators with profit maximization as the primary objective, it is possible to distribute assessments among beneficiaries so as to meet the commutative justice norm. Benefits of flood protection are measured as the expected increase in profit attributable to flood protection assuming a profit maximizing land use pattern both with and without flood protection. Assessments are allocated among beneficiaries relative to total benefits received or relative to the increase in profit possible with flood protection. To assess, based on the potential increase in profit, it is necessary to estimate profit maximizing cropping patterns for alternative flood plain conditions; i.e., with and without flood protection.

Flood plain land is typically operated by farmers having a combination of flood plain and upland in their farming units. To avoid the difficulty of maximizing returns to the fixed resources on each farm operating some flood plain land, it is assumed that land is the most limiting resource. With land the most limiting resource, the objective is maximization of net revenue per unit of land. By maximizing net revenue per acre of land, net revenue is maximized over the aggregate land resource.[11] Confining the analysis to flood plain, it is assumed the farm operator attempts to maximize per acre net revenue considering the conditions of the flood plain; i.e., the existence of a system of structures or no protection provided.

The model developed to maximize profit per acre of flood plain requires cost and return estimates for alternative land uses. To satisfy this data requirement, crop budgets were constructed.[12] A farm enterprise budget is a statement of inputs and expected outputs and is presumed to represent one point on a production function. Production is dryland in the study area flood plain and only one budget was constructed for each crop. The budgets were developed

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[11]It is realized this will not necessarily result in a profit maximizing organization for individual farm firms with both flood plain and upland. However, the results of this study, based on the simplifying assumption regarding land, serves as a useful guide in planning individual farm organization. The farm operator must consider all scarce resources (flood plain, upland, labor, capital, etc.) in an effort to establish an individual profit maximizing farm organization. This study provides a means of appraising flood plain alternatives available, resource requirements and expected profit. This data in conjunction with upland data and linear programming techniques or other appropriate procedures offer the farm operator an opportunity to organize farm production so as to maximize profit or minimize risk or some combination of both.

[12]R. D. Lacewell and Vernon R. Eidman, Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils of East Central Oklahoma, Oklahoma Agricultural Experiment Station Processed Series P-606, April, 1969.

with the aid of previous flood plain budget data, agricultural specialists familiar with the study area and economically recommended practices under present technology. The budgets are expected to closely approximate the optimum allocation of resources in each production period.

Given the assumption of land being the most limiting resource, production theory indicates the use of each of the other inputs x_i for each product y_j so that:

$$\frac{MVP_{x_i y_j}}{MFC_{x_i}} = 1 \qquad \begin{array}{l} i = 1, \ldots, n \\ j = 1, \ldots, m \end{array}$$

where:

$MVP_{x_i y_j}$ = marginal value product of input x_i used in the production of product y_j, and

MFC_{x_i} = marginal factor cost of the input x_i.

The profit maximizing concept with least cost combination of variable resources for multiple products and inputs is obtained by adhering to the conditions specified in the equation.

The budgets define expected net returns with optimum resource allocation for each land use assuming there is no flood damage. In determining optimum land use by flood plain location the flooding threat must be considered. Net returns are maximized by considering alternative land uses and selecting the land use with the largest return net of production costs and average annual flood damages. The following chapter discusses the methodology developed for estimating the incidence of agricultural flood damages which in turn permits determining optimum land use patterns as well as pursuing the other watershed analysis and evaluations discussed.

CHAPTER III

FLOOD PLAIN ANALYSIS MODELS

Watershed and flood plain evaluation calls for an examination of many characteristics and properties associated with area flooding. This study developed three models available as computer routines, to aid in small watershed research and planning. Models developed and discussed in this chapter are: (1) a simulator to determine the incidence of agricultural flood damages for a given set of conditions; i.e., land use, location, and productivity of a field, (2) an assessment model for assessing beneficiaries of an approved watershed flood control project by calculating the percent of total project benefits each flood plain location receives, and (3) an optimizing routine which selects the land use at each flood plain location maximizing net returns considering average annual flood damages. The computations and procedures involved in each of the models is discussed in turn.

Flood Damage Simulation Model[1]

The simulation model allows the computation of more

[1]See Appendix A, Figure 8 for a simplified flowchart of the simulation model.

accurate estimates of flood damages for small tracts and also derives damage estimates for an entire flood plain. The model uses the basic mechanics of the frequency method of flood damage estimation. However, the computation of flood damages is based on a point sample method rather than the concept of a composite acre. The point sample used in this model is a uniform assignment of sample points throughout the flood plain, with each sample point representing a specified number of acres. The model computes flood damages for each of the sample points assigned throughout the flood plain, with the damages based on unique characteristics of the point (land use, location, soil productivity, elevation of the sample point and flood elevation).

The simulation model utilizes data presently available in flood damage studies, such as crop damage factors, cross section data and hydrology through which flood elevation data is determined. Crop damage factors (percent reduction in gross returns due to flooding) typically utilized in discrete form in present methods, are converted to continuous functions to increase the accuracy of resulting damage estimates. The simulation model estimates damages for specific floods and average annual flood damages. These estimates can be made for a sample point or any combination of sample points up to the number representing the entire flood plain. Thus, flood damage estimates can be derived for one sample point, one field, one farm, a group of farms or the entire flood plain depending on the requirements of the person utilizing the model.

The model is composed of a series of computational steps for each sample point contained in the portion of the flood plain being studied. The sequential steps for a sample point are: (1) calculate sample point elevation, (2) calculate depth of inundation at the sample point for specified flood sizes, (3) weight damage factors by seasonal probability of flooding and convert to a continuous function of inundation depth, (4) calculate flood damages at the sample point, (5) determine proportion of potential gross revenue lost to flooding, and (6) calculate sample point returns net of production costs and average annual flood damages. The input data required, type of computational procedures and results obtained for each of the steps or segments are presented below.

Sample Point Elevation

The elevation of a sample point is computed by relating the sample point to the appropriate cross section.[2] Data utilized are elevations at stations across the channel (cross section stations), feet between stations, total stations on each channel side, and sample point location; i.e., channel side and the sample point as a percent of the

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[2]The matter of selecting the appropriate cross section is discussed later.

distance from the channel to the flood plain boundary.[3] The elevation of sample points is computed similarly on each channel side. For illustrative purposes, the elevation of a sample point located on the left channel bank is computed as follows:

$$\text{LDIST} = \text{LSTA} \cdot \text{LINTER}$$
$$\text{Dp} = \text{XOCATE} \cdot \text{LDIST}$$
$$\frac{\text{Dp}}{\text{LINTER}} = \text{SSTA} \Rightarrow \text{ELV}$$

where:

LDIST = total feet of flood plain from channel to left boundary,

LSTA = number of stations on cross section for flood plain located left of the channel,

LINTER = feet between stations,

Dp = feet sample point would lie from channel bottom if it were located on the cross section,

XOCATE = sample point location as a proportion of the distance from the channel bottom to flood plain edge,

SSTA = stations the sample point would lie from channel bottom if located on the cross section, and

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[3]The flood plain elevations on a cross section are recorded for given feet intervals. Cross section stations refer to the points on the cross section for which flood plain elevations are recorded.

ELV = elevation of the sample point which corresponds to the elevation on the cross section at station SSTA.

Briefly, the procedure determines where the sample point would lie if it were located on the cross section. The elevation of the cross section at that point is then assigned to the sample point. The elevation of sample points falling between two stations on a cross section is calculated using the elevation of the nearest station on each side of the sample point and linear interpolation procedures.

Depth of Inundation

The extent of flood damages are influenced by depth of inundation, the duration floodwater covers the point and speed with which it passes over a location. However, depth of inundation is the most significant factor affecting flood damages and is the only basis for computing damages considered in this model. Inundation depth for each sample point by storm size is computed as:

$$DEPTH = FELV - ELV$$

where:

DEPTH = depth of inundation for the flood on the sample point,

FELV = flood elevation at the cross section which represents the sample point.

This is determined based on hydrology and provided as input to the model, and

ELV = sample point elevation as related to the cross section.

Depth of inundation for a flood is the difference in the elevation reached by the flood and the elevation computed in the previous step for the sample point. A series of floods are normally considered using the frequency method for computing flooding damages. Therefore, each sample point has a depth of inundation associated with each of the floods. Many of the sample points in a typical watershed have negative inundation depths for specific flood sizes indicating the elevation of the sample point exceeds that of the flood and no flooding occurs.

An accounting procedure has been included in the model for the purpose of measuring acres inundated by each flood. The technique involves summing for each flood the number of sample points with a positive inundation depth and expanding to the acres the points represent. As the flood size increases any increase in acreage inundated will be specified.

Damage Factors

Damage factors used in current methods of estimating flood damages represent the percent reduction in expected gross returns by crop and season for a specific depth of inundation increment. For example, one factor may apply to the increment of zero to one foot inundation, another for one to three feet inundation, etc. The model adjusts these damage factors for probability of flooding in each season considered and further converts the adjusted factor from a discrete to a continuous function of inundation depth.

Damage factors for each crop are weighted for seasonal probability of flooding as follows:

$$SDAMA_{ij} = SWAIT_i \cdot FACTOR_{ij} \qquad i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, m$$

where:

$SDAMA_{ij}$ = percentage reduction in gross returns from flooding in season i at inundation depth increment j adjusted for probability of flooding,

$SWAIT_i$ = probability of a flood occurring in season i, and

$FACTOR_{ij}$ = percentage reduction in gross returns from flooding in season i for inundation depth increment j.

Damage factors ($FACTOR_{ij}$) are weighted so that damages from flooding will not be overestimated. Each season has a probability of a flood occurring ($SWAIT_i$) which is calculated by dividing all floods recorded into those occurring in the season. The damage factors are weighted by multiplying the damage factors for each season by the probability of a flood occurring in that season. This spreads each of the floods over all seasons and results in the damage factors that are utilized in further computations. However, the damages from a specific flood in a given season can be calculated when desired by assigning a probability of 1.0 to a flood occurring in a particular season and a 0.0 probability to remaining seasons.

The model converts these weighted damage factors for the j^{th} discrete inundation increment to a continuous function of inundation depth. This conversion is made so that estimated damages from flooding are more sensitive to depth of inundation; thus, more closely approximate the relationship between depth of inundation and the losses producers actually incur.

To convert from a discrete to a continuous function, the weighted damage factor for an inundation depth increment is assumed to be the average factor for that increment and is assigned to the median inundation depth of the interval. These weighted damage factors can be plotted at the median depth of inundation of each increment. Connecting the plotted values with straight line segments results in a unique damage factor for each depth of inundation. These computations are accomplished algebraically for a given depth of inundation μ (where μ is a specific level of inundation rather than an interval) and crop for season i as:

$$SDAMA_{i\mu} = SDAMA_{ij} - b_i \ (DE) + b_i \ (DEPTH_{\mu}) \qquad i = 1, 2, \ldots, n$$

or

$$SDAMA_{i\mu} = SDAMA_{ij} + b_i \ (DEPTH_{\mu} - DE)$$

where:

$SDAMA_{i\mu}$ = weighted damage factor applicable in season i for $DEPTH_{\mu}$ depth of inundation,

$SDAMA_{ij}$ = weighted crop damage factor for season i at the start of the redefined interval within which $DEPTH_{\mu}$ is located,

DE = depth of inundation at the beginning of the interval in which $DEPTH_{\mu}$ is contained; i.e., the level of inundation at which $SDAMA_{i\mu} = SDAMA_{ij}$,

$DEPTH_{\mu}$ = depth of inundation for which a damage factor is sought, and

b_i = change in season i of the weighted damage factor within the redefined depth of inundation interval in which $DEPTH_{\mu}$ is located.

The damage factor does reach a maximum, however, and remains constant for further levels of inundation. Hence, the maximum weighted damage factor for each crop and season is not changed. Figure 3 illustrates a hypothetical relationship between damage factors and depth of inundation.

Calculating Flood Damages

Gross value of production is used in estimating flood damages because it is a realistic measure of the loss that occurs due to flooding. Consider the problem of estimating damages for one flood on one acre at one sample point. The

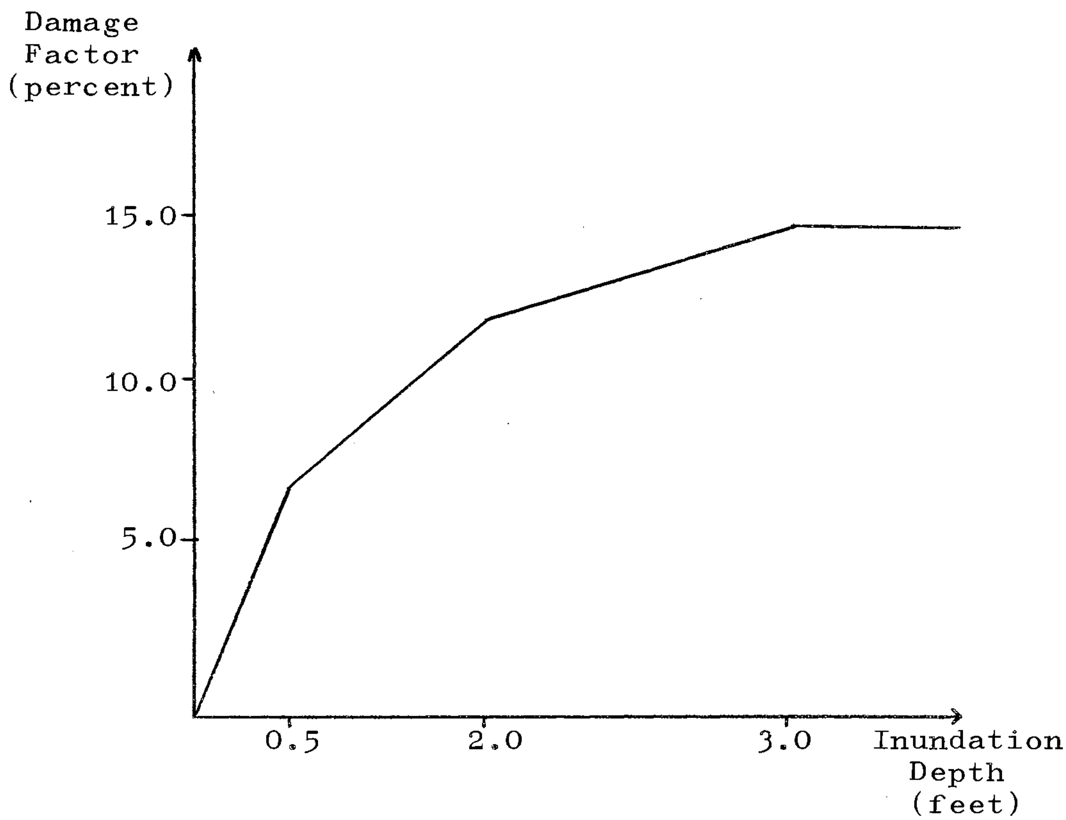

Figure 3. Illustration of Damage Factor as a Continuous Function of Inundation Depth

gross returns value per acre at a sample point r is calculated by:

$$GVAL_r = YIELD_r \cdot PRICE$$

where:

$GVAL_r$ = per acre gross value on sample point r assuming no flooding occurs,

$YIELD_r$ = expected per acre yield at point r if no flooding occurs, and

PRICE = price per unit for the output of the crop enterprise.

Expected damages per acre from flood size k for a sample point r are written as:

$$DAMA_{kr} = \sum_{i=1}^{n} [(GVAL_r)\ (SDAMA_{i\mu}/100)]$$

where:

$DAMA_{kr}$ = expected damages per acre resulting from flood size k at point r,

$GVAL_r$ = gross value per acre of the crop produced on sample point r assuming no flooding,

$SDAMA_{i\mu}$ = seasonal weighted damage factor for $DEPTH_\mu$ depth of inundation as computed above, and

n = total seasons considered.

A depth of inundation on a sample point of $DEPTH_\mu$ for a flood gives rise to the specific weighted damage factor for each season as computed above ($SDAMA_{i\mu}$). The expected damages per acre from this flood k are the sum of the gross value assuming no flooding occurs ($GVAL_r$) multiplied by the weighted damage factor expressed as a decimal for each season. This expected damage value ($DAMA_{kr}$) is for a given flood size k, and land use at point r with no specification being made as to the season in which the flood occurred. Since flood k is an anticipated flood, there is no way of knowing in which season it will occur. Therefore, the damages that would result in each season from flood size k are weighted by seasonal probability of flooding. Summing the weighted seasonal damage estimates gives estimated damages from flood size k.

Expected flood damages ($DAMA_{kr}$) are computed for each of the several flood sizes considered using the preceding equation. Using the damages from each flood, average annual flood damages per acre on the sample point are calculated as follows:

$$RDAMA_r = \sum_{k=1}^{K} [(DAMA_{kr})(SWEIGH_k)]$$

where:

$RDAMA_r$ = average annual flooding damages per acre on sample point r,

$DAMA_{kr}$ = expected damages per acre from the k^{th} flood size for a year in which it occurs, and

$SWEIGH_k$ = probability of the k^{th} flood size occurring in any given year.

Since all the flood sizes considered are not expected to occur in any given year, a simple summation of expected damages from each flood is not appropriate for determining expected average annual damages. Each of the flood sizes has an associated frequency, such as occurring every year, once in two years, once in five years, once in twenty years, etc. The probability of each flood occurring in a given year ($SWEIGH_k$) is obtained by dividing the frequency of the flood in years into one. Multiplying the damages expected in the year each flood occurs ($DAMA_{kr}$) by the flood's probability of occurrence in any given year ($SWEIGH_k$) results in the expected damages per acre for flood size k in any given year. Average annual damages per acre at the sample point are the summation of the expected damages for each flood in any given year.

The average annual damages computed ($RDAMA_r$) are for only one acre and must be expanded to include the acres the sample point represents. In equation form:

$$TDAMA_r = RDAMA_r \cdot SPA$$

where:

$TDAMA_r$ = total average annual damages for all acres represented by sample point r,

$RDAMA_r$ = average annual damages for one acre at sample point r, and

SPA = expansion factor (acres each sample point represents).

Average annual damages can be determined for any combination of R sample points (such as one field or one farm) using the estimates of average annual damages for the acres represented by each sample point as follows:

$$XDAMA = \sum_{r=1}^{R} TDAMA_r$$

where:

XDAMA = average annual damages for the R points,

$TDAMA_r$ = expanded average annual flood damages for each sample point, and

R = number of sample points representing the portion of the flood plain for which average annual damages are desired.

The summation of the expanded average annual flooding damages for all sample points representing any portion of the flood plain, whether it is one field, one farm, or a group of farms, results in total expected average annual damages for that area. Likewise, summation of the expanded average annual damages of all sample points comprising the flood plain yields expected average annual flood damages for that flood plain.

Proportion of Gross Value Lost to Flooding

Gross returns assuming no flooding can be computed for the entire flood plain as:

$$COMRET = \sum_{r=1}^{R} [(GVAL_r)\ (SPA)]$$

where:

COMRET = total flood plain gross value if no flooding occurs,

$GVAL_r$ = per acre gross value of sample point r assuming no flooding,

SPA = expansion factor (acres each sample point represents), and

R = in this case R refers to all sample points in the flood plain.

This procedure expands the expected gross value of each sample point if no flooding occurs from a per acre basis to a total value for all acres represented by the sample point. Summation of the expanded value for all sample points in the flood plain yields a gross value for the entire flood plain that would be expected assuming no flooding occurred.

After determining aggregate flood plain expected gross returns with no flooding, average annual flood damages as a percent of this gross return value can be computed as:

$$CDAMPE = \frac{XDAMA}{COMRET} \cdot 100$$

where:

CDAMPE = percent flood plain average annual damages are of flood plain gross value with no flooding,

XDAMA = flood plain average annual flood damages, and

COMRET = total flood plain gross value if no flooding occurs.

Again this is a straight forward calculation consisting simply of dividing average annual damages for the flood plain by gross returns with no flooding. The resulting value gives some indication of the extent of flood damages relative to gross returns.

Net Returns Considering Flooding

This part of the simulation model is included as an option to be used at the discretion of the user. The calculation involves the deletion of average annual damages and production costs from gross revenue for the acres represented by sample point r. The computation for sample point r can be expressed as:

$$PROFIT_r = GCVAL_r - [(COST_r \cdot SPA) + TDAMA_r]$$

where:

$PROFIT_r$ = net returns considering flooding damages for the acres represented by sample point r,

$GCVAL_r$ = gross value for the crop produced on the acres represented by sample point r assuming no flooding,

$COST_r$ = per acre production cost for the crop produced on sample point r,

SPA = expansion factor (acres each sample point represents), and

$TDAMA_r$ = average annual damages for acres represented by sample point r.

Net returns can be obtained for any portion up to and including the entire flood plain by accumulating the net returns value for the sample points included in the designated land tract.

Another option included in the simulation model is a provision whereby average annual flood damages for the acres represented by each sample point can be obtained as card output. This option is utilized to provide data for the assessment model without risking the possibility of a keypunch error.

The computational procedures of the model are somewhat more complex than those currently used in estimating average annual flood damages. However, the additional information of flood damages by sample point and any desired aggregation of sample points may well be worth the additional computational effort, particularly when a computer can be used to perform the routine calculations.

Assessment Model[4]

The simulation model for generating agricultural flood damages at a sample point makes a large quantity of flood damage data available. The flood damage data for each sample point are necessary to establish insurance premiums and estimate damages from individual floods. The sample point data can also be summed to provide aggregate damage data for cross section areas and the flood plain. However, there are occasions when work to be done with damage values obtained in the simulation model becomes very burdensome; i.e., the problem of assessing beneficiaries throughout the flood plain for specified project costs after a project has been approved. Provisions to expedite such an analysis have been provided for in the assessment computer model discussed below.

The assessment model utilizes the average annual flood damages for the area represented by each sample point (available as card output from the simulation model). The average annual flood damages on each sample point are for a specified set of conditions (for example, present land use and a system of flood retention structures). The assessment model is designed to compare average annual flood damages considering two specified sets of conditions; i.e., present flood plain conditions and alternatively, a particular

[4]See Appendix A, Figure 9 for a simplified flowchart of the assessment model.

system of proposed flood retention structures.

To assess with the model, average annual flood damages are simulated with present conditions (first set of conditions) and with the approved project (second set of conditions). Utilizing the assessment model, the system calculates the reduction in expected flood damages at each sample point and for the entire flood plain attributable to the project. The reduction in damages at each point is then divided by the total flood plain reduction to obtain the percent of project benefits each point receives. The assessment for each flood plain operator is determined by summing the percentage values above over the sample points representing his flood plain acreage.

The first computation of the model is subtracting by sample point average annual damages with a project from average annual damages without a project. This gives the reduction in each point's average annual damages with the project and can be expressed as follows:

$$DIFF_r = TDAM1_r - TDAM2_r$$

where:

$DIFF_r$ = difference in average annual flood damages for the r^{th} sample point considering two alternative sets of conditions,

$TDAM1_r$ = average annual flood damages for the r^{th} sample point with the first set of conditions (without project), and

$TDAM2_r$ = average annual flood damages of the r^{th} sample point with the second set of conditions (with project).

To aggregate the difference in flood damages between the two sets of conditions, the sample point values calculated above are summed over the total flood plain. This is given by the following equation:

$$TTDIF = \sum_{r=1}^{R} DIFF_r$$

where:

TTDIF = difference or reduction in flood plain average annual damages,

$DIFF_r$ = reduction in flood damages for the acres represented by the r^{th} sample point, and

R = total sample points representing the flood plain.

The two preceding computations yield the reduction in average annual flood damages (benefits) attributable to flood protection for each sample point ($DIFF_r$) and for the aggregate flood plain (TTDIF). The proportion of total flood plain benefits received by each sample point is in turn calculated based on this data. That is, the reduction in damages at each sample point is divided by reduction in damages over the aggregate flood plain. The specific computation is as follows:

$$TBENI_r = (DIFF_r / TTDIF) \times 100$$

where:

$TBENI_r$ = percentage of the aggregate flood plain reduction in flood damages received by the r^{th} sample point,

$DIFF_r$ = reduction in flood damages at the r^{th} sample point, and

TTDIF = total reduction in flood damages over the entire flood plain.

The value of $TBENI_r$ is the percent of total project benefits received by sample point r and, therefore, the percent of total specified project costs that are to be allocated to sample point r. The sum of $TBENI_r$ over all sample points is 100.0 since 100 percent of the reduction in flood damages must be accounted for.

Optimizing Model[5]

This model provides a method for selecting the land use which yields maximum net returns at each sample point considering expected flooding at that point. If net returns are maximized at each sample point throughout the flood plain, then net returns will have been maximized for the entire flood plain. By altering land use so as to increase or maximize net returns, benefits will arise as primary

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[5]See Appendix A, Figure 10 for a simplified flowchart of the optimizing model.

benefits to flood plain farmers from increased returns and secondary and tertionary benefits from increased income in the area as a whole due to increased farmer spending. Farmers will buy more farm supplies and consumer goods resulting in increased income for nonfarm business in the community through the multiplier effect. This study is concerned with identifying appropriate flood plain land use changes and the associated primary benefits or increased farm income forthcoming.

Maximizing profit over the aggregate flood plain indicates to farmers and watershed planners flood plain potential, a guide to future land use changes, flood plain characteristics and optimum cropping patterns. This study is not concerned with the farm organization problem. However, individual farmers utilizing data from the model can plan a farm organization suited to their needs and desires; i.e., profit maximizing or risk minimizing. The model selects the profit maximizing land use by sample point; hence, some flood plain fields as presently delineated can have more than one optimum land use. In this case the farmer has two alternatives. First, the farmer can consider redefining field boundaries. Alternatively or in conjunction with the first, the farmer can consider separately and individually each crop for a field and select that land use with the largest field profit. The optimum land use for each sample point serves as an organizational guide to the farmer in determining cropping patterns and in delineating fields.

The procedure utilized in the optimizing model is based on the previously discussed simulation model. Computations conducted in determining flood damages are identical for both models but with one major addition in the optimizing model. Rather than land use at each sample point being input data, the optimizing model considers each alternative crop on each sample point. Returns at each sample point net of average annual flood damages and production costs are then calculated. The crop at each sample point with the largest net return value is selected as the optimum land use for the sample point under the specified set of conditions. Optimum land use at a sample point could be expected to vary as conditions of the watershed change; i.e., installing flood protection projects.

The discussion of the optimizing procedure is limited to specific aspects or characteristics of the routine not discussed in connection with the simulation model. To properly account for net returns by crop, assuming no flooding, appropriate production costs must be included as input data. The model subtracts production costs from the "no flooding" gross revenue to obtain a no flooding net return value for each crop. Also incorporated within the optimizing model is an alternative permitting card output of optimum land use by sample point. This land use can then be read into the simulation model to make available the flood damage data discussed in conjunction with the simulation model.

The discussion of the optimizing model computations is built on those presented in the simulation model section. Net returns by crop for each sample point area are calculated by taking each crop's net revenue assuming no flooding and deleting average annual flood damages. The computation can be illustrated as:

$$PROFIT_{s\,r} = (DTRTN_{s\,r} \cdot SPA) - CDAM_{s\,r}$$

where:

$PROFIT_{s\,r}$ = net returns for crop s on acres represented by sample point r considering flooding,

$DTRTN_{s\,r}$ = per acre net returns for crop s on sample point r assuming no flooding,

SPA = expansion factor (acres each sample point represents),

$CDAM_{s\,r}$ = average annual flooding damages for crop s on the acres represented by sample point r.

The model continues by checking each of the net return values ($PROFIT_{s\,r}$) on sample point r. The largest value for the variable $PROFIT_{s\,r}$ on sample point r is selected as optimum. In notation form, this can be given as:

$$OPTUM_r = \max_s PROFIT_{s\,r}$$

where:

$OPTUM_r$ = largest net return value on the acres represented by sample point r considering flooding.

The crop on sample point r which yields maximum net returns considering flooding ($OPTUM_r$) is then the optimum land use for sample point r. The specific crop ($LDUSE_r$) which is optimum for sample point r, is identified from the subscript s on max $PROFIT_{s\,r}$.

The above procedure selects the optimum land use at sample point r for a given set of prices. To provide insight into the stability of the optimum land use solution, the second best land use and corresponding net returns for sample point r are identified. This can be illustrated as:

$$OPTUM2_r = \underset{s}{\text{2nd}}\ PROFIT_{s\,r}$$

where:

$OPTUM2_r$ = second largest net return value on the acres represented by sample point r considering flooding.

With this information available, it is now possible to determine the price of the optimum land use on sample point r that will result in a net return value equal to the second best land use net return value. This serves to illustrate the stability of the solution at each sample point by pointing out the optimum land use price decline necessary to change the solution. The optimum land use price at sample point r that gives net returns equal to the second best land use is computed by:

$$CPRICE_{h\,r} = \frac{OPTUM2_r + PCOST_{h\,r}}{YIELD_{h\,r} - (Fac_{h\,r} \cdot YIELD_{h\,r})}$$

where:

$CPRICE_{h\,r}$ = price of optimum land use on point r that gives net returns equal to second best land use,

$OPTUM2_r$ = net revenue with second best land use on point r,

$PCOST_{h\,r}$ = production cost of optimum land use on point r,

$YIELD_{h\,r}$ = optimum crop yield on point r, and

$Fac_{h\,r}$ = percentage reduction in gross returns due to flooding on sample point r with optimum land use.[6]

In addition to providing sample point optimum and second best land use and expected net returns, the model accumulates over the flood plain: (1) acreage of each crop with optimum and second best land use, (2) gross returns with no flooding, (3) net returns considering flooding, (4) production costs, and (5) average annual flood damages. Other data available through utilization of the optimizing model includes for each sample point: (1) average annual flood damages of each crop considered in the flood plain,

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[6]See Appendix D for development of the equation which determines the optimum land use price that will yield a net return value equal to the second best land use.

(2) gross returns with no flooding for all considered crops, and (3) net returns considering flooding for all crops.

The three models discussed in this chapter utilized in conjunction with hydrologic flood input data provided by the Soil Conservation Service permit a rather comprehensive analysis of flood damages in a small watershed. However, data requirements are especially rigorous for the models discussed above. The following chapter pertains to input data required, methods of development and practicable sources.

CHAPTER IV

DATA DEVELOPMENT FOR FLOOD PLAIN ANALYSIS

To utilize the simulator and optimizing models (dyad model) developed by this study, data requirements are both broad and exacting.[1] This chapter discusses the source of specific data and a means of organizing and developing input data for the dyad model. The dyad model was developed to utilize much of the same input data that current estimating procedures require. Of course, some of these data are modified or serve only as a facility for obtaining other data before being applied to the point sample procedure of flood damage analysis. The discussion of the input data required is illustrated by development of data for Nuyaka Creek Watershed in southeast Oklahoma, the study area.

The data demands of the dyad model can be grouped into three classifications. The first classification encompasses that data applicable to the flood plain as a whole. This includes aerial photos with cross sections and flood plain boundaries located. Other flood plain data required are

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[1] Since data requirements for both the simulator and optimizing models are identical, there is no need to distinguish between the two models. For convenience, future reference to the simulator and optimizing models collectively will employ the term "dyad" model.

statistics on historical flooding, particular flood sizes used in the analysis, crop damage factors, expansion factor for sample points, and crop characteristics such as yield, price per unit and production costs. The second classification refers to the data of a cross section area.[2] Data included in this grouping are elevations of cross section stations, elevation of the channel bottom at the cross section and elevations at the cross section of the specific flood sizes considered in the analysis. The last classification includes the land use, coordinate location and productivity group at each sample point. The data requirements of the dyad model are discussed below for each of the three classifications.

Flood Plain

Study Area Delineation

To initiate the analysis, it is imperative to define the flood plain area of study. Large scale aerial photos (1" = 400') containing the Nuyaka Creek flood plain were utilized to define the flood plain area of study and to provide a vehicle for locating sample points throughout the study area. Boundaries of the flood plain with no retention structures were established by SCS hydrologists in developing

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[2] A cross section area is that part of the flood plain which a particular cross section represents. The entire flood plain is, therefore, divided into several mutually exclusive cross section areas. These areas serve as a focus of analysis for this study.

a watershed plan. Also SCS personnel located cross sections on the channel and outlined that part of the flood plain each cross section represented. This boundary and cross section information was transferred to the aerial photos and a grid of sample points was assigned throughout the flood plain.

The density of sample points is based upon the physical characteristics of the flood plain. One sample point per five acres was the density rate selected for representation of the Nuyaka Creek flood plain. Sample points located near the flood plain boundary typically represent more or less flood plain acres than specified in the model due to meandering of the channel and accompanying flood plain.

Care should be exercised in selecting the acres a sample point is to represent to avoid sizable errors in estimated damages for the acres represented by these border sample points. Assuming a carefully chosen sample point density rate, the sample points near the flood plain boundary are flooded by only large and infrequent storms. Therefore, the adjustments to attain average annual flood damages reduces the size of the damage error, if any; i.e., if a border sample point is flooded by just the 100 year flood and estimated damages are $100 for the acres represented, average annual flood damages are $1.00 and any error included would be less than $1.00.

Since computations of the dyad model for a sample point are on a per acre basis, an expansion factor is necessary to dilate to the area represented by a sample point. With one sample point per five acres, the expansion factor is five. A portion of a hypothetical flood plain including a cross section, cross section boundary, flood plain boundary, channel, and a grid of assigned sample points is illustrated in Figure 4.

Floods

Floods, as related to the aggregate flood plain of the designated study area, constitute a second major data requirement. Selection of several specific flood sizes and the historical flood record of the area is needed. Flood damage estimates are based on selected flood sizes. The probability of occurrence of any selected flood does not vary over the flood plain and is used as a weighting mechanism to determine average annual damages. The historical record of floods is used to determine the probability of a flood in each season. Seasonal probability of a flood is used to estimate damages from an anticipated flood.

The frequency method of flood damage estimation is based on a selected distribution of flood sizes. Flood size refers to the years between occurrences (the larger a flood size, the less frequent its occurrence). That is, an annual flood is expected each year. It has a probability of 1.0 of occurrence in any given year, while the two year flood would be expected once in two years and has a probability of 0.5 of occurrence in any given year, etc.

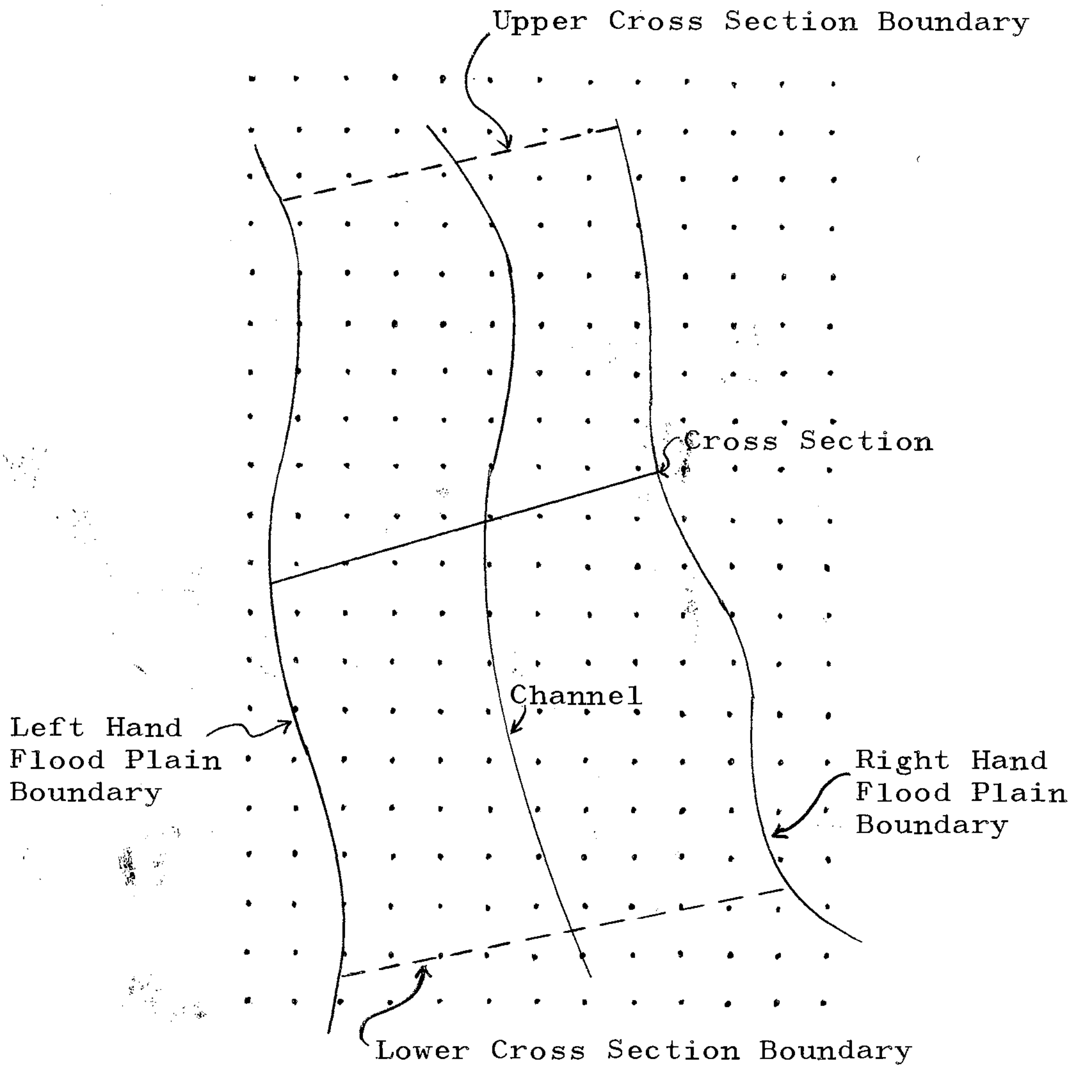

Figure 4. Hypothetical Representation of a Portion of Flood Plain With Cross Section, Cross Section Boundary, Flood Plain Boundary, Channel and Assigned Sample Points

Through consultation with the SCS Watershed Planning Party responsible for Nuyaka Creek Watershed, eight alternative flood sizes were selected. The distribution of flood sizes selected is not unlike distributions used in other studies based on the frequency method. Alternative flood sizes are selected to be representative of expected floods in the study area. The flood sizes range from the twice a year flood to the 100 year flood. The flood sizes selected and the probability of occurrence of each size in any given year are presented in Table I. As indicated previously, the probability of occurrence of a specific flood size is used to weight damages estimated for that flood to ascertain the expected flood damages in any given year rather than the year in which it occurs.

The dyad model estimating procedure, in addition to considering the flood size, also considers the seasonal probability of flooding. Following the SCS workplan for Nuyaka Creek, the year is divided into three seasons. The historical record of floods from 1941 through 1960 includes a total of 69 floods in Nuyaka Creek. The seasons with the months included in each, number of floods by season and month, and seasonal probability of flooding are presented in Table II. In addition, colum 4 of Table II gives the probability of a flood occurring in each month given a flood occurs in the season of which the month is a part.

The dyad model requires the probability of flooding by season. The probabilities are used to weight crop damage

TABLE I

FREQUENCY AND PROBABILITY OF OCCURRENCE OF OF EIGHT FLOOD SIZES SELECTED FOR THE ANALYSIS

Frequency (year)	Probability of Occurrence in Any Given Year (percent)
.5	200
1	100
3	33
5	20
10	10
25	4
50	2
100	1

TABLE II

FLOODS FROM 1941-1960 BY SEASONS AND MONTHS: NUYAKA CREEK WATERSHED

Seasons	Number[a]	Seasonal Probability of Flooding (percent)	Seasonal Floods by Month (percent)
(1)	(2)	(3)	(4)
Spring	41	59.42	100.0
April	12	-	29.3
May	17	-	41.4
June	12	-	29.3
Summer	17	24.64	100.0
July	5	-	29.4
August	1	-	5.9
September	6	-	35.3
October	5	-	29.4
Winter	11	15.94	100.0
November	4	-	36.3
December	2	-	18.2
January	1	-	9.1
February	1	-	9.1
March	3	-	27.3
Total	69	100.00	-

[a]Source: Soil Conservation Service Personnel, WPS, Claremore, Oklahoma.

factors given for each season. This weighting procedure permits estimating expected damages from an anticipated flood for which the season of occurrence is unknown and, hence, unspecified.

In many flood plains, crop damage factors are not available and must be derived. The percent of a seasons floods that occur in each month of the season (column 4 of Table II) is utilized to develop seasonal crop damage factors for a specific area or flood plain. The following section relates to crop damage factors and the method of calculation of a seasonal crop damage factor.

Crop Damage Factors

Crop damage factors must be calculated for alternative inundation depth increments given each of the three above seasons. Damage factors for each of the three seasons were calculated by SCS for corn, alfalfa, and native hay. Following SCS procedure, damage factors were calculated for other crops selected for consideration in this study. The procedure for calculating a damage factor for a specific land use, season and inundation increment is as follows:

1. The crop damage factor for each month of the season by depth of inundation is based on SCS data.[3]

[3]United States Department of Agriculture, Soil Conservation Service, Economics Guide for Watershed Protection and Flood Prevention, Economics Guide Oklahoma Supplement 4, March, 1964.

2. The total number of floods for each season is tabulated from the record of floods in the watershed.

3. The total floods in a given season are divided into the number of floods occurring in each month of the season to obtain the percent of the floods of a season that occur in each month (see Table II, column 4).

4. The results of (3) above serve as weights for the damage factors of each month; i.e., monthly crop damage factors are weighted by the percent of seasonal floods that occur in the given month.

5. The crop damage factor that applies to a season and depth increment is the summation of the weighted monthly crop damage factors of that depth increment and season.

The crop damage factors which served as input data for the dyad model are presented in Appendix B, Table XX. These damage factors were weighted by season probability of flooding and converted to a continuous function in the dyad model.[4] Damage factors were derived for all crops selected

[4]Appendix B, Figures 11-13 present damage factors as a continuous function of inundation depth for pastures (bermuda grass, native pasture and woodland pasture), alfalfa and wheat. Pastures and alfalfa were chosen for the illustration since they comprised 90 percent of the present land use in the flood plain. Conversely, wheat, which has little tolerance to flooding, illustrates the increased flood damage potential from a change in present land use.

as feasible alternatives in the study area. The discussion is now directed toward the crops applicable to Nuyaka Creek flood plain and their expected yields, prices, and costs of production.

Crop Characteristics

Selection of Relevant Crops

Crops to be considered in flood plain analysis should be selected early in the study so that data can be developed with respect to the crops selected. The length of the growing season, climatic conditions and soil potential of the study area affect feasible alternatives. Thirteen crops were chosen for this study based on present land use in the Nuyaka Creek flood plain and interviews with Soil Scientists familiar with the area. The crops chosen consist primarily of small grains, grain sorghum, corn, soybeans, peanuts, cotton, alfalfa and various pastures. Soil productivity groups were identified and a determination was made as to which crops could be produced on each productivity group.

Flood Plain Productivity Groups

A given flood plain is normally composed of several soil types. Although yield potential on some soil types is very similar, there may be large yield variations among others. The dyad model has the capability of including as a part of the computational procedure crop yields which are associated with different soil productivity groups. A consistent and representative means of designating soil productivity groups in any given flood plain is necessary to produce meaningful results. The method utilized in the Nuyaka Creek flood plain for developing productivity groups and estimating the yield potentials for each crop on each group is discussed below.

The initial step in the development of soil productivity groups was to identify all soil types present in the study area. This was accomplished by outlining the flood plain boundaries on a soils map and recording all soils that fell within the boundaries. The next step was grouping soils of similar characteristics and yield potential.[5] Yield data were developed in consultation with SCS state soil scientists, Oklahoma State University Agronomy and Agricultural Economics staff members, area farm management specialists and county extension directors. The productivity groups and corresponding expected yield for each crop considered in the analysis are presented in Table III.[6] The yield of each crop on each productivity group was developed to reflect yields attained by the better farmers of the area. The first productivity group (F_1) represents the better yielding loamy soils; F_2 refers to better yielding

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[5]See Appendix B, Table XXI for the soils included in each of the designated productivity groups.

[6]Based on the suggestion of state soil scientists, some soils not applicable for given crops were assigned a zero yield potential for those crops; i.e., alfalfa is not suited to a very shallow soil, so shallow soils are assigned a zero yield potential for alfalfa.

TABLE III

PRODUCTIVITY GROUPS AND CORRESPONDING PER ACRE CROP YIELDS: NUYAKA CREEK FLOOD PLAIN

Productivity Group[a]	Yield												
	Cotton (lb.)	Grain Sorghum (cwt.)	Corn (bu.)	Soybeans (bu.)	Wheat (bu.)	Oats (bu.)	Barley (bu.)	Peanuts (lb.)	Bermuda Grass (AUM)	Alfalfa (ton)	Native Hay (ton)	Woodland Pasture (AUM)	Native Pasture (AUM)
F_1	450	30	43	29	29	50	40	1500	7.2	4.5	1.5	0.7	2.7
F_2	450	30	43	29	29	50	40	b	7.2	4.5	1.5	0.7	2.7
F_3	360	25	36	26	26	48	38	1800	7.2	3.5	1.2	0.6	2.2
F_4	b	b	b	b	b	b	b	b	3.2	b	b	0.3	0.8

[a]See Appendix B, Table XXI for the soils included in each productivity group.

[b]The soils of this classification are neither adaptable nor normally utilized in the particular land use indicated, therefore, a zero yield is assumed even though some yield would be possible.

Source: Consultation with soil scientists of the Agronomy Department of Oklahoma State University and the Soil Conservation Service, and Fenton Gray. <u>Productivity of Key Soils in Oklahoma</u>, Oklahoma Experiment Station Bulletin No. B-650, October, 1966.

clays, F_3 includes loams not in F_1, and F_4 represents the poorest flood plain land which is not suitable for cultivation. The yields of all crops on F_1 and F_2 are similar except that F_2 is not suited to peanut production.

Some of the problems encountered in establishing yields and productivity groups in the study area include upland soils in the flood plain and pecan trees scattered about in the woodland pasture. Many of the soils taken from the soils map for the flood plain are not flood plain soils. Only seven of the 22 soils in the flood plain are classified as flood plain soils, but this group accounts for approximately 90 to 95 percent of the flood plain. Therefore, the 15 upland soils comprise less than 10 percent of the study area land subject to flooding. Upland soil inclusion in the designated flood plain can be resolved by considering that the water level rises sufficiently to inundate some upland soils located at the flood plain edge for very large floods such as 25 or 100 year occurrence. Therefore, large flood sizes inundate limited acreages of upland soils.

The second problem encountered was the difficulty of getting expected yield data for native pecan trees growing in the wooded areas of the flood plain. The native pecan trees are not uniformly spaced throughout the wooded areas and presently very few of the pecans produced on these trees are commercially harvested due to the density of other trees around them. Also, there is little or no management of trees, hence, pecan production associated with one of these trees is quite low. For these reasons, it was decided that the study would only consider those pecan trees that are in groves. It is felt the bias resulting from eliminating the pecan trees from the analysis is far less than would be incorporated by attempting to include them. Therefore, any future returns from native pecans can be considered a windfall to the farm operator. The discussion above illustrates the approach of this study in establishing soil productivity groups and indicates some of the problems that may arise.

Prices Received by Farmers

A market price per unit is required to determine the per acre gross value of each crop associated with each productivity group. In determining the appropriate price for each crop, it is necessary to consider government programs and past price trends. The influence of government price support programs is removed when conducting an evaluation of watershed projects. However, benefits of government price support programs are included in developing an optimum cropping pattern.

Four alternative sets of commodity prices were used in this study (Table IV).[7] The different sets of prices are

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[7]The normalized and benefit prices specified in Table IV were used to compute damages with present land use and alternative flood plain conditions while all four sets of prices were used in determining optimum land use patterns. The different computations made are specified in Appendix C, Table XXX.

TABLE IV

ALTERNATIVE CROP PRICES UTILIZED IN THE ANALYSIS AND EVALUATION OF NUYAKA CREEK FLOOD PLAIN

Crop	Unit	Prices (dollars)			
		Normalized[a]	Benefit[b]	Adjusted[c]	Mixed[d]
Cotton	lb.	0.288	0.337	0.00	0.00
Grain sorghum	cwt.	1.69	1.75	1.69	1.69
Corn	bu.	1.05	1.20	1.05	1.05
Soybeans	bu.	2.45	2.40	2.45	2.40
Wheat	bu.	1.30	1.84	1.30	1.30
Oats	bu.	0.60	0.75	0.60	0.60
Barley	bu.	0.85	0.90	0.85	0.85
Peanuts	lb.	0.10	0.13	0.00	0.00
Bermuda grass	AUM	2.50[e]	2.50[e]	2.50[e]	2.50[e]
Alfalfa	ton	22.00	22.50	22.00	22.50
Native hay	ton	22.00	15.00	22.00	15.00
Woodland pasture	AUM	2.50[e]	2.50[e]	2.50[e]	2.50[e]
Native pasture	AUM	2.50[e]	2.50[e]	2.50[e]	2.50[e]

[a]Normalized prices computed to reflect farm prices with benefits of government farm programs deleted. Source: Interim Price Standards for Planning and Evaluating Water and Land Resources, Interdepartmental Staff Committee of the Water Resources Council, April, 1966, p. 4.

[b]Area prices received by farmers including benefits of government programs. Source: R.D. Lacewell and Vernon R. Eidman, Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils at East Central and South Central Oklahoma, Oklahoma Agricultural Experiment Station Processed Series P-606, April, 1969.

[c]Normalized prices (benefits of government price support programs not included) with peanuts and cotton deleted from consideration.

[d]Normalized prices for surplus crops, cotton and peanuts deleted and benefit prices for all other crops.

[e]Source: Gordon Sloggett, and Neil Cook, Evaluating Flood Prevention in Upstream Watersheds with an Areal Point Sample -- Interim Report, Washita River Basin, Oklahoma, USDA, NRED, ERS-353, July, 1967, Table 17, p. 21.

termed normalized, benefit, adjusted and mixed to aid in the discussion and for convenience in future references. The prices designated as normalized have been adjusted so as to minimize the influence of government price support programs. Alternatively, benefit prices include the advantages of government programs.

Crop prices are influenced by allotments and the study area is characterized by very limited cotton and peanut allotments. Since cotton and peanuts are not normally grown without an allotment, the last two sets of prices (adjusted and mixed) delete these two crops as feasible alternatives. Adjusted prices are the same as normalized prices, except for the deletion of peanuts and cotton. Mixed prices, given in the last column of Table IV, are made up of normalized prices for surplus crops, peanuts and cotton deleted, and benefit prices for all other crops.

Crop prices often include returns from joint products of production and payments of government price support programs. For example, the composition of specific crop prices for this study includes: (1) the benefit price of wheat which consists of $1.25 per bushel farm price plus 59 cents per bushel attributable to government programs, (2) the price per pound of peanuts which includes $18.00 per ton from peanut straw sold as hay assuming one ton of hay is produced for every 1800 pounds of peanuts, and (3) the price of cotton which includes returns from cottonseed (at $48.00 per ton) assuming 1.58 hundred weight of cottonseed is produced for every one hundred weight of lint produced. The benefit price per pound of cotton includes 20 cents farmer price plus 9.6 cents from government programs. Crop prices in conjunction with yield data, provide a basis for estimating flood damages. However, any effort to determine expected profit or to develop an optimum cropping pattern requires additional data, namely, production costs.

Production Costs

Production costs are required by the optimizing model and are also necessary input if the researcher elects to compute net return values with the simulation model. A set of enterprise budgets were constructed by productivity group for the study area.[8] Production costs for each crop by productivity group were taken from these budgets. The production costs are shown in Appendix B, Table XXII. The production cost estimates reflect the alternative per acre input requirements associated with the different land types considering economic and physical principles of production. Included in the costs are direct production expenses (such as seed, fertilizer and machinery operating expenses), labor costs, machinery ownership costs and interest on power and machinery capital. The last three cost items above (fixed costs) were included since crops such as native hay assume a

[8] R. D. Lacewell and Vernon R. Eidman, Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils of East Central and South Central Oklahoma, Oklahoma Agricultural Experiment Station Processed Series P-606, April, 1969.

ten year depreciation period. In determining optimum land use, the long run prospective is viewed; i.e., machinery costs were considered as variable rather than fixed. Hence, the machinery and operator labor costs normally considered as fixed are included as production expenses. Even with the long run perspective of this study, there were fixed overhead costs which were not included as part of production costs. These fixed overhead costs included charges associated with land (taxes, insurance, land payments, and opportunity cost of investment), a return to management, and a risk consideration.

Present land use of woodland pasture throughout much of the flood plain complicated the development of appropriate production costs for many sample points. The wooded areas must be cleared and improved before land presently in woodland pasture can be considered for cultivation, alfalfa, or bermuda grass. The cost of clearing and preparing an acre of woodland for other crops varies with the density and size of the brush and trees. Large and numerous trees are characteristic of this particular area. Based on interviews with specialists familiar with both the study area and cost of clearing and preparing land, a clearing and land preparation cost of $100 per acre was estimated. It was further assumed the $100 was borrowed at 7 percent interest and was repaid over a 35 year period. This is not inconsistent with current Federal Land Bank policy concerning loans secured by real estate. Amortizing the $100 over 35 years at 7 percent interest yields an annual charge of $7.72 per acre. Therefore, to consider crops other than woodland pasture on an acre of land presently in woodland pasture the $7.72 is entered as an annual production cost in addition to the other production costs. This provides for the cost of clearing and preparing land as well as aiding in analyzing the economic feasibility of clearing particular fields or land areas.

The native hay and bermuda grass production budgets were modified to reflect the average yield and production costs over the assumed depreciation period. The native hay establishment cost was prorated over the ten year depreciation period. The years immediately following establishment with below normal yields were combined with years of normal yield to establish an average annual yield for native hay and bermuda grass. The value of the yield reduction below a normal year's production due to averaging over the depreciation period was considered a cost since yields in Table III are for a normal year.[9] The production costs and other data discussed above satisfy the rather extensive data requirements applicable to the entire flood plain. Therefore, the following discussion of the dyad model data requirements is focused more toward individual parts of the flood plain. The first step in the flood plain disaggregation is

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[9]See Appendix B, Table XXIII for computation of native hay establishment cost and Appendix B, Table XXIV for the value of yield reduction due to averaging for native hay and bermuda grass.

consideration of data requirements by cross section area.

Cross Section Area

A cross section area serves as a basis of analysis for the dyad model. The model is designed to perform the calculations on a sample point matrix not to exceed 14 rows and 14 columns. The actual number of rows and columns utilized in each sample point matrix must be included as part of the dyad model input data. A 14 by 14 sample point matrix size is large enough to encompass most cross section areas. For those cases where this is not true, the cross section area must be subdivided to meet the above specifications. Sample points not located in the flood plain are typically included in the sample point matrix. These points are, of course, ignored in the computational procedure. Cross section area input data which are applied to the sample point matrix or matrices in the computational procedure include station elevations of the cross section and elevation at the cross section of each flood size selected for the analysis.

Flood Plain Cross Section

The SCS located 21 cross sections along Nuyaka Creek to represent the flood plain. An illustration of the flood plain and cross section locations is presented in Figure 2. The surveyed cross sections were illustrated graphically with elevation on the vertical axis and distance on the horizontal axis. A hypothetical cross section for one side of a flood plain is illustrated in Figure 5.

The feet between stations on each cross section was determined based on the nature of elevation changes across the flood plain. The distance between stations was selected so that significant cross section elevation changes would not be omitted. The less erratic the elevation changes of a cross section the greater the permissible distance between stations. The interval between cross section stations ranged from five to 20 feet and the number of stations from five to 448 for the study area cross sections.[10] The elevation of cross section stations is read off the SCS graphical illustration with x feet between each station.

Other than the elevation of cross section stations, data applicable at the cross section and required by the dyad model include elevation of selected flood sizes, elevation of the channel bottom and an elevation in excess of any flood plain elevation. The last elevation is assigned to those sample points in the sample point matrix lying outside the flood plain. This assures that there will be no flood damages computed for non-flood plain sample points.

Flood Elevation

To obtain depth of inundation for sample points located in a cross section area, it is necessary to have elevations

[10]See Appendix B, Table XXV for the interval between cross section stations and number of stations on each channel bank for each of the 21 Nuyaka Creek cross sections.

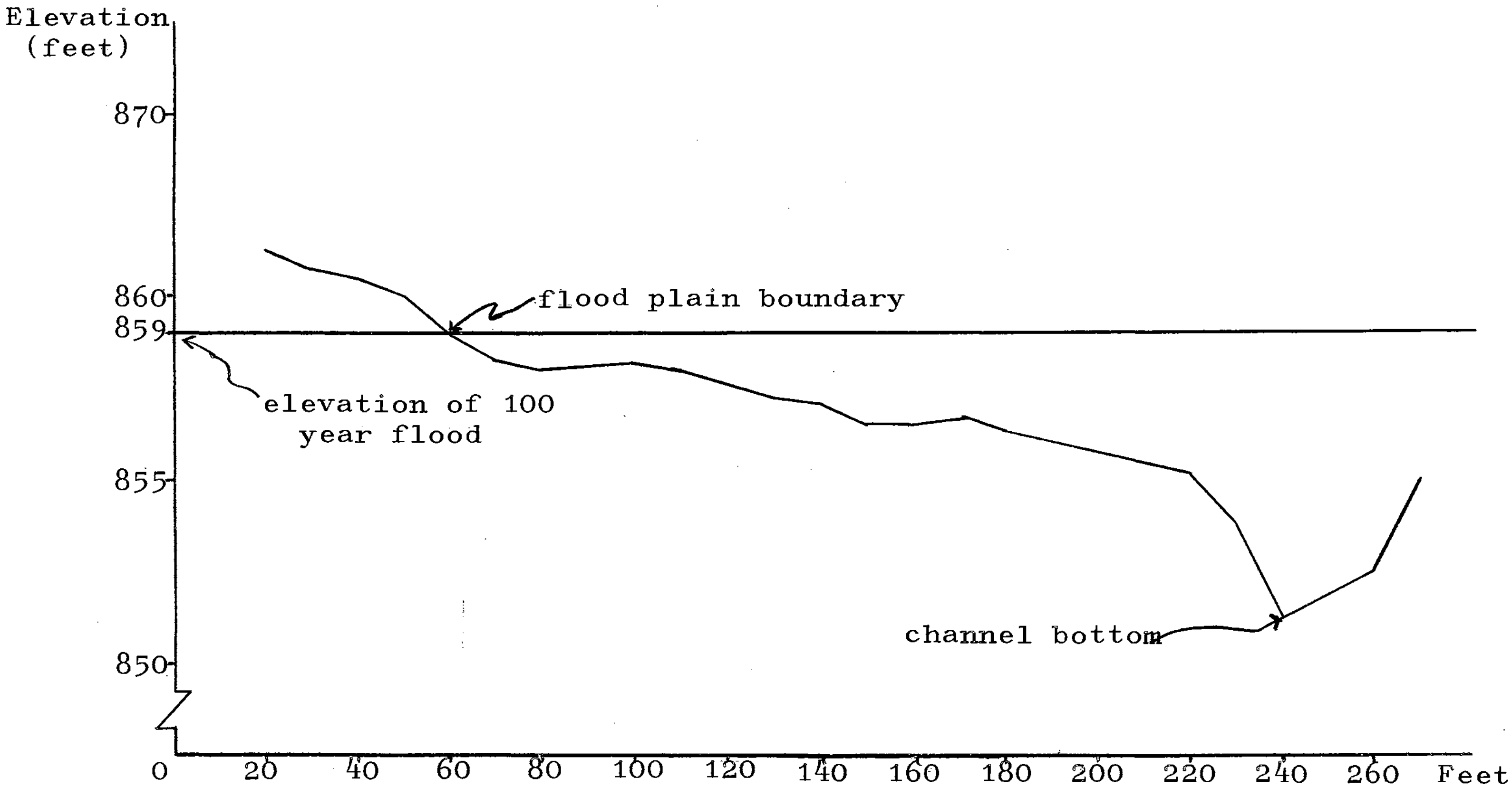

Figure 5. Hypothetical Cross Section Illustrating the Left Bank of a Flood Plain

for the flood sizes considered in an analysis. SCS hydrologists computed the peak elevation of each flood size selected at each cross section. These elevations depend upon the condition of the watershed; i.e., present conditions and alternative systems of structures. This study considered two alternative systems of structures designed by SCS watershed planning party engineers (designated as SS I and SS II with SS II approved by Congress for construction) along with present flood plain conditions in utilizing the dyad model for analysis of Nuyaka Creek flood plain.[11]

Even though the flood elevations are obtained from SCS, the procedure through which they are obtained is briefly summarized here. The first step is to determine the rainfall necessary to produce each of the chosen floods in the flood plain under analysis. These data are available in the form of maps with iso-rainfall curves illustrating the required rainfall for realization of each flood size. Associated with rainfall is runoff which is obtained from current conversion curves. Using hydrologic relationships developed for the study area, runoff is converted to cubic feet per second (CFS) for each cross section and flood size without retention structures or with any given system of retention structures. The hydrology of the flood plain is

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[11]See Appendix B, Tables XXVI-XXVIII for peak elevation of each selected flood size at each cross section given the three watershed conditions. Structure system SS I includes 13 flood retention structures and structure system SS II includes 11 flood retention structures. Ten of the structures are the same for both SS I and SS II.

further utilized to convert from the CFS value above to a peak elevation at each cross section for the given flood size and retention structure system, if any. A more thorough discussion of these procedures is contained in the SCS National Engineering Handbook, Section 4, Hydrology.

The remaining data requirements of the dyad model relate to a sample point and constitute the final disaggregation of the flood plain. The following section discusses sample point characteristics upon which the computations regarding flood damages in a specific field are dependent.

Sample Point

Land Use

Land use at each sample point is only necessary as input data for the simulation model. Present land use at each sample point was obtained by field observation and enumeration of flood plain farmers. The distribution of present land use over the 748 flood plain sample points is presented in Table V. The sample points recorded as in the Soil Bank were considered as pasture in the analysis so that damages from flooding could be estimated for those flood plain locations.

Results from the optimizing model under alternative pricing and flood plain conditions produce a series of land uses at each sample point which can be utilized in the simulation model. Any number of land use patterns other than present land use are possible depending upon the goals and

TABLE V

DISTRIBUTION OF SAMPLE POINTS BY PRESENT LAND USE: NUYAKA CREEK FLOOD PLAIN[a]

Land Use	Number of Sample Points	Percent of Total
Wheat	11	1.47
Oats	16	2.14
Soybeans	7	.94
Corn	2	.27
Cotton	2	.27
Alfalfa	58	7.75
Native Hay	13	1.74
Bermuda Grass	50	6.68
Pasture	218	29.14
Woodland Pasture	350	46.79
Soil Bank	14	1.87
Barley	7	.94
Total	748	100.00

[a]Present land use refers to the 1968 flood plain land use.

objectives of a flood plain or watershed research project. A significant factor influencing possible land use choices for a sample point, however, is the production potential of the sample point. To permit consideration of alternative production potentials, each sample point was assigned to an appropriate productivity group.

Productivity Group

The productivity group of each sample point was determined by utilizing the data in Table III.[12] The procedure of establishing the productivity group applicable to a sample point involves identifying the soil type at the sample point and determining the productivity group to which it belongs. The productivity group specifies the yield of each crop for the sample point. The last data requirement of the dyad model is the elevation of the sample point (used to calculate depth of inundation).

Coordinate Location

Elevation of a sample point is computed by relating the point to the appropriate cross section. The coordinate location of a sample point is expressed as the percent of the distance from the channel to the flood plain boundary the sample point lies. This percentage value is calculated from aerial photos bearing the grid of sample points and channel

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[12]See Appendix B, Table XXIX for the distribution of the 748 flood plain sample points among the productivity groups.

and flood plain boundaries. Special consideration is given those sample points that do not lie in the flood plain. For those sample points lying in the channel, the coordinate location is given as 0.0, on the flood plain boundary 1.0, and outside the flood plain 2.0.

For those sample points that lie in the flood plain, it is necessary to identify, in addition to coordinate location, on which flood plain bank (right or left) the point lies. This does not apply to sample points that lie in the channel, on the flood plain boundary or outside the flood plain. Identifying flood plain bank for a sample point is accomplished by a one or a two preceding the coordinate location value, with a one indicating the left bank and a two the right bank. Therefore, flood plain sample points on the left bank take on a location value of 100.0 to 199.9, and those on the right bank 200.0 to 299.9.

The above input data satisfy the needs of the dyad model. The following chapters present an application of the models developed in this study utilizing the data discussed above. An attempt is made to illustrate the model's potential for flood plain analysis and planning and present in part the massive quantity of output that results.

CHAPTER V

THE EFFECT OF FLOOD PROTECTION

An application of the simulation model to Nuyaka Creek flood plain is presented in this chapter. There are no provisions for optimization incorporated in the simulator.[1] Therefore, the discussion focuses on flood damages incurred assuming 1968 land use, hereafter referred to as present land use. Present land use in the study area is presented in Table V.

Flood damage values were computed for present flood plain conditions (no protection) as well as for structure systems SS I and SS II. The computations were based on two sets of commodity prices and two separate classifications of sample point productivity groups. Sample points were initially assigned to the productivity group which designates crop yields representative of those expected at the sample point. Alternatively, all sample points were placed in a single productivity group (F_1) to determine the effect of a single grouping on damage estimates. Productivity group F_1 was selected as the single grouping since it is applicable to over 50 percent of the flood plain and would appear to be

[1] Optimum flood plain land use patterns and associated values are presented in the following chapter.

the most reasonable single productivity group if only one is to be considered.

Discussion of the simulator output, with and without flood protection, concentrates primarily on (1) acres inundated, (2) effect of alternative assumptions on flood damage dollar values, and (3) applicability in establishing flood insurance premiums. Output from the assessment model (utilizing average annual flood damages from the simulator as input data) is also included in the analysis to illustrate assessment capabilities and indicate the effect of alternative assumptions on individual assessments. Land use is specified by sample point in the simulator and benefits of flood protection and all damage values in this chapter are based on present sample point land use.

Acres Inundated

The acres inundated by flood size assuming present flood plain conditions (no protection) and structure systems SS I and SS II are illustrated in Figure 6. Of these three alternative flood plain conditions, acres inundated by flood size are least for SS I. The reduction in acres inundated due to the installation of SS I, with respect to present conditions, ranges from 725 acres for the twice a year flood to 1,380 acres for the flood occurring every third year. The reduction in acres flooded with SS II, considering these same flood sizes, ranges from 405 acres to 930 acres. The average annual percentage reduction in acres

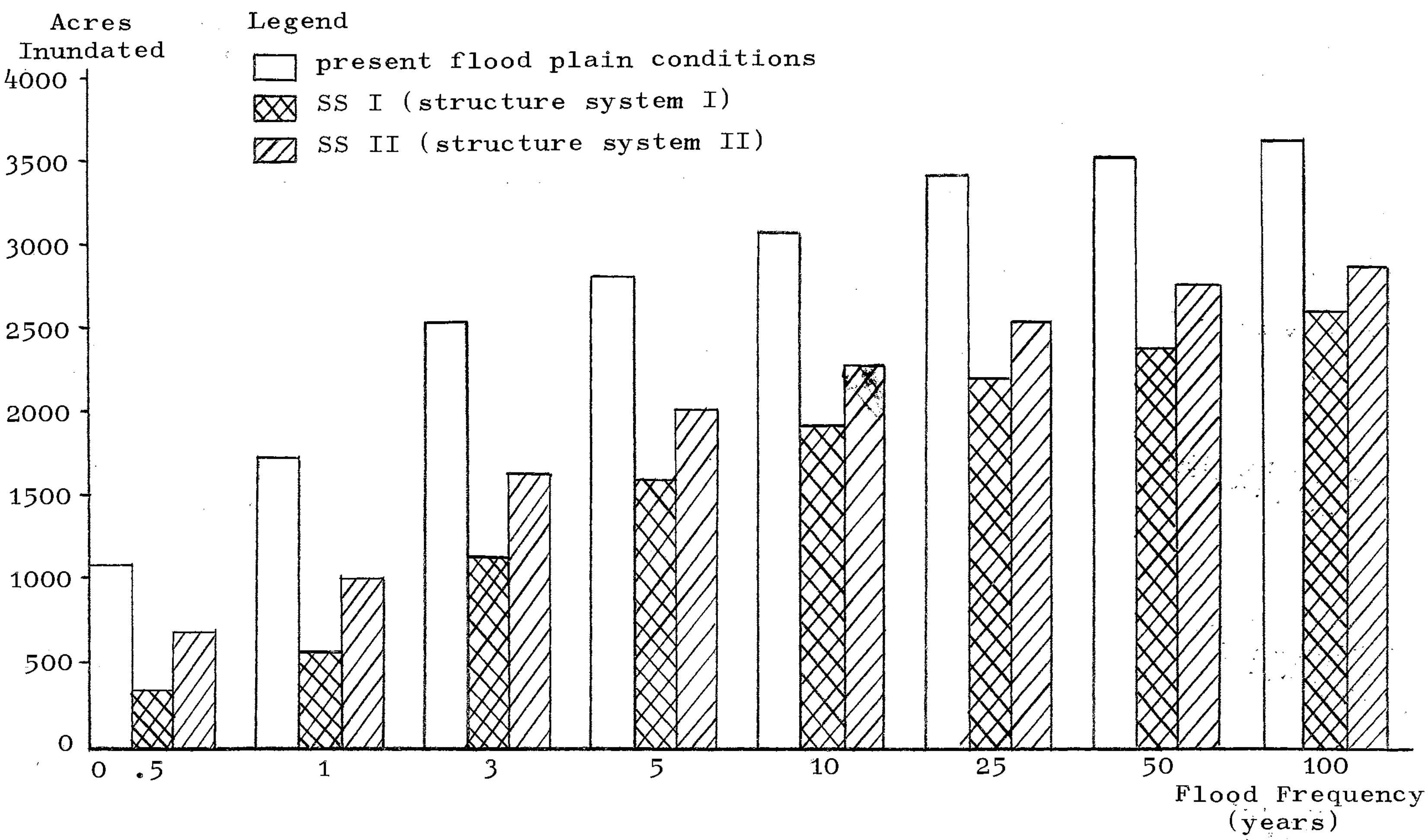

Figure 6. Total Flood Plain Acres Inundated by Flood Size for Alternative Flood Plain Conditions

flooded over all flood sizes is 26.5 percent and 15.8 percent for SS I and SS II, respectively.[2] Considering only acres inundated, SS I is characterized by the least amount of flooding. Measurements of acres flooded or the reduction in acres flooded, however, provide little insight into the significance of floods and methods proposed for reducing the flood hazard. Dollar values regarding flood damages and benefits of protection serve as a common denominator and an approximate measure of utility. The remainder of this chapter is concerned with these dollar values and how they are influenced by changes in assumptions.

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[2]Computation of average annual percentage reduction in acres flooded utilized the following equation (see Appendix C, Table XXXI for derivation of the equation);

$$\frac{\sum_{i=1}^{8} (R_i \cdot Swait_i)}{\sum_{i=1}^{8} (P_i \cdot Swait_i)} \cdot 100$$

where:

R_i = structure system reduction in acres flooded by the i^{th} flood size with respect to present flood plain conditions,

P_i = acres flooded by the i^{th} size flood assuming present flood plain conditions, and

$Swait_i$ = percentage chance of occurrence in a specific year of the i^{th} size flood.

Comparing Average Annual Damages Computed Under Alternative Assumptions

Flood damages, as computed by the simulation model, are a function of a series of variables. Changes in assumptions which affect the variable values can be expected to cause adjustments in computed average annual damages.

Flood damage changes that result from manipulation of variables are in some cases very small in relation to the total damage value involved. The question of a statistically significant difference as verified by an appropriate statistical test arises in these situations. Utilizing the simulation model as developed for this study, any difference in computed damages due to a change in a variable is statistically significant regardless of the size of the deviation.

The model computes damages for each of the sample points that have been assigned throughout the flood plain based on predetermined input data. Since sample points are not altered as to location and represent the total flood plain, they are in effect the population. Therefore, the use of alternative predetermined variable values that result in different magnitudes of computed damages is interpreted as a change in the population value. Any change in a population value is in and of itself significant and does not require confirmation by a formal statistical test.[3] The following discussion is concerned with the variables of commodity price, flood plain condition, and sample point productivity group and how changes in each of these are reflected in estimated flood damages.

Normalized and Benefit Crop Prices

To determine current average annual flood damages and expected benefits of flood protection (reduction in average annual damages) two sets of crop prices were utilized. To estimate the benefits to society and provide a basis for justifying flood protection, this study used current normalized commodity prices which remove the benefits of government price support programs. However, to express the individual farmer viewpoint, flood damages were computed utilizing commodity prices with benefits of price support programs included (benefit prices).

Total flood plain gross returns, production costs, average annual flood damages, net returns, and average per acre net returns computed with benefit prices and normalized prices are presented in Table VI. The cost and return

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[3]A statistical test, such as the paired "t" test, to determine if a significant difference exists between two alternative damage computations would be applicable if: (1) the grid of sample points was relocated for each computation, (2) there was a probability associated with the value assumed by a variable, or (3) the analysis was based on a sample of the points rather than the entire population.

TABLE VI

COSTS AND RETURNS ASSOCIATED WITH PRESENT LAND USE UNDER ALTERNATIVE FLOOD PLAIN CONDITIONS AND COMMODITY PRICE ASSUMPTIONS

Assumption	Aggregate Flood Plain				Net Returns Per Acre
	Gross Returns[a]	Production Costs	Average Annual Flood Damages	Net Returns	
	(thousand dollars)				(dollars)
Normalized Prices[b]					
Present Flood Plain Conditions	54.6	31.3	11.6	11.7	3.12
SS I[c]	54.6	31.3	3.1	20.2	5.40
SS II[c]	54.6	31.3	4.9	18.4	4.92
Benefit Prices[d]					
Present Flood Plain Conditions	56.3	31.3	12.3	12.7	3.39
SS I[c]	56.3	31.3	3.3	21.7	5.81
SS II[c]	56.3	31.3	5.2	19.8	5.28

[a]Gross returns assuming no flooding occurs.

[b]Crop prices with benefits of government price support programs deleted (Table IV).

[c]Watershed protection plans developed by SCS watershed planning party. SS II has been approved by Congress for construction.

[d]Crop prices with benefits of government price support programs included (Table IV).

values were calculated for present flood plain conditions, structure system SS I, and structure system SS II. Production costs remain the same, $31,300, over all conditions since there is no alteration in land use or price of inputs.

The difference in estimated flood damages as computed with benefit prices and normalized prices is sensitive to flood plain crops produced. The output of some land uses will have an identical normalized price and benefit price; i.e., pasture, bermuda grass, and alfalfa. Therefore, the larger the proportion of flood plain allocated to these land uses, the smaller the difference in flood damages as estimated by the two sets of prices. Eighty-five percent of present production in Nuyaka Creek flood plain is in pasture and other crops with the same benefit and normalized price. However, even with only 15 percent of the flood plain in crops having a different benefit and normalized price there are notable differences between flood damage estimates based on the two sets of prices for each of the alternative flood plain conditions.

Benefit prices result in larger gross returns and average annual flood damage estimates than do normalized prices under each of the flood plain conditions. Also, the increase in gross returns, using benefit prices as opposed to normalized prices, is larger than the increase in average annual flood damages. Therefore, with production costs constant, net returns computed with benefit prices are larger than computed with normalized prices.

Gross returns computed with benefit prices are $1,700 larger than computed with normalized prices over all flood plain conditions. The corresponding increase in average annual flood damages is $700, $200, and $300 for present flood plain conditions, SS I, and SS II, respectively, and net returns increase by $1,000, $1,500, and $1,400. The values in Table VI indicate that the greater the amount of flood protection provided (SS I), the smaller the difference in flood damages as calculated with benefit and normalized prices. Conversely, the difference in net returns for the two sets of prices would be greater the more effective the flood protection.

Added insight regarding the changes in average annual flood damages resulting from a change in crop prices is made by considering the data in Table VII. Flood plain acres applicable to each increment of average annual flood damages for alternative assumptions of flood plain condition, commodity prices, and designation of sample point productivity group are presented in Table VII. By comparing appropriate columns of Table VII, some indication of the effect of assumption changes on distribution of damages can be identified. All sample points by increment are included in the distribution. Therefore, the number of shifts that take place may tend to be understated since some shifts may be offset by others.

The distribution of flood plain acres by flood damage increment, resulting from the two sets of prices, are given

TABLE VII

DISTRIBUTION OF FLOOD PLAIN ACREAGE BY MAGNITUDE OF AVERAGE ANNUAL FLOOD DAMAGES INCURRED FOR ALTERNATIVE COMMODITY PRICE, FLOOD PLAIN CONDITIONS AND PRODUCTIVITY GROUPING ASSUMPTIONS

Interval of Average Annual Flood Damages	Assumptions Underlying Flood Damage Estimates											
	Respective Productivity Group[a]						Single Flood Plain Productivity Group[b]					
	Benefit Prices[c]			Normalized Prices[d]			Benefit Prices[c]			Normalized Prices[d]		
	Present Flood Plain Conditions	SS I	SS II	Present Flood Plain Conditions	SS I	SS II	Present Flood Plain Conditions	SS I	SS II	Present Flood Plain Conditions	SS I	SS II
(dollars)	(acres)											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
No damages	175	1,255	965	175	1,230	965	155	1,225	940	155	1,225	940
0.00 - 0.05	655	780	765	655	800	765	645	765	740	645	765	740
0.06 - 0.20	695	570	525	690	565	525	670	585	540	665	575	540
0.21 - 1.00	990	595	685	995	600	680	1,025	610	695	1,030	615	690
1.01 - 5.00	745	410	570	750	415	585	750	415	585	755	420	600
5.01 - 20.00	340	110	175	340	100	160	345	115	180	345	105	165
20.01 - 40.00	75	15	40	90	30	55	80	20	40	95	35	55
40.01 - 60.00	25	5	15	5	-	5	25	5	15	5	-	5
60.00 or more	40	-	-	40	-	-	45	-	5	45	-	5
Total Average Annual Flood Damages (thousand dollars)	12.3	3.3	5.2	11.6	3.1	4.9	13.0	3.5	5.7	12.3	3.4	5.3

[a]Each of the 748 flood plain sample points is assigned to the productivity grouping corresponding to its yield potential.

[b]All 748 flood plain sample points are arbitrarily assigned to productivity grouping F_1 irregardless of differing yield potentials between individual points.

[c]Crop prices with benefits of government price support programs included (Table IV).

[d]Crop prices with benefits of government price support programs not included (Table IV).

in Table VII. The distribution of present flood plain conditions is given in columns two and five, the SS I distribution in columns three and six, and the SS II distribution in columns four and seven. A comparison of the two columns for each flood plain condition reveals very similar acreage distributions. The largest discrepancy for a single increment is 20, 25, and 15 acres for present flood plain conditions, SS I, and SS II, respectively. The total acres falling in a different damage interval is 50 acres for present flood plain conditions, 90 acres for SS I, and 60 acres for SS II. Although the total discrepancy due to different commodity prices is greatest for SS I, more of the discrepancy appears in the smaller damage intervals than with the other two flood plain conditions. The result is a smaller difference in average annual damages computed with benefit and normalized prices for flood plain condition SS I than for either present flood plain conditions or SS II.

The shift of sample points between average annual damage increments due to a change in crop prices (as given in Table VII) reveals very little with regard to damages estimated for individual sample points. The discussion of sample point average annual flood damages as influenced by crop price is limited to present flood plain conditions. The acres represented by four sample points account for over $300 of the $700 increase in computed damages using benefit prices as compared to normalized prices. Average annual flood damages for each of these four sample points are approximately $260 to the individual as reflected in benefit prices. Alternatively, the loss incurred by society due to flooding on each of these same sample points is only $185; i.e., the loss to society from flooding is $75 less than for the flood plain occupant on each of the four sample points. These four sample points help illustrate the extent to which a crop price change or particular point of view (society versus individual) can affect or influence flood damage estimates.

Considering the aggregate flood plain, the effect of crop prices on average annual flood damages is small in relation to total damage values (less than six percent for any given flood plain condition). A change in crop prices does change estimated damages, but there are other assumptions which exert a much greater influence on flood damages for both sample points and the aggregate flood plain. Such an example is a change in assumed flood plain conditions (present flood plain conditions, SS I and SS II).

Alternative Flood Plain Conditions

Benefits of flood protection are measured by the reduction in average annual damages. This study is concerned with the reduction in present damages (present flood plain conditions) due to installation of structure systems SS I and SS II. Flood protection project benefits are presented for both society and the flood plain occupant.

There are benefits other than agricultural which are outside the scope of this report that also accrue to the structure systems; i.e., reduced damage to roads, pipelines, houses, fences, etc.[4] Also, reduction in flooding permits more intensive utilization of flood plain, therefore, benefits result from land enhancement. Flood protection benefits in the form of land enhancement, however, must be tabulated in some form other than reduced damages. Flood damages may very well increase after installation of flood protection due to an increased production of higher income crops which have an associated higher flood loss but also have a higher expected net income considering flooding.

With present land use projected over all conditions, benefits of flood protection, whether measured by reduction in average annual damages or increase in expected net revenue, will be equal. However, with land use changes, benefits of flood protection would be more accurately estimated by the increase in expected net returns. The following chapter discusses benefits of structure systems with changes in land use patterns.

Nuyaka Creek flood plain values are presented in Table VI based on a present land use projected over all conditions. These values applicable to society, as implied by

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[4]All average annual benefits are included in justifying a project. Cost of installation of SS II is estimated by the watershed project plan at $816,688. Amortized over 100 years at 3% gives an average annual cost of $25,845 not including operation and maintenance. Average annual benefits must exceed the average annual cost to obtain a favorable benefit-cost ratio and justify the project.

estimates based on normalized prices, include gross returns, assuming no flooding, of $54,600 for the three flood plain conditions. By installing flood retention structures, average annual flood damages are reduced from $11,600 to $3,100, and $4,900 with SS I and SS II, respectively. Benefits to society, as measured by the reduction in flood damages, are $8,500 with SS I and $6,700 with SS II. The increase in net returns resulting from flood protection is the same as the reduction in flood damages since there are no land use adjustments and any reduction in flood damages increases profit by a like amount. Average net returns per acre of flood plain increase from $3.12 for present conditions to $5.40 and $4.92 with SS I and SS II, respectively.

Flood protection benefits for the flood plain occupant, reflected in computations using benefit prices, are somewhat larger than for society. Farmer gross returns are $1,700 higher than for society or $56,300. Similarly, the reduction in average annual damages is larger for flood plain occupants amounting to $9,000 for SS I and $7,100 for SS II. Per acre net returns increase from $3.39 with present conditions to $5.81 and $5.28 with SS I and SS II, respectively. The percentage increase in per acre net returns due to flood protection is approximately the same for normalized and benefit prices when considering the same structure system; i.e., SS I results in a 72 percent increase in net returns and SS II results in a 57 percent increase in net returns.

The effect of alternative flood plain conditions on the distribution of flood plain acres over flood damage increments is illustrated in Table VII. The appropriate columns for comparison of (1) present flood plain conditions and SS I are two versus three and five versus six, (2) for present flood plain conditions and SS II, two versus four and five versus seven, and (3) for SS I and SS II, three versus four and six versus seven. There are two comparisons for each of the three situations above since two sets of crop prices were used to compute damages.

Structure systems SS I and SS II, under both price assumptions, show a significant redistribution of flood plain acres among damage increments as compared to present flood plain conditions. As would be expected, flood protection results in the larger damage increments applying to less acreage and the smaller damage increments applying to more acreage. The acreage applicable to each of the damage increments beginning with six cents and extending through $60 or more is greater under present flood plain conditions than for either SS I or SS II. Alternatively, SS I and SS II are characterized by an additional 800 to 1000 acres incurring no damages compared to present flood plain conditions.

Comparing SS I to SS II for both price assumptions, SS I is characterized by an additional 265 to 290 acres incurring no damages. Also, the distribution of flood plain acres with SS II shows a greater number of acres applicable to the larger damage increments than with SS I. The result is added evidence of a smaller incidence of flood damages with SS I compared to SS II.

As before, the distribution of acreage over damage increments provides general indications but avoids individual sample points. The effect of alternative flood plain conditions on flood plain represented by a sample point is given in terms of changes in average annual damages. Structure system SS I results in a reduction of average annual damages of approximately $9,000 compared to present flood plain conditions. For each of four sample points, the reduction in damages is in excess of $300 and for another seven is in excess of $200. These 11 sample points account for over $3,000 of the total $9,000 difference.

The difference in damages between SS I and SS II is not nearly so dramatic, amounting to less than $2,000 over the aggregate flood plain. Reduction in damages of more than $100 is incurred by only four of the 748 sample points with the reduction less than $175 in each case. The difference in average annual damages between a structure system (SS I or SS II) and present flood plain conditions is much larger, both for the aggregate flood plain and specific sample points, than between SS I and SS II.

The discussion of the effect of alternative assumptions on average annual damages has been thus far limited to crop prices and flood plain conditions. The following section extends this same general type analysis to include the effect of alternative productivity groups.

Alternative Productivity Groups

Much effort is required in developing alternative productivity groups to which sample points can be assigned. Of the 748 study area sample points, 52 percent are classified as F_1, 42 percent F_2, and the remaining as F_3 and F_4.[5] Since the majority of the flood plain sample points are classified as F_1, this would appear to be the most reasonable single flood plain productivity group if only one is to be considered. Average annual damages for the aggregate flood plain when each sample point is assigned to its appropriate productivity grouping and with each sample point assigned to productivity group F_1 are presented in Table VIII. The damage estimates are made utilizing normalized prices and benefit prices in conjunction with the three alternative flood plain conditions.

The objective of this particular analysis is to determine if the computations based on the single productivity group over all sample points are approximately equal to computations based on a classification of each sample point into a productivity group consistent with its yield potentials. It is evident from Table VIII that damage estimates for the single productivity group exceed the "correct"

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[5]See Appendix B, Table XXIX for a classification of sample points by productivity group and Table III for crop yields associated with each productivity group.

TABLE VIII

AVERAGE ANNUAL FLOOD DAMAGES WITH PRESENT LAND USE UNDER ALTERNATIVE ASSUMED FLOOD PLAIN CONDITIONS, PRODUCTIVITY GROUPINGS AND COMMODITY PRICES

Commodity Price and Flood Plain Conditions	Respective Productivity Group[a]			Single Flood Plain Productivity Group[b]		
	Average Annual Flood Damages		Average Annual Damages as a Percent of Gross Revenue	Average Annual Flood Damages		Average Annual Damages as a Percent of Gross Revenue
	Flood Plain (thousand dollars)	Per Acre (dollars)	(percent)	Flood Plain (thousand dollars)	Per Acre (dollars)	(percent)
Benefit Price[c]						
Present Flood Plain Conditions	12.3	3.30	21.91	13.0	3.48	22.49
SS I[d]	3.3	0.88	5.82	3.5	0.95	6.10
SS II[d]	5.2	1.41	9.33	5.7	1.52	9.80
Normalized Price[e]						
Present Flood Plain Conditions	11.6	3.11	21.31	12.3	3.28	21.84
SS I[d]	3.1	0.83	5.70	3.4	0.90	5.98
SS II[d]	4.9	1.31	8.99	5.3	1.42	9.46

[a]Each of the 748 flood plain sample points is assigned to the productivity grouping corresponding to its yield potential.

[b]All 748 flood plain sample points are assigned to productivity group F_1 irregardless of differing yield potentials between individual points.

[c]Crop prices with benefits of government price support programs included (Table IV).

[d]Watershed protection plans developed by SCS watershed planning party. SS II has been approved by Congress for construction.

[e]Crop prices with benefits of government price support programs not included (Table IV).

calculations.[6] Turning to present flood plain conditions, damages with one flood plain grouping are $700 higher for the aggregate flood plain and approximately 18 cents higher per acre than the "correct" values for both benefit and normalized price estimates.

The result of using the one productivity group selected for Nuyaka Creek is overestimation of flood protection benefits. For example, calculating with normalized prices, benefits of SS I and SS II are $400 and $300 greater, respectively, for the single grouping compared to a "correct" classification and similarly, $500 and $200 greater for the benefit price calculations. Gross returns are $1,600 greater with the single flood plain grouping as compared to a "correct" grouping for both sets of price assumptions. Production costs, for the single grouping would be the same as given in Table VI, $31,300, and since the increase in average annual damages is less than the gross return increase it would be expected net returns would also be overestimated.

The direction of the bias that would result from the selection of any one of the productivity groups as the single flood plain group can be projected based on the distribution of sample points between productivity groups.

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[6] The computations made with each sample point classified according to its appropriate productivity group are also estimates and subject to error. However, these estimates are referred to as "correct" for the sake of simplicity since they represent an improved estimating procedure over the single flood plain productivity grouping.

Productivity group F_1 causes an overestimation of flood plain values. Productivity group F_2 would bring forth the same result since the only difference in F_1 and F_2 concerns peanuts which are not presently being produced in the flood plain. The overestimation of values is due to sample points characterized by soil types with a lower yield potential than F_1 being assigned to group F_1; i.e., sample points correctly classified as F_3 or F_4 placed in group F_1. This inflates yields for affected sample points and, consequently, for the total flood plain. The inapplicable yields which exceed expected yields cause excessive gross return and flood damage estimates. The yield on 48 sample points is affected assuming the F_1 single productivity grouping but in each case the yield designed in group F_1 is greater than the sample point's correct grouping yield.

Alternatively, flood plain values would be underestimated if all sample points were assigned to productivity group F_3. Although an F_3 grouping would overestimate yields for 42 sample points, yields would be underestimated for 700 sample points. The underestimated yields are proportionately much greater and far outweigh the overestimated yields. Therefore, gross return and average annual flood damage estimates will be underestimated based on yield estimates lower than appropriate for given soil types. Since flood damages are computed as a percentage of gross returns, it follows that this misclassification will reduce gross returns more than it will reduce average annual flood damages. Therefore, with little or no change in production costs, net returns will also be underestimated due to the F_3 flood plain classification. An F_4 flood plain classification would bring forth these same results since each of the 706 sample points misclassified would be assigned a lower yield potential than expected with the soil types present.

This study did not compute flood plain values assuming a single flood plain grouping of F_3 or F_4, but rather limited the analysis to F_1. Some indication of the number of sample points having a change in flood damages resulting from the arbitrary classification of all sample points into productivity group F_1 can be shown by referring once again to Table VII. The columns to compare in evaluating the effect of productivity groups are (1) two and eight, (2) three and nine, (3) four and ten, (4) five and eleven, (5) six and twelve, and (6) seven and thirteen. In comparing the respective columns above, approximately 90 acres fall into a different flood damage class in each case. The single productivity grouping (F_1) results in increased flood damage estimates which cause a shifting of flood plain acres to larger increments. (Less acres are in the very small damage increments under the single productivity grouping than under the correct productivity grouping.) The effect of alternative productive groupings on the distribution is greater in the smaller damage increments than in the larger damage increments. However, acreage differences in the larger damage increments can indicate for the sample point involved a significant bias in damage estimates. The repercussions of inaccurate damage estimates for specific sample points is explored in more detail in the following section.

Assessing Beneficiaries for Flood Protection

Flood protection results from the action of a conservancy district which can plan and apply land treatment and structural measures required in watershed projects.[7] The Conservancy District Act permits conservancy districts to appraise benefits and levy assessments to pay the cost of installing, operating and maintaining works of improvement not included in legislative appropriations.

Simulator output utilized in the assessment model provides a method of establishing flood protection benefits (measured by the reduction in average annual damages) for each sample point and proportion of total benefits each receives.[8] Beneficiary assessment is determined by accumulating the proportion of total benefits received over the sample points representing each flood plain farmer. This provides a basis for assessment of a flood plain operator relative to total flood protection benefits received.

The discussion of assessment by sample point in Nuyaka

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[7] The position of a soil and water conservation district with respect to watershed projects was obtained from an unpublished paper outlining present assessment procedures in Oklahoma.

[8] See Chapter III for a discussion of the assessment model methodology.

Creek flood plain is limited to benefits provided by SS II since it has been approved by Congress for construction. The reduction in average annual flood damages at each sample point, attributable to flood protection, is affected by the assumptions under which damage estimates are made; i.e., commodity prices and sample point productivity group designation. The proportion of total flood protection benefits received by each sample point is first examined considering normalized prices and benefit prices. This is followed by a discussion of the effect of alternative sample point productivity group designations on the proportion of benefits received. Lastly, the sample points of one cross section area, associated flood damages and flood protection benefits are presented for illustrative purposes.

Effect of Alternative Prices on Assessments

Table IX gives the distribution of flood plain sample points by percent of total benefits received under alternative assumptions. The percent of total benefits received corresponds to the percent of specified costs each sample point would be assessed and could, therefore, be referred to as an assessment factor. The concern, at this point, is the relationship between flood protection benefits calculated with alternative sets of prices, given each sample point is classified in the productivity group corresponding to its yield potential (columns two and three of Table IX).

Comparing the distribution in columns two and three of

TABLE IX

DISTRIBUTION OF FLOOD PLAIN SAMPLE POINTS BY PROPORTION OF TOTAL FLOOD PROTECTION BENEFITS RECEIVED FROM INSTALLATION OF STRUCTURE SYSTEM SS II FOR ALTERNATIVE COMMODITY PRICE AND PRODUCTIVITY GROUPING ASSUMPTIONS[a]

Percent of Total Flood Protection Benefits[a]	Respective Productivity Group[b]		Single Flood Plain Productivity Group[c]	
	Normalized Price[d]	Benefit Price[e]	Normalized Price[d]	Benefit Price[e]
	(Sample Points)			
(1)	(2)	(3)	(4)	(5)
no benefits	87	82	87	82
0.0001 - 0.0025	124	118	120	121
0.0026 - 0.0050	54	46	52	47
0.0051 - 0.0075	64	69	71	76
0.0076 - 0.0100	54	44	50	47
0.0101 - 0.0200	92	97	91	89
0.0201 - 0.0300	60	70	60	66
0.0301 - 0.0400	31	27	29	30
0.0401 - 0.0500	15	13	14	13
0.0501 - 0.0750	33	32	34	34
0.0751 - 0.1000	22	29	29	29
0.1001 - 0.5000	66	62	54	53
0.5001 - 1.0000	22	34	33	35
1.0001 - 2.5000	17	17	17	19
2.5001 or more	7	7	7	6
Total	748	748	748	748

[a]Benefits refer to the reduction in average annual flood damages attributable to flood protection. Each sample point represents five acres of flood plain; hence, the sample point numbers in the table are synonymous with five acre units of flood plain.

[b]Each of the 748 flood plain sample points is assigned to the productivity group corresponding to its yield potential.

[c]All 748 flood plain sample points are assigned to productivity group F_1 irregardless of differing yield potentials between individual points.

[d]Crop prices with benefits of government price support programs not included (Table IV).

[e]Crop prices with benefits of government price support programs included (Table IV).

Table IX, the largest difference in the number of sample points applicable to a single assessment factor increment is twelve with an average difference per increment of approximately five. Over the total distribution, the discrepancy between columns two and three is 79 sample points. This indicates little difference in assessments comparing benefits calculated with normalized prices to those based on benefit prices. Although for the majority of the sample points, the difference is small, the difference is significant for a few.

For example, the difference between assessment factors for one specific sample point based on benefits computed with benefit prices and normalized prices was 0.7215 percent. This appears as a very small value, but consider for a moment the specified costs to be paid by beneficiaries. If beneficiaries of flood protection are to pay $100,000 of the costs incurred, the above sample point would be assessed $720 more if benefit prices are used in the calculations. Even if the costs borne by beneficiaries is only $10,000, this results in a $72 dollar assessment difference for the sample point in question when comparing estimates based on normalized prices and benefit prices. For an individual flood plain farmer a difference in assessment factors over several sample points could accumulate into a very significant dollar value.

Effect of Productivity Group Designation on Assessment

A change in the productivity group assigned to a sample point can also alter a sample point assessment factor. If yields are higher or lower than can be expected based on soil type, average annual damage estimates will be incorrect both before protection and after protection. This can be expected to result in an incorrect estimate of benefits (reduction in damages) and incorrect assessment factor. The feasibility of this proposition is pursued based on assessment factors computed from damage estimates evolving from the single flood plain productivity group (F_1) and, alternatively, from the correct sample point productivity group designation.

In evaluating the effect of alternative sample point productivity group designations upon the assessment factor of a sample point, columns two and four as well as columns three and five of Table IX can be compared and assessment factors for specific sample points presented. The sample point distributions are very similar over the assessment factor increments indicating that sample point productivity group designation exerts little effect on assessments in the aggregate study area. The largest difference between columns two and four as well as three and five for a single assessment factor increment is approximately 10 sample points with the average difference for each increment less than five sample points. The total difference in number of sample points over all increments is 52 for normalized prices (columns two and four) and 44 for benefit prices (columns three and five). The difference of 52 indicates that the alternative productivity groupings affect assessment factors for sample points not affected by the grouping since only 48 sample points have any yield change with the single grouping.

By considering the total distribution by increment, as in Table IX, the number of shifts that take place due to an assumption change tends to be understated since some sample point shifts may be offsetting. That is, sample points may shift among increments resulting in the same number but not the same sample points applicable to an increment.

The values in Table IX also reveal very little when considering an individual sample point and the assessment factor that results from a productivity group misclassification. For simplicity, discussion on this point is limited to assessments based on the reduction of flood damages as calculated with benefit prices. Flood damage values are presented in Table X for four sample points with an expected production that is equivalent to productivity group F_4. With the single productivity grouping, these points are misclassified as F_1. The reduction in average annual flood damages due to SS II is overestimated by \$123.60 for sample point four resulting in an assessment factor of 1.6823 when it should be zero. This flood plain farmer, with the single flood plain productivity group of F_1, will be assessed for

TABLE X

FLOOD PROTECTION BENEFITS AND ASSESSMENT FACTORS[a] FOR FOUR SAMPLE POINTS CORRECTLY CLASSIFIED IN PRODUCTIVITY GROUP F_4 AND ALTERNATIVELY MISCLASSIFIED AS GROUP F_1

Sample Point	Land Use	Sample Point Reduction in Average Annual Flood Damages or Flood Protection Benefits		Assessment Factor or Percent of Total Benefits Received		Assessment Factor Error Due to Misclassification
		F_4	F_1	F_4	F_1	
		(dollars)		(percent)		(percent)
1	pasture	3.38	11.43	0.0477	0.1556	0.1079
2	alfalfa	0.00	46.31	0.0000	0.6303	0.6303
3	alfalfa	0.00	56.45	0.0000	0.7683	0.7683
4	oats	0.00	123.60	0.0000	1.6823	1.6823

[a]Assessment factors refer to the percent of total benefits received by one sample point as a result of the installation of SS II.

[b]For the misclassification, all sample points in the flood plain were designated as F_1, whereas the "correct" classification infers each sample point was placed in the productivity group corresponding to its expected yield.

1.6823 percent of the flood plain costs borne by beneficiaries based on this one sample point when in fact no benefits were incurred. The four sample points in the table are all overassessed and, hence, result in an underassessment of other sample points which are receiving flood protection benefits.

The greater the value of the crop produced on sample points with productivity potential of F_3 of F_4, the greater will be the error resulting in the assessment factor for those sample points based on an F_1 productivity group classification. For pasture, the error in the assessment factor was only one-tenth of one percent, while a more intensive flood plain use such as alfalfa or oats brings forth an error of from one-half of one percent to over one and one-half percent. When the erroneous assessment factors such as those in Table X are applied to costs such as $100,000 or even $1,000 the magnitude of the error becomes clearer, especially to affected flood plain operators. Based on the results of this study and the values in Table X, it appears "commutative justice" commands the use of more than one productivity group for a flood plain if the model is to be used for purposes of assessing or comparing alternative land use patterns.

<u>Cross Section Area Illustration of Sample Point Assessments</u>

One cross section area of Nuyaka Creek flood plain was selected to illustrate sample point assessments, the effect of land use and elevation on these assessments, and the procedure for determining each flood plain operator's assessment factor. As in the preceding section, the discussion is limited to assessing for specified costs in relation to benefits provided by SS II computed with benefit prices. The benefits of SS II are measured as the reduction in average annual flood damages comparing SS II to present flood plain conditions.

The cross section area selected to illustrate the methodology for assessing was N-8 (shown in Figure 2). Presented in Table XI are the 30 sample points comprising N-8 and associated land use, elevation, average annual flood damages with present flood plain conditions and SS II, benefits of flood protection and assessment factor.[9] Benefits to the aggregate cross section area (flood plain represented by the 30 sample points) are $478.77 or 6.76 percent of the total benefits for Nuyaka Creek flood plain.

Assessment of each sample point is based on the total flood plain benefits, which in this case are $7079. The sample point benefits of SS II (column six of Table XI) are divided by $7079 to obtain the assessment factor applicable to each sample point. For N-8, the assessment factors range from zero to 0.6761 percent.

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[9]Flood protection benefits and assessment factors are computed and printed by sample point in the assessment model with very little time or effort involved in obtaining these values.

TABLE XI

PRESENT LAND USE, ELEVATION AND FLOOD DAMAGE DATA COMPUTED WITH BENEFIT PRICES FOR PRESENT FLOOD PLAIN CONDITIONS AND STRUCTURE SYSTEM SS II FOR EACH SAMPLE POINT INCLUDED IN CROSS SECTION AREA N-8[a]

Sample Point Location in the N-8 Matrix[b]		Present Land Use	Elevation	Average Annual Flood Damages		Benefits of SS II[c]	Assessment Factor[d]
				Present Flood Plain Conditions	SS II		
row	column	(crop)	(feet)	(dollars)		(dollars)	(percent)
(1)		(2)	(3)	(4)	(5)	(6)	(7)
9	1	pasture	719.1	0.57	0.13	0.44	0.0062
10	1	pasture	719.4	0.53	0.08	0.45	0.0064
11	1	pasture	715.4	4.03	2.91	1.12	0.0158
6	2	alfalfa	719.2	56.48	10.66	45.82	0.6473
7	2	alfalfa	719.4	52.48	7.50	44.98	0.6354
8	2	alfalfa	719.4	54.21	8.00	46.21	0.6528
9	2	pasture	719.4	0.53	0.08	0.45	0.0064
10	2	pasture	710.8	5.07	5.07	0.00	0.0000
11	2	pasture	718.8	0.61	0.21	0.40	0.0057
4	3	alfalfa	718.3	73.83	45.97	27.86	0.3935
5	3	alfalfa	719.5	50.56	6.95	43.61	0.6160
6	3	corn	719.4	40.76	5.81	34.95	0.4937
7	3	pasture	715.7	3.79	2.00	1.79	0.0253
8	3	pasture	717.5	1.58	0.61	0.97	0.0137
9	3	pasture	714.9	4.29	3.48	0.81	0.0114
11	3	pasture	719.2	0.55	0.10	0.45	0.0064
3	4	pasture	718.4	0.67	0.36	0.31	0.0044
4	4	soybeans	719.4	56.00	8.14	47.86	0.6761
5	4	pasture	715.5	3.98	2.70	1.28	0.0181
6	4	corn	715.5	258.00	211.75	46.25	0.6533
7	4	alfalfa	718.8	62.03	21.94	40.09	0.5663
8	4	alfalfa	719.0	59.27	15.28	43.99	0.6214
2	5	pasture	719.5	1.76	0.21	1.55	0.0219
3	5	pasture	715.0	4.24	3.44	0.80	0.0113
4	5	pasture	718.6	0.65	0.28	0.37	0.0052
5	5	pasture	718.8	0.62	0.22	0.40	0.0057
6	5	pasture	718.8	0.61	0.21	0.40	0.0057
7	5	alfalfa	719.0	59.02	14.69	44.33	0.6262
1	6	pasture	718.8	0.61	0.21	0.40	0.0057
2	6	pasture	719.4	0.53	0.08	0.45	0.0064
N-8 Total				857.86	379.09	478.77	6.7637

[a]Prices that include the benefits of government price support programs.

[b]Each sample point represents five acres; hence, the values given in the table refer to five acre units of flood plain.

[c]Benefits are measured by the reduction in average annual flood damages due to SS II.

[d]Assessment factor refers to the percent of total flood plain SS II benefits each sample point receives.

The assessment factor applicable to the beneficiaries farming in cross section area N-8 can be obtained by summing the assessment factors of the sample points representing the bottomland of each farmer. Assuming all 30 sample points represent a single farming operation, the assessment factor for the farm would be 6.7637.

The land use of a sample point relative to other sample points greatly influences the value of benefits received and, hence, the assessment factor or proportion of total benefits derived. For example, more intensive flood plain utilization such as corn, soybeans and alfalfa, instead of pasture, results in a sample point assessment factor of approximately one-half of one percent (0.5 percent), whereas, the assessment factor on pasture is approximately five thousandth of one percent (0.005 percent).

The influence of land use can be verified by sample points 8 x 2 and 9 x 2 which have the same elevation but different land uses. The benefits of SS II are $46.21 for the sample point currently in alfalfa but only 45 cents for a current land use of pasture. In this case, the operator producing alfalfa is assessed for 0.6528 percent of specified project costs as opposed to an assessment factor of 0.0064 percent for pasture production. This suggests that assessing on the basis of benefits for present land use can result in a small proportion of the flood plain farmers paying a very large proportion of assessed flood protection costs. The sum of the assessment factors for the 19 cross section area sample points with pasture is 0.1817 percent compared to 6.5820 percent for the other 11 sample points with land uses of alfalfa, corn, and soybeans. This points out the magnitude of the discrepancy between the assessment factor for an operator with bottom land in pasture and conversely, the farmer producing high income crops.

If no land use changes occur, then the commutative justice norm is met with the assessment procedure used in Table XI. But, after installation of flood protection, many farmers can be expected to respond to the reduced flooding hazard by undertaking a more intensive utilization of the flood plain; i.e., allocating flood plain formally in pasture to alfalfa, cotton, or wheat. Benefits of flood protection for these operators are, therefore, greater than that shown by the reduction in flood damage for present land use and a shortcoming of the assessment procedure presented above.[10]

Assessments are levied to help pay for operation and maintenance of systems of structures. In addition to flood protection projects, the concept of flood insurance could provide a social and individual service by helping the individual bear more easily the risks of flood damage and discouraging unwise occupancy of flood-prone areas.[11]

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[10]The following chapter presents an alternative method of computing benefits of flood protection based on the potential net returns of a sample point.

[11]U.S., Congress, Senate, Committee on Banking and Currency, Insurance and Other Programs for Financial Assistance to Flood Victims, Committee Print, 89th Cong., 2d Sess., Sept., 1966, p. IX.

Agricultural Flood Insurance

Insurance involves substituting a smaller but sure annual cost for a small probability of a larger loss. Considering flood damages over the very long run for a particular flood plain field, average annual flood damages are analogous to the smaller but sure annual cost. Therefore, the annual premium, not including administrative costs, is derived by computing average annual flood damages in a specific field with respect to land use and crop prices that reflect the farmers' expected returns.

Average annual flood damages computed with benefit prices for present land use with no flood protection (present conditions) and flood retention structure system SS II are given in Table XI. The benefit prices include benefits of government price support programs and represents a farmer's potential loss to flood water. The flood damages in Table XI are for the sample points comprising cross section area N-8 and provide a means of illustrating the application of the simulation model to agricultural flood insurance. The average annual damages are based on present sample point land use, but since land use is a variable in the model any crop can be considered on any sample point and the annual insurance premium computed.

The annual flood insurance premium for the five acres represented by each sample point under present flood plain conditions are presented in column four of Table XI. The range in annual premiums over all sample points is $0.53 to

$258.00. For sample points in pasture, the range is $0.53 to $5.07 and the alfalfa premium range per sample point is $50.56 to $73.83.

The wide ranges in sample point premiums with the same land use indicates the effect of flood plain location on magnitude of average annual flood damages. By comparing insurance premium rates for alternative sample point elevations with the same land use, the sensitivity of the model to depth of inundation is emphasized. For example, a 1.2 foot lower elevation, 718.3 versus 719.5, results in a preminum increase of $13.27 for alfalfa production.

Sample point 6 x 4, characterized by corn production, has an average annual damage value equivalent to expected gross returns with no flooding. An insurance premium rate that is equal to the no flooding gross returns indicates an inefficient use of flood plain. In this case, the flood hazard exceeds corn's tolerance to floodwater, hence, corn at this location can be expected to be completely lost to flooding. The flood plain represented by sample point 6 x 4 should be utilized in producing crops with greater resistance to flooding; i.e., alfalfa, pasture, etc.

Average annual flood damages for each sample point with structure system SS II are presented in column five of Table XI. By comparing columns four and five for each sample point, the adjustment in premium rate relative to flood hazard is illustrated. With SS II, the range in premiums for nonpasture land use is $5.81 to $211.75. The reduction in annual insurance premiums attributable to SS II for sample points with a land use other than pasture ranges from $27.86 to $46.25.

Annual flood insurance premiums for a flood plain field would be calculated by adding average annual flood damages of the sample points representing the field. Sample point average annual damages would be computed based on the crop produced, and utilizing the simulator, sample point land use could be changed for any year, hence, be easily made to conform to the crop being produced in the field that is to be insured. Assuming cross section area N-8 is a field to be insured, the annual premium rate would be $857.86 with present flood plain conditions and $379.09 after the installation of SS II.

The discussion of this chapter has been based on present land use which leaves much to be desired in assessment considerations, flood plain planning and other aspects of flood plain evaluation. Chapter VI presents alternative land use patterns developed by the optimizing model for Nuyaka Creek flood plain. This provides estimates of the benefits possible through flood plain land use changes and another dimension to the benefits of flood protection.

CHAPTER VI

OPTIMUM LAND USE PATTERNS IN THE STUDY AREA FLOOD PLAIN

The land use at each sample point that maximizes returns net of production costs and average annual flood damages is referred to as the optimum and profit maximizing land use. Optimum land use patterns (optimum land use aggregated over the flood plain) improve knowledge of a flood plain and permit a more complete watershed evaluation. Basing flood protection assessments on increased net revenues assuming an optimum land use before and after installation of a structure system results in a more equitable distribution among beneficiaries than basing the assessments on nonoptimum land use. By comparing an optimum land use to the present land use, expected profits being foregone by a less than optimum cropping pattern can be calculated and appropriate adjustments to attain an optimum determined. Utilizing profit as a measure of efficiency of flood plain land use, the profit maximizing cropping pattern indicates the most efficient use of flood plain and can serve as a guide in watershed development policies.

The optimum land use pattern selected for a given set of assumptions identifies an upper limit for potential flood plain profit. Given an optimum farm organization for each flood plain farm, profit from the flood plain can be expected to be smaller than designated in the model since farmers consider other limiting resources (in addition to land) and do not typically mix crop production in one field. Optimum flood plain land use patterns provide improved knowledge and serve as an aid in policy and managerial decisions.

Optimum land use was determined assuming four alternative sets of commodity prices and three alternative flood plain conditions. This yields 12 optimum flood plain land use patterns, one for each of the three flood plain conditions in conjunction with each of the four sets of prices. The three flood plain conditions considered are no protection (present conditions) and structural systems SS I and SS II. The four sets of prices utilized in the computations are designated as normalized, benefit, adjusted, and mixed (Table IV).

The second most profitable land use at each sample point is also selected and, when aggregated over the flood plain, yields a second best land use pattern. There is a unique second best land use pattern associated with each of the 12 optimum land use patterns. The stability of the calculated optimum land use at each sample point is estimated by calculating the percentage decline in the price of the optimum land use which would equate the optimum land use net returns with the net returns of the second best land use. This yields the price decline necessary to give a condition of indifference between optimum and second best land use at each sample point.

Discussed in this chapter are the following: optimum land use patterns, associated costs and returns, gains or benefits to be derived from appropriate land use changes, stability of solutions, a suggested optimum land use assessment procedure, and occupancy charges with indemnification for losses. The following section pertains to optimum land use and associated dollar values, acres with a land use change between alternative optimums, and the extent of present land use change indicated.

Optimum Flood Plain Land Use Patterns

The present land use pattern in the flood plain and, alternatively, the 12 optimum land use patterns and associated gross returns, production costs, average annual damages, net returns, and net returns per acre as computed under the various price and flood plain condition assumptions are presented in Table XII.[1] A notational procedure was initiated to facilitate references to the alternative optimum

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[1]The optimizing model includes in the printout for each sample point the gross revenue with no flooding, average annual damages, and expected net returns for each alternative crop considered. Average annual flood damages and expected net returns, assuming mixed prices, for the sample points included in cross section area N-8 are presented in Appendix C, Tables XXXIII and XXXIV. By analyzing this data for sample points representing specific fields, the flood plain farmer is in an improved decision making position with respect to profit and flood risk involved.

TABLE XII

FLOOD PLAIN LAND USE PATTERNS MAXIMIZING RETURNS NET OF FLOODING AND PRODUCTION COSTS FOR ALTERNATIVE CROP PRICES AND FLOOD PLAIN CONDITIONS AND ASSOCIATED COSTS AND RETURNS

Item	Unit	Present Land Use	Optimum Land Use Patterns[a]											
			Benefit Prices[b]			Normalized Prices[c]			Adjusted Prices[d]			Mixed Prices[e]		
			Present Conditions (O_{12})	SS I (O_{22})	SS II (O_{32})	Present Conditions (O_{11})	SS I (O_{21})	SS II (O_{31})	Present Conditions (O_{13})	SS I (O_{23})	SS II (O_{33})	Present Conditions (O_{14})	SS I (O_{24})	SS II (O_{34})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Crops														
Cotton	acre	10	610	1,160	1,000	-	-	-	-	-	-	-	-	-
Grain Sorghum	acre	-	-	-	-	-	-	-	-	-	-	-	-	-
Corn	acre	10	-	-	-	-	-	-	-	-	-	-	-	-
Soybeans	acre	35	-	-	-	650	1,220	1,030	1,435	2,680	2,370	20	30	25
Wheat	acre	55	-	-	-	-	-	-	-	-	-	-	-	-
Oats	acre	80	-	-	-	-	-	-	-	-	-	-	-	-
Barley	acre	35	-	-	-	-	-	-	-	-	-	-	-	-
Peanuts	acre	-	1,330	1,735	1,615	875	1,580	1,445	-	-	-	-	-	-
Bermudagrass	acre	250	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	acre	290	610	310	370	970	375	435	1,060	495	540	2,530	3,175	2,960
Native Hay	acre	65	-	-	-	190	45	165	190	50	165	-	-	-
Woodland Pasture	acre	1,750	635	330	480	630	325	450	630	325	450	635	330	480
Native Pasture	acre	1,160	555	175	275	425	165	215	425	160	215	555	175	275
Idle	acre	-	-	30[f]	-	-	30[f]	-	-	30[f]	-	-	30[f]	-
Flood Plain Values														
Gross Returns	($000)	56.3	418.8	548.1	507.2	283.8	364.4	340.7	216.5	241.9	228.8	261.8	324.6	303.5
Production Costs	($000)	31.3	213.4	283.5	261.0	158.3	203.3	190.3	105.9	107.5	102.6	147.5	185.3	172.3
Average Annual Flood Damages	($000)	12.3	55.7	30.8	37.8	34.1	18.9	23.8	29.9	14.9	19.0	29.9	15.3	20.0
Net Returns	($000)	12.7	149.7	233.8	208.4	91.4	142.2	126.6	80.7	119.5	107.2	84.4	124.0	111.2
Net Returns Per Acre	($)	3.39	40.01	62.51	55.73	24.43	38.01	33.85	21.57	31.96	28.66	22.57	33.16	29.73

[a]In the O_{ij} designation, i refers to flood plain condition and j refers to prices used (Appendix C, Table XXX).

[b]Crop prices with benefits of government programs included (Table IV).

[c]Crop prices with no government program benefits included (Table IV).

[d]Crop prices with no government program benefits included and peanuts and cotton deleted from consideration (Table IV).

[e]Normalized prices for surplus crops, cotton and peanuts deleted, and benefit prices for all other crops (Table IV).

[f]Flood plain acreage designated as reservoir.

land use patterns. Each of the 12 optimum flood plain land use patterns is designated as O_{ij} where i refers to flood plain condition and j to prices applicable. Regarding the values of subscript i, the number one refers to present flood plain conditions, two refers to SS I, and three refers to SS II. The j subscript takes on the values one, two, three, and four where one indicates normalized prices, two benefit prices, three adjusted prices, and four mixed prices. For example, O_{32} refers to the optimum land use pattern computed assuming structure system SS II and benefit prices.[2]

Grain sorghum, corn, wheat, oats, barley, and bermuda grass failed to enter any of the 12 optimum solutions. Under the assumptions of this study, these crops should not be considered as economic alternatives for Nuyaka Creek flood plain. The optimum land uses are, therefore, restricted to cotton, soybeans, peanuts, alfalfa, native hay, woodland pasture, and native pasture. Other land uses not considered in this study could possibly prove to be economically profitable in the flood plain, especially with flood protection provided; such as, vegetables, orchards, and other specialty crops.

Optimizing with respect to benefit prices (columns

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[2]The appropriate O_{ij} designation for the assumed conditions that applies to each of the optimum land use patterns is presented in Appendix C, Table XXX.

four, five, and six of Table XII) results in a large allocation of flood plain to cotton and peanuts (1,940 acres under present conditions, 2,895 acres with SS I, and 2,615 acres with SS II). It was shown in Chapter V that SS I had a smaller incidence of flooding than SS II. The increased flood protection results in additional flood plain being allocated to both cotton and peanuts with compensating acreage reductions in alfalfa, woodland pasture, and native pasture. This indicates that the latter three crops above have a greater tolerance to flood water and are optimum in areas of the flood plain characterized by a relatively high incidence of flooding; i.e., fields inundated by floods occurring twice a year and annually.

Net returns assuming present land use are $12,700 with present flood plain conditions, $21,700 with SS I, and $19,800 with SS II.[3] With the optimum land use computed under benefit prices, these values are increased to $149,700, $233,800, and $208,400 for present flood plain conditions, SS I, and SS II, respectively. However, associated with the increase in expected net revenues is an increase in average annual flood damages and production costs. Expected flood damages increase from less than $12,500 to greater than $30,000 and production costs increase from approximately $31,000 to over $200,000. Assuming optimum

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[3]Flood plain dollar value estimates applicable to structure systems SS I and SS II, assuming present land use, are not given in Table XII.

land use, increases in the amount of flood protection provided result in an increase in both net returns and production costs and a decrease in expected flood loss. For example, comparing the optimum land use with SS I to the optimum land use with SS II shows that the added protection of SS I increases expected net returns $25,400, production costs increase $22,500, and flood damages decrease $7,000.

The optimum land use pattern estimated under benefit prices defines an upper profit limit for the flood plain by assuming there are sufficient acreage allotments for the cotton and peanuts specified. Since acreage allotments are not available to farmers in the flood plain at this time nor do they appear a likely possibility in the forseeable future, this upper limit is not a realistic alternative.

The optimum land use patterns developed with normalized prices (columns seven, eight, and nine of Table XII) provide what the study terms a "society" optimum since benefits of government price support programs are deleted. The lower prices for surplus crops result in complete elimination of cotton from the optimum solution and reduced acreages for peanuts. Much of the flood plain allocated to cotton under benefit prices are reallocated to soybeans under normalized prices (610 acres, 1,160 acres, and 1,000 acres for present conditions, SS I, and SS II, respectively). The normalized price solutions increase alfalfa acreage above the benefit price solutions and bring small acreages of native hay into the optimum land use patterns. The effect of increased flood protection on optimum land use patterns computed with normalized prices is allocation of additional acreages to soybeans and peanuts with an offsetting reduction in alfalfa, woodland pasture, and native pasture production.

The flood plain values calculated for "society" optimum land use patterns are considerably smaller than the values estimated for optimum land use assuming benefit prices. Net returns computed for the normalized price solutions are $91,400, $142,200, and $126,600 for present flood plain conditions, SSI, and SS II, respectively. These net returns represent a reduction in the benefit price net return estimates of 40 percent. Similarly, production costs and expected flood damages are lower for solutions computed under normalized prices than those computed under benefit prices. Production costs are $158,300, $203,300, and $190,300, and average annual damages are $91,400, $142,200, and $126,600 for present flood plain conditions, SS I, and SS II, respectively, assuming normalized prices.

Because peanuts and cotton are not normally produced without acreage allotment, an optimum land use pattern was developed with "adjusted prices". The "adjusted prices" are zero for cotton and peanuts, and equal to normalized prices for all other crops. The optimum land use patterns developed using adjusted prices (columns ten, eleven, and twelve of Table XII) are similar to the normalized price solutions with the exception of peanut and soybean acreages. Peanut production is not permitted with adjusted prices, resulting in peanut acreage specified with normalized prices being allocated to soybeans under adjusted prices.

The flood plain values for adjusted prices solutions reflect the deletion of peanuts in lower costs and returns, as compared to normalized prices. Net returns calculated for the adjusted prices solutions are $80,700 for present flood plain conditions, $119,500 for SS I, and $107,200 for SS II, more than $10,000 below the corresponding normalized prices estimates. Production costs are approximately $105,000 for each set of flood plain conditions, while expected flood damages range from $14,900 with SS I to $29,900 with present flood plain conditions.

The final set of prices considered are referred to as mixed prices and consist of a zero price for cotton and peanuts, normalized prices for surplus crops, and benefit prices for all other crops. Mixed prices, as compared to adjusted prices, are characterized by a decrease in the price of soybeans from $2.45 to $2.40 a bushel, an increase in the price of alfalfa from $22.00 to $22.50 a ton and a decrease in the price of native hay from $22.00 to $15.00 per ton. The effect of these price changes is a significant reallocation of land use over the flood plain to satisfy the profit maximization norm. Native hay did not enter the mixed prices solution and only small acreages of soybeans are included. However, the reduced soybean and native hay acreages were compensated for by increases in alfalfa acreage. A five cent per bushel or two percent decrease in soybean price in conjunction with a 50 cent or two and one-fourth percent increase in alfalfa price results in a decrease in soybean acres and an increase in alfalfa acres. The acreage changes caused by the price changes above are a reduction of soybean production of 1,415, 2,650, and 2,345 acres for present conditions, SS I, and SS II, respectively, and an increase in alfalfa production of 1,470, 2,680, and 2,420 acres, respectively, to maintain an optimum. With cotton and peanuts deleted, the optimum solution consists primarily of soybeans and alfalfa. The effect of price changes for soybeans and alfalfa, as given above, indicates the sensitivity of the solution to price; i.e., small changes in soybean and alfalfa price result in large flood plain acreages being reallotted in the optimum solution.

Although the small price changes between adjusted and mixed prices cause large shifts in land use among flood plain acreage, the flood plain values change very little. Net returns decrease less than $6,000 comparing mixed prices solutions to adjusted prices solutions, and average annual flood damages change less than $1,000 for each of the flood plain conditions. Production costs are the exception and show a significant increase in response to the shift from soybeans to alfalfa. Expected production costs increase over $40,000 and range from $147,500 with present flood plain conditions to $185,300 with SS I.

Comparisons of the alternative optimum land use patterns have, thus far, been of a general nature. A better understanding of the land use changes between alternative land use patterns is provided by enumerating not only the change in number of acres of a specific land use, but also the acres changing from one particular land use to another particular land use. The following discussion relates to specific shifts occurring between alternative land use patterns.

<u>Present Land Use Changes Required for Optimization</u>

An opportunity exists for study area farmers to increase expected net returns regardless of whether or not flood protection is provided. The following discussion relates only to present flood plain conditions (no protection) and indicates land use changes that would maximize expected net revenue assuming benefit prices, adjusted prices, and mixed prices.

Production of small grains and bermuda pasture does not maximize profit for any sample point under any of the assumptions (Table XII). The 430 acres of flood plain presently utilized in the production of these crops can, therefore, immediately be identified as a misallocation or inefficient utilization of flood plain.

Optimum land use patterns determined under present flood plain conditions with benefit prices (Optimum I or O_{12}), adjusted prices (Optimum II or O_{13}), and mixed prices (Optimum III or O_{14}) are shown in Table XIII. These entries can be used to identify other acreages presently under

TABLE XIII

COMPARISON OF PRESENT LAND USE AND OPTIMUM LAND USE WITH THREE ALTERNATIVE SETS OF PRICES BY SAMPLE POINT ACREAGE

Optimum Land Use Present Conditions	Optimum Land Use Total	Change in Present Land Use for Optimization[d]										
		Cotton	Corn	Soybeans	Wheat	Oats	Barley	Bermuda Pasture	Alfalfa	Native Hay	Woodland Pasture	Native Pasture
		(acres)										
Present Land Use Total	3,740	10	10	35	55	80	35	250	290	65	1,750	1,160
Optimum I (O_{12})[a]												
Cotton	610	5	-	30	5	10	15	50	45	25	165	260
Soybeans	-	-	-	-	-	-	-	-	-	-	-	-
Peanuts	1,330	5	5	5	25	10	5	75	145	5	665	385
Alfalfa	610	-	-	-	5	30	15	35	50	10	285	180
Native Hay	-	-	-	-	-	-	-	-	-	-	-	-
Woodland Pasture	635	-	-	-	-	-	-	-	-	-	635	-
Native Pasture	555	-	5	-	20	30	-	90	50	25	-	335
Optimum II (O_{13})[b]												
Cotton	-	-	-	-	-	-	-	-	-	-	-	-
Soybeans	1,435	10	-	35	10	15	20	120	105	25	580	515
Peanuts	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	1,060	-	5	-	25	35	15	35	135	15	515	280
Native Hay	190	-	-	-	10	5	-	15	-	5	25	130
Woodland Pasture	630	-	-	-	-	-	-	-	-	-	630	-
Native Pasture	425	-	5	-	10	25	-	80	50	20	-	235
Optimum III (O_{14})[c]												
Cotton	-	-	-	-	-	-	-	-	-	-	-	-
Soybeans	20	-	-	-	-	-	-	-	-	-	15	5
Peanuts	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	2,530	10	5	35	35	50	35	160	240	40	1,100	820
Native Hay	-	-	-	-	-	-	-	-	-	-	-	-
Woodland Pasture	635	-	-	-	-	-	-	-	-	-	635	-
Native Pasture	555	-	5	-	20	30	-	90	50	25	-	335

[a]Prices used include government price support program benefits.

[b]Prices used are normalized (do not include government price support program benefits) with cotton and peanuts deleted, (adjusted prices).

[c]Normalized prices for surplus crops, cotton and peanuts deleted, benefit prices used for all other crops (mixed prices).

[d]The first row of the table indicates present acreage of each crop. The values in rows two through eight, nine through fifteen, and sixteen through twenty two, indicate the allocation of present land use acreage among land uses for Optimum I, Optimum II, and Optimum III, respectively.

utilized. The acres of each crop included in the optimum patterns above are shown by present flood plain land use to indicate the nature of the land use changes necessary for profit maximization. For example, consider the entries in the first eight rows of the table under the soybean column. The 35 in the first row indicates that 35 acres of flood plain land are currently allocated to soybeans. Of this acreage, the number in the second row indicates 30 of these acres should be allocated to cotton production and the number in the fourth row indicates five of these acres should be planted to peanuts to satisfy the Optimum I solution.

A present land use of woodland pasture must be cleared and prepared before any other cropping is possible. To provide for this, an annual charge of $7.72 per acre has been incorporated into the program. Therefore, to replace woodland pasture, a crop must be most profitable for the sample point after allowing for the annual clearing costs.

The optimum land use pattern calculated with benefit prices (O_{12}) requires a change in present land use on 2,720 acres. The changes called for are shown in the rows under Optimum I (O_{12}) of Table XIII. Some of the major changes specified are converting 1,940 acres of woodland and native pasture and 320 acres of corn, soybeans, wheat, oats, barley, and bermuda pasture to cotton, peanuts, and alfalfa. There is also some reallocation of flood plain to less intensive uses; that is, 220 acres currently in corn, wheat, oats, bermuda pasture, alfalfa, and native hay would be more profitable if used in the production of native pasture. This indicates some flood plain is currently in production which, due to the extent of the flood hazard, should be in pasture. There are 970 acres currently in woodland and native pasture which corresponds to optimum land use and signifies a correct allocation of flood plain acreage.

The optimum land use developed with adjusted prices calls for a change in present land use on 2,705 acres with the specific changes enumerated in the rows below Optimum II (O_{13}) in Table XIII. The present land use changes in this case are for the same crops and are approximately the same acreages as discussed for Optimum I except that conversions are to soybeans, alfalfa, and native hay.

For Optimum III (O_{14}), 2,545 acres are inefficiently allocated under present land use. Alfalfa is optimum on 2,530 acres, hence, the major alteration is from the present land use to alfalfa. Exceptions include 970 acres with a correct present allocation of pasture and 220 acres in other crops which should be in pasture.[4]

The increase in flood plain net revenue attributable to the land use changes called for by the benefit price optimum (O_{12}) is $137,000. The nonavailability of peanut and cottom allotments in the flood plain indicate optimum cropping

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[4]The number of acres under present land use that requires a cropping modification as specified by the other nine optimum land use patterns as well as acres of flood plain with a different land use specified when comparing the alternative optimum land use patterns, are presented in Appendix C, Table XXXII.

patterns with benefit prices are not applicable for the analysis. Consequently, benefits of land use changes called for assuming normalized, adjusted, and mixed prices are examined. The respective net revenue increases are \$78,700 with O_{11}, \$68,000 with O_{13}, and \$71,700 with O_{14}. This indicates that net returns per acre of flood plain could be increased from \$3.39 to greater than \$20 by appropriate land use changes.

By adjusting land use patterns in the flood plain to increase net revenue, average annual damages increase from \$12,300 to \$55,700, \$34,100, \$29,900, and \$29,900 for O_{12}, O_{11}, O_{13}, and O_{14}, respectively. The increased damage values indicate that the flood plain operator must necessarily accept more risk to increase net returns. It should be pointed out, however, that even though expected flood damages increase with the land use changes specified, flooding is only one-fourth of the production costs. So, in addition to an increased risk, the land use adjustments are characterized by vastly increased capital requirements. Production costs with present land use are \$31,300 as compared to the \$100,000 to over \$200,000 associated with the optimum land use patterns.

In addition to comparing present land use to proposed optimum land use patterns, sample point comparisons are made between alternative optimum land use patterns. These comparisons indicate the effect of changes in assumed prices and flood plain conditions on optimum land use.

Comparison of Selected Optimum Land Use Patterns

Five alternative optimum land use pattern comparisons are selected to illustrate the effect of specific assumption changes on sample point land use and aggregate flood plain values. The land use comparisons between alternative optimums presented in Table XIV include: (1) optimum land use estimated with benefit prices and present flood plain conditions (O_{12}) contrasted to the optimums determined assuming adjusted prices with present flood plain conditions (O_{13}) and benefit prices with SS II (O_{32}), (2) optimum land use calculated with adjusted prices and present flood plain conditions (O_{13}) contrasted to the optimums determined assuming mixed prices with present flood plain conditions (O_{14}) and adjusted prices with SS II (O_{33}), and (3) optimum determined with mixed prices and present flood plain conditions (O_{14}) contrasted to the optimum developed with mixed prices and SS II (O_{34}).

The first comparison mentioned above (O_{12} compared to O_{32} and O_{13}) shows the effect of a price change (from benefit, O_{12}, to adjusted, O_{13}) and change in flood plain conditions (from present, O_{12}, to SS II, O_{32}) on the optimum solution. The first row of the matrix in the upper left hand corner of Table XIV gives the O_{12} optimum land use pattern and the following rows show how the land use specified in O_{12} is affected by flood protection (O_{32}). The rows in the lower left hand matrix indicate the effect of a price change on the O_{12} land use pattern.

TABLE XIV

COMPARISONS BY SAMPLE POINT ACREAGES OF OPTIMUM LAND USE PATTERNS DEVELOPED ASSUMING ALTERNATIVE PRICES AND FLOOD PLAIN CONDITIONS[a]

O_{12} Compared with O_{32} and O_{13}

O_{32} and O_{13} Land Use	Total O_{32} and O_{13}	Change in O_{12} Land Use to Attain O_{32} and O_{13} Land Use[b]				
		Cotton	Peanuts	Alfalfa (acres)	W. Pasture	N. Pasture
Total O_{12}	3,740	610	1,330	610	635	555
O_{32}						
Cotton	1,000	610	-	375	10	5
Peanuts	1,615	-	1,330	155	45	85
Alfalfa	370	-	-	80	100	190
W. Pasture	480	-	-	-	480	-
N. Pasture	275	-	-	-	-	275
O_{13}						
Soybeans	1,435	610	785	40	-	-
Alfalfa	1,060	-	545	515	-	-
N. Hay	190	-	-	55	5	130
W. Pasture	630	-	-	-	630	-
N. Pasture	425	-	-	-	-	425

O_{13} Compared with O_{33} and O_{14}

O_{33} and O_{14} Land Use	Total O_{33} and O_{14}	Change in O_{13} Land Use to Attain O_{33} and O_{14} Land Use[c]				
		Soybeans	Alfalfa	N. Hay (acres)	W. Pasture	N. Pasture
Total O_{13}	3,740	1,435	1,060	190	630	425
O_{33}						
Soybeans	2,370	1,435	845	35	25	30
Alfalfa	540	-	215	135	110	80
N. Hay	165	-	-	20	45	100
W. Pasture	450	-	-	-	450	-
N. Pasture	215	-	-	-	-	215
O_{14}						
Soybeans	20	20	-	-	-	-
Alfalfa	2,530	1,415	1,060	55	-	-
W. Pasture	635	-	-	5	630	-
N. Pasture	555	-	-	130	-	425

O_{14} Compared with O_{34}

O_{34} Land Use	Total O_{34}	Change in O_{14} Land Use to Attain O_{34} Land Use			
		Soybeans	Alfalfa	W. Pasture (acres)	N. Pasture
Total O_{14}	3,740	20	2,530	635	555
O_{34}					
Soybeans	25	20	-	5	-
Alfalfa	2,960	-	2,530	150	280
W. Pasture	480	-	-	480	-
N. Pasture	275	-	-	-	275

[a]Alternative optimum land use patterns are referred to as O_{ij} where i specifies flood plain condition and j specifies prices used. Flood plain conditions are: 1 = present flood plain conditions, 2 = SS I and 3 = SS II. Prices used are: 1 = normalized, 2 = benefit, 3 = adjusted and 4 = mixed.

[b]The first row indicates O_{12} acreage of each crop. The values in rows two through six and seven through eleven indicate the allocation of O_{12} land use acreage among land uses for O_{32} and O_{13}, respectively.

[c]The first row indicates O_{13} acreage of each crop. The values in rows two through six and seven through ten indicate the allocation of O_{13} land use acreage among land uses for O_{33} and O_{14}, respectively.

[d]The first row indicates O_{14} acreage of each crop. The values in rows two through five indicate the allocation of O_{14} land use acreage among land uses for O_{34}.

Flood protection (O_{32}) has no effect on the O_{12} solution with respect to 610 acres of cotton, 1,330 acres of peanuts, 80 acres of alfalfa, 480 acres of woodland pasture, and 275 acres of native pasture. However, the increased flood protection does result in reallocating (1) 530 acres of O_{12} alfalfa to 375 acres of cotton and 155 acres of peanuts, (2) 155 acres of O_{12} woodland pasture to 10 acres of cotton, 45 acres of peanuts, and 100 acres of alfalfa,[5] and (3) 280 acres of O_{12} native pasture to five acres of cotton, 85 acres of peanuts, and 190 acres of alfalfa.

In general, optimum land use with flood protection and benefit prices results in cotton and peanut production on much of the land allocated to alfalfa, woodland and native pasture by O_{12} and alfalfa production on part of the flood plain denoted as woodland and native pasture by O_{12}. Flood protection and appropriate land use changes result in a net return increase of $58,700, a production costs increase of $47,600 and an expected flood damage decrease of $17,900.

Using adjusted prices (O_{13}) results in a reallocation of a larger acreage (2,170) than flood protection (965). Changes in land use from O_{12} to O_{13} are primarily from cotton to soybeans, from peanuts to soybeans and alfalfa, and 130 acres from native pasture to native hay. Optimizing with adjusted prices changes the O_{12} land use on 2,170 acres

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[5]Flood protection reduces damages to the extent that crops other than woodland pasture become sufficiently profitable at some sample points to warrant undertaking the annual clearing costs in order to pursue their production.

and results in a reduction of $69,000, $25,800, and $107,500 for net returns, average annual flood damages, and production costs, respectively.

Turning to the second comparison (O_{13} compared to O_{33} and O_{14}), the initial optimum is given for adjusted prices and present flood plain conditions (O_{13}) and is shown in the first row of the upper right hand matrix of Table XIV. The optimum O_{33} land use (rows of upper right hand matrix) indicates the effect of flood protection (SS II) and O_{14} (rows of lower right hand matrix) indicates the effect of mixed prices on O_{13}. Flood plain protection (O_{33}) results in substituting: (1) 845 acres of soybeans for O_{13} alfalfa, (2) 35 acres of soybeans and 135 acres of alfalfa for O_{13} native hay, (3) 180 acres of soybeans, alfalfa, and native hay for O_{13} woodland pasture, and (4) 210 acres of soybeans, native hay, and alfalfa for O_{13} native pasture. The land use adjustments resulting from flood protection reduce O_{13} expected damages $10,900, reduce production costs $3,300, and increase net returns $26,500.

Optimizing with mixed prices (O_{14}) results in alfalfa production on 1,415 acres of the 1,435 acres in soybeans under adjusted prices (O_{13}). The 190 acres of native hay determined as optimum for O_{13} are transferred to 130 acres of native pasture, 55 acres of alfalfa, and five acres of woodland pasture by the O_{14} solution. Average annual flood damages are the same for O_{13} and O_{14} ($29,900). Expected net returns are $3,700 larger for O_{14} than for O_{13}. The larger profit requires added production expenses and the result is an increase in O_{13} production costs of $41,600 for O_{14}.

The final comparison (O_{14} with O_{34}) shows the effect of flood protection (SS II) on optimum land use assuming mixed prices. The O_{14} and O_{34} comparison are shown in the matrix located at the bottom and center of Table XIV. The first row of the matrix is O_{14} land use (present flood plain conditions and mixed prices) and the following rows enumerate the changes called for by flood protection. Assuming flood protection with mixed prices results in a reallocation of 430 acres of woodland and native pasture to alfalfa, a more intensive land use. The optimum land use with flood protection reduces expected flood damages by $9,900, increases net returns by $26,800, and increases production costs by $24,800 as compared to the present flood conditions solution.

A logical extension of the discussion at this point is a comparison of optimum land use net returns with and without flood protection. The structure system approved by Congress for construction (SS II) results in an increased net return of $58,700, $35,200, $26,500, and $26,800 assuming optimum land use under benefit, normalized, adjusted, and mixed prices, respectively. This is an increase in net returns of from $7 to $15 per acre of flood plain. SS II flood protection results in a more intensive use of flood plain, decrease in average annual flood damages of approximately 30 percent, and with the exception of adjusted prices (O_{13} and O_{33}) an increase in production costs (Table XII).

A measure of average annual flood damages, in addition to absolute dollar values, is its relationship to gross revenue assuming no flooding. Average annual damages as a percent of the gross revenue assuming no flooding occurs, is approximately 11.5 percent for present flood plain conditions, 5.5 percent with SS I, and 7.3 percent with SS II.[6]

From the optimum land use patterns and comparisons presented above, it is evident that optimum land use for a sample point is sensitive to both assumed prices and flood plain conditions. The second most profitable land use at each sample point was tabulated for a more complete evaluation to permit empirical estimates of the stability of optimum solutions. By comparing costs and returns of the optimum land use to the second best land use pattern, the income possibilities of the flood plain can be better understood. The second best land use for each of the 12 optimum land use patterns is considered in the following section.

Second Best Land Use Patterns

The second most profitable land use at each sample point, aggregated over the flood plain, is referred to as

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[6] See Appendix C, Table XXXV for average annual damages as a percent of gross revenue assuming no flooding with respect to each of the 12 optimum land use patterns.

the second best land use pattern for a particular optimum. Table XV presents the second best land use pattern for each of the 12 optimums given in Table XII. Also included in Table XV are the gross returns, production costs, average annual flood damages, net returns, and net returns per acre associated with each of the second best land use patterns. Profit for the second best land use at a sample point is useful in establishing the price decline necessary to make the optimum land use equally as profitable as the second best land use. Second best land use also identifies the best alternative in case the optimum specified is infeasible for one reason or another.

Woodland pasture is typically the second most profitable crop on those points for which native pasture was optimum. However, it would not be rational to degrade native pasture by seeding trees which do not produce a marketable product. In view of this it is reasonable to consider idle acreage or no production as the second best land use for optimum native pasture in those cases where woodland pasture is given as second best. Second best land use for many acres currently in woodland pasture was no production or idle acreage. Due to the flooding hazard and land preparation, negative net returns would be incurred as a result of any land use changes. This serves, in part, to explain why some bottomland is not being brought into cultivation.

Second best land use patterns assuming benefit prices are given in columns three, four, and five of Table XV.

TABLE XV

SECOND MOST PROFITABLE LAND USE PATTERNS AND ASSOCIATED COSTS AND RETURNS FOR ALTERNATIVE CROP PRICES AND FLOOD PLAIN CONDITIONS

Land Use	Unit	Second Most Profitable Land Use Patterns											
		Benefit Prices[a]			Normalized Prices[b]			Adjusted Prices[c]			Mixed Prices[d]		
		Present Conditions (O_{12})	SS I (O_{22})	SS II (O_{32})	Present Conditions (O_{11})	SS I (O_{21})	SS II (O_{31})	Present Conditions (O_{13})	SS I (O_{23})	SS II (O_{33})	Present Conditions (O_{14})	SS I (O_{24})	SS II (O_{34})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Crops													
Cotton	acre	1,025	1,700	1,500	-	-	-	-	-	-	-	-	-
Grain Sorghum	acre	-	-	-	-	-	-	-	-	-	-	-	-
Corn	acre	-	-	-	-	-	-	-	-	-	-	-	-
Soybeans	acre	425	150	280	1,545	1,785	1,690	875	450	480	2,445	3,135	2,905
Wheat	acre	-	-	-	-	-	-	-	-	-	-	-	-
Oats	acre	-	-	-	-	-	-	-	-	-	-	-	-
Barley	acre	-	-	-	-	-	-	-	-	-	-	-	-
Peanuts	acre	20	10	15	25	5	25	-	-	-	-	-	-
Bermudagrass	acre	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	acre	1,000	1,310	1,155	770	1,370	1,190	1,465	2,710	2,425	25	35	45
Native Hay	acre	10	-	10	365	60	110	365	60	110	10	-	10
Woodland Pasture	acre	595	205	290	285	160	210	285	160	210	595	205	290
Native Pasture	acre	30	5	25	135	10	75	135	10	75	30	5	25
Idle	acre	635	360[e]	465	615	350[e]	440	615	380[e]	440	635	360[e]	465
Flood Plain Values													
Gross Returns	($000)	291.3	402.5	367.1	203.0	265.2	245.9	220.1	301.9	278.1	173.6	221.4	207.0
Production Costs	($000)	165.3	235.7	212.6	97.6	133.4	122.4	115.8	171.2	156.1	72.5	93.0	86.9
Average Annual Flood Damages	($000)	34.7	20.9	25.2	28.0	14.6	18.9	27.5	14.5	18.4	27.3	14.5	18.9
Net Returns	($000)	91.3	145.9	129.3	77.4	117.2	104.6	76.8	116.2	103.6	73.8	113.9	101.2
Net Returns Per Acre	($)	24.40	39.01	34.57	20.70	31.35	27.97	20.54	31.06	27.71	20.00	30.45	27.07

[a] Crop prices with benefits of government programs included (Table IV).

[b] Crop prices with no government program benefits included (Table IV).

[c] Crop prices with no government program benefits included and peanuts and cotton deleted from consideration (Table IV).

[d] Normalized prices for surplus crops, cotton and peanuts deleted, and benefit prices for all other crops (Table IV).

[e] Includes 30 acres designated as reservoir.

Cotton was typically the second most profitable crop on those points for which peanut production was optimum, alfalfa was typically the second most profitable crop on those points for which cotton production was optimum, and soybeans were typically the second most profitable crop on those points for which alfalfa was optimum. The second best land use shows an increase in cotton, alfalfa, and idle acreage and a decrease in peanut acreage, as compared to the optimum.

A comparison of costs and returns between an optimum and the second best land use pattern can be made for each set of assumed prices and include all flood plain conditions. Production of the second best rather than the most profitable alternative for each sample point under benefit prices results in a reduction of gross returns of approximately 28 percent, production costs 20 percent, average annual flood damages 35 percent, and net returns 38 percent. The reductions indicate a decrease in the risk and capital requirements associated with the optimum (reduced flood damages and production costs). However, the decrease in net returns is greater than the reduced flooding damages and reduced production costs with respect to both dollars and percentages.

Under normalized prices (columns six, seven, and eight of Table XV) soybeans are typically second best on those points for which peanuts and alfalfa are optimum and alfalfa is typically second best to optimum soybeans. The second best land use pattern, as compared to the optimum, shows an increase in soybeans, alfalfa, and idle acreage and decrease in peanut acres.

Assuming normalized prices, the reduction in optimum values resulting from a land use change to second best are 28 percent, 37 percent, 21 percent, and 17 percent for gross revenue, production costs, flood damages, and net revenue, respectively. In this case, the resulting decrease in capital requirements (production costs) is much larger than for net returns. The percentage reduction in flood damages is greater than for net returns but the dollar reduction is greater for net returns. Second best under normalized prices shows some promise as a feasible alternative for the farmer desiring production costs and risks smaller than estimated for the optimum solution.

Assuming adjusted prices and mixed prices (columns nine through fourteen of Table XV), soybeans are typically second best to optimum alfalfa and alfalfa is typically second best to optimum soybeans. This is reflected in the land use patterns in that the second best land use patterns, assuming adjusted prices, have smaller soybean acreage and larger alfalfa acreages than the optimum land use. With mixed prices, the opposite situation is observed; i.e., second best land use patterns show larger soybean acreages and smaller alfalfa acreages than applicable to the optimum land use pattern.

Comparing the second best to optimum for adjusted prices, there is an increase in gross revenue and production costs. The increased production costs mean capital requirements are larger than with optimum land use. With second best land use, the percentage reduction in optimum land use expected flood damages and net returns are approximately equal. However, the dollar reduction is greater for net returns than for expected damages. Assuming mixed prices, production of second best rather than the most profitable land use reduces gross returns approximately 33 percent, production costs 50 percent, average annual flood damages six percent, and net returns 10 percent. For the flood plain operator hard pressed for operating capital, the second best in this case is a feasible alternative to the optimum specified since capital requirements are reduced five times as much as the reduction in net returns.

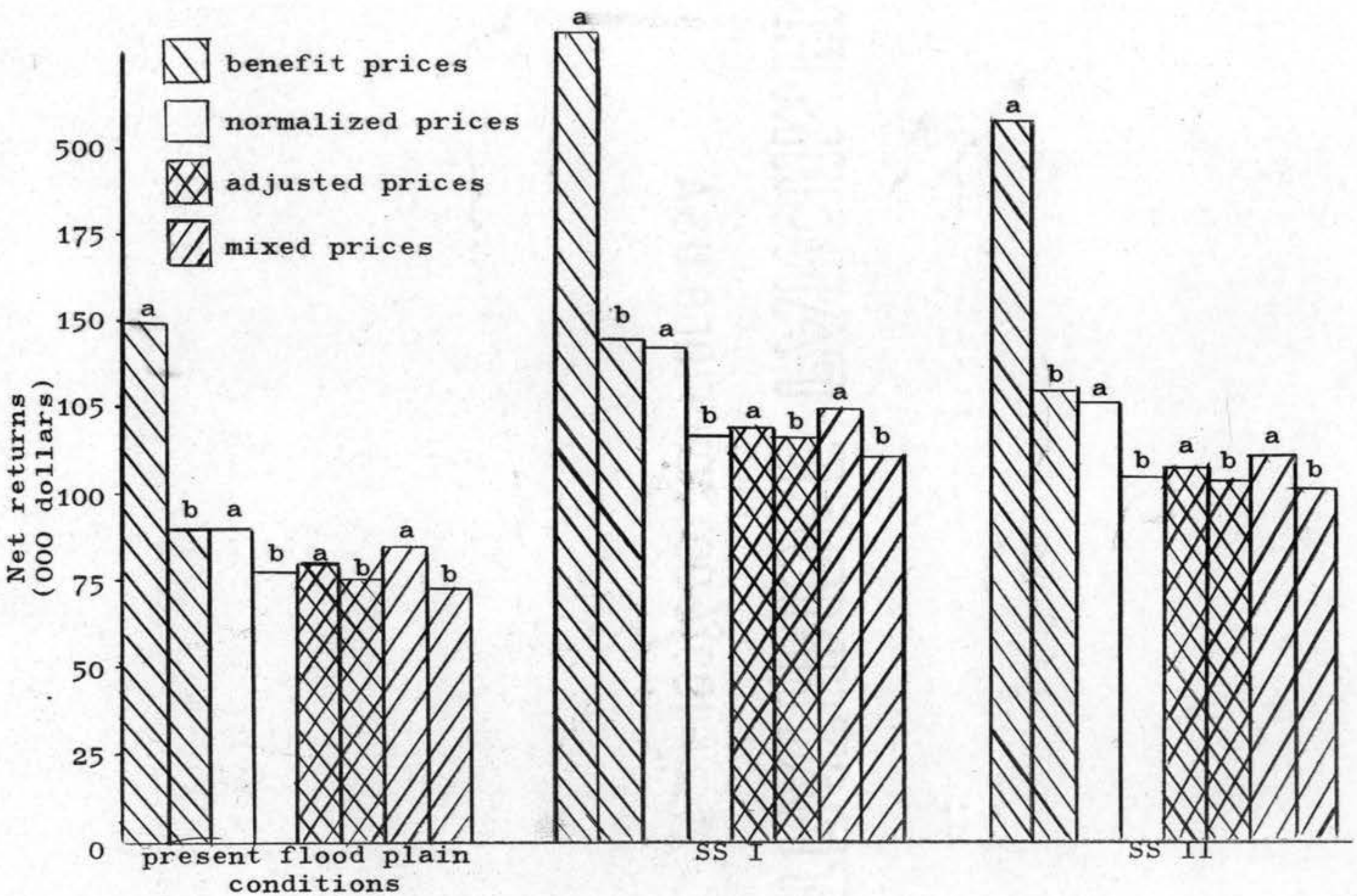
In addition to permitting a simple comparison between an optimum land use pattern and the associated second best land use pattern, net returns for the second best land use can be utilized to estimate the stability of the optimum solution.

Stability of Optimum Land Use Pattern Solutions

The stability of the optimum land use patterns is estimated by calculating the percentage price decline required to establish a condition of indifference between the optimum land use and second best land use; i.e., optimum land use price that equates the optimum land use net returns and second best land use net returns. An indication of the stability of an optimum solution for the aggregate flood plain is estimated by comparing flood plain net returns for the optimum and second best land use patterns.

The level of flood plain net returns for the optimum and second best land use is illustrated in Figure 7 for each of the four sets of prices and three flood plain conditions. For instance, the first two columns of Figure 7 indicate optimum and second best land use net returns assuming benefit prices and present flood plain conditions. Optimum land use net returns are designated by the letter "a" at the head of the column and second best by the letter "b". For the above example, expected net returns are approximately $150,000 for optimum land use as opposed to $91,000 with second best land use. This represents a difference of $59,000 or second best land use net returns are 40 percent less than optimum land use net returns.

The greater the difference in net returns between an optimum and its second best, the more stable the optimum solution. The optimum and second best net return difference is approximately 38 percent over all flood plain conditions assuming benefit prices and indicates solutions O_{12}, O_{22}, and O_{32} have the greatest stability. The solutions with the least stability are those determined with adjusted prices (O_{13}, O_{23}, and O_{33}) in which the net return difference is approximately four percent. Assuming normalized prices and mixed prices, the difference in optimum and second best land



[a]Net returns associated with the optimum land use pattern.

[b]Net returns associated with the second best land use pattern.

Figure 7. Net Returns for Optimum and Corresponding Second Best Land Use Patterns Assuming Three Alternative Flood Plain Conditions and Four Sets of Commodity Prices

use net returns is approximately 17 and 10 percent, respectively.

Aggregate flood plain values such as those above give little or no insight into the stability position of individual sample points. The stability of an optimum solution with respect to sample point acreages is appraised by referring to the data in Table XVI. The percentage price decline that equates optimum land use net returns with second best land use net returns is divided into increments as shown in column one. The flood plain acres falling into each percentage increment are shown for each of the twelve solutions in columns two through 13.[7] For example, column two of Table XVI applies to the optimum land use determined with benefit prices and present flood plain conditions. Second best land use net returns equal optimum land use net returns for 50 of the acres in the O_{12} solution with a price decline of from zero to 0.5 percent, for 35 acres with a 0.5 to 1.0 percent price decline, for 90 acres with a 1.0 to 2.0 percent price decline, etc.

Based on Figure 7, solutions computed under adjusted prices were assumed to have the least stability. The data in Table XVI confirms this proposition by the small price declines required to invalidate the optimum solutions on a

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[7]A graphical presentation of Table XVI is presented in Appendix C, Figure 14. The bar graphs provide a visual illustration of the relative stability of the alternative solutions; i.e., the larger the number of acres in the higher price decline increments the more stable the solution.

TABLE XVI

DISTRIBUTION OF FLOOD PLAIN ACREAGE BY PERCENTAGE PRICE DECLINE THAT EQUATES OPTIMUM AND SECOND BEST LAND USE NET RETURNS FOR TWELVE OPTIMUM LAND USE PATTERNS[a]

Percentage Price Decline Interval	Optimum Land Use Patterns											
	Benefit Prices[b]			Normalized Prices[c]			Adjusted Prices[d]			Mixed Prices[e]		
	Present Conditions (O_{12})	SS I (O_{22})	SS II (O_{32})	Present Conditions (O_{11})	SS I (O_{21})	SS II (O_{31})	Present Conditions (O_{13})	SS I (O_{23})	SS II (O_{33})	Present Conditions (O_{14})	SS I (O_{24})	SS II (O_{34})
	(acres)											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0.00 - 0.50	50	50	15	315	240	170	490	400	405	5	-	-
0.50 - 1.00	35	55	35	365	195	255	845	790	755	-	-	-
1.00 - 2.00	90	90	90	760	1,120	1,020	880	1,885	1,635	15	-	10
2.00 - 3.00	55	35	40	190	55	120	170	35	95	880	2,045	1,760
3.00 - 4.00	100	75	95	165	115	95	145	65	40	775	820	805
4.00 - 5.00	140	55	140	35	20	80	20	5	40	365	145	185
5.00 - 10.00	555	405	390	460	450	440	75	-	50	510	195	225
10.00 - 15.00	290	720	610	380	985	850	65	30	30	-	-	5
15.00 - 20.00	145	45	60	35	20	25	20	10	25	-	-	-
20.00 - 25.00	1,070	1,645	1,500	15	-	25	15	-	20	-	-	5
25.00 - 50.00	20	35	30	90	25	25	85	5	10	-	5	10
50.00 - 99.99	555	170	270	315	165	195	315	165	195	555	170	270
100.00[f]	635	360[g]	465	615	350[g]	440	615	380[g]	440	635	360[g]	465

[a]Acres of each crop comprising optimum and second best land use are presented in Tables XII and XV, respectively for each of the 12 assumed conditions.

[b]Crop prices with benefits of government programs included.

[c]Crop prices with no government program benefits included.

[d]Crop prices with no government program benefits included and cotton and peanuts deleted.

[e]Normalized prices for surplus crops, cotton and peanuts deleted, and benefit prices for all other crops.

[f]This row applies to sample points in which second best land use nets negative returns; hence, no production or idle land is second best.

[g]Includes 30 acres designated as reservoir.

large number of acres. Less than a four percent price decline will equate optimum and second best net returns on over 2,000 acres. Conversely, optimum solutions estimated with benefit prices show relative stability in that a price decline in excess of 10 percent is required to invalidate the solutions on approximately 3,000 acres.

Generalizing for the 12 alternative optimum land use patterns, sample points with a designated optimum land use of native or woodland pasture are characterized by the greatest stability with a price decline of from 70 percent to 100 percent required to invalidate them as optimum. After pasture, cotton or peanuts as optimum land use have the largest degree of solution stability with a price decline of 10 percent to 25 percent necessary to nullify either as optimum. Optimum land uses characterized by the least stability are soybeans and alfalfa where less than a four percent price decline will equate second best land use profits with the optimum land use profits. Elaborating briefly on alfalfa and soybeans, net returns by sample point, considering average annual flooding, are similar for soybeans and alfalfa with soybeans typically second best to optimum alfalfa and alfalfa typically second best to optimum soybeans. This indicates the flood plain operator has a degree of flexibility between alfalfa and soybean production for fields involving either as optimum since very small price changes will replace one with the other in an optimum solution.

The above discussion is concerned with optimum land use patterns, solution stability, and the effect of assumption changes. Another factor that exerts considerable influence on flood damages and in turn the most profitable land use is, of course, flood plain location. Fields located near a channel are expected to incur a larger frequency of flooding and increased depth of inundation as compared to fields located near the flood plain boundary. The following section relates flood plain location to optimum land use for the study area.

Effect of Flood Hazard Zones on Optimum Land Use

Optimum land use assuming alternative commodity prices, productivity groups, and flood hazard zones is discussed below. Designation of flood hazard zones is based on how frequently land is expected to be inundated. A severe flood hazard zone might be flood plain inundated by the twice a year flood and, conversely, a clement flood hazard exists for flood plain inundated no more frequently than every 50 or 100 years.

To determine the optimum land use for the alternative conditions, 32 sample points divided into four sets of eight sample points were utilized in each cross section area. The first set of eight sample points in each cross section area was assigned to productivity group F_1, the second set to F_2, the third set to F_3, and the fourth set to F_4. To establish flood hazard zones, the eight sample points in each set were assigned an elevation equal to that of the eight flood sizes considered in this study. The optimizing program was then run for alternative prices.[8]

The optimum land use for each of the conditions is presented in Table XVII. Assuming benefit prices and productivity group F_2, the optimum land use by flood exposure is shown in the second row of Table XVII. Alfalfa is optimum on land exposed to the twice a year flood and also on land exposed to the once a year flood. Cotton is optimum on flood hazard zones specified by the three year flood and all larger flood sizes.

Optimum land use in the flood plain with a severe flood exposure is alfalfa, native pasture, or native hay, depending upon the specific conditions; that is, alfalfa for F_1 and F_2 land and native hay or native pasture for F_3 and F_4 land. For the flood exposure zone designated by the once a year flood, the optimum land use is alfalfa for productivity group F_2 and also F_1 except for optimum peanuts under the benefit price assumption. Peanuts are optimum on F_3 land assuming benefit and normalized prices with soybeans optimum for adjusted and mixed prices.

The optimum land use by flood hazard zone remains unchanged from the three year flood exposure zone to the flood plain boundary. Peanuts are optimum for productivity groups

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[8]The alternative flood plain conditions were also considered but they exerted no influence on optimum land use by flood hazard. Flood protection simply decreased the number of acres applicable to a particular flood hazard.

TABLE XVII

LAND USE MAXIMIZING RETURNS NET OF FLOODING AND PRODUCTION COSTS FOR ALTERNATIVE CROP PRICES AND PRODUCTIVITY GROUPS BY FLOOD PLAIN LOCATION

Productivity Group	Flood Exposure (flood frequency - years)[a]		
	.5	1	3 and larger
<u>Benefit Prices</u>[b]			
F_1	alfalfa	peanuts	peanuts
F_2	alfalfa	alfalfa	cotton
F_3	native pasture	peanuts	peanuts
F_4	native pasture	native pasture	native pasture
<u>Normalized Prices</u>[c]			
F_1	d	alfalfa	peanuts
F_2	d	alfalfa	soybeans
F_3	native hay	peanuts	peanuts
F_4	native pasture	native pasture	native pasture
<u>Adjusted Prices</u>[e]			
F_1	d	alfalfa	soybeans
F_2	d	alfalfa	soybeans
F_3	native hay	soybeans	soybeans
F_4	native pasture	native pasture	native pasture
<u>Mixed Prices</u>[f]			
F_1	alfalfa	alfalfa	alfalfa
F_2	alfalfa	alfalfa	alfalfa
F_3	native pasture	soybeans	soybeans
F_4	native pasture	native pasture	native pasture

[a]Flood exposure refers to the land inundated only by the flood occurring every X years and all larger floods, where X refers to flood frequency in years.

[b]Crop prices with benefits of government price support programs included.

[c]Crop prices with benefits of government price support programs not included.

[d]There is no obvious optimum land use but rather crops alfalfa and native hay enter the solution in approximately equal proportions.

[e]Crop prices with benefits of government price support programs not included and peanut and cotton deleted from consideration.

[f]Normalized prices apply to surplus crops, cotton and peanuts deleted, and benefit prices apply to all other crops.

F_1 and F_3 assuming benefit and normalized prices. On F_2 land cotton is optimum under benefit prices and soybeans are optimum under normalized prices. With adjusted prices, soybeans maximize net returns on F_1 and F_2 land and on F_3 land for adjusted and mixed prices. Alfalfa enters the optimum solution on F_1 and F_2 land under mixed prices. Over all flood hazard zones and all prices, the optimum land use on F_4 land is native pasture.

The stability of the optimum land use (Table XVII) is estimated following the same procedure as discussed in the previous section.[9] Table XVIII presents the optimum land use price decline that will invalidate the solution by productivity group, flood exposure, and assumed prices. Considering benefit prices and productivity group F_2, the second row of Table XVIII indicates stability of the optimum solution. For the twice a year flood zone, a 7.11 percent price decrease invalidates the optimum alfalfa, for the once a year flood zone a 4.07 percent price decline invalidates the optimum alfalfa, for the once every three years flood zone a 6.68 percent price decline invalidates the optimum cotton, etc. Land with an F_4 productivity group rating has a second best land use of no production, hence, these

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[9]Stability of an optimum solution is estimated by calculating the percentage price decline necessary to make optimum and second best land use equally profitable. The second most profitable land use by flood hazard, productivity group and assumed prices is presented in Appendix C, Table XXXVI. The stability of the optimum land use was calculated with respect to the second best land use as given in this table.

TABLE XVIII

PERCENTAGE PRICE DECLINE OF OPTIMUM LAND USE REQUIRED FOR A CONDITION OF INDIFFERENCE BETWEEN OPTIMUM AND SECOND BEST LAND USE BY FLOOD PLAIN LOCATION[a]

Productivity Groups	Flood Exposure (flood frequency - years)[b]							
	.5	1	3	5	10	25	50	100
	(percent)							
Benefit Prices[d]								
F_1	7.25	18.82	21.36	21.51	21.58	21.61	21.62	21.63
F_2	7.11	4.07	6.68	9.43	10.74	11.37	11.50	11.56
F_3	27.55	36.17	41.86	43.37	43.51	43.58	43.59	43.60
F_4	c	c	c	c	c	c	c	c
Normalized Prices[e]								
F_1	4.68	2.12	6.08	8.78	10.02	10.57	10.74	10.82
F_2	4.51	1.51	1.27	1.61	1.80	1.88	1.90	1.90
F_3	15.86	16.30	23.69	26.01	27.09	27.56	27.71	27.78
F_4	c	c	c	c	c	c	c	c
Adjusted Prices[f]								
F_1	4.68	2.29	0.43	0.71	0.86	1.13	1.01	1.01
F_2	4.51	1.51	1.27	1.61	1.80	1.88	1.90	1.90
F_3	18.86	9.43	12.78	13.15	13.35	13.43	13.45	13.45
F_4	c	c	c	c	c	c	c	c
Mixed Prices[g]								
F_1	7.69	5.58	3.40	3.16	3.02	2.96	2.95	2.94
F_2	7.11	4.85	2.74	2.52	2.39	2.33	2.32	2.32
F_3	19.47	4.26	8.07	8.49	8.72	8.82	8.84	8.85
F_4	c	c	c	c	c	c	c	c

[a]The optimum and second best land use is given in Tables XVII and Appendix C, Table XXXVI, respectively, for each of the above conditions.

[b]Flood exposure refers to land inundated only by the flood occurring every X years and all larger floods.

[c]Second best land use to optimum native pasture is no production.

[d]Crop prices with benefits of government price support programs included.

[e]Crop prices with benefits of government price support programs not included.

[f]Crop prices with benefits of government price support programs not included and cotton and peanuts deleted from consideration.

[g]Normalized prices apply to surplus crops, cotton and peanuts deleted, and benefit prices apply to all other crops.

solutions would require a percent price decline sufficient to reduce profits to zero before they become invalid.

Comparing optimums among prices, benefit price solutions have the greatest stability by productivity group and flood hazard. Productivity group classifications characterized by optimums with the greatest relative stability are F_1 and F_2 under benefit prices, F_1 under normalized prices and F_3 under all assumed prices. Conversely, the least stable solutions are associated with flood plain having an F_2 productivity grouping especially under normalized, adjusted, and mixed prices.

The discussion of results obtained by application of the optimizing model to a particular study area (Nuyaka Creek flood plain) illustrates the capability and potential of the model. Data generated by the optimizing model has implications for purposes other than providing guidance to the flood plain farmer in his land use planning decisions, even though this in itself is justification enough to warrant model development. The following section examines some of these other uses.

Optimizing Model Relevance to Assessing and Policy

An assessment procedure to meet specified costs of flood protection was presented in Chapter V based on the reduction of average annual flood damages with respect to present land use. It was pointed out that with flood protection, land uses could be expected to change in which case assessments based on present land use would be inequitable. In view of this and with the disaggregated flood plain data generated by the optimizing model an alternative flood protection assessment procedure is proposed. In addition, the discussion focuses upon application of the optimizing model to policy, specifically efficiency of flood plain use and the concept of flood plain occupancy charges with indemnification for flood losses (compulsory flood insurance with a new twist).

Flood Protection Assessments: An Alternative

Assessments based on the reduction in flood damages assuming present land use, in effect, penalizes the efficient farmer. In many fields of a flood plain, returns net of production costs and average annual flood damages could be significantly increased by a more intensive utilization of flood plain; i.e., production of alfalfa, row crops, etc., in place of pasture. Therefore, the efficient farmer presently producing high value crops, compared to pasture, will incur the greatest dollar benefit per acre of flood plain and be assessed accordingly. However, in many cases after flood protection is provided, the farmers previously making inefficient use of flood plain will convert pasture to the more intensive land uses deriving added benefits. The efficient farmer is penalized because, based on the land use before flood protection, he receives a much greater reduction in flood losses than the farmer making inefficient use of flood plain. The farmer making inefficient use of flood plain is assessed based on reduced flood damages for pasture, a very low per acre assessment compared to cotton, soybeans, alfalfa, etc., but receives flood protection benefits on the land uses to which he converts after protection is provided.

To more equitably distribute assessments among flood plain occupants, this study proposes that the expected increase in returns net of production cost and average annual flood damages would be a more appropriate measure of flood protection benefits. However, rather than assume present land use, an optimum flood plain land use pattern (profit maximizing pattern) would be assumed both with and without flood protection. The assumed optimum flood plain land use patterns render the decrease in flood damages attributable to flood protection inapplicable as a measure of flood protection benefits. With flood protection provided, it is possible that land use adjustments called for in specific fields to maintain an optimum will result in an increase in average annual flood damages. Such a land use adjustment has an associated gross return increase sufficient to more than offset any production cost and flood damage increase. This results in an increase in net returns for the field even though average annual flood damages are larger than without protection.

Distribution of flood protection assessments based on increased net revenue assuming optimum land use patterns would encourage efficiency in flood plain land use and penalize, if anyone, the farmer making inefficient use of flood plain. By assessing based on flood plain potential, the beneficiaries are given an incentive to better utilize the bottomland. Assessments based on the potential increase in net returns results in a more uniform allocation of the specified flood protection costs over the flood plain. Underlying such an assessment procedure is the assumption that all flood plain operators are rational and have as their objective maximization of profit. In this case, with knowledge of the actual flood hazard, flood plain operators would adjust land use in each field so as to maximize returns net of production cost and average annual flood damages.

To illustrate the proposed assessment procedure, the sample points comprising cross section area N-8 were again selected so that some comparisons could be made with the assessment illustration in Chapter V. For this presentation, optimum land use and associated net returns were determined assuming adjusted prices.[10] Table XIX gives each sample point in N-8 and the associated optimum land use and expected net returns for present flood plain conditions and structure system SS II. Benefits attributable to SS II,

[10]The commodity prices referred to as "adjusted" prices were selected to permit the illustration and are not necessarily defended as most appropriate. Commodity prices in an actual model application will be determined by the particular area's allotments, markets, etc.

TABLE XIX

OPTIMUM LAND USE AND EXPECTED NET RETURNS COMPUTED WITH ADJUSTED PRICES FOR PRESENT FLOOD PLAIN CONDITIONS AND SS II AND POTENTIAL INCREASE IN NET RETURNS ATTRIBUTABLE TO SS II FOR EACH SAMPLE POINT INCLUDED IN CROSS-SECTION AREA N-8[a]

Sample Point Location in the N-8 Matrix[b] row	column	Present Flood Plain Conditions: Optimum Land Use (crop)	Average Annual Damages (dollars)	Net Returns (dollars)	SS II: Optimum Land Use (crop)	Net Returns (dollars)	Potential Benefits of SS II[c] (dollars)	Proportion of all SS II Benefits[d] (percent)
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
9	1	alfalfa	57.18	125.82	soybeans	172.61	46.79	0.176
10	1	alfalfa	53.00	130.00	soybeans	178.29	48.29	0.182
11	1	w. pasture	4.03	4.72	w. pasture	5.84	1.12	0.004
6	2	alfalfa	55.23	166.37	soybeans	214.09	47.72	0.180
7	2	soybeans	55.32	173.03	soybeans	220.56	47.53	0.179
8	2	soybeans	57.16	171.19	soybeans	220.04	48.85	0.184
9	2	alfalfa	53.00	130.00	soybeans	178.29	48.29	0.182
10	2	w. pasture	5.07	3.68	w. pasture	3.68	0.00	0.000
11	2	soybeans	67.40	122.35	soybeans	166.75	44.40	0.167
4	3	alfalfa	72.19	149.41	soybeans	176.72	27.31	0.103
5	3	alfalfa	49.44	172.16	soybeans	217.99	45.83	0.173
6	3	alfalfa	53.00	168.60	soybeans	216.89	48.29	0.182
7	3	w. pasture	3.79	4.96	native hay	11.74	6.78	0.026
8	3	alfalfa	149.16	33.84	alfalfa	122.14	88.30	0.333
9	3	w. pasture	4.29	4.46	w. pasture	5.27	0.81	0.003
11	3	alfalfa	55.07	127.93	soybeans	175.69	47.76	0.180
3	4	alfalfa	65.25	117.75	soybeans	151.03	33.28	0.126
4	4	soybeans	57.16	171.19	soybeans	220.04	48.85	0.184
5	4	w. pasture	3.98	4.77	w. pasture	6.05	1.28	0.005
6	4	n. pasture	15.33	18.42	native hay	32.13	13.71	0.052
7	4	soybeans	67.40	160.95	soybeans	205.35	44.40	0.167
8	4	soybeans	63.79	164.56	soybeans	212.37	47.81	0.180
2	5	soybeans	49.25	179.10	soybeans	222.48	43.38	0.164
3	5	w. pasture	4.24	4.51	w. pasture	5.31	0.80	0.003
4	5	alfalfa	63.32	119.32	soybeans	156.52	36.84	0.139
5	5	alfalfa	61.01	121.99	soybeans	162.68	40.69	0.153
6	5	alfalfa	60.65	122.35	soybeans	163.60	41.25	0.156
7	5	alfalfa	57.71	163.89	soybeans	209.85	45.96	0.173
1	6	alfalfa	60.65	122.35	soybeans	163.60	41.25	0.156
2	6	alfalfa	52.60	130.40	soybeans	178.41	48.01	0.181
N-8 Total			1476.69	3290.43		4376.01	1085.58	4,092

[a]Prices that do not include benefits of government price support programs with peanuts and cotton deleted from consideration.

[b]Each sample point represents five acres; hence, the values given in the above table refer to five acre units of flood plain.

[c]Benefits of flood protection as measured by the potential increase in net returns assuming optimum land use before and after protection.

[d]This could serve as an assessment factor and refers to percent of total flood plain SS II benefits each sample point receives.

measured as potential increase in net returns, and the proportion of total SS II flood plain benefits each sample point receives are also enumerated in the table. The total flood plain benefits (increase in potential net returns under optimum land use) for SS II are $26,516.07.

The last column of Table XIX would be the assessment factor under the proposed procedure. An examination of the assessment factors reveals a range of zero to 0.333 compared to a range in the Chapter V assessment factors of zero to 0.6761. This indicates the burden of specified flood protection costs is more evenly distributed over the sample points. Also the assessment factor for the aggregate cross section area is 4.092 in Table XIX compared to 6.7637 in Chapter V which indicates a reallocation of flood protection financial responsibility among cross section areas as well as among sample points.

Comparing assessment factors in Table XIX and Table XI for specific sample points provides insight into the net returns assessment procedure and assessment reallocation. Sample points with a present land use of pasture have an assessment factor of approximately 0.01 in Table XI, whereas, the assessment factor for these same sample points based on an optimum land use of soybeans or alfalfa is approximately 0.18; i.e., the assessment factor in Table XIX is approximately 18 times as large as that given in Table XI for sample points with a present land use of pasture and optimum land use of alfalfa or soybeans. Conversely, sample points presently in alfalfa or soybeans and which have an optimum land use of alfalfa or soybeans will have a net return assessment factor of about one-fourth the assessment factor computed based on the reduction of flood damages assuming present land use (0.18 compared to 0.63). The aggregated net return assessment factor is 1.757 for the 11 sample points with a present land use other than pasture and 2.335 for the 19 sample points presently in pasture (compared to 6.5820 and 0.1817, respectively, in Table XI). This indicates net returns assessment factors will significantly reallocate financial flood protection responsibility. However, for sample points presently in pasture and with an optimum land use of pasture the assessment factor will either decrease or be unchanged by going from an assessment procedure based on damage reduction to one based on the potential increase in net returns (sample point 10 x 2 had no change with 3 x 5 and 11 x 1 decreasing).

To assess based on increased potential net returns would be a significant change from present techniques and would require foresight and determination on the part of the conservancy district. The reaction to such a procedure will depend upon the proportion of farmers making efficient use of flood plain to those making an inefficient use of flood plain. If all farmers are operating at about the same level of efficiency, controversy should be minimized. However, in flood plains similar to cross section area N-8 where a larger number of farmers are using flood plain inefficiently than efficiently, criticism will abound with the inefficient claiming discrimination.

In the field of economics and in the government, there is a preoccupation with efficiency. The proposed assessment procedure based on potential increase in net returns is one means of encouraging efficiency of flood plain land use and providing for a more equitable distribution of assessments among beneficiaries. Another method of providing incentive to bring about a more efficient flood plain land use involves the concept of compulsory flood insurance.

Flood Plain Occupancy Charges

Compulsory flood insurance or flood plain occupancy charges with indemnification for losses incurred will theoretically bring about land use adjustments toward some optimum.[11] The procedure involves an annual charge in proportion to flood hazard faced; i.e., an annual levy against each flood plain farmer based on the average annual damages of the crops produced each year in the bottomland. The optimizing program computes average annual damages for up to 15 crops on each sample point, hence, with compulsory flood insurance on crops being produced the levy rates are available by sample point. With shifts in flood plain land

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[11] U.S., Congress, House, Task Force on Federal Flood Control Policy, A Unified National Program for Managing Flood Losses, House Document No. 465, 89th Cong., 2d Sess., August 10, 1966, p. 38.

use, the appropriate occupancy charge to be levied is average annual flood damages for the new crop.

The annual charges of a compulsory flood insurance program based on crops produced can be calculated with the simulator. Thus, the optimizing model does not have anything new to contribute on this point. Regarding the optimum forthcoming from occupancy charges, this could very well be a minimizing of flood losses rather than maximizing of expected flood plain net returns. The lower occupancy charges associated with pasture (as compared to soybean, alfalfa, etc.) could result in some cropland reverting back to pasture and very little pasture being reallocated to a more intensive use. The occupancy charge could, however, be expected to discourage allocation of bottomland with a high incidence of flooding to crops highly vulnerable to flood water.

To attain an optimum flood plain land use pattern (maximization of expected net returns), this author proposes a flood occupancy charge based on the average annual flood damages of the profit maximizing crop as determined by the optimizing model. Assuming present flood plain conditions and adjusted prices, the N-8 sample point occupancy charges would be the values given in column three of Table XIX. An annual charge equivalent to average annual damages of an optimum land use would provide economic incentives to adjust flood plain land use toward profit maximization. For example, the occupancy charge based on a present land use of pasture would be in most cases less than one dollar for a sample point representing five acres. If the optimum land use of this sample point is alfalfa or soybeans, the optimum land use occupancy charge would be in excess of $50.00 (see sample points 9 x 1, 10 x 1, 9 x 2, and 11 x 2 in Chapter V, Table XI and Table XIX of this chapter).

Another alternative available to policy makers striving for optimum flood plain land use would be to tax flood plain land at its potential as given by expected net returns for the optimum land use. This author does not necessarily advocate the occupancy charge or tax procedure based on optimum land use as he is aware of the difficulties associated with each but rather points them out to illustrate possible applications of the optimizing model.

This chapter presented some of the applications of the optimizing model and has shown how optimum land use can be used as an alternative to present land use in a flood plain evaluation. Data generated by the optimizing model can aid flood plain farmers in significantly increasing their annual net returns by designating the flood hazard at each sample point for up to 15 crops. A reorganization of production can be made to increase profit and at the same time keep risk (average annual flood damages) within the range a farmer is willing to accept. Knowledge of sample point optimum land use also helps establish the potential of a flood plain, better evaluate proposed flood protection measures and can serve as a guide to policy makers when contemplating compulsory flood insurance, tax policies, and distribution of assessments.

CHAPTER VII

SUMMARY AND INTERPRETATIONS

Much of the dissatisfaction with present methods of estimating flood damages results from an inability to accurately predict flood damages for individual tracts of land. A more meaningful and significant evaluation of small watersheds could be attained with improved knowledge of the incidence of flood damages. More accurate estimates of the incidence of average annual flood losses can help establish: (1) more equitable assessments of the local cost of flood protection, (2) annual premiums for flood insurance, and (3) optimum cropping patterns. The over-all purpose of this study was to develop methodology whereby flood damages could be estimated for a specific field with respect to the particular characteristics of that field; i.e., land use, productivity, depth of inundation, and location.

Two models were developed providing additional flood damage data for small watersheds. A general model or simulator was designed to provide improved estimates of the incidence of flood damages. A maximizing or optimizing model was designed to specify land use by flood plain location that maximizes returns net of production costs and average annual flood damages.

Nuyaka Creek Watershed in East Central Oklahoma was selected as the study area for developing the model. The selection was based on the availability of watershed planning information and the absence of dikes, levies, or other physical characteristics that would render the model invalid or inoperative. In developing a watershed protection plan for Nuyaka Creek, the Soil Conservation Service designed two alternative systems of structures. Therefore, the incidence of flood damages could be estimated for two proposed structure systems as well as under present flood plain conditions. The structure systems designed by the SCS are designated SS I and SS II (SS II has been approved by Congress for construction). The two models, results, and implications of their application to the study area, model limitations, and need for further study are discussed below.

The Simulation Model

The principal objective of this study was to develop a general model for estimating average annual flood damages to crop and pastures on any specific area within a Soil Conservation Service project size watershed (less than or equal to 250,000 acre drainage area). The general model was developed as a simulation program and includes many of the procedures of present estimating methods.

The simulation model developed is designed to use the frequency method of estimating flood damages.[1] However, the computation of flood damages is based on a point sample method rather than the presently utilized composite acre (a hypothetical acre composed of the same percentage of each land use as in the flood plain). The sample used in this model is a uniform assignment of sample points throughout the flood plain with each sample point representing a specified number of flood plain acres. The model computes flood damages for each of the sample points assigned throughout the flood plain. Damages at sample points can then be aggregated over any part of the flood plain desired.

The computational procedure utilizes data readily available in flood damage studies; i.e., crop damage factors, cross section data, and hydrology through which flood elevation data is determined. Crop damage factors, typically utilized in discrete form, are converted to continuous functions, increasing the sensitivity of flood damages to depth of inundation.

The computational procedure can be divided into six major segments. The first segment relates sample points to the appropriate cross section and estimates the elevation of each sample point using measured elevations on the cross sections and linear interpolation procedures. The second segment determines the depth of inundation at each sample

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[1]The frequency method consists of selecting several flood sizes such as those occurring annually, every two years, every 10 years, etc., and computing expected annual damages for the resulting inundation levels.

point by subtracting the flood elevation from the calculated elevation. The depth of inundation is computed for each sample point and size of flood considered in the analysis. Damage factors are converted to a continuous function of inundation depth and weighted by the seasonal probability of flooding in the third segment of the model. The fourth segment utilizes these crop damage factors to compute average annual flood damages for each sample point. The damages are aggregated to provide estimates of average annual damages for any part or the entire flood plain. The fifth segment involves the computation of average annual flood damages as a percent of gross value of production with no flooding. The final segment subtracts from gross returns, by sample point, the production costs and average annual flood damages. This provides an expected net return value at each sample point considering flooding damages.

Applying the simulator or general model with alternative structure systems provides estimates of: (1) acres inundated by specific flood sizes with alternative systems of structure, (2) flood damages for specific storms and average annual damages on any selected area within the flood plain of the watershed, (3) average annual benefits for proposed systems of structures for specific fields and to land owners, and (4) flood damages with alternative land use patterns.

The Optimizing Model

A second objective of the study was to convert the simulation or general model into a decision model to determine profit maximizing flood plain cropping patterns. To satisfy this objective, the simulation model was modified to select the land use at each sample point that maximizes revenue net of production costs and average annual flood damages. This modified simulation model was termed an optimizing model.

Utilizing the optimizing model, sample point land use was not specified. With land use not specified, flood damages were estimated for all potentially profitable crops at each sample point. The optimum flood plain cropping patterns, net returns, and flood damages for alternative systems of structures as well as with no structures were estimated by applying the optimizing model.

Results of the Application

A final objective of the study was to illustrate the two models by applying them to the Nuyaka Creek Watershed. It was possible to estimate the implications for the watershed from appropriate land use changes. Welfare and economic considerations such as equitability and efficiency were incorporated as improved assessment procedures and profit maximizing flood plain use.

Simulation Model Results

Average annual flood damages were computed for present flood plain conditions and flood protection system SS I and SS II based on 1968 sample point land use. The flood damages were estimated with two sets of commodity prices; normalized prices portraying societies value of the crops and benefit prices indicating crop value to individual farmers.

By installing the flood retention structures, flood damages to society are reduced from $11,600 to $3,100 and $4,900 with SS I and SS II, respectively. For individual farmers, benefits of flood protection are $9,000 for SS I and $7,100 for SS II.

The influence of flood protection upon the per acre value of bottomland, based upon 1968 land use, is indicated by the capitalized value of increased returns to land attributable to reduced flooding. Total per acre increase in returns is $2.42 for SS I and $1.89 for SS II. Assuming an interest rate of seven percent, the per acre value of flood plain would be increased $8.46 with SS I and $6.75 with SS II given a rental rate of one-fourth. By increasing the rent to one-third, per acre flood plain values increase by $11.52 and $9.00 for SS I and SS II, respectively. These increases in per acre values of bottomland do not include an adjustment for flood protection assessment. Therefore, the increased values could be expected to be somewhat lower, assuming assessments for flood protection. The reduction in average annual flood damages and increase in per acre land values for the alternative flood protection systems indicate structure system SS I is characterized by a lower incidence of flooding than SS II.

With the implementation of a flood insurance program, the average annual flood damages computed for each sample point constitute the annual premium since this would be expected damages for any given year. The premium for a field to be insured is obtained by summing average annual damages over all sample points included in the field. The reduced damage estimates attributable to flood protection indicate the reduction in annual premium resulting from a change in flood plain conditions.

The productivity group designation of each sample point defines crop yield and, hence, exerts influence over the estimated average annual flood damages. In the study area, the difference between aggregate flood plain damages computed with one flood plain productivity grouping (all sample points assigned to the same productivity group) and damages computed with each sample point assigned to a productivity group corresponding to its yield potential is less than 10 percent. The difference in average annual flood damages between the two productivity groupings is \$700, \$300, and \$400 for present flood plain conditions, SS I, and SS II, respectively.

This difference in average annual flood damages is reflected in sample point assessments. For example, the reduction in flood damages for one specific sample point is zero, but with the single productivity grouping the reduction is $123.60. Assessment based on the proportion of total flood plain benefits received is zero, but based on the single productivity grouping, the sample point is assessed for 1.68 percent of the specified flood protection costs. If these costs are $10,000, the single productivity group assessment will be $168 when, in fact, it should be zero. This implies that a distribution of assessments or establishment of flood insurance premiums requires sample point damage estimates based on a classification of sample points according to production potential.

Optimizing Model Results

The implications of the optimizing model with respect to the study area can be seen focusing on results obtained with mixed prices for present flood plain conditions, SS I, and SS II. Mixed prices refer to commodity prices with benefits of government price support programs deleted for surplus crops, cotton and peanuts entered at zero price, and market price for all other crops. Benefits from the land use changes resulting from mixed prices optimum solution yields conservative estimates for there is the implied assumption of no allotments for government support crops and no market for cotton or peanuts.

The optimizing model selects the most profitable and second most profitable land use for each sample point. In addition the model calculates average annual flood damages and expected net returns for each crop considered by sample point. Providing this information facilitates the decision making process for the flood plain farmer. The land use with the largest expected net returns for a particular field may have an associated flood damage expectancy larger than the risk a farmer is prepared to face. By comparing the expected net returns to expected flood damages, the farmer can better correlate the risk he as an individual is willing to assume with land use and associated net returns.[2]

The optimum land use patterns for the alternative flood plain conditions are comprised primarily of alfalfa in conjunction with some pasture and a very small allocation of soybeans. With increased flood protection, profit maximization requires additional acres of alfalfa and a corresponding reduction of pasture. Soybeans were typically the second most profitable crop on those points for which alfalfa production was optimum. And, in fact, with less than a four percent decline in the price of alfalfa, soybeans replace alfalfa as optimum. There is very little difference in net returns between alfalfa and soybeans. For those sample points with an optimum land use of alfalfa, the flood plain farmer could consider soybean production with little or no loss in net revenue.

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[2]Average annual damages and net returns associated with alternative crops for each sample point included in cross section area N-8 are presented in Appendix C, Tables XXXIII and XXXIV.

By adjusting present land use to the optimum specified by the model, flood plain net returns are increased from $12,700 to $84,400 assuming no flood protection measures. This is an increase in average per acre net returns of $19.18 ($3.39 compared to $22.57). To achieve the increased net revenue there is an increase in realized gross revenue of $187,900 for the aggregate flood plain or average of $50.24 per acre of flood plain. The effect of appropriate land use changes are estimated by capitalizing the increased returns to land (increase in rent attributable to land use adjustments). Assuming an interest rate of seven percent with a rental rate of one-fourth and one-third of production, land use changes increase the average per acre value of flood plain $179.46 and $239.29, respectively. Comparing the benefits of flood protection (assuming no land use changes) with the benefits possible through appropriate land use changes indicates that flood protection should perhaps not have top priority but that rather a revaluation of flood plain land use is in order.

Average annual flood damages more than double and production cost increase more than five times (compared to present land use) due to the land use adjustments necessary to maximize expected net revenue. This presents an interesting phenomenon in that a more optimum land use requires increasing damages from flooding, especially at a time when there is increasing alarm over the trend of increasing flood damages. With respect to agricultural flood plain, increasing damages from flooding could very well indicate adjustments to land uses that result in greater expected net returns. However, it is necessary to identify the relationship between flood damages and expected net returns throughout a flood plain to avoid a misallocation of bottomland to a crop with little tolerance to floodwater. The optimizing model indicates appropriate land use changes and designates infeasible crops through an excessive flood damage value in relation to returns.

The potential flood plain net returns with flood protection is $124,000 for SS I and $111,200 for SS II. Considering a profit maximizing land use before and after flood protection, SS I would increase net returns $40,000 and SS II would increase expected net returns $26,800. Assuming optimum flood plain land use and an interest rate of seven percent, SS I flood protection increases per acre land values $73.96 with a rent of one-fourth of production and $98.62 with a one-third rental rate. The corresponding increase in per acre land values for SS II are $49.29 and $65.71. The increased per acre land values do not include an adjustment for flood protection assessment. With assessments levied to meet specified flood protection costs the increases in per acre values would be lower than indicated. Flood protection did result in an optimum land use with lower average annual flood damages than applicable for present flood plain conditions but the land use changes increased total production costs approximately $30,000.

Based on the results of the model application, it is concluded that flood plain net returns could be increased approximately sixfold by appropriate land use changes. However, to obtain the increase in net returns it is necessary to double or triple exposure to flood damages and meet capital requirements seven to eight times that applicable under present land use. Increased exposure to flood water is the result of substituting alfalfa or soybeans for a crop such as pasture having greater tolerance to flood water.

Increased capital requirements (measured by production costs) of the optimum land use patterns may constitute a limitation to land use adjustments for flood plain farmers operating with little available capital. However, the $230,000 additional production costs of an optimum land use pattern yield an increase in net returns of approximately $71,100. Assuming the additional production capital (production costs) are tied up for an entire year net returns to the investment are in excess of 30 percent. This suggests farmer benefits to be gained from flood plain land use changes significantly exceed the negative factors of increased risk and capital requirements.

In addition to indicating potential profit increases, optimum land use patterns can be used to more equitably distribute flood protection assessments among beneficiaries. By assuming optimum land use before and after flood protection and assessing based on increased profit, an allowance for adjustments in present land use are incorporated into the assessing procedure. This avoids the inequitable assessments based on present land use; i.e., underassessing flood plain presently in pasture that is converted to high value crops after flood protection.

The above discussion suggests that estimates resulting from application of the methodology developed in this study will be of use to: flood plain farmers, flood insurance programs (private or federal), conservancy districts and federal, state, and local agencies. The farmer is provided with improved knowledge of the flood hazard by field, facilitating the decision making process regarding farm operations and land use. Sample point estimated average annual damages for a particular crop provides a sound basis for establishing annual flood insurance premiums. The conservancy district can relate benefits of flood protection to each flood plain farmer and assess for specified costs accordingly. Governmental agencies can use results obtained from the models to evaluate flood protection measures, set property taxes, implement a compulsory flood insurance program and serve as a guide in various policy considerations.

Limitations

The methodology developed is limited to agricultural production and does not consider losses for buildings or urban properties. In addition to ignoring buildings, fences, and other improvements, accuracy of the depth of inundation estimates is sensitive to the nature of flood plain elevation changes. The accuracy of the estimates is least for those flood plains with the most erratic elevation changes. This limitation eliminates application of the model to some flood plains.

The model developed is designed to consider a maximum of 15 crops. This may be a limitation in some flood plains with very diversified production. Thirteen alternative crops were considered in this study and no vegetables, orchards or other specialty crops were included. Some of the uses not considered could have been included by deleting crops that obviously did not serve as a feasible alternative. The real problem in this case was not model capacity, but rather lack of reliable data for land uses not considered.

The analysis included in this study did not consider either the possibility of irrigation or recreational benefits from the structures. Water in the reservoirs may be used to meet water needs during critical periods of plant growth and, thus, increase crop yields. The reservoirs also have a potential recreation value through a stocking of fish and development of camping facilities. However, these values can be computed with present procedures and added to the results available with the model.[3]

This study was further limited in that repercussions

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[3]As an example of procedures proposed for estimating the demand for recreation, see Marion Clawson and Jack W. Knetsch, Economics of Outdoor Recreation, RFF (Baltimore, 1966).

beyond the flood plain of land use adjustment or installation of structure systems were not considered. Increased returns to farmers result in increased purchases of farm supplies and household goods. Hence, the benefits of watershed development are extended to the community and region as a secondary and tertiary effect. The model does provide some information needed to estimate secondary and tertiary benefits and could result in improved estimates calculated with present procedures.

Because the model determines optimum land use on a sample point by sample point basis, all sample points representing one field need not have the same optimum land use. It is necessary to manually sum net returns for each of the crops that may be optimum over all sample points in the field to determine a profit maximizing land use for the field. This is not an involved process, but must be calculated outside the model.

The selection of appropriate commodity prices is always a problem and this study is no exception. Several sets of prices were used to reflect different flood plain conditions (allotments) and position with respect to crop value (society versus individual). Selecting an appropriate set of prices will be a problem for any flood plain evaluation because of government program allotments and the resulting difference in crop prices received by farmers and the actual value of the production to society.

Need for Further Study

There is need for further study in three areas: (1) refinements and extensions of the model, (2) general watershed evaluation, and (3) individual farmer considerations. With regard to the model, one need is to improve the accuracy of sample point elevation estimates. One way to improve the model is to modify the procedure to locate the sample point both with respect to the cross section on either side and with respect to the channel and flood plain boundary. The elevation could then be estimated by linear interpolation between the appropriate point on the two cross sections. To incorporate this refinement into the model, it would be necessary to have the elevation of a flood at a sample point a function of the flood's elevation at the cross sections located on either side of the sample point. Deriving sample point elevation and flood elevation in this manner would improve the accuracy of the model for flood plains with erratic elevation changes.

Model extensions include considering property other than agricultural land and providing for a risk factor. The model would be more inclusive if damage to fences, buildings, and other improvements was determined by the computational procedure and included in the resulting output. The optimizing model maximizes returns net of production costs and average annual flood damages. A logical consideration would be maximizing profit subject to a certain degree of risk (expected flood damages) or minimizing expected flood damages for a specified level of income. Incorporating decision theory models into the optimizing model represents a possible approach to consideration of risk.

This study considered several alternative factors with regard to a watershed evaluation but, of course, did not pursue all possibilities. Research directed toward determining the effect of an increasing population and associated increasing aggregate demand on flood plain development would be an aid to watershed planning and evaluation. This research could relate aggregate demand to supply potential and ascertain the degree of natural resource development necessary to meet projected aggregate demand. Watershed projects, in this case, could use need as a basis for justification.

Additional research to determine the effect of upstream improvements on downstream flooding is also needed. For example, straightening and clearing the channel upstream reduces upstream flooding by providing for a more rapid movement of water from the immediate area, but this results in an increased overflow of the downstream channel. The effect of reduced damages upstream is increased damages downstream. Channel clearing in small watersheds also reduces the opportunity for sediment to become trapped, and increases the contribution of watersheds to river pollution. A watershed project with structural systems and measures to control erosion could reduce river pollution, but research is needed to establish the degree of effectiveness.

Large expenditures have been made to install watershed projects and reduce flooding. However, there is a definite need for complete evaluations of how well a watershed project works once installed. Too often, after a watershed project is completed, little or no attention is given to the influence of the project. Research is needed to determine the effect of a project on incidence of flooding, land use changes eminating and the reliability of the project work plan estimates. These results would be helpful in planning other watershed projects.

Turning to the individual farmers in a flood plain, studies are needed to improve the organization of production by farm. Data from the optimizing model, not previously available, indicates costs and returns by crop for specific flood plain fields. This information could be used to develop an improved farm organization considering both upland and flood plain for specified risk (average annual flood damages) and production cost restraints. Also, profit maximizing farm plans could be developed for farmers operating land in the flood plain using this information.

In conclusion, it is the synopsis of this study that although there are limitations to the methodology developed and further testing and application of the model is in order, the methodology does represent a significant contribution to the realm of flood plain evaluation.

SELECTED BIBLIOGRAPHY

Anderson, Decima M. Computer Programming: Fortran IV. New York: Appleton-Century-Crofts, 1966.

Ciriacy-Wantrup, S. V. "Benefit-Cost Analysis and Public Resource Development." Journal of Farm Economics, XXXVII (November, 1955), pp. 676-689.

Clawson, Marion, and Jack L. Knetsch. Economics of Outdoor Recreation, RFF. Baltimore: John Hopkins Press, 1966.

Federal Reserve Bank of Kansas City. "Economic Analysis of Water Resource Development Projects." Monthly Review (October, 1958), pp. 9-16.

Fox, Irving K. New Horizons in Water Resources Administration, RFF Report, 1965.

Gray, Fenton. Productivity of Key Soils in Oklahoma. Stillwater: Oklahoma Agricultural Experiment Station Bulletin No. B-650, 1966.

Henderson, James M., and Richard E. Quandt. Microeconomic Theory. New York: McGraw-Hill Book Company, 1958.

Hillier, Frederick S., and Gerald J. Lieberman. Introduction to Operation Research. San Francisco: Holden-Day, Inc., 1968.

Kletke, Darrel D., and Luther G. Tweeten. Enterprise Budgets and Farm Plans for Sandy Soils of Southwest Oklahoma. Stillwater: Oklahoma Agricultural Experiment Station Processed Series P-553, 1966.

Lacewell, R. D., and Vernon R. Eidman. Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises: Bottomland Soils of East Central and South Central Oklahoma. Stillwater: Oklahoma Agricultural Experiment Station Processed Series P-606, 1969.

Leftwich, Richard H. The Price System and Resource Allocation, rev. ed. New York: Rinehart, 1964.

Naylor, Thomas, H., Joseph L. Balintfy, Donald S. Burdick, and Kong Chu. Computer Simulation Techniques. New York: John Wiley and Sons, Inc., 1968.

Reder, Melvin W. Studies in the Theory of Welfare Economics. New York: Columbia University Press, 1947.

Shubik, Martin. "Simulation of the Industry and the Firm." American Economic Review, L, No. 5 (1960), p. 909.

Sloggett, Gorden, and Neil R. Cook. Evaluating Flood Prevention in Upstream Watersheds With an Areal Point Sample -- Interim Report, Washita River Basin. Washington: United States Department of Agriculture Report, ERS-353, 1967.

Soil and Water Conservation Districts. "Appraisal of Benefits in a Conservancy District." A Procedure for Assessing in Oklahoma (Mimeographed).

Tweeten, Luther G. "Public Welfare and Economic Efficiency," Unpublished Manuscript, 1968.

U.S. Congress, Senate, Committee on Banking and Currency. Insurance and Other Programs for Financial Assistance to Flood Victims, Committee Print, 89th Cong., 2d Sess., 1966.

U.S. Congress, Task Force on Federal Flood Control Policy. A Unified National Program for Managing Flood Losses, House Document No. 465, 89th Cong., 2d Sess., 1966.

U.S. Department of Agriculture, Soil Conservation Service, Economics Guide for Watershed Protection and Flood Prevention. Washington: Government Printing Office, 1964.

U.S. Department of Agriculture, Soil Conservation Service. Work Plan, Okfuskee Tributaries Watershed. Stillwater: USDA, SCS, 1966.

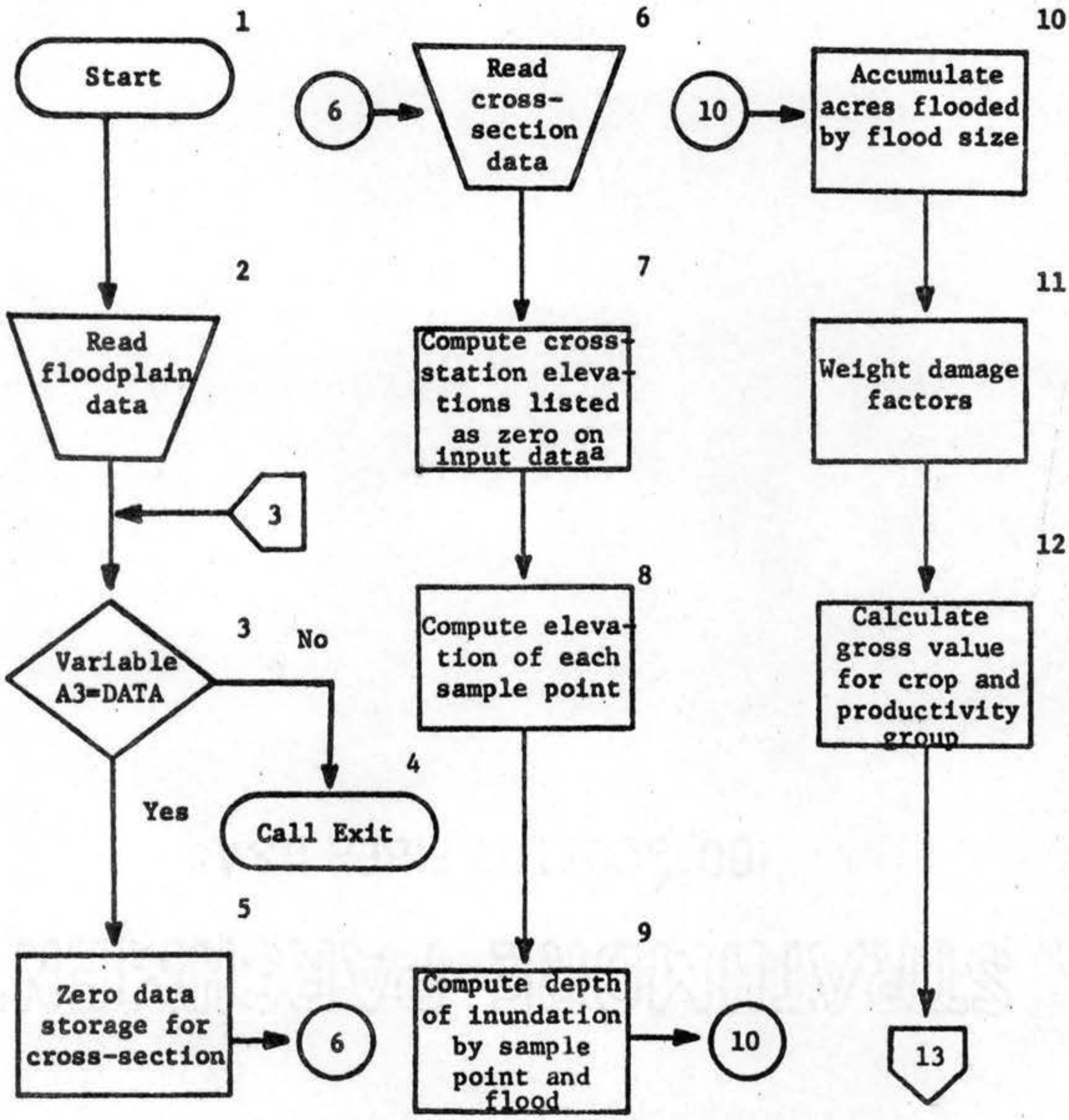
U.S. Department of the Army, Corps of Engineers. Flood Insurance Study, Agricultural Area Along Mississippi River Winfield Levee and Drainage District Missouri. A Report Prepared by the Army for the Department of Housing and Urban Development, Washington: 1966.

U.S. Department of the Army, Corps of Engineers. Technical Information On Average Annual Flood Damages for Classes of Properties by Flood Risk Zones. A Report Prepared by the Army for the Department of Housing and Urban Development, Washington: 1966.

Water Resources Council. Interim Price Standards for Planning and Evaluating Water and Land Resources. A Report by the Interdepartmental Staff Committee of the Water Resources Council, Washington: 1966.

APPENDIX A

FLOW CHART REPRESENTATION OF MODELS



[a]To facilitate data collection and keypunch operation efficiency, the computer program was designed so that the elevation of the cross-section stations lying on a linear segment could be left blank with only the beginning and ending station elevation of the segment listed. The program then computes the elevation of all stations left blank with respect to the stations location in the linear segment and the beginning and ending station elevations.

Figure 8. Simplified Flow Chart of the Simulation Model Developed to Compute the Incidence of Agricultural Flood Damages

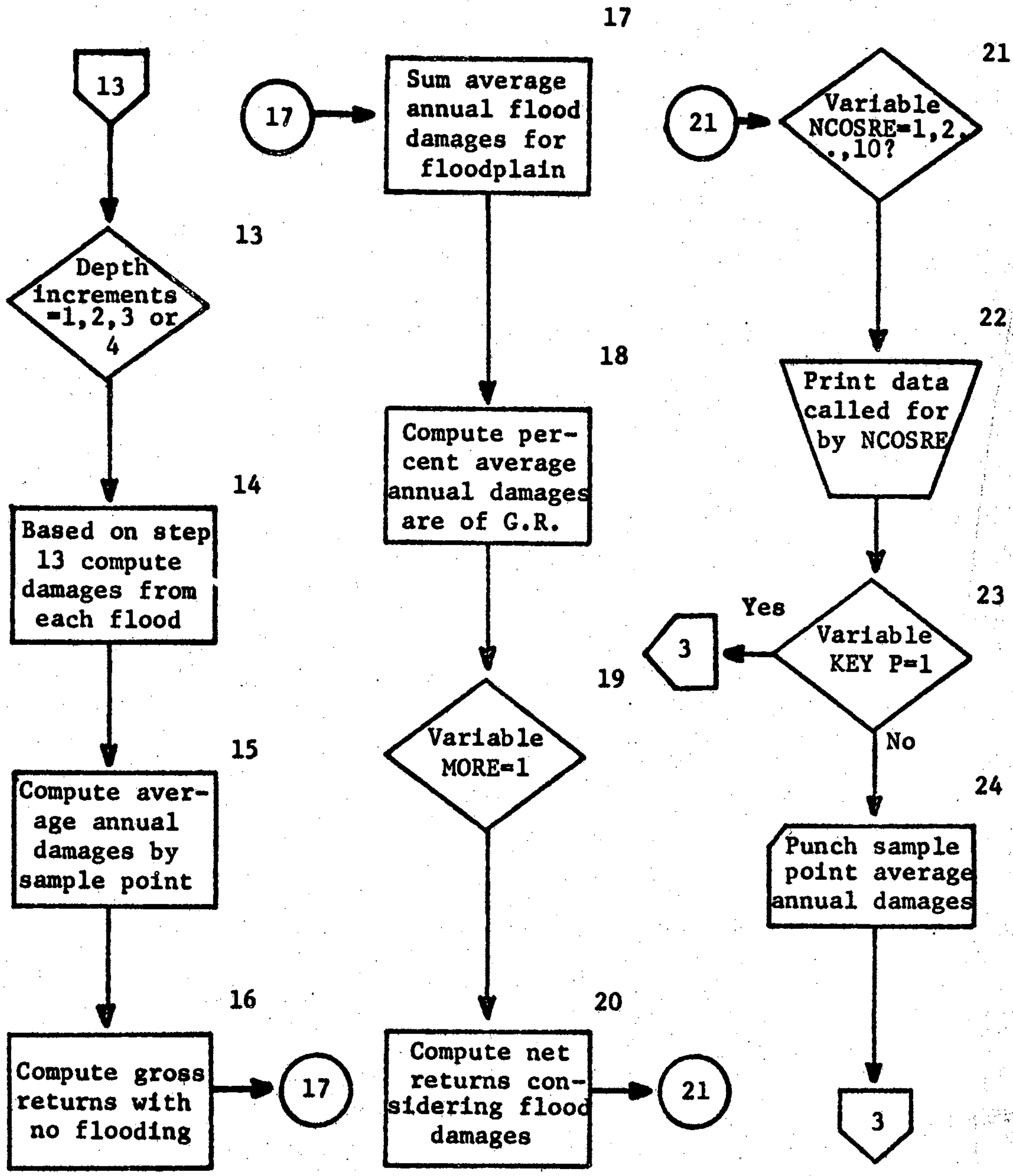


Figure 8. (Continued)

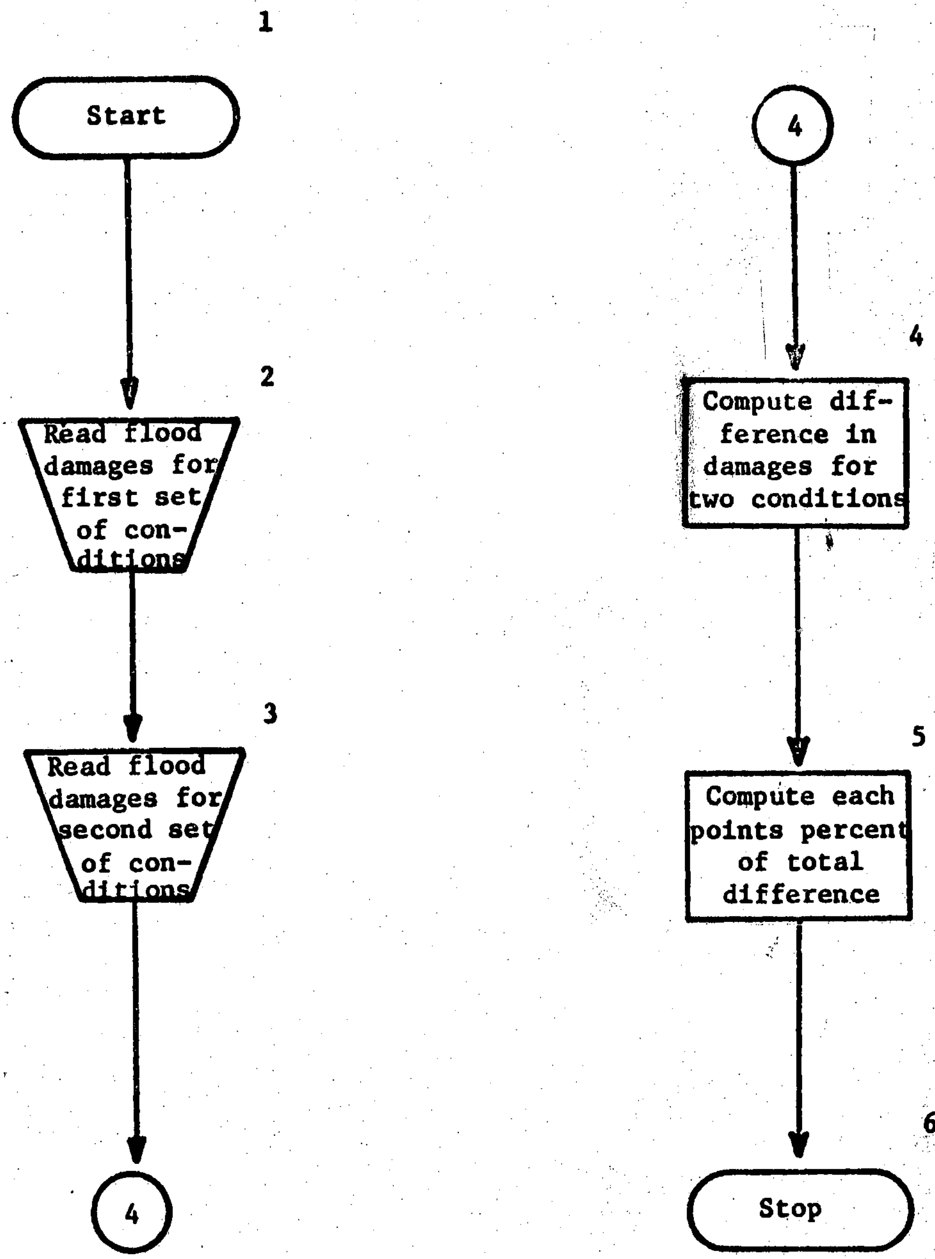


Figure 9. Simplified Flow Chart of the Assessment Model

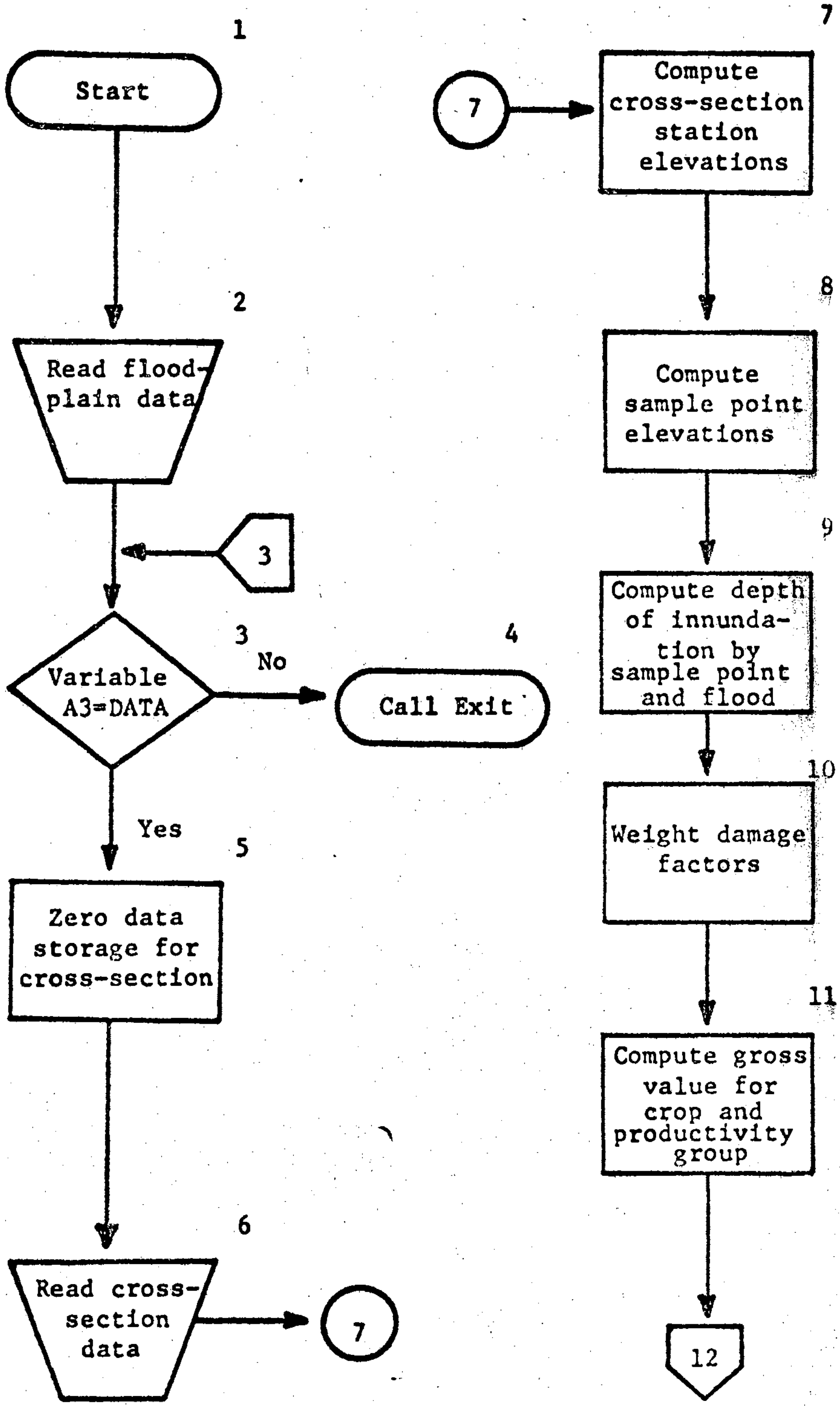


Figure 10. Simplified Flow Chart of the Optimizing Routine Developed to Maximize Net Returns at Each Flood Plain Location

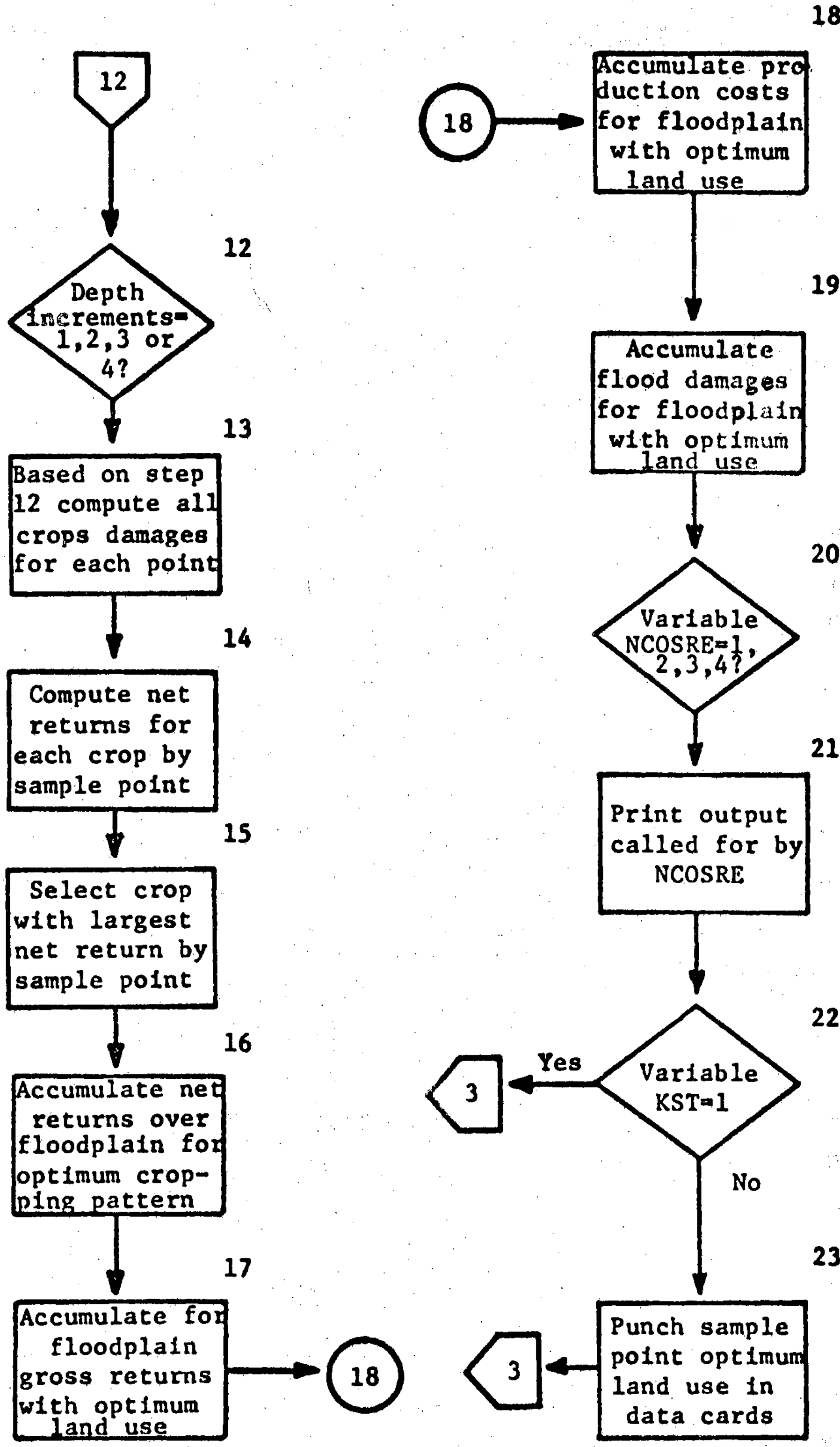


Figure 10. (Continued)

APPENDIX B

INPUT DATA FOR THE FLOOD PLAIN EVALUATION MODELS

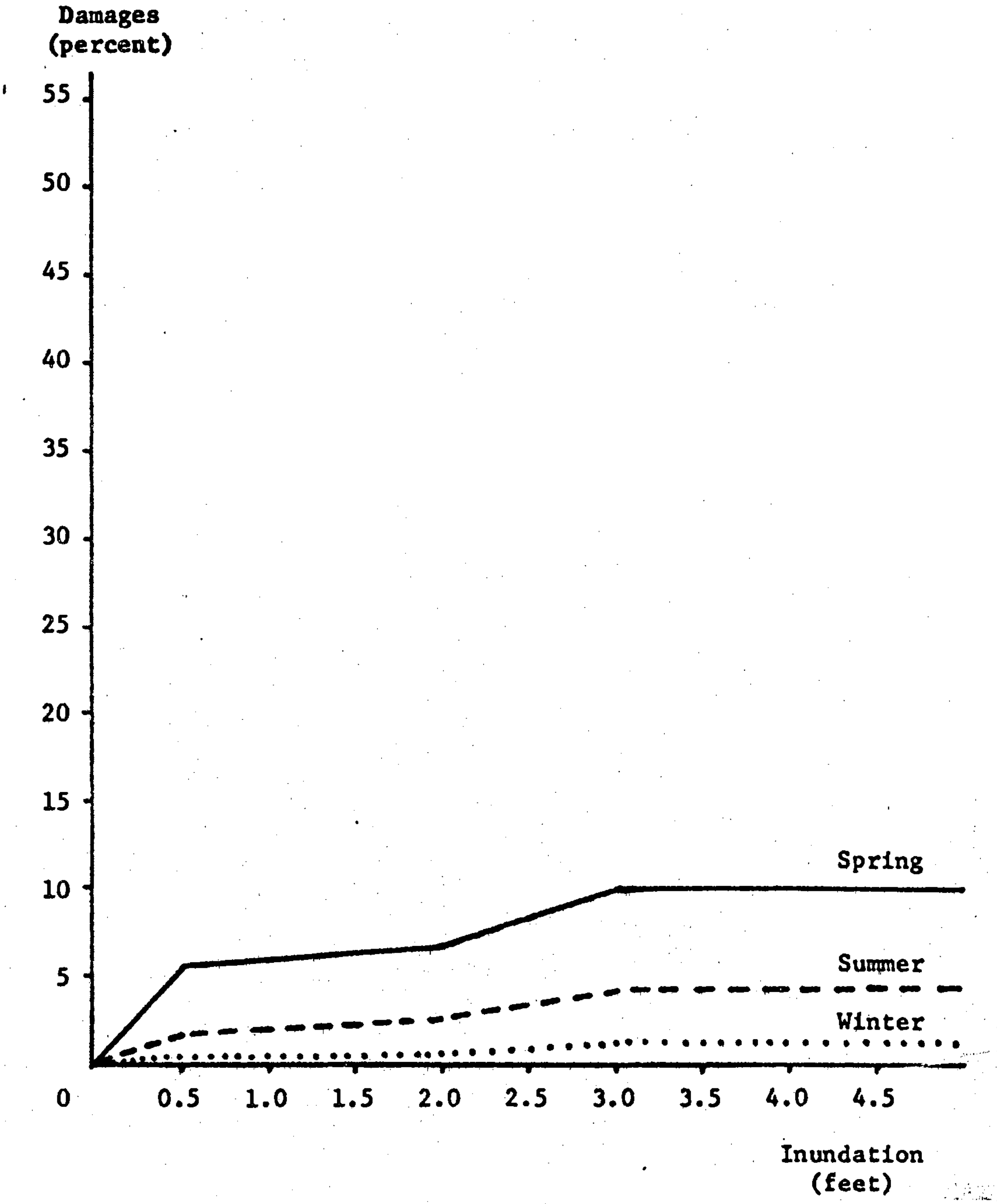


Figure 11. Percent Reduction in Gross Returns of Pastures by Season and Depth of Inundation: Nuyaka Creek Flood Plain

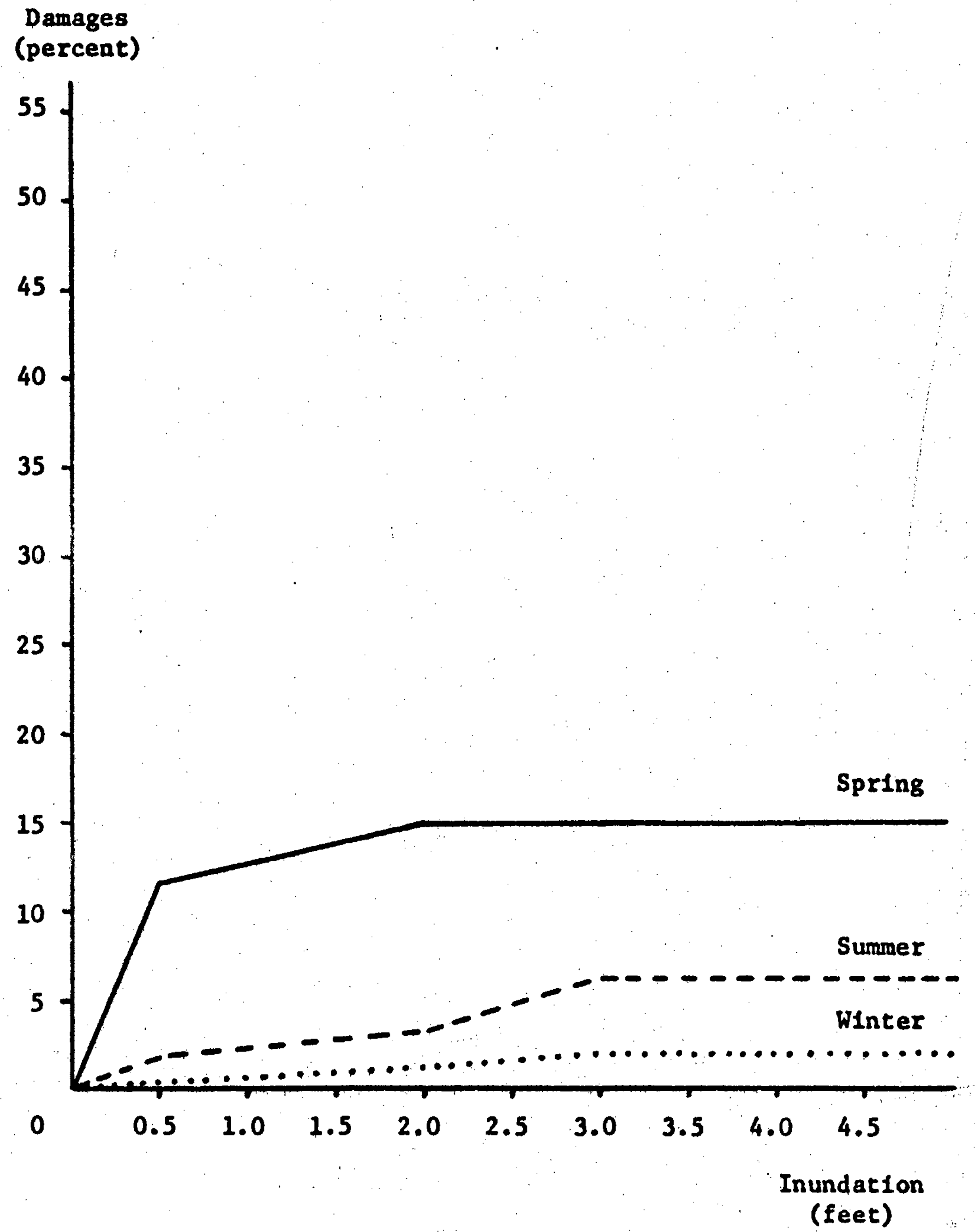


Figure 12. Percent Reduction in Gross Revenue of Alfalfa by Season and Depth of Inundation: Nuyaka Creek Flood Plain

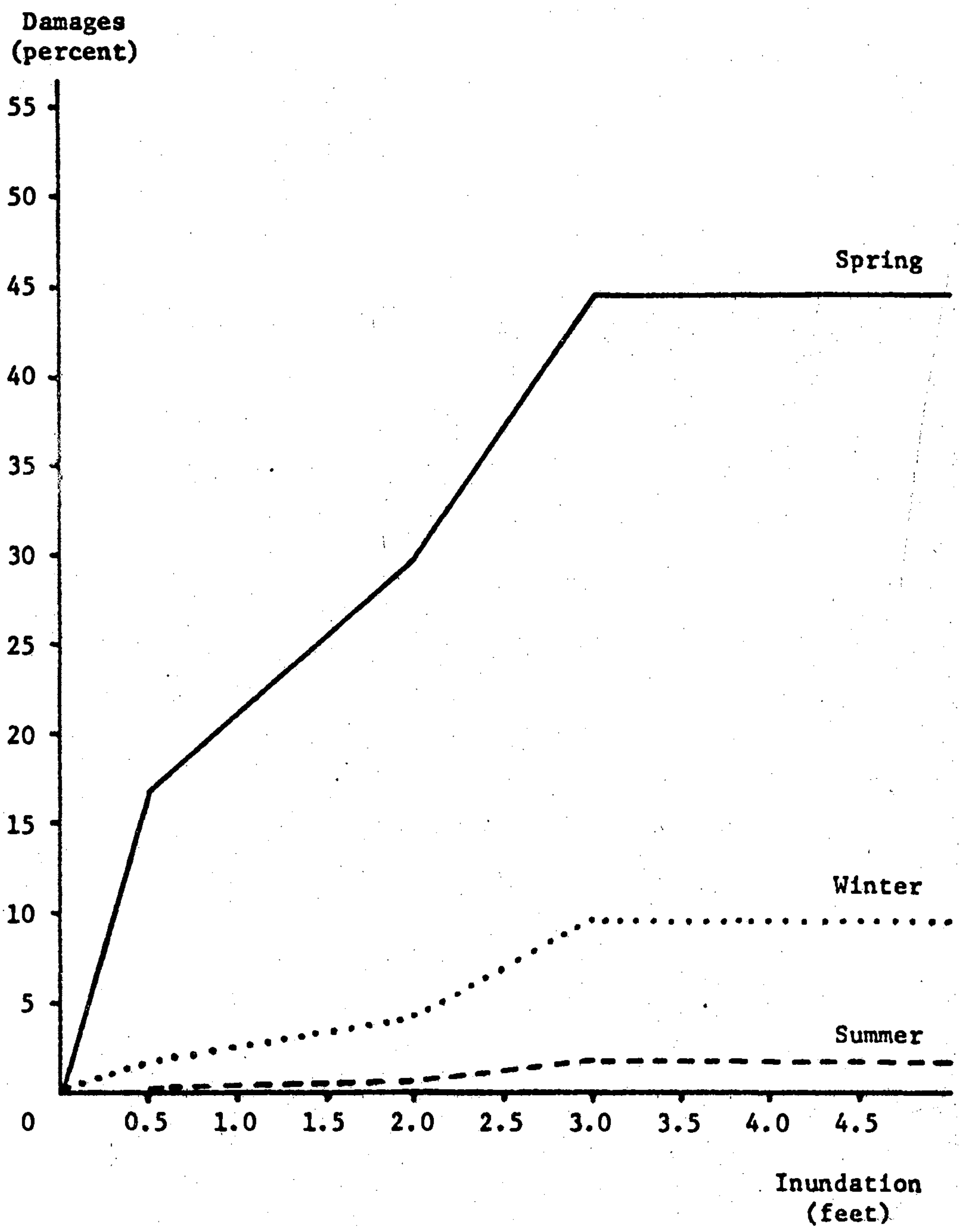


Figure 13. Percent Reduction in Gross Revenue of Wheat by Season and Depth of Inundation: Nuyaka Creek Flood Plain

TABLE XX

PERCENT REDUCTION IN GROSS RETURNS FOR SPECIFIED CROPS DUE TO FLOODING BY DEPTH OF INUNDATION AND SEASON[a]

Crop	Depth of Inundation (feet)	Season		
		Spring[b]	Summer[c] (percent)	Winter[d]
Wheat	0-1.0	28.5	0.0	10.3
	1.1-3.0	50.4	2.4	26.8
	3.1 & over	75.1	7.1	60.8
Oats	0-1.0	30.9	1.6	10.4
	1.1-3.0	60.9	8.1	23.6
	3.1 & over	66.8	10.3	28.6
Grain Sorghum	0-1.0	21.7	14.9	0.8
	1.1-3.0	36.2	32.4	3.5
	3.1 & over	43.2	40.1	6.1
Soybeans	0-1.0	20.0	31.0	5.0
	1.1-3.0	31.0	43.0	8.0
	3.1 & over	40.0	57.5	12.0
Corn	0-1.0	21.3	26.0	1.3
	1.1-3.0	36.8	36.3	5.3
	3.1 & over	42.4	64.2	7.1
Peanuts	0-1.0	25.5	31.8	0.8
	1.1-3.0	33.8	50.1	1.4
	3.1 & over	39.5	55.4	3.9
Cotton	0-1.0	22.7	27.9	11.8
	1.1-3.0	32.4	42.0	17.5
	3.1 & over	42.8	55.4	22.6
Alfalfa	0-1.0	19.5	7.7	2.2
	1.1-3.0	25.1	13.2	7.4
	3.1 & over	25.2	25.8	12.3
Native Hay	0-1.0	13.1	12.2	0.6
	1.1-3.0	15.5	21.1	2.4
	3.1 & over	19.2	34.4	3.7
Bermuda Grass	0-1.0	10.2	6.4	1.1
	1.1-3.0	13.3	9.9	3.0
	3.1 & over	17.6	17.1	6.3

TABLE XX (Continued)

Crop	Depth of Inundation (feet)	Season Spring[b]	Summer[c] (percent)	Winter[d]
Pasture	0-1.0	10.2	6.4	1.1
	1.1-3.0	13.3	9.9	3.0
	3.1 & over	17.6	17.1	6.3
Woodland Pasture	0-1.0	10.2	6.4	1.1
	1.1-3.0	13.3	9.9	3.0
	3.1 & over	17.6	17.1	6.3
Barley	0-1.0	30.9	1.6	10.4
	1.1-3.0	60.9	8.1	23.6
	3.1 & over	66.8	10.3	28.6

[a]Factors derived from: Economics Guide for Watershed Protection and Flood Prevention, Soil Conservation Service, USDA, Economics Guide Oklahoma Supplement 4, March, 1964.

[b]Spring consists of April, May, and June.

[c]Summer consists of July, August, September, and October.

[d]Winter consists of November, December, January, February, and March.

TABLE XXI

SOILS INCLUDED IN EACH DESIGNATED PRODUCTIVITY GROUP: NUYAKA CREEK FLOOD PLAIN[a]

Productivity Group	Soil
F_1	Cleora very fine sandy loam
	Dennis silt loam
	Mason very fine sandy loam
	Okemah silt loam
	Switzer silt loam
	Taloka very fine sandy loam
	Vanoss very fine sandy loam
	Verdigris silt loam
F_2	Mason silty clay loam
	Switzer silty clay loam
	Verdigris clay
F_3	Stidham very fine sandy loam
F_4	Breaks allevial land complex
	Broken allevial land
	Eram clay - rolling phase
	Eram clay - sloping phase
	Hector complex
	Rough stony land (Pottsville and Muskingum)
	Parsons silt loam - eroded
	Vann silt loam
	Vanoss - eroded phase

[a]The flood plain acreage consists primarily of bottomland soils, but some upland soils are subject to the larger floods, therefore, the table includes both upland and bottomland soils.

TABLE XXII

PER ACRE PRODUCTION COSTS FOR ALTERNATIVE CROP ENTERPRISES BY PRODUCTIVITY GROUP: NUYAKA CREEK FLOOD PLAIN[a]

Crop	Productivity Group (dollars)			
	F_1	F_2	F_3	F_4
Cotton	87.55	87.55	81.36	NA
Grain Sorghum	28.86[b]	27.16[b]	26.26	NA
Corn	33.20[b]	32.45[b]	33.43	NA
Soybeans	26.01[b]	25.38[b]	25.71	NA
Wheat	32.73[b]	31.87[b]	32.43	NA
Oats	35.06[b]	34.20[b]	34.86	NA
Barley	32.69[b]	31.83[b]	32.49	NA
Peanuts	88.73	NA	92.01	NA
Bermuda Pasture	30.19	30.19	30.19	29.44
Alfalfa	54.68	54.68	47.58	NA
Native Hay	12.80	12.80	10.82	NA
Woodland Pasture	c	c	c	c
Native or Range Pasture	c	c	c	c

NA = Not Applicable

[a]R. D. Lacewell and Vernon R. Eidman, Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils of East Central and South Central Oklahoma, Oklahoma Agricultural Experiment Station, Processed Series P-606, April, 1969.

[b]The difference in the production cost between F_1 and F_2 land is explained by different fertilizer requirements of loamy and clay soils.

[c]There are no production costs associated with woodland and native or range pasture since there is no maintenance, fertilizer or other production requirements.

TABLE XXIII

NATIVE HAY: ESTIMATED PER ACRE ESTABLISHMENT COST[a]

Item	Unit	Price Per Unit	Quantity	Cost
Grass seed	lb.	0.60	1.00	0.60
Tractor operating cost	hr.	1.37	0.32	0.44
Other machinery operating cost	hr.	1.28	0.29	0.37
Tractor ownership cost	hr.	0.97	0.32	0.31
Other machinery ownership cost	hr.	1.49	0.29	0.43
Interest on power and machinery capital	dol.	0.07	5.41	0.38
Labor	hr.	1.25	0.35	0.44
Total establishment cost				2.97
Annual charge for establishment[b]	year	0.30	1.00	0.30
Interest on establishment cost	dol.	0.07	1.49	0.10
Annual establishment cost[b]				0.40

[a]Darrel D. Kletke and Luther G. Tweeten, Enterprise Budgets and Farm Plans for Sandy Soils of Southwest Oklahoma, Oklahoma Agricultural Experiment Station, Processed Series P-553, December, 1966, Table 10, p. 19.

[b]A depreciation period of ten years is assumed.

TABLE XXIV

NATIVE HAY AND BERMUDA GRASS: AVERAGE ANNUAL COST OVER THE DEPRECIATION PERIOD DUE TO LOW PRODUCTION IMMEDIATELY FOLLOWING ESTABLISHMENT[a]

Item	Unit	Price Per Unit	F_1 Land		F_2 Land		F_3 Land		F_4 Land	
			Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Native Hay										
Difference in normal yield on established grass and average yield[a]	ton	15.00	0.3	4.50	0.3	4.50	0.24	3.60	NA	NA
Decrease in harvesting cost for lower yield	bale	0.15	9.0	-1.35	9.0	-1.35	7.20	-1,08	NA	NA
Annual charge for establishment	acre	0.40	1.0	0.40	1.0	0.40	1.0	0.40	NA	NA
Total annual charge for establishment				3.55		3.55		2.92		
Bermuda Grass										
Difference in normal yield on established grass and average yield[a]	AUM	2.50	0.54	1.35	0.54	1.35	0.54	1.35	0.24	0.60

NA = Not Applicable.

[a]Production budget yields apply to established grasses and do not consider the initial low yields immediately following establishment. By averaging all yields over the entire depreciation period an average annual yield is obtained which is lower than the normal yield on established grass. The yields utilized in programming are the normal yields; hence, the value of the difference in average annual yield and normal yield is considered as part of the annual establishment cost for native hay and bermuda grass. These are costs added to those given in R. D. Lacewell and Vernon R. Eidman, Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils of East Central and South Central Oklahoma, Oklahoma Agricultural Experiment Station, Processed Series P-606, April, 1969. Establishment cost of bermuda grass is included in the budget costs.

TABLE XXV

NUMBER OF STATIONS AND INTERVAL BETWEEN STATIONS ON THE LEFT AND RIGHT BANKS FOR EACH CROSS SECTION: NUYAKA CREEK FLOOD PLAIN

Cross Section	Left of Channel			Right of Channel			Total Distance
	Number of Stations (number)	Interval between Stations (feet)	Distance (feet)	Number of Stations (number)	Interval between Stations (feet)	Distance (feet)	(feet)
N-2	196	10	1,960	109	10	1,090	3,050
N-3	251	5	1,255	295	5	1,475	2,730
N-4	238	10	2,380	14	5	70	2,450
N-5	5	10	50	410	10	4,100	4,150
N-6	55	20	1,100	120	10	1,200	2,300
N-7	47	20	940	167	10	1,670	2,610
N-8	67	20	1,340	53	10	530	1,870
N-9	117	20	2,340	22	10	220	2,560
N-10	131	5	655	64	5	320	975
N-11	149	5	745	84	5	420	1,165
N-12	45	5	225	76	5	380	605
N-13	68	10	680	62	5	310	1,595
N-14	28	5	140	132	5	660	800
NA-1	39	5	195	13	5	75	270
NA-2	35	5	175	180	5	900	1,075
NB-1	36	5	180	448	5	2,240	2,420
NB-2	133	5	665	21	5	105	770
NC-1	48	5	240	34	5	170	410
NC-3	13	5	65	285	5	1,425	1,490
ND-1	47	5	235	238	5	1,190	1,930
ND-2	76	5	380	25	5	125	505

TABLE XXVI

PEAK ELEVATION OF EACH FLOOD CONSIDERED AT EACH CROSS SECTION WITH PRESENT CONDITIONS: NUYAKA CREEK FLOOD PLAIN

Cross Section	Flood Frequency in Years							
	.5	1	3	5	10 (feet)	25	50	100
N-2	679.0	679.9	680.9	681.3	681.8	682.3	682.6	683.0
N-3	683.6	684.2	685.3	685.7	686.1	686.5	686.9	687.2
N-4	688.9	690.4	692.2	692.6	692.9	693.6	693.9	694.2
N-5	698.0	698.5	699.3	699.7	700.1	700.5	700.7	701.0
N-6	703.2	704.6	705.5	706.1	706.5	706.9	707.2	707.5
N-7	710.5	712.0	713.3	713.5	713.7	713.9	713.9	713.9
N-8	717.0	718.3	719.9	720.3	720.8	721.3	721.5	722.0
N-9	723.6	726.4	729.1	729.8	730.5	731.1	731.4	731.9
N-10	731.6	733.7	736.9	737.7	738.7	739.5	740.0	740.6
N-11	741.2	743.4	746.9	747.8	748.6	749.3	749.8	750.2
N-12	749.4	751.8	754.8	755.5	756.4	757.2	757.7	758.3
N-13	768.4	769.7	771.2	771.7	772.2	772.7	773.0	773.1
N-14	774.9	776.5	778.4	779.0	779.6	780.0	780.3	780.6
NA-1	680.0	683.1	685.5	686.1	686.7	687.2	687.5	687.8
NA-2	687.4	688.4	690.8	691.3	691.7	692.1	692.4	692.7
NB-1	701.8	702.5	703.4	703.7	704.1	704.4	704.6	704.9
NB-2	709.8	711.3	713.0	713.4	713.8	714.8	715.1	715.3
NC-1	703.4	704.8	708.4	710.2	712.7	715.9	716.1	717.1
NC-3	725.0	726.4	729.7	730.2	733.2	734.9	735.9	737.0
ND-1	723.6	726.2	729.6	730.3	730.9	731.6	731.9	732.3
ND-2	740.6	742.8	745.8	746.3	746.8	747.3	747.7	748.0

TABLE XXVII

PEAK ELEVATION OF EACH FLOOD CONSIDERED AT EACH CROSS SECTION WITH STRUCTURE SYSTEM SS I: NUYAKA CREEK FLOOD PLAIN

Cross Section	Flood Frequency in Years							
	.5	1	3	5	10	25	50	100
				(feet)				
N-2	677.6	678.5	679.6	680.0	680.4	680.7	681.0	681.3
N-3	680.2	682.5	683.8	684.1	684.5	684.9	685.2	685.4
N-4	684.2	686.3	688.9	689.9	690.7	691.4	691.9	692.3
N-5	695.4	697.2	697.9	698.2	698.4	698.7	698.9	699.1
N-6	699.4	700.4	703.2	703.9	704.5	705.1	705.4	705.7
N-7	706.4	708.3	710.7	711.9	712.6	713.0	713.3	713.5
N-8	711.6	713.5	715.9	717.1	717.9	718.7	719.2	719.7
N-9	716.6	717.9	720.0	720.4	722.1	723.2	724.2	725.1
N-10				(site location)				
N-11	738.9	740.0	742.4	743.7	745.0	746.4	747.2	747.8
N-12	748.6	750.6	754.0	755.1	755.8	756.6	757.2	757.7
N-13	767.3	769.1	770.4	771.2	771.7	772.1	772.5	772.8
N-14	772.8	774.7	777.2	778.1	778.8	779.5	779.8	780.1
NA-1	678.0	679.0	680.0	683.0	683.8	684.3	685.0	685.5
NA-2	685.8	686.3	687.6	688.4	689.4	690.2	691.1	691.4
NB-1	700.4	701.0	701.6	702.2	702.6	702.9	704.0	704.1
NB-2	708.4	708.4	708.4	708.4	708.4	708.4	708.4	708.4
NC-1	701.6	702.0	702.9	703.7	704.4	705.4	706.3	707.4
NC-3	722.6	723.0	723.4	724.0	724.6	725.4	725.7	726.4
ND-1	721.0	722.0	723.2	724.8	726.0	727.2	729.0	729.4
ND-2	737.0	737.0	737.0	737.0	737.0	737.0	737.0	737.0

TABLE XXVIII

PEAK ELEVATION OF EACH FLOOD CONSIDERED AT EACH CROSS SECTION WITH STRUCTURE SYSTEM SS II: NUYAKA CREEK FLOOD PLAIN

Cross Section	Flood Frequency in Years							
	.5	1	3	5	10	25	50	100
				(feet)				
N-2	678.4	678.9	679.8	680.2	680.5	680.8	681.0	681.2
N-3	682.7	683.4	684.2	684.5	684.8	685.1	685.3	685.5
N-4	687.2	688.4	690.2	690.9	691.4	691.9	692.2	692.4
N-5	697.5	697.9	698.4	698.6	698.8	699.1	699.2	699.4
N-6	702.1	703.0	704.3	704.8	705.1	705.5	705.7	705.9
N-7	709.2	711.4	712.5	712.7	712.9	713.2	713.3	713.5
N-8	715.8	717.1	718.6	719.1	719.6	720.0	720.2	720.5
N-9	722.1	723.8	727.2	728.4	729.2	729.9	730.3	730.3
N-10	731.4	733.1	735.9	737.1	737.9	738.7	739.2	739.8
N-11	740.9	742.6	745.9	747.3	748.0	748.7	749.1	749.5
N-12	748.4	750.2	753.3	754.6	755.4	756.1	756.6	757.1
N-13	767.3	768.7	770.1	770.6	771.0	771.4	771.7	771.9
N-14	771.8	773.3	775.8	776.9	777.7	778.4	779.0	779.4
NA-1	678.0	679.1	680.0	782.3	683.2	684.3	684.9	685.6
NA-2	685.8	686.3	687.6	688.4	689.4	690.4	691.0	691.3
NB-1	700.4	701.0	701.6	702.2	702.5	702.8	703.1	703.3
NB-2	708.4	708.4	708.4	708.4	708.4	708.4	708.4	708.4
NC-1	701.7	702.0	703.0	703.7	704.4	705.5	706.4	707.4
NC-3	722.6	723.0	723.4	724.0	724.6	725.4	725.7	726.4
ND-1	721.0	722.0	723.2	724.8	726.0	727.2	729.0	729.4
ND-2	737.0	737.0	737.0	737.0	737.0	737.0	737.0	737.0

TABLE XXIX

DISTRIBUTION OF SAMPLE POINTS BY PRODUCTIVITY GROUP: NUYAKA CREEK FLOOD PLAIN

Cross-section	Productivity Group				
	F_1	F_2	F_3	F_4	Total
N-2	13	20	-	-	33
N-3	22	47	2	8	79
N-4	36	54	-	1	91
N-5	36	45	1	4	86
N-6	23	31	1	1	56
N-7	26	16	1	-	43
N-8	21	9	-	-	30
N-9	23	29	-	-	52
N-10	20	2	-	2	24
N-11	16	1	-	-	17
N-12	12	10	-	-	22
N-13	13	4	-	-	17
N-14	22	3	-	-	25
NA-1	11	2	-	8	21
NA-2	21	3	1	14	39
NB-1	9	6	-	-	15
NB-2	4	-	-	1	5
NC-1	5	3	-	-	8
NC-3	35	8	-	3	46
ND-1	10	11	-	-	21
ND-2	10	8	-	-	18
Total	388	312	6	42	748
Percentage	51.87	41.71	0.80	5.62	100.0

APPENDIX C

RESULTS OF FLOOD PLAIN ANALYSIS

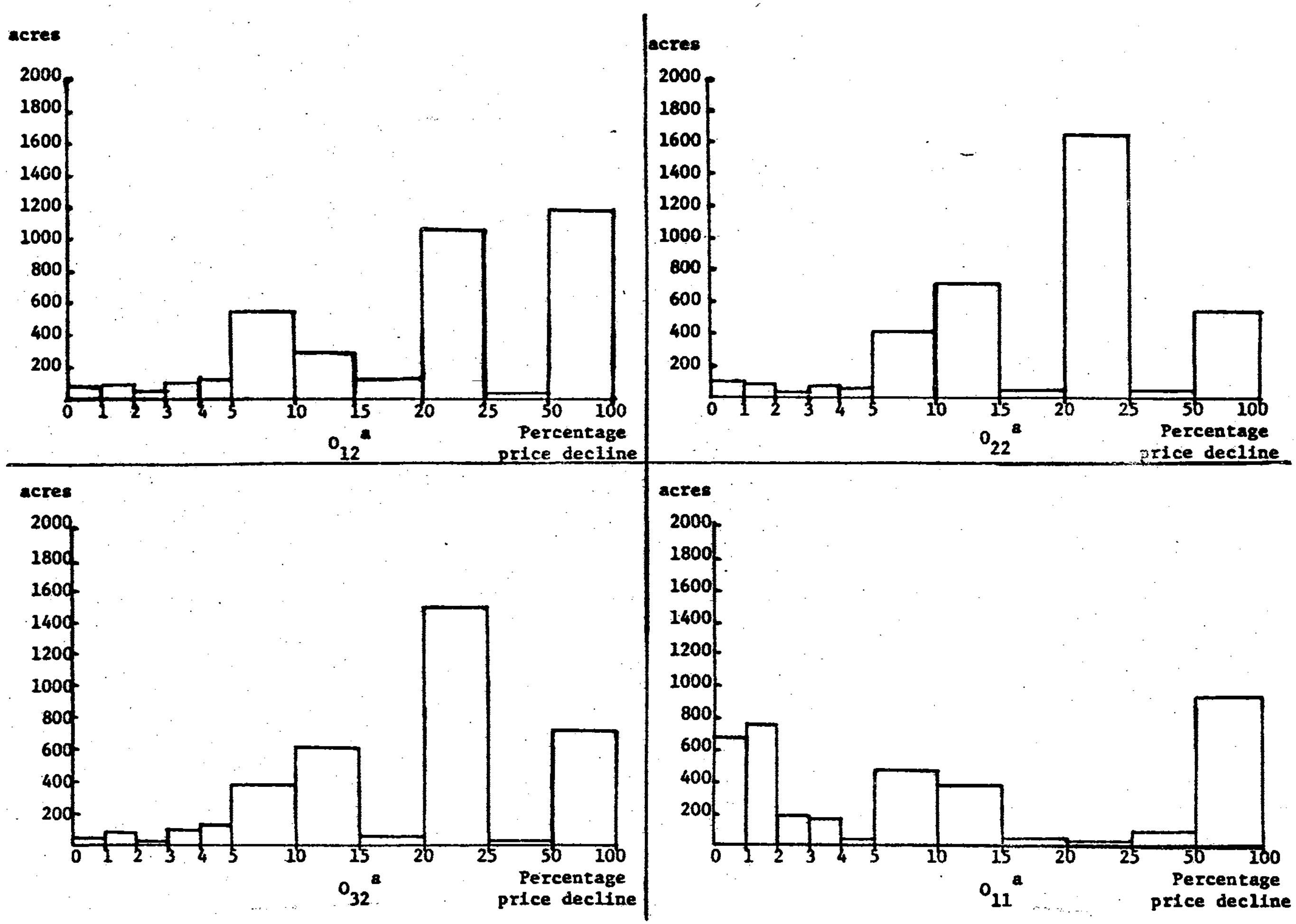


Figure 14. Interval Distribution of Flood Plain Acreage by Percentage Price Decline Necessary to Make Optimum and Second Best Land Use Equally Profitable

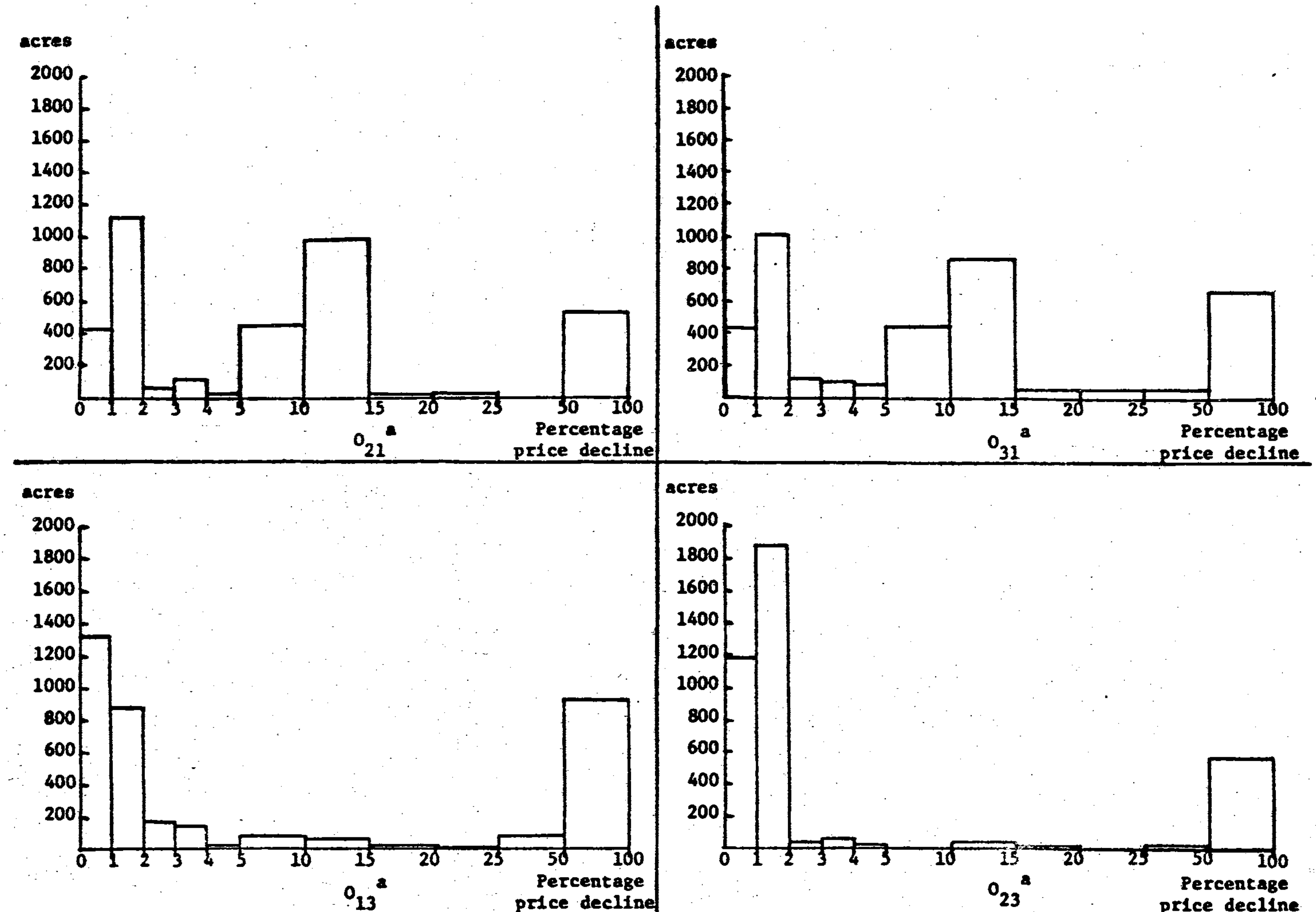
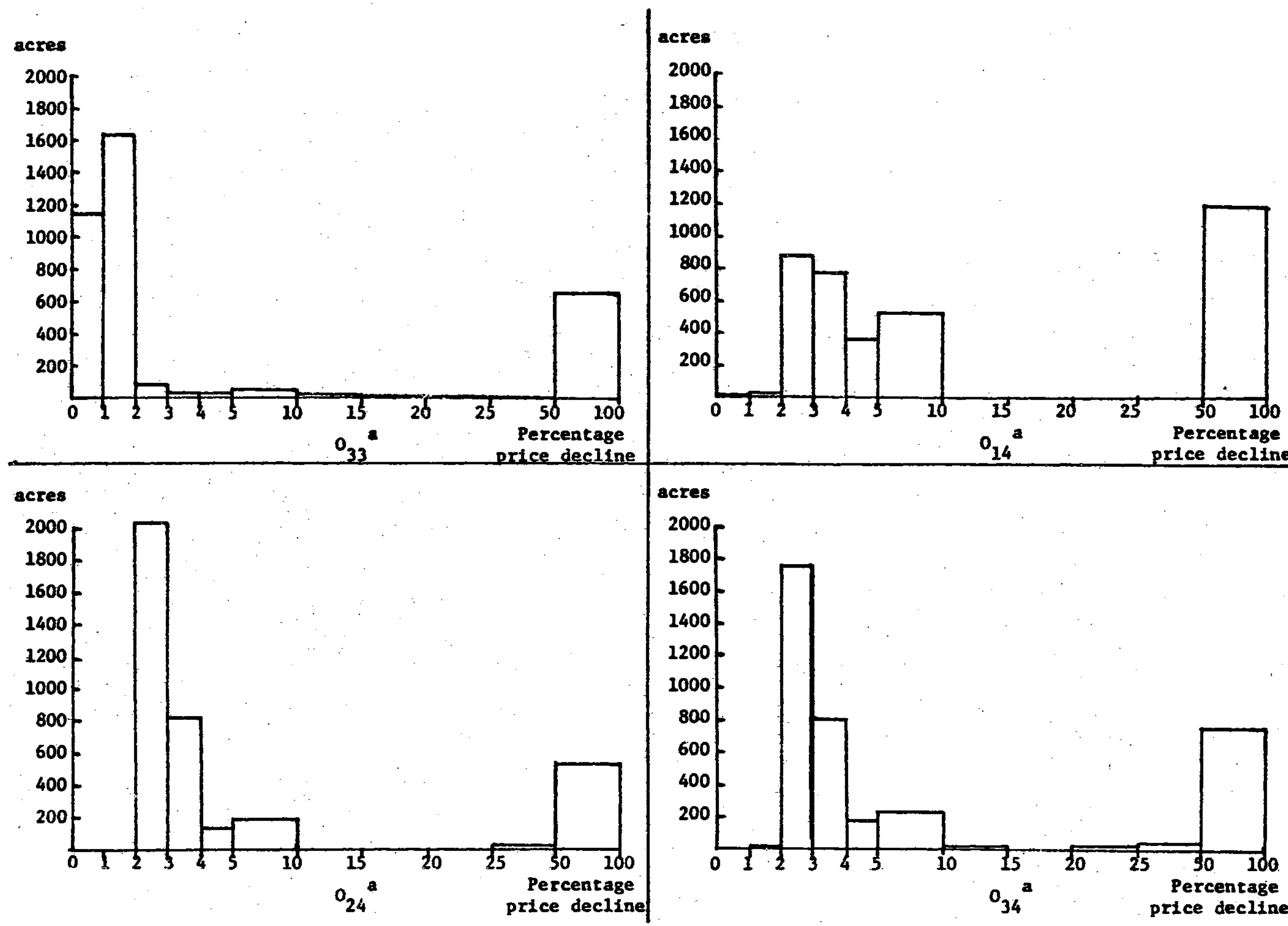


Figure 14. (Continued)



[a]See Appendix C, Table XXX, for assumptions under which each optimum land use was developed.

Figure 14. (Continued)

TABLE XXX

DESIGNATION OF OPTIMUM LAND USE PATTERNS DEVELOPED UNDER ALTERNATIVE ASSUMPTIONS AND SPECIFIED FLOOD DAMAGE COMPUTATIONS MADE ASSUMING PRESENT LAND USE

Floodplain Condition	Set of Crop Prices			
	Benefit[a]	Normalized[b]	Adjusted[c]	Mixed[d]
I. Optimum Land Use[e]				
Present	O_{11}	O_{12}	O_{13}	O_{14}
SS I	O_{21}	O_{22}	O_{23}	O_{24}
SS II	O_{31}	O_{32}	O_{33}	O_{34}
II. Damage Computations				
Present Land Use				
Designated Productivity Group[f]				
Present	D_{11}	D_{12}		
SS I	D_{21}	D_{22}		
SS II	D_{31}	D_{32}		
All Productivity Group F_1[g]				
Present	D_{41}	D_{42}		
SS I	D_{51}	D_{52}		
SS II	D_{61}	D_{62}		

[a]Prices with benefits of government price support programs deleted (Table IV).

[b]Prices with benefits of government price support programs included (Table IV).

[c]Normalized prices with cotton and peanuts deleted (Table IV).

[d]Normalized prices for surplus crops, cotton and peanuts deleted and benefit prices for all other crops (Table IV).

[e]Considering optimum land use O_{ij} the subscripts have special significance; i.e., i refers to the flood plain condition and j to the set of crop prices used.

[f]Each sample point remains in the productivity group to which it rightfully belongs.

[g]All sample points are arbitrarily assigned to productivity group F_1 with no differentiation made between productivity of one sample point and another.

TABLE XXXI

DERIVATION OF THE FORMULA FOR COMPUTING AVERAGE ANNUAL PERCENTAGE REDUCTION IN ACRES FLOODED DUE TO INSTALLATION OF A STRUCTURE SYSTEM

(1) $\frac{R_i}{P_i} \cdot 100 = F_i$

(2) $(P_i \cdot Swait_i)/100 = X_i$

(3) $(X_i \cdot F_i)/100 = Y_i$

(4) $\frac{\sum_{i=1}^{8} Y_i}{\sum_{i=1}^{8} X_i} \cdot 100$ = average annual percentage reduction in acres flooded

Substituting in Equation (4)

(5) $$\frac{\sum_{i=1}^{8} \left[(P_i \cdot Swait) \left(\frac{R_i}{P_i} \right) \right]}{\sum_{i=1}^{8} (P_i \cdot Swait_i)} \cdot 100$$

(6) $$\frac{\sum_{i=1}^{8} (R_i \cdot Swait_i)}{\sum_{i=1}^{8} (P_i \cdot Swait_i)} \cdot 100$$

where:

R_i = reduction in acres flood by the i^{th} size flood, with respect to present flood plain conditions, due to a structure system.

P_i = acres flooded by the i^{th} size flood assuming present conditions.

F_i = percentage reduction in acres flooded by the i^{th} flood size due to a structure system.

$Swait_i$ = percentage change of occurrence of the i^{th} size flood in a specific year.

TABLE XXXI (Continued)

X_i	=	average annual acres flooded in a specific year by the i^{th} size flood assuming present flood plain conditions.
Y_i	=	average annual reduction in acres flooded by the i^{th} size flood in a specific year due to a structure system.

TABLE XXXII

ACRES OF FLOOD PLAIN WITH A DIFFERENT CROP FOR ALTERNATIVE LAND USE PATTERNS

Land Use Pattern	Designation[e]	Optimum Land Use Patterns: Benefit Prices[a] Present Conditions (O_{12})	Benefit Prices[a] SS I (O_{22})	Benefit Prices[a] SS II (O_{32})	Normalized Prices[b] Present Conditions (O_{11})	Normalized Prices[b] SS I (O_{21})	Normalized Prices[b] SS II (O_{31})	Adjusted Prices[c] Present Conditions (O_{13})	Adjusted Prices[c] SS I (O_{23})	Adjusted Prices[c] SS II (O_{33})	Mixed Prices[d] Present Conditions (O_{14})	Mixed Prices[d] SS I (O_{24})	Mixed Prices[d] SS II (O_{34})
		(acres)											
Present Land Use		2,720	3,270	3,065	2,715	3,265	3,095	2,705	3,255	3,070	2,545	3,015	2,810
<u>Benefit Prices</u>[a]													
Present Conditions	(O_{12})	0	1,295	965	1,295	1,930	1,630	2,170	3,170	2,865	1,945	2,625	2,375
SS I	(O_{22})		0	510	2,365	1,420	1,710	3,220	3,000	3,135	3,210	2,895	3,070
SS II	(O_{32})			0	2,045	1,635	1,360	2,920	2,905	2,805	2,905	2,865	2,615
<u>Normalized Prices</u>[b]													
Present Conditions	(O_{11})				0	1,710	1,395	875	2,515	2,190	1,730	2,265	2,015
SS I	(O_{21})					0	660	2,565	1,580	2,070	3,210	2,845	3,055
SS II	(O_{31})						0	2,270	2,025	1,445	2,935	2,805	2,635
<u>Adjusted Prices</u>[c]													
Present Conditions	(O_{13})							0	1,750	1,405	1,620	2,155	1,905
SS I	(O_{23})								0	2,820	3,140	2,695	2,925
SS II	(O_{33})									0	2,820	2,680	2,510
<u>Mixed Prices</u>[d]													
Present Conditions	(O_{14})										0	710	450
SS I	(O_{24})											0	275
SS II	(O_{34})												0

[a] Crop prices with benefits of government programs included.

[b] Crop prices with no government program benefits included.

[c] Crop prices with no government program benefits included and cotton and peanuts deleted.

[d] Normalized prices for surplus crops, cotton and peanuts deleted, and benefit prices for all other crops.

[e] The notation designating the results of each set of assumptions is consistent with that presented in other tables and corresponds to the conditions outlined in Appendix C, Table XXX.

TABLE XXXIII

EXPECTED AVERAGE ANNUAL FLOOD DAMAGES COMPUTED WITH MIXED PRICES BY LAND USE FOR THE SAMPLE POINTS COMPRISING CROSS SECTION AREA N-8 ASSUMING PRESENT FLOOD PLAIN CONDITIONS[a]

Sample point Location in the N-8 Matrix[b] row	column	Grain Sorghum	Corn	Soybeans	Wheat	Oats	Barley (dollars)	Bermuda Pasture	Alfalfa	Native Hay	Woodland Pasture	Native Pasture
9	1	40.88	40.01	61.46	35.39	31.97	36.73	5.90	58.48	10.14	.57	2.21
10	1	35.85	35.67	56.00	30.36	27.33	30.97	5.44	54.21	9.41	.53	2.04
11	1	253.50	225.75	348.00	188.50	150.00	170.00	41.47	378.66	69.26	4.03	15.55
6	2	38.55	37.98	58.90	33.01	29.83	33.81	5.68	56.48	9.80	.55	2.13
7	2	34.68	34.51	54.19	29.35	26.42	29.95	5.27	52.48	9.11	.51	1.98
8	2	35.85	35.67	56.00	30.36	27.33	30.97	5.44	54.21	9.41	.53	2.04
9	2	35.85	35.67	56.00	30.36	27.33	30.97	5.44	54.21	9.41	.53	2.04
10	2	253.50	225.75	348.00	188.50	150.00	170.00	52.18	436.13	85.16	5.07	19.57
11	2	45.06	43.64	66.03	39.60	35.81	40.59	6.29	62.03	10.76	.61	2.36
4	3	55.69	53.90	80.27	51.18	44.55	50.49	7.66	73.83	12.98	.74	2.87
5	3	33.37	33.22	52.19	28.22	25.42	28.81	5.07	50.56	8.78	.49	1.90
6	3	35.85	35.67	56.00	30.36	27.33	30.97	5.44	54.21	9.41	.53	2.04
7	3	253.50	225.75	348.00	188.50	150.00	170.00	39.00	360.99	65.48	3.79	14.63
8	3	109.07	109.13	165.58	104.46	83.78	94.95	16.29	152.55	27.53	1.58	6.11
9	3	253.50	225.75	348.00	188.50	150.00	170.00	44.11	399.26	73.36	4.29	16.54
11	3	38.36	37.82	58.69	32.82	29.66	33.61	5.67	56.32	9.77	.55	2.13
3	4	50.32	48.56	72.35	45.80	40.36	45.74	6.88	66.74	11.68	.67	2.58
4	4	35.85	35.67	56.00	30.36	27.33	30.97	5.44	54.21	9.41	.53	2.04
5	4	253.50	225.75	348.00	188.50	150.00	170.00	40.90	374.57	68.39	3.98	15.34
6	4	253.50	225.75	348.00	188.50	150.00	170.00	40.87	374.39	68.35	3.97	15.33
7	4	45.06	43.64	66.03	39.60	35.81	40.59	6.29	62.03	10.76	.61	2.36
8	4	41.81	40.82	62.48	36.34	32.82	37.20	5.99	59.27	10.28	.58	2.25
2	5	30.80	30.67	48.24	26.01	23.43	26.56	4.69	46.78	8.12	.46	1.76
3	5	253.50	225.75	348.00	188.50	150.00	170.00	43.63	397.07	72.66	4.24	16.36
4	5	48.11	46.49	69.70	43.20	38.44	43.57	6.64	64.76	11.30	.65	2.49
5	5	45.47	44.02	66.52	40.09	36.17	40.99	6.34	62.40	10.83	.62	2.38
6	5	45.06	43.64	66.03	39.60	35.81	40.59	6.29	62.03	10.76	.61	2.36
7	5	41.52	40.57	62.16	36.04	32.55	36.89	5.96	59.02	10.24	.58	2.24
1	6	45.06	43.64	66.03	39.60	35.81	40.59	6.29	62.03	10.76	.61	2.36
2	6	35.57	35.39	55.56	30.12	27.11	30.72	5.40	53.79	9.34	.53	2.03

[a]The prices do not include benefits of government price support programs for surplus crops, delete peanuts and cotton and include benefits of government price support programs for all other crops.

[b]Each sample point represents five acres; hence, the values given in the table refer to five acre units of flood plain.

TABLE XXXIV

EXPECTED RETURNS NET OF PRODUCTION COSTS AND AVERAGE ANNUAL FLOOD DAMAGES COMPUTED WITH MIXED PRICES BY LAND USE FOR THE SAMPLE POINTS COMPRISING CROSS SECTION AREA N-8 ASSUMING PRESENT FLOOD PLAIN CONDITIONS[a]

Sample Point Location in the N-8 Matrix[b] row	column	Grain Sorghum	Corn	Soybeans	Wheat	Oats	Barley (dollars)	Bermuda Pasture	Alfalfa	Native Hay	Woodland Pasture	Native Pasture
9	1	29.72	-18.86	117.89	-49.14	-95.87	-68.28	-105.45	135.77	-0.24	8.18	-7.06
10	1	34.75	-14.52	123.35	-44.11	-91.23	-63.02	-104.99	140.04	0.49	8.22	-6.89
11	1	-182.90	-204.60	-168.65	-202.25	-213.90	-202.05	-141.02	-184.41	-59.36	4.72	-20.40
6	2	70.65	21.77	159.05	-8.16	-55.13	-27.26	-66.63	176.37	38.70	8.20	31.62
7	2	83.02	28.99	166.91	-0.20	-47.42	-19.10	-66.22	180.37	39.39	8.24	31.77
8	2	81.85	27.83	165.10	-1.21	-48.33	-20.12	-66.39	178.64	39.09	8.22	31.71
9	2	34.75	-14.52	123.35	-44.11	-91.23	-63.02	-104.99	140.04	0.49	8.22	-6.89
10	2	-174.40	-200.85	-165.50	-197.95	-209.60	-197.75	-151.73	-241.88	-75.26	3.68	-24.42
11	2	34.04	-18.74	116.47	-49.05	-95.41	-68.34	-105.84	132.22	-0.86	8.14	-7.21
4	3	53.51	5.85	137.68	-26.33	-69.85	-43.94	-68.61	159.02	35.52	8.01	30.88
5	3	75.83	26.83	165.76	-3.37	-50.72	-22.26	-66.02	182.29	39.72	8.26	31.85
6	3	73.35	24.08	161.95	-5.51	-52.63	-24.42	-66.39	178.64	39.09	8.22	31.71
7	3	-182.90	-204.60	-168.65	-202.25	-213.90	-202.05	-138.55	-166.74	-55.58	4.96	-19.48
8	3	-38.47	-87.98	13.77	-118.21	-147.68	-127.00	-115.84	41.70	-17.63	7.17	-10.96
9	3	-182.90	-204.60	-168.65	-202.25	-213.90	-202.05	-143.66	-205.01	-63.46	4.46	-21.39
11	3	32.24	-16.67	120.66	-46.57	-93.56	-65.66	-105.22	137.93	0.13	8.20	-6.98
3	4	28.78	-23.66	110.15	-55.25	-99.96	-73.49	-106.43	127.51	-1.78	8.08	-7.43
4	4	81.85	27.83	165.10	-1.21	-48.33	-20.12	-66.39	178.64	39.09	8.22	31.71
5	4	-182.90	-204.60	-168.65	-202.25	-213.90	-202.05	-140.45	-180.32	-58.49	4.77	-20.19
6	4	-144.30	-166.00	-130.05	-163.65	-175.30	-163.45	-101.82	-141.54	-19.85	4.78	18.42
7	4	72.64	19.86	155.07	-10.45	-56.81	-29.74	-67.24	170.82	37.74	8.14	31.39
8	4	75.89	22.68	158.62	-7.19	-53.82	-26.35	-66.94	173.58	38.22	8.17	31.50
2	5	86.90	32.83	172.86	3.14	-44.43	-15.71	-65.64	186.07	40.38	8.29	31.99
3	5	-182.90	-204.60	-168.65	-202.25	-213.90	-202.05	-143.18	-202.82	-62.76	4.51	-21.21
4	5	22.49	-25.34	109.65	-56.95	-102.34	-75.62	-106.19	129.49	-1.40	8.10	-7.34
5	5	25.13	-22.87	112.83	-53.84	-100.07	-73.04	-105.89	131.85	-0.93	8.13	-7.23
6	5	25.54	-22.49	113.32	-53.35	-99.71	-72.64	-105.84	132.22	-0.86	8.14	-7.21
7	5	67.68	19.18	155.79	-11.19	-57.85	-30.34	-66.91	173.83	38.26	8.17	31.51
1	6	25.54	-22.49	113.32	-53.35	-99.71	-72.64	-105.84	132.22	-0.86	8.14	-7.21
2	6	35.03	-14.24	123.79	-43.87	-91.01	-62.77	-104.95	140.46	0.56	8.22	-6.88

[a]The prices do not include benefits of government price support programs for surplus crops, delete peanuts and cotton and include benefits of government price support programs for all other crops.

[b]Each sample point represents five acres; hence, the values given in the table refer to five acre units of flood plain.

TABLE XXXV

AVERAGE ANNUAL FLOOD DAMAGES AS A PERCENT OF GROSS REVENUE ASSUMING NO FLOODING FOR ALTERNATIVE OPTIMUM FLOOD PLAIN LAND USE PATTERNS

Conditions Assumed for Determining Optimum Land Use	Optimum[a] Land Use Designation	Prices Used for Computing Returns and Damages			
		Benefit[b]	Normalized[c]	Adjusted[d]	Mixed[e]
		(percent)			
<u>Present Flood Plain Conditions</u>					
Benefit Prices[b]	O_{12}	13.29	13.72	NA	NA
Normalized Prices[c]	O_{11}	11.11	12.02	NA	NA
Adjusted Prices[d]	O_{13}	NA	NA	9.95	NA
Mixed Prices[e]	O_{14}	NA	NA	NA	11.42
<u>SS I</u>[f]					
Benefit Prices[b]	O_{22}	5.81	6.02	NA	NA
Normalized Prices[c]	O_{21}	4.87	5.20	NA	NA
Adjusted Prices[d]	O_{23}	NA	NA	6.14	NA
Mixed Prices[e]	O_{24}	NA	NA	NA	4.71
<u>SS II</u>[f]					
Benefit Prices[b]	O_{32}	7.47	7.80	NA	NA
Normalized Prices[c]	O_{31}	4.65	6.99	NA	NA
Adjusted Prices[d]	O_{33}	NA	NA	8.29	NA
Mixed Prices[e]	O_{34}	NA	NA	NA	6.58

NA = Not Applicable.

[a]The notation designating the results of each set of assumptions is consistent with that presented in other tables and corresponds to the conditions outlined in Appendix C, Table XXX.

[b]Crop prices with benefits of government price support programs included (Table IV).

[c]Crop prices with benefits of government price support programs deleted (Table IV).

[d]Crop prices with benefits of government price support programs deleted and cotton and peanuts deleted from consideration (Table IV).

[e]Normalized prices for surplus crops, cotton and peanuts deleted, and benefit prices for all other crops (Table IV).

[f]Watershed protection plan developed by SCS watershed planning party. SS II has been approved by Congress for construction.

TABLE XXXVI

SECOND MOST PROFITABLE LAND USE FOR ALTERNATIVE CROP PRICES AND PRODUCTIVITY GROUPS BY FLOOD PLAIN LOCATION

Productivity Group	Flood Exposure (flood frequency - years)[a]		
	.5	1	3 and larger
Benefit Prices[b]			
F_1	soybeans	alfalfa	cotton
F_2	soybeans	soybeans	alfalfa
F_3	idle[c]	soybeans	soybeans
F_4	idle[c]	idle[c]	idle[c]
Normalized Prices[d]			
F_1	e	soybeans	soybeans
F_2	e	soybeans	alfalfa
F_3	native pasture	soybeans	soybeans
F_4	idle[c]	idle[c]	idle[c]
Adjusted Prices[f]			
F_1	e	soybeans	alfalfa
F_2	e	soybeans	alfalfa
F_3	native pasture	alfalfa	alfalfa
F_4	idle[c]	idle[c]	idle[c]
Mixed Prices[g]			
F_1	soybeans	soybeans	soybeans
F_2	soybeans	soybeans	soybeans
F_3	native hay	alfalfa	alfalfa
F_4	idle[c]	idle[c]	idle[c]

[a]Flood exposure refers to land inundated only by the flood occurring every X years and all larger floods, where X refers to flood frequency in years.

[b]Crop prices with benefits of government price support programs included.

[c]Second best land use to optimum native pasture is no production.

[d]Crop prices with benefits of government price support programs not included.

[e]There is no single, obvious second best crop but rather alfalfa and native hay enter the solution in approximately equal proportions.

[f]Crop prices with benefits of government price support programs not included and peanuts and cotton deleted from consideration.

[g]Normalized prices apply to surplus crops, cotton and peanuts deleted and benefit prices apply to all other crops.

APPENDIX D

DEVELOPING A SOLUTION STABILITY EQUATION

DEVELOPING AN EQUATION TO ESTABLISH THE STABILITY OF OPTIMUM LAND USE SOLUTIONS

The solution stability equation was developed in the following manner:

$$OPTUM_r = TVAL_{h\,r} - (CDAM_{h\,r} + PCOST_{h\,r})$$

$$CDAM_{h\,r} = Fac_{h\,r}\ (TVAL_{h\,r})$$

$$TVAL_{h\,r} = PRICE_h \cdot YIELD_{h\,r}$$

$$Fac_{h\,r} = \frac{CDAM_{h\,r}}{TVAL_{h\,r}}\ ;$$

therefore,

$$OPTUM_r = PRICE_h \cdot YIELD_{h\,r} - \left[\frac{CDAM_{h\,r}}{TVAL_{h\,r}}\ (PRICE_h \cdot YIELD_{h\,r}) + PCOST_{h\,r}\right]$$

where:

$OPTUM_r$ = net returns for optimum crop on the acres represented by sample point r considering flooding.

$TVAL_{h\,r}$ = gross returns for optimum crop on the acres represented by sample point r considering flooding.

$CDAM_{h\,r}$ = average annual flood damages on acres represented by sample point r with optimum crop.

$PCOST_{h\,r}$ = production cost of optimum crop for acres represented by sample point r.

$PRICE_h$ = price per unit of optimum crop.

$YIELD_{h\,r}$ = yield of optimum crop for sample point r.

SPA = expansion factor (acres each sample point represents).

$Fac_{h\,r}$ = percentage reduction in gross returns due to flooding on sample point r with optimum land use.

Net returns of the optimum land use on sample point r ($OPTUM_r$) is equal to the gross value of the optimum crop ($TVAL_{hr}$) less the summation of the optimum crop's average annual flood damages ($CDAM_{hr}$) and production cost ($PCOST_{hr}$). In turn, the gross value of the optimum crop on sample point r ($TVAL_{hr}$) is equal to the price per unit of the optimum crop ($PRICE_h$) times the optimum crop yield. Average annual flood damages of the optimum crop on sample point r are a percentage of the optimum crop gross returns (Fac_{hr}). The percentage of gross returns lost to flood damage is obtained by dividing average annual flood damages for the optimum crop on sample point r ($CDAM_{hr}$) by optimum crop gross returns on point r ($TVAL_{hr}$).

Considering the final equation given above, attention is directed to net returns on sample point r with the optimum land use ($OPTUM1_r$). To estimate solution stability, net returns with second best land use ($OPTUM2_r$) is substituted for $OPTUM1_r$. Of course, to obtain the second best land use net return value with optimum land use, the value of some variable on the right hand side of the equation must be altered. All variables in the equation are fixed with the exception of the price of the optimum land use ($PRICE_h$). Therefore, the price of the optimum land use on sample point r is moved to the left hand side of the equation and becomes the variable for which to solve. Since net returns with the second best land use on sample point r are used in the computing equation, the value computed for $PRICE_{hr}$ will be the price of the optimum land use on sample point r that gives net returns equivalent to the second best land use. This final equation can be expressed as:

$$CPRICE_{h\,r} = \frac{OPTUM2_{r} + PCOST_{h\,r}}{YIELD_{h\,r} - \left[\frac{CDAM_{h\,r}}{TVAL_{h\,r}} \cdot YIELD_{h\,r}\right]}.$$

VITA 3

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Candidate for the Degree of

Doctor of Philosophy

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