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Mathematical Modeling of a Sociological and Hydrologic Decision System

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MATHEMATICAL MODELING OF A SOCIOLOGICAL AND HYDROLOGIC DECISION SYSTEM

By

Wade H. Andrews
J. Paul Riley
Malcolm B. Masteller

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A Joint Project of

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ABSTRACT

The general goal of this study was to develop a functional model of the sociological and related hydrologic elements in flood control decision-making. Conceptual system models were developed for the hydrologic system and for the sociological system. The sociological variables were identified as they related to the steps in the process of the model. Following the conceptual decision process model the social elements of the model were calibrated from data obtained from field studies and mathematical equations were developed and tested. Finally simulations of the process were run. After adjustments were made the model was found to function. Several methodological factors were devised to make the model more realistic and operable. These were: 1) Distortion Factors, which are differences that exist between various actual situations and perception of these situations; 2) Importance Factors, which are measures of the relative degrees of importance of each of the major characteristics of a proposal such as economic, aesthetic, effectiveness, etc.; 3) Acceptance Functions, defined as a combination of the perceived value of a characteristic and the Importance Factors; 4) Expansion Effect, which provides for changes in behavior related to values that are in a latent state of unimportance to a state of high importance stimulating high level action; 5) Threshold Levels, that determine the point between no activity and public action. These concepts permit the model to adjust to changes in social behavior related to the social structure of the decision process. The system provides for the function of social values as they relate to the social structures and the hydrologic components.

FOREWORD AND ACKNOWLEDGMENTS

This is the completion report prepared for the Office of Water Research and Technology of the U. S. Department of the Interior for contract number 14-31-0001-4207. In addition, it is the culminating report of a three phase study. The two earlier phases included Contract No. 14-31-0001-3712 and No. 14-31-0001-9053.

This work represents an effort to identify and quantify a system of social variables that are linked to the physical hydrologic system for the purpose of developing an operational model that will function in a simulation process for use in planning and development.

Early interest in this problem developed from participation in a conference on Urban Hydrology Systems at Andover, New Hampshire, in 1969. It was there that some insight into Urban Hydrologic problems and their concomitant social structures began to grow. It became apparent that through a systems approach one might be able to identify social variables in their relevant social systems that could be functional in a systems model. In this approach it is posited that in sociological phenomena two equally important types of social data are involved. They are the behavior of individuals and the structure of social systems. Finally both of these are associated with the physical hydrologic system.

This was an interdisciplinary study involving resource sociologists, engineers, and natural resources scientists. The engineers had primary responsibility in the hydrologic components while the sociologists had primary responsibility for the sociological components. However, there were close involvement of all throughout every phase and both participated in the resulting simulation process.

Many people assisted with this research especially those that provided information and data including several officials of government agencies, both federal and local, private organizations and the sample populations that were interviewed. Agencies of particular note included: the Salt Lake County Flood Control Department, the U. S. Army Corps of Engineers, the Salt Lake County Planning Department, and the Salt Lake County Commission.

Personnel on the project at the end were the authors listed, but several other people were a part of the staff at different points along the way. Those who had important roles were: Craig W. Colton, Natural Resource and Social Scientist; George B. Shih, Civil Engineer; Eugene K. Israelsen, Civil Engineer; V. V. Dhruva Narayana, Civil Engineer; Melvin D. Chambers, Civil Engineer; Dennis C. Geertsen, Resource Sociologist; and Bruce L. Brower, Resource Sociologist. Special appreciation for editing the manuscript is extended to L. Douglas James and Donna Falkenborg, and appreciation for their reviews and suggestions is expressed to Gary E. Madsen and Barton Sensenig III.

Others to whom we express particular appreciation for their service and assistance are Julia Packard, who typed the draft manuscript; and Becky Hansen, who typed the final report as well as the draft manuscript. However, the results, conclusions and recommendations made are those of the study staff.

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CHAPTER I

THE PROBLEM IN MODELING SOCIAL AND PHYSICAL ELEMENTS

Nature of the Problem

Introduction

The purpose of this study is to create a conceptual and mathematical sociological model of the social processes in formulating a decision in response to actual or potential physical conditions and to develop the related model of the hydrologic system of the area requiring flood control decisions.

The problem approached in this study is the development of a method for analyzing and modeling urban, metropolitan hydrologic problems through a consideration of social dimensions that are physically related to the flood control decision. This report identifies and describes relevant social variables to flooding, develops methods for the assignment of mathematical values to these variables and places them in a process model for flood control decision-making. The physical-hydrologic system of the related area is specified and elements in the hydrologic system are clarified.

Urban flood control programs have been largely planned to achieve a cost effective physical solution to the economic damage problem and have given little consideration to the social problems to be expected in implementing the solution. This failure is largely due to the lack of a workable methodology for integrating these physical and social dimensions. This report seeks to develop a usable model by identifying and defining social variables relating to flood control implementation, so they can be quantified and used to develop a model of the urban flood control decision-making process. The goal is to provide planners, managers, and the relevant public a method of predicting both physical and social consequences of alternative solutions to urban flooding problems. The same design may also be adapted to considering land use management, water development, and similar resource decisions.

Conceptualizing the real world system and identifying probable causal elements are the first steps of process modeling. Many variables and relationships were examined in identifying the components or elements of the system to be modeled and the basic relationships among these elements. The various components of the model were then calibrated and tested after suitable measurements were developed.\(^1\)

Complexity of Flood Management

Flood management in urban areas is complicated by a number of social and physical factors which can be identified as follows:

1. Natural runoff patterns are greatly altered by urban development. Quantification of the change requires predicting what urban development will occur and assessing its effects upon the runoff process. Attitudes, costs, and most other social and physical factors also change with urban development and as a result greatly complicate the prediction process.

2. Piecemeal solutions to urban drainage problems often result when diverse interest groups cannot agree to a general solution and available capital is limited.

3. The difficulty in identifying beneficiaries and allocating costs in densely settled urban areas makes it more difficult to get public support and financial backing for urban flood control programs.

4. Conflicts of interest often result in delay, compromise, or abandonment of remedial plans. Such conflicts may be the result if intensive interest or too little interest from the parties involved, and may result from lack of understanding each others' problems or viewpoints, or may represent opposing priorities and concerns. Such conflicts are further complicated by political subdivisions which seldom coincide with natural drainage areas.

5. Conflicting attitudes also produce difficulties. People are often suspicious of the motives of public officials. Landowners may resist giving up pre-

\(^1\)This is a summarizing report including the results of a three-phase study.
sent advantage for flood control benefits. For example, they may be reluctant to sacrifice property along stream banks as right-of-way for flood control through such methods as channelization or streamside park development.

Flood control planning is thus difficult because of the many varied technological, economic, and social aspects that must be balanced in a management scheme. The dynamic nature of the physical system adds further complexity. The computer model of this study attempts to capture the complexity of this hydrologic-sociologic system and thereby provides a means for evaluating flood control alternatives such as retention dams, lined channels, natural channels, storm sewers, and other control measures.

The Need for Social Behavioral Inputs in a Systemic Approach

Current procedures for planning for urban flood control do not adequately consider all the needs of modern society. According to federal policy, decisions should be based on sound social and environmental as well as technological and economic considerations (Principles and Standards of the Water Resources Council, 1973; Social Assessment Manual of the Bureau of Reclamation, Fitzsimmons et al., 1975, as well as others). Under a democratic form of government, the decision procedure for adjusting the physical system to achieve particular social goals or objectives requires public involvement. Simultaneously, the condition of the physical system, past and present, affects a number of parameters of the social system.

The two major dimensions of flood control examined in this research were the physical or hydrologic factors and the social aspects. Perturbations in either dimension cause changes throughout the entire system. For example, a dam constructed to provide flood control reduces the risks associated with floodplain development while simultaneously affecting transportation, farming, aesthetics, ecology, and recreation within and near the reservoir area as well as in the flood plain. A modification at any point in either dimension initiates a series of adjustments, some of which may be positive and others negative. Both physical and social impacts, direct and indirect, need to be anticipated in deciding whether or not to make the modification.

Urban development has complex ramifications in both the hydrologic and social dimensions. High population densities, for example, increase impervious areas, magnify the severity of flooding, and alter the ecological balance as well as endanger human life and property. In a flood management program for a metropolitan area, it should be possible also to provide, simultaneously, greater recreational opportunities, increased aesthetic benefits, enhanced land values, increased water supplies, a modified micro-climate, and a carrier for municipal wastes.

The physical and economic aspects of urban drainage are fairly well understood while the social aspects are traditionally accorded little consideration. The importance of the social dimension, however, is becoming recognized. W. R. D. Sewell (1969: 3) noted:

Social guides comprise a wide variety of influences that encourage or discourage development taking place in particular ways. They include informal influences such as social mores, customs, and attitudes, and formal influences such as laws, policies, and administrative arrangements. Knowledge of the effects of such factors is essential to sound water resources planning.

In order to incorporate these influences into an objective planning model, it is necessary to identify them and define them so they can be quantified. In this study various physical and social processes and the way they interact within the total system have been conceptualized; and from these conceptualizations, significant variables have been identified and measured. Equations for describing the relationships in the conceptual model have been developed, tested, and integrated to form a model. This model provides a framework for considering extra-economic benefits in urban flood-control planning that should facilitate the design of effective solutions to flood control problems that will be acceptable and thereby greatly lessen the time, money, and dissatisfaction involved in flood-control implementation.

Objectives

The research objectives of this study are:
1. To define a hydrologic and a related social system and identify and specify its sociological and interacting hydrological components.
2. To develop conceptual models of the sociological and hydrologic subsystems.
3. To determine appropriate mathematical expressions for representing observed relationships within the physical and social systems.
4. To formulate mathematical equations for each part of the total process.
5. To develop detailed field data for the calibration and testing of the equations of the model.
6. To apply the model to a real situation and simulate various values for the variables.

The Study Area

The study site selected to provide a real setting for model development and testing is a part of the
rapidly developing metropolitan area which includes Salt Lake City and several suburban communities in Salt Lake County, Utah. Because of rapid urban growth and the consequent effects on runoff and potential damage, flood control is of increasing concern to city and county officials.

The Salt Lake Valley is in the Great Basin. It is a "U" shaped valley bordered on the east and west by mountains and by lower spurs of these mountain ranges to the south. The valley, which is about 15 miles wide (east and west) and 25 miles long, is bisected by the Jordan River which flows northward and discharges into the Great Salt Lake. The average elevation of the valley floor is approximately 4,000 feet above mean sea level. The valley is semiarid with an annual average of 15 inches of rainfall.

The Wasatch Mountains, with peaks up to 11,000 feet above sea level, rise abruptly on the east side of the valley. Because of this sharp rise, much of the precipitation is produced by the orographic lifting of air masses moving in an easterly direction and falls in the mountains. The Wasatch Mountain Range thus provides a large portion of the water supply for the valley below. Several small streams run westward from mountain canyons into the valley and discharge into the Jordan River.

The site selected for this study is limited to the part of the eastern side of the valley shown in Figure 1.1. This specific area was chosen because of the history of flood control proposals that would affect the inhabitants. This area is bordered on the west by the Jordan River, on the east by the Wasatch Mountains, on the north by the heavily urbanized Parley's Creek drainage, and on the south by the less urbanized but developing Little Cottonwood Creek watershed. Altogether, the area contains about one-half of the eastern section of the Salt Lake Valley.

The population within the 1970 census tracts of the study area, was 131,882. It is of varying density and growing rapidly. From the 1970 figure of 383,035 people, the population of Salt Lake County is expected to grow to about 785,000 people by 1985. The area's proximity to the central business district of Salt Lake City and present rapid development suggest that a large part of this expected growth will occur in the study area as indicated by the master plan for the county (A Master Plan for Salt Lake County, 1965). The area has a long history of flooding (Corps of Engineers, 1969A: 11-19), and continuing urban development is increasing the urgency of the flood problem. Some of the present development is occurring in the flood plains and mountain canyons and "new residential developments are rapidly expanding..." (Corps of Engineers, 1969A: 5). This urban growth not only alters run-off relationships by producing higher peak flows, but also increases the damage potential from a flood.

The Process of Model Development

Computer Simulation Models

In a computer simulation model, one uses an understanding of the fundamental processes and the coupling relationships among them to predict the consequences of possible changes. For example, one could predict changes which result from increasing urbanization and the consequent flood damage and demand for flood control. Mathematical simulation is achieved by using arithmetic relationships to represent the various processes within the prototype system and by linking these equations into a model that represents the functioning of the system as a whole. Thus, computer simulation uses a model developed to behave like a prototype system to predict probable responses to situations for which prototype response has not been recorded or responses one might expect from the prototype to be altered.

Steps in Developing a Working Model

A computer model simplifies the real world in representing it and thus becomes an abstraction from reality. The degree of simplification is a function of both modeling intent and knowledge about the real world. Verbal information and conceptualization are translated into mathematical form for use in a computer (Forrester, 1961). Model development proceeds from verbal symbols which result from theoretical and empirical studies to the mathematical symbols which compose the model.

The development of a working mathematical model thus requires two major steps. The first is the creation of a conceptual model of the various elements of the system and the interrelationships among them. In practice, the hypotheses necessary for the real world for a particular study area are formulated from the most pertinent and accurate data available. As additional information is obtained, the conceptual model is improved and revised to more closely approximate reality.

The second step is the operationalization of the conceptual model into a working computer. During this step, an attempt is made to express the various processes and relationships identified or hypothesized in the conceptual model in mathematical form. This step usually requires further simplification and thus means that the resulting model is further removed from reality.

The loss of information, first, between the real world and the conceptual model and, second, between
the conceptual model and computer representation, can be pictured as the filtering process depicted by Figure 1.3. The real world is "viewed" through various descriptive data. The conceptual model is produced from these data and previous experience and then becomes the basis for the working model. The descriptive data may be improved by addition or refinement. Improvements in the conceptual model lead to improvements in the working model. Output from the working model can be compared with corresponding situations in the real world; and when significant discrepancies (with respect to the intended model application) exist between the two, adjustment can be made.

Three aspects of the model construction process are thus particularly important: 1) Operational definitions of variables need to be specified; 2) data need to be analyzed to formulate mathematical relationships as well as to verify them; 3) models are always sub-

Figure 1.1. Watershed boundaries and locations of the streamflow gages climatological stations within the study area.
Figure 1.2. Steps in the development and application of a simulation model (Riley, 1970).
ject to change as more information is obtained. The changes can be in either the form of the process equations or in the way they are combined to represent the system in order to match the mathematical construction more closely to reality.

Real World

Figure 1.3. Steps in the development of a model of a real world system.

Conceptualizing the System

The social response to the urban flood control problem is seen as being composed of interrelated and interacting subsystems or parts:

The most general and fundamental property of a system is the interdependence of parts or variables. Interdependence consists of the existence of determinate relationships among the parts or variables as contrasted with randomness of variability. (Parsons and Shils, 1951: 107).

Such a situation was hypothesized for the initial conceptualization of the sociological system related to flooding and flood-control.

The interdependent parts are called the elements of the system. Systems are composed of interrelated, connected, and interacting elements linked to form a unity or whole. Modeling a system requires identifying the system elements and determining the characteristics of the interrelationships among them.

Social systems, those which are composed of social elements, have many interrelated and interacting elements. Behavioral research and theory indicate that cultural commonalities of characteristics, values, and behavior exist among individuals. It is these commonalities that provide a basis for modeling.

Figure 1.4 notes four interacting groups of people who respond to urban flood problems and thus need to be represented in the conceptual model of the social system for this study. These groups are: 1) individuals; 2) governing or regulating institutions or bodies (federal, state, or local) having executive, legislative and judicial function; 3) other institutions (for example, educational, economic, and religious); 4) other groups (for example, special interest groups, etc.).

Individuals are included separately in the conceptual model because they are able to influence flood control policy and the effectiveness of flood control design both as owners or managers and by interacting with the other three groups. The total conceptual model needs to include an individual acting both as a single unit and as a part of a group.

One individual can interact with more than one group. In this manner, some individuals play a greater role in the formation and implementation of resource policy than others. Also, the amount of "input" that an individual can introduce into a particular group varies from person to person and from group to group. Individuals and groups possess specific differing and changing attitudes in relation to many factors such as aesthetics and recreation and consequently have different types of influences; both attitudes and influences change with them.

Management decisions and their implementation are outputs of a social system. This output comes from either government (public) management or from private management (Figure 1.4), and is partly a consequence of hydrologic conditions. As with physical systems, responses of social systems vary both spatially (from system to system) and temporally. Implementation of management decisions changes the physical characteristics or parameters of the watershed (the physical and biological conditions) which are represented in the hydrologic part of the model (Figure 1.4). Social induced changes in the watershed result in response and are mathematically modeled by the response functions of the hydrologic system and are fed back as input to the social system by altering appropriate parameters in the sociological model. This is done by equations which represent important effects of the respective systems upon each other. Through a set of interactive linkages between the two subsystems, a dynamic interaction process occurs within the system as a whole.

Figure 1.4 displays a simplistic summary of the conceptual model, its component subsystems, and their linkages. Each subsystem within the social component of the overall model is very broad and includes many related and interacting processes. Further development of the conceptual model of the social component and some corresponding mathematical relationships are presented in subsequent chapters of this report.
The remainder of the report is divided into the following subject areas: Chapter II discusses the social and hydrologic methodology and some of the developments in this respect; Chapter III analyzes the hydrologic model and data for the area studied; Chapter IV develops the sociological conceptual model and the concepts necessary for the operation of the mathematical model; Chapter V develops the sociological mathematical model; Chapter VI presents the computer model; Chapter VII presents the application to sensitivity analysis; and Chapter VIII is a summary, conclusion, and indication of further work needed.

Figure 1.4. Preliminary concepts and interactions relating to the sociologic part of the hydrologic-sociology system and their relationship to the hydrologic part of the model.
CHAPTER II

METHODOLOGICAL DEVELOPMENT OF SOCIOLOGICAL AND HYDROLOGIC ELEMENTS

The Study Format

The model was developed in three phases. The first goal was to identify sociological and hydrologic components, develop a conceptual framework for relationships among them, and postulate mathematical expressions defining the relationships in terms of the identified components. The second phase was the development of operative sociological and hydrologic models as well as the collection and analysis of data to calibrate and test them. The third phase was calibration, testing, and revision of the total model as well as its use in simulation analyses.

The procedure may be outlined as follows:

I. Structure of the Modeling Process, Social and Physical (note Figures 1.4 and 4.1):
   A. Developing a conceptual social model of the decision system.
   B. Developing a theoretical conceptual structure of the social model for calibration.
      1. Conceptual elements: acceptance function, etc.
      2. Identification of social variables related to stages of the model, Table 2.1.
   C. Developing the mathematical model:
      1. Calibration of the social variables.
      2. Programming and testing the calibrated model.
   D. Developing the hydrologic model:
      1. Preliminary development.
      2. Expansion.
      3. Identification and description of the physical functions of the hydrologic system that impacts upon the social system.

II. Simulation Operations of the Model.

Collection and Analysis of Social Data for Variable Selection

Field data from an urbanized area of the watershed were used to gain a conceptual understanding of the social system and to test mathematical relationships. Various procedures were used to obtain the necessary field data, to process these data, and to develop the framework for the formulation of mathematical relationships.

Preliminary Identification of Variables

A variety of sources provided information for identifying sociological variables. When this project began, work was already in progress on defining variables for predicting the response of the sociological systems to flood control problems in the Salt Lake County area (Andrews and Geertsen, 1974a). These survey data provided preliminary information for defining social variables to begin the first phase of work. The survey method was used to obtain information on flood control perception from the public in order to identify social variables associated with the physical aspects of flooding.

The preliminary survey sampled randomly selected individuals of the areas studied to determine attitudes, felt needs, perspectives, perceptions, knowledge, impact of flooding problems, and other factors related to flood control. In addition, information was gathered on overt opposition to or support for flood control proposals and membership in certain groups. Demographic and other social characteristics of those interviewed were obtained.

Additional questions were asked all those who had heard of proposed flood control plans for the local area. Such a respondent was asked to rate each proposal according to: cost, effectiveness for flood control, effect on recreation, appearance, and ecological effect (Variables 168-208 Appendix A). This helped to determine the relative importance of the respon-
dent's perceptions and expressed feelings about these proposals.

Expansion and Testing of Social Variables

The second phase of this study sought to improve the instrument used to measure these social factors. Specifically, the goal was to scale respondents on a continuum for particular variables. Therefore, the survey questions were changed to replace discrete categories with continuous scales except in such discrete situations as the sex of respondent. At the same time, it was desired to preserve as much comparability as possible between the first and second questionnaires for the purpose of reliability; consequently, changes in the questions were constructed to permit data from the second phase schedule to be collapsed to the same categories as the data from the first phase. Almost all of the variables tested and found to be significant in the first phase were included in the second phase survey. A complete list of variables measured in the second phase is shown as Appendix A. A reduced list of the important variables (in one or more of the regression equations) is found in Table 2.1.

Attitude Measurement

Special groups of questions were scored and structured into scales to measure the attitudes likely to be important in the public evaluation of flood control methods. These scales are titled as follows along with their code identity:

I. Concern for Flooding as a Problem in the Respondent's Area (CONCL)
II. Attitude Toward the Effect of Man-Made Objects Upon Beauty of Nature (MANL)
III. Leisure Orientation (LEIL)
IV. Outdoor Recreation Orientation (RECL)
V. Willingness to Pay for Government Expenditures (PAYL)
VI. Ecological Orientation (ECOL)
VII. Willingness to Follow Advice of Experts (EXPTL)
VIII. Willingness to Follow Government Agencies (AGENL)

Each variable was evaluated from Likert-Type summated score scales. Appendix B shows the method, the variables, and the questions (items) constituting each scale in the main questionnaire. Each item may itself be treated as a variable as well as be used in forming the total scale.

The items composing each scale were derived from the results of a pre-test sample (N = 37) from the same population as the main sample. The techniques used to analyze the pretest results to select scale items for the main schedule were item analysis.

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>Variables found important in one or more regression equations and their theoretical ranges as measured in the First Phase of the study for identifying significant variables.</th>
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<tbody>
<tr>
<td>A =</td>
<td>Range from Minimum to Maximum</td>
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10
factor analysis, and a measure in the process of being developed called a "discrimination index" (Masteller, 1975). This index is a measure of the ability of an item to discriminate respondents into different groups or to order respondents in ranked categories. The questions used were also pretested for clarity and consistency of respondent interpretation.

The measurement of social variables is made complex (Torgerson, 1958; Lazarsfeld and Henry, 1968; Stouffer et al., 1973) by the number and types of variables that may be measured (attitudes, needs values, goals, beliefs, characteristics, and behavior of various types). A great deal of model improvement can be expected through the development of improved measures of the social variables.

Interviewing and the Sample Population

The schedule was given to a sample of study area residents. Each block and household was randomly selected. The sex of the respondent was previously assigned.

The interviewers were instructed on how to administer the questionnaire. The interviewing required nearly three months time. Effort was made to interview all those designated in the sample, and only about 10 percent of the original sample were not interviewed. The total number of usable interviews completed in this sample was 395.

Agency and Group Data

In addition to data collected from people living within the study area, data were also collected from people in various government agencies and special interest groups. The objective for this data was to develop a technique for weighting the response of the agencies toward flood control proposals with known characteristics. Notes on meetings the researchers attended, interviews with officials of flood-control related agencies, legal statutes and descriptions of organizational structures were also useful for this purpose. The notes were analyzed by content analysis. Finally, for purposes of this study only, as explained more fully below, a short cut method of independent judgments of a panel of knowledgable judges or experts was used to establish numerical values for agency characteristics for use in the agency evaluation equations of the model.

Officials in government agencies dealing with flood control in the urbanized east Salt Lake County area were contacted to obtain information that could be used in defining relationships between these agencies and problems related to flooding within the study area. This was an exploratory attempt to identify forces which affect agency decisions and to begin to evaluate the effects of these decisions.

Contacts with public agencies were made by interviews, letters, and attendance at meetings and hearings. Information was obtained on agency goals, values, and objectives not only as set forth in enabling legislation, but also as these goals or objectives were interpreted and perceived within the agency itself. This analysis considered the perception of agency administrators and the relationships between the agencies and other social systems.

Relevant federal laws, state statutes and local ordinances were searched to identify variables for measuring such legal factors as primary responsibility for flood control, limitations of power, and authority structure. Other agency characteristics for which data were gathered related to funding limitations, the technical capabilities of personnel, and the physical limitations of the agency (equipment and staff available). These factors limit the physical actions an agency may implement to change a hydrologic system.

The data from the original interviews were used to identify the most important flood control agencies in the Salt Lake area. Each interview was tabulated to find which group was mentioned most often, second most often, etc. The three agencies mentioned most often were recorded in sociograms. The highest score was attained by the County Flood Control Department. The U. S. Army Corps of Engineers and the Salt Lake County Commission were second with identical scores.

The Salt Lake County Commission is directly superior to and works through the Salt Lake County Flood Control Department on flooding issues, and the two groups may be considered in certain aspects as a unit in relation to flood control decisions. Also, few data were available on the Salt Lake County Commission itself in relation to flood control proposals. Consequently, the Salt Lake County Flood Control Department and the U. S. Army Corps of Engineers were the main agencies used in construction of the model.

The data needed for the agency equation were not all available in the information from the agency interviews and there was not adequate time or funds to collect more detailed data directly from the agencies. As a substitute to collecting the additional data needed, a group of knowledgable judges or experts were used to provide the necessary data to complete construction of the model. The questionnaire prepared for administering directly to the agency was instead administered to eight judges who were familiar with the interviews with the agencies and were asked to predict the answer one could expect from the two agencies of main concern. Each judge made an evaluation for each agency on each of the three flood control proposals making a total of 48 observations. This
indirect method cannot be defended as reliable for model application but was selected as the most practical method for supplying the needed data for calibrating the model.

Content Analysis of Agency Information

Techniques of content analysis were used to develop a method for scoring and tabulating the data obtained in agency and group interviews. Content analysis has been used to render unlike data into like forms for comparison and to obtain quantitative measures from qualitative data for mathematical analyses. Variations permit one to compare several sources of information or one or more sources at different periods of time (see also Holsti, 1968). One technique employed here was a simple count of each time an interviewee mentioned an agency, public group, or individual associated with an agency or group. It was thought that such a count would reveal which agencies are considered most important.

The type of relationship one agency had with others that it mentioned was also explored. Each statement that referenced a type of relationship was extracted and the proper nouns removed. Later "judges" were asked to evaluate these statements and rank the legal and hierarchical aspects of the relationships. For example, interview notes might contain a statement such as, "We must submit our plans to the County Commission for approval." The statement would be put in the following form: "X must submit its plans to Y for approval." This and all other statements which might have some bearing on the legal and hierarchical relationship between two agencies were then grouped and considered by the judges. An example of such a set of statements might be as follows: "X must submit its plans to Y for approval." "Y determines which problems X will study." "Y has X hold monthly public meetings."

Within such a set of statements, X is always the same agency and Y is always the same agency. The judges were individually asked to review the set of statements and then classify the relationship of X to Y as an hierarchical or horizontal power relationship, etc. Other statements were similarly extracted, and the judges were asked to evaluate the quality and intensity of the relationship, the involvement of each group in flood control, the intensity of the involvement, the time orientation of the group (i.e., if its plans were of a short term or a long term nature), and the group reaction to various flood control proposals.

The choice of information to be probed by content analysis was limited by the time available for interviews. It took some time to develop a feel for the kinds of questions to ask officials. One interview did not always contain answers to questions probed in other interviews, and it was not until interviews were well along that the list of questions was able to be standardized. Some interviews occurred in public or interagency meetings where the researcher was not at full liberty to ask questions. Another deficiency in this approach is that interviews are recorded by note taking, and quotations may not be complete or may be paraphrased. Ideally, every interview should be recorded verbatim. Content analysis, however, is a viable method for quantifying qualitative data.

Data Analysis for Sociological Variables

Statistical Tests Used and Identification of Variables

After the public interviewing was completed, a number of steps were necessary to prepare the data to develop relationships for the sociological component of the model. Each response to each item was coded and punched on cards for computer processing. Responses to each item were first tabulated and analyzed for distribution and number of no-answers.

A second set of decks was then made for cross-tabulation of pairs of items and the results were analyzed for significance by several non-parametric and correlation tests. Chi square, Cramer's V, Contingency Coefficient, and Gamma rank-order (Nie et al., 1970: 275-277; also note James et al., 1971: 57). The objective was to identify significant variables and establish the relative importance of those identified.

The principal method used in quantifying social relationships for inclusion in the model was multiple regression analysis. Multiple regression equations were developed for the significant relationships for inclusion in the sociological component of the model. Certain variables which had been assumed to be independent, however, appeared in several equations. As an example, the variable titled, "Knowledge of flood control projects" was found to be correlated with whether persons favored or opposed particular projects. In order to increase understanding of the "knowledge variables, and those variables which might be correlated with it was run as a dependent variable with some of the other variables being used as independent, or in other words, as predictors of knowledge." Through this method, knowledge of interrelationships among variables was increased. Another example is shown in the model presented in Chapter V, where Concern About Flooding is the dependent variable and Perceived Likelihood of Flooding is an independent variable in Equation I (shown later in Table 5.9).

Several studies demonstrate the versatility of regression analysis in the social sciences. Techniques similar to those used elsewhere were applied in this.
study to: 1) identify important dependent variables, and 2) develop equations for the sociological component of the model. Weightings for the theoretical relationships described later in this report were also obtained using this methodology.

**Standardization of Measurements**

Combining unlike measurements into the same equation requires a standardization or weighting procedure. Therefore, the mathematical equations in this study are expressed in two forms. The first form uses nonstandardized coefficients based on the numbers directly measured. The second or standardized form is derived from the nonstandardized form by multiplying the coefficient by its standard deviation and by dividing by the standard deviation of the dependent variable in the equation. The standardized form thus compensates for differences in the measurement scales used and for variations in the distributions of variable values. The standard deviation is used as a measure of variability and not for statistical inference. No particular underlying distribution is assumed, but the values of each of the variables should be reasonably well distributed, (Blalock, 1961; Coleman, 1966; and Duncan, 1966).

The standardized form permits an evaluation of the relative sensitivity of the dependent variable to changes in the various independent variables in the relationship under consideration. The sign of the coefficient indicates the type of relationship, direct or inverse, between the respective independent variable and the dependent variable. The larger the coefficient associated with an independent variable, the greater is the sensitivity of the dependent variable to variations in that variable alone. However, the variable with the largest coefficient in the standardized form is not necessarily the "most important" because that variable itself may vary considerably less than does a variable with a relatively low coefficient. Also, a variable with low coefficient may have concomitant variation with other variables in the equation (Gordon, 1968) and thereby be capable of introducing considerable variation in the dependent variable (Blalock, 1964).

**Statistical Assumptions**

The standardized relationships are valid for model building provided the equation is accurate and recursive (Blalock, 1964). While accuracy and recursiveness are not entirely attained with sociological data, these limitations do not mean the equation are inappropriate or inapplicable to social science work providing the user is aware of the consequent degree of approximation (Coleman, 1964). In addition, as an increased understanding of the sociological system is reflected in improved data and relationships, the two conditions are expected to be met more closely.

A further problem associated with statistical relationships is explained by Coleman (1964: 101) as follows:

Other variables which affect the dependent variable are assumed to be uncorrelated to the independent variable, and this assumption is not normally entirely true...if this assumption is not true, as often it is not, then the observed relation may be a spurious one because of the variables not taken into account. It is to reduce this difficulty that more variables are added and multiple regression is used.

However, too many variables cause redundancy and lead to serious problems (see Gordon, 1968; Schoenberg, 1971).

Two other assumptions (Coleman, 1964) are: 1) the independent variables are theoretically causally related as described by the equation to the dependent variable; and 2) the parameters of the equations are alike or nearly so for all units in which observations are made. The second assumption is often met in sociological samples drawn from the same population. Meeting the first assumption requires knowledge of the system being studied.

For the initial model, the relationships within the sociological component of the system are assumed to be linear in order to simplify the analysis and because the system was not sufficiently well defined to develop more complex relationships. The linear hypothesis is a first approximation. Since the relationships of some important social variables in the hydrologic-sociologic system are not linear, efforts should be made in the future to develop more accurate nonlinear equations.

One frequently stated requirement for linear regression analysis and related statistical techniques is that variables should be measured on a continuous scale even though multiple regression can be run with variables classified by discrete categories. Recent investigations have shown that powerful parametric statistics are useful even when scales do not meet all of the assumptions for the statistics. Labovitz (1967, 1970) and Baker et al. (1971) demonstrated that even radically different numbering systems for ordinal data do not greatly change the results when statistical techniques normally requiring interval measurements are applied to ordinal scales. He wrote:

Empirical evidence supports the treatment of ordinal variables as if they conformed to interval scales. Although some small error may ac-
company the treatment of ordinal variables as interval, this is offset by the use of more powerful, more sensitive, more highly developed, and more clearly interpretable statistics with known sampling error. For example, well defined measures of dispersion (variance) require interval or ratio based measures. Furthermore, many more manipulations (which may be necessary to the problem in question) are possible with interval measurement, e.g., partial correlation, multivariate correlation and regression, analysis of variance and co-variance, and most pictorial presentations (Labovitz, 1970: 515).

For the purpose of this study, the specification of important variables and of the general nature of the relationships among them, the data have been formulated and treated as interval information. Dummy variables are generally not used in the regression equations since the data are treated as if they measured the underlying variable continuously. It is expected that measurement methods can later be improved to approximate continuous scales more closely in the real sense.2

Evaluation and Analysis of the Physical and Hydrologic Data from the Study Area

The physical data provide a description of the real world hydrologic system that establishes a basis for formulation and testing of the combined sociological-hydrologic model. The accuracy of predictions from a model are governed by the reliability of the information used to develop the model and the accuracy of the input data used in predictions.

As shown on Figure 1.1, the three streams within the study area are tributaries to the Jordan River. The urban portions of the drainage of Mill Creek, Big Cottonwood and Little Cottonwood Creeks (Figure 2.2) contain approximately 14, 23, and 10 square miles, respectively, and extend from the foot of the Wasatch Mountains to the Jordan River. Urbanization is predominately residential in nature with a few areas of light industrial and commercial development. The rural portions of the three watersheds (Figure 1.1) extend to the tops of the Wasatch Mountains. Most of the water flow is generated within the mountainous rural areas.

Topography

The general topography of the urbanizing portion of the study area is shown by Figure 2.1. Elevations range from 4200 feet at the Jordan River to 4800 feet along the Wasatch Boulevard on the east. The slopes also steepen to the east. The fast runoff down the steep slopes tends to accumulate in ditches, curbs, and gutters on the flatter areas near the Jordan River.

Geology

Where the steep mountain slopes merge into the upper planes of the valley, rocks and gravel are overlain with sand and soil. Vegetation is of the scrub oak variety mixed with some grasses. Because of its high gravel and sand content, the infiltration capacity of the soil is generally high. The sand soil is easily eroded by high velocity flows to form gullies, and erosion as increased by grading, trenching, or other movement of the soil during construction of buildings and roads. Near the Jordan River the soils are heavy. Water tends to pond in surface depressions rather than infiltrate, and lower flow velocities reduce erosion hazards.

Degree of Urbanization Within the Study Area

In order to model urban runoff, it is necessary to select readily determined parameters which correlate with changes in the runoff hydrograph due to urbanization. Two parameters proposed by Narayana et al. (1969), the percentage impervious cover, C, and the characteristic impervious length factor, L, are used in this study. These two parameters represent physical conditions existing on the watershed and can be estimated from aerial photos.

Computation of Urban Parameters

Some size of spatial unit must be adopted for the model. Narayana et al. (1969) chose the entire watershed as the primary catchment unit. Evelyn et al. (1970) found that accurate synthesis of hydrographs at selected locations within a basin required that small subwatersheds be chosen as the primary catchment units. The outflows from the subzones then can be routed and combined to determine outflow hydrographs at downstream points. An even smaller unit, the urban block, would permit synthesis of inlet hydrographs for storm drain and gutter design under various assumed degrees of urbanization.

Evelyn et al. (1970) proposed the following procedure for evaluating the urban parameters, and this procedure was adopted for this study.

I. Divide the watershed into sub-zones as illustrated by Figure 2.2.
   A. Factors which influence the number of subzones and their boundaries are:

2Recently methods for attaining actual ratio scale levels has been developed that should be applicable to some of the variables in this study. (See Stevens, 1966; Hamblin, 1971, 1974.)
Figure 2.1. The general topography of the urbanized study area.
1. Natural topography and street configurations.
2. Location of rainfall and streamflow gages.
3. Objectives of the study, for example, different boundaries might be chosen for investigations involving (a) storm characteristics, (b) land use, and (c) the design of flood control structures.
4. Locations and densities of diversions.

B. A subwatershed model requires that all outflow from a subzone be defined and preferably be at a single point. A single outflow point is not essential, but it simplifies model development.

II. Determine the impervious cover associated with roads, buildings, parking lots, and sidewalks. The use of large scale aerial photographs (in this study, a scale of $1" = 400'$ was used) greatly reduced the work involved. It is possible to work directly on the aerial photographs, delineating boundaries, subzones, and units within subzones by means of wax pencils of various colors. The important parameter is the total impervious area, but the additional work necessary to differentiate among roads, buildings, parking lots, and sidewalks often is worthwhile. With this information, the research can examine the effects of a particular kind of impervious cover on the runoff characteristics of the watershed. In addition, the information is useful for economic analysis. The following procedure is suggested for determining average values of various kinds of impervious cover within a study area.

A. Choose a set of residential blocks that includes a representative of each type of block within the watershed.
1. For each block chosen, carefully measure each type of impervious cover. The total area of the block is considered to be the area enclosed within lines joining the midpoints of the intersections of adjacent roadways (see Figure 2.3). Linear measurements can be made with a scale and a rotometer. A planimeter is also useful.

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**Figure 2.2.** Dividing the flood plain area into subzones.

**Figure 2.3.** Typical urban residential block showing the pervious and the impervious areas.
2. For each block, calculate the percentage impervious area for each type of surface.
3. Average the results over all the blocks to obtain a mean impervious area for residential houses including garage roofs, driveways, and home sidewalks. In this study the average area of impervious cover associated with a single residential house was determined to be approximately 2400 square feet.
4. In the same manner, average values are estimated for the widths of residential streets and thoroughfares. Freeways and main highways are considered on an individual basis.

B. Divide the subzones (Figure 2.2) into smaller spatial units (Figure 2.4) based on the following criteria:
1. That the amount of impervious cover and its distribution are nearly homogenous within a unit.
2. That a geometric center of the unit, and from which all runoff from the unit might be considered to originate, can be assigned by visual inspection.

---

Figure 2.4. Division of Mill Creek and Big Cottonwood Creek subzones into smaller spatial units.
C. Estimate the percentage impervious cover for each unit.
   1. Use a rotometer to estimate road length and multiply by the average road width to estimate the area of roadways.
   2. Estimate parking lot areas by directly measuring their dimensions or by using a planimeter.
   3. Estimate the impervious area connected with dwelling by counting the number of homes and multiplying by the average impervious area for a single home. Add to this total individual estimates for larger structures such as industrial plants, hospitals, and churches.
   4. Estimate sidewalk area from a measurement of dimensions.

III. The characteristic impervious length factor is estimated as shown by Figure 2.5. Drainage paths usually can be predicted by the conjunctive use of contour and street maps. In this study, only a few field observations of flow at street corners were needed.

Summary of Calculated Urban Parameters

The impervious cover and characteristic impervious length factors for the specific urban area of this study were all measured mostly from aerial photographs dated 1975. Raw data for each unit shown by Figure 2.4 were input to a computer program (Appendix B) to estimate the following: 1) the impervious cover by categories; 2) the characteristic impervious length factor; and 3) the fraction of impervious cover. The estimates for items (2) and (3) for the subzones of Figure 2.2 are summarized by Table 2.2.

The figure of 2400 square feet of impervious area for an average urban dwelling was derived by sampling 21 residential blocks in two urban watersheds. For each block, mean areas were calculated for the driveway and for the dwelling. By averaging for the entire study area, a mean residence area of 1833.2 square feet and a mean driveway area of 553.6 square feet (for a total of 2386.8 square feet) were obtained. Confidence limits of 95 percent were computed for residences as between 1716.0 square feet and 1949.4 square feet, and for driveways as between 476.6 square feet and 630.0 square feet.

Hydrologic Characteristics of the Study Area

The Mill, and Big and Little Cottonwood Creek watersheds are frequently subject to storm runoff which exceeds the capacity of the storm drainage system and which, therefore, produces flood damages. Most of the climatologic, hydrologic, and geologic data pertaining to the area are published in agency annual reports or other public files, and therefore, were available for this study. In addition, aerial photographs taken in June and July of 1975 were obtained from the U. S. Department of Agriculture.

Climate

Runoff originates as precipitation, and precipitation patterns, as modified by snow storage, cause flooding conditions. The influence of the Wasatch Mountain Range on the general precipitation pattern throughout the easterly portion of Salt Lake County is shown by Figure 2.6 (U. S. Weather Bureau, 1963; Kaliser, 1973). More than two-thirds of the precipitation along the Wasatch Front occurs during the winter months, mostly in the form of snow that fall during orographic lifting as air currents pass from west to east over the mountain front. In summer, the uneven heating of the ground surface creates vertical lifting, leading to high intensity convective storms of short durations and of small aerial extent. The Weather Bureau (National Weather Service) has maintained continuous precipitation records at Salt Lake City for more than 85 years.

Temperatures

The warmest temperatures of spring induce new leaf and vegetative growth. Warm summer tempera-
Table 2.2. Physical characteristics for the urbanizing portion of Mill Creek, Big Cottonwood Creek, and Little Cottonwood Creek Drainages.\(^a\)

<table>
<thead>
<tr>
<th>Sub-Zone</th>
<th>Area within subzone (miles(^2))</th>
<th>Length of channel (feet)</th>
<th>Slopes (ft/ft#)</th>
<th>Fraction impervious area (C_f)</th>
<th>Characteristic impervious length factor (L_f)</th>
<th>Interception storage (S_I) (in)</th>
<th>Depression infiltration rate (F_D) (In/Hz)</th>
<th>Minimum infiltration rate (F_C) (In/Hz)</th>
<th>Maximum infiltration rate (F_C) (In/Hz)</th>
<th>Hydrograph time (t_R) (min)</th>
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<td><strong>Big Cottonwood Creek</strong></td>
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<td>0.329</td>
<td>0.23</td>
<td>0.23</td>
<td>0.64</td>
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<td>0.0017</td>
<td>0.093</td>
<td>0.706</td>
<td>0.26</td>
<td>0.23</td>
<td>0.72</td>
<td>0.22</td>
<td>10.9</td>
</tr>
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</table>

\(^a\) Average values for the watershed channel width - 30 feet. - Manning's "n" assumed to equal 0.037.
Surface air temperatures in the Salt Lake area range from an average January temperature of 28°F to a July average of 77°F. The low and high temperature of record at Salt Lake City are -20°F and 105°F, respectively.

Because of the high intensity and short duration of convective storms, only a relatively small portion of the total rainfall infiltrates at the point of incidence. Thus, surface runoff rates usually are high, and flooding is common. Because it tends to reduce infiltration rates and speed surface runoff, urbanization usually increases flood flows. These effects, coupled with the greatly increased damage opportunities, make the flood protection in urban areas a matter of prime concern for municipal planners and engineers.

Drainage Conditions

Surface runoff from the study area flows to the Jordan River in either natural or man-made water courses. The drainage pattern is strongly influenced by such man-made barriers as railroad and highway embankments. In many cases, culverts do not have adequate capacity, and ponds are formed. In other cases, flows are conveyed along the embankments to culverts at central locations. Streets with their accompanying curbs and gutters also profoundly influence drainage patterns. Irrigation channels and storm sewers also affect surface drainage. Characteristics of the main natural drainage channels for the subzones of Figure 2.2 are shown by Table 2.3.

Instrumentation

The basic hydrologic data network for the study area consists of two precipitation stations and one stream flow gage in the rural portions (Figure 1.1), and nine precipitation stations and eight stream gages in the urbanizing portions (Figure 2.7). Three stream gages were added in the urbanizing portion.
gages are situated on Mill Creek, three are on Big Cottonwood Creek, one is on Little Cottonwood Creek, and three are on the Jordan River. Of the 11 precipitation gages, only one is a recording type. Three non-recording precipitation stations are situated within the Mill Creek watershed, three are in the Big Cottonwood Creek drainage, and two are on Little Cottonwood Creek. The single recording precipitation station (W-9, Figure 2.7) is situated on Cottonwood Creek. A Thiessen network (Figure 2.7) was used to estimate average precipitation on the three watersheds.

Table 2.3. Characteristics of the main drainage channels of Mill, Big Cottonwood, and Little Cottonwood Creeks within the urbanizing portions of the study area.

<table>
<thead>
<tr>
<th>Sub-Zone* (Figure 2.3)</th>
<th>Length of Channel Within Subzone (miles²)</th>
<th>Widtha (feet)</th>
<th>Slopes ft/ft³</th>
<th>Manning's n²</th>
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</thead>
<tbody>
<tr>
<td>Mill Creek</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW₁</td>
<td>2.20</td>
<td>9200</td>
<td>30</td>
<td>0.0370</td>
</tr>
<tr>
<td>SW₂</td>
<td>1.95</td>
<td>5600</td>
<td>30</td>
<td>0.0228</td>
</tr>
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<td>SW₃</td>
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<td>30</td>
<td>0.0284</td>
</tr>
<tr>
<td>SW₄</td>
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<td>7400</td>
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<td>14.83</td>
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<tr>
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</tr>
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<td>SW₁</td>
<td>6.86</td>
<td>9800</td>
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</tr>
<tr>
<td>Little Cottonwood Creek</td>
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<tr>
<td></td>
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a Average values for the subzones
CHAPTER III

MODELING THE HYDROLOGIC COMPONENT OF THE SYSTEM

Introduction

Urban land use planners must work with a limited available land area in supplying the needs of the community for housing, commerce, industry, recreation, and transportation. Interspersed over the same land area, the hydrologic system must carry away treated waste effluent and often supplies water used by those downstream. Simultaneously, it must carry away the storm runoff from the city but convey the flow at sufficiently low rates so as not to inflict excessive flood damages.

Planners with urban flood water management responsibility need quantitative information on how storm runoff is affected by various urban land use patterns 1) so that they can effectively design structural measures for conveying the flood water through the urban area and/or 2) select nonstructural measures to keep damageable property out of the way of the flooding that does occur. One approach to getting this information and using it in design is computer simulation using a mathematical model to investigate the behavior of the system. In the study reported here, a computer model is used to simulate the hydrologic responses of an urban watershed from measured variables representing urbanization. The model represents the system by functions which describe various physical phenomena on the watershed and can be used to appraise proposed changes within the corresponding prototype.

The Conceptual Models of the Hydrologic System

The hydrologic models utilized in this study are outgrowths of those developed earlier for both rural and urban watersheds (Narayana et al., 1969, Evelyn et al., 1970, Shih, 1971, and Chambers, 1973). The hydrologic models are developed through mathematical representation of the various hydrologic processes and routine functions that are not specific to any particular geography.

The outflow hydrograph is modeled by chronologically deducting from precipitation input losses due to interception, infiltration, and depression storage and then routing the residual through surface and channel storages (Figure 3.1). Testing and verification of the basic mathematical model is done by using observed rainfall and runoff data from instrumented watersheds. The coefficients representing interception, depression storage, and infiltration are calibrated by trial-and-error matching of the outflow hydrograph predicted.

[Figure 3.1. Schematic representation of the steps used to obtain the runoff hydrograph.]
by the model with the corresponding measured hydrograph from the prototype. From the results, relationships between model coefficients and various urbanization characteristics, such as percent impervious cover, are established. These relationships then can be applied in predicting the effects of future urban development. For urban flood studies, only surface runoff need be considered. The relevant processes for both rural and urban drainage areas are shown within the dotted line of Figure 3.2.

Experimental and analytical results also are used in establishing and testing the mathematical relationships included with the model. Hydrologic parameters needed for operation of the hydrologic model are estimated: 1) from available data, 2) by statistical correlation techniques, and/or 3) through calibration of the model itself.

The Hydrologic Balance

A dynamic system consists of 1) a medium or media acted upon, 2) a set of constraints, and 3) an energy supply or driving force. In a hydrologic system, water is the medium of interest. The constraints are properties of the physical basin, and the driving forces are supplied by solar energy, gravity, and capillary potential. The flow of water through the system is governed by principles of continuity of mass and momentum. Except where high velocities are encountered, such as in channel flow, the effects of momentum are negligible, and the continuity of mass predominates.

Continuity of mass is expressed by the equation:

\[ \text{Output} = \text{Input} \pm \text{Change in storage} \cdots (3.1) \]

A hydrologic balance is the application of this equation to physical or hydrologic measurements within a particular unit. It provides a basis for routing to predict the movement of water through a system in space and time. The inputs to a hydrologic unit are precipitation and surface and groundwater inflow while the output is divided among surface outflow, groundwater outflow, and evapotranspiration. As water passes through, storage changes occur on the land surface, in the soil moisture zone, in the groundwater zone, and in the stream channels. These changes occur rapidly in surface locations and more slowly in the subsurface zones.

![Figure 3.2. A schematic diagram of a typical hydrologic system.](image)
Time and Space Increments

The increments of time and space need to be carefully selected during model design. Data, such as temperature and precipitation readings, usually are available as point measurements in time and space, and integration in both dimensions usually is accomplished by the method of finite increments.

The complexity of a model to represent a hydrologic system varies with the magnitude of the time and space increments utilized. Large increments, however, cannot be used for phenomena which change over relatively small increments of space and time. In addition, the time increment can be chosen to coincide with the period of cyclic changes in certain hydrologic phenomena so that net changes in these phenomena during a time interval are usually negligible. For example, storage changes within a hydrologic system from year to year are often insignificant whereas, the magnitude of these changes from month to month are frequently appreciable and need to be considered. As one attempts to achieve finer resolution in time and space, improved definition of the hydrologic processes is required. Short-term transient effects or appreciable variations in space cannot be neglected, and the required mathematical model, therefore, becomes more complex with an accompanying increase in required computer capacity and capability.

However, as shown on Figure 3.2, it is often possible to simplify high resolution models by eliminating processes which do not appreciably affect the output of interest. For example, in modeling the rural portions of the watershed, both a daily time increment (Figure 3.3) and an hourly time increment (Figure 3.4) were used. For the daily time increment model, all of the hydrologic processes are included. On the other hand, to estimate peak surface runoff rates from cloudburst storms, some processes, such as snowmelt and soil moisture movement, need not be included but a high degree of resolution in the time dimension is necessary. For this reason, the hourly time increment model (Figure 3.4) represents fewer processes than the daily model, but at a high degree of time resolution. Thus, the application is a prime consideration in model formulation.

For the urban hydrology model of the study, a 30-minute time increment and small space units (zones) were adopted. Zones were defined to enable spatially varying watershed conditions, such as slope and infiltration rate, to be considered by the model and marked off as shown by Figure 2.2 along hydrologic boundaries matching points of data availability. The probable issues in reaching flood management decisions were considered in selecting the time and space increments for the models.

System Processes

The system processes included in the hydrologic models of this study (for both urban and rural drainage areas) are discussed in the following paragraphs.

Precipitation

Water enters the hydrologic system as precipitation. Precipitation on a catchment area is estimated by a spatial integration technique, such as the isohyetal method or the Thiessen weighting procedure, from point data from a gage network. The Thiessen network was applied in this study (Figure 2.7), and the input hydrographs for individual storm events were determined by a computer program. Since rain causes the major flood events in the Salt Lake Valley, the snow accumulation and melt processes are not included in the model.

Surface Water Inflows

Streamflow is precipitation which streams and rivers collect from a drainage area. If only a portion of the drainage area is included within the boundary of the area being modeled, streamflow inputs to the modeled area are either measured or estimated by correlation.

Interception

Rainfall excess is calculated by subtracting interception on the leaves of trees and other intercepting objects from the measured precipitation. The rate of interception is assumed to reduce exponentially with an increase in interception storage, and can be expressed as follows:

\[ i_{cc} = i_{ea} \cdot \frac{P}{S_{l}} \quad \ldots \ldots \ldots \ldots (3.2) \]

in which

- \( i_{cc} \) = capacity rate of inflow into interception storage
- \( i \) = rate of precipitation
- \( P \) = cumulative precipitation
- \( S_{l} \) = volume of interception storage capacity expressed as an average depth over the catchment area

The actual interception rate, \( i_{ea} \), is defined by the following expressions:

\[ i_{ea} = i, \text{ for } i \leq i_{cc} \quad \ldots \ldots \ldots \ldots (3.3) \]

and

\[ i_{ea} = i_{cc}, \text{ for } i > i_{cc} \]
Figure 3.3. Flow chart showing the various hydrologic process represented within the daily time increment model.

Figure 3.4. Flow chart showing the various hydrologic process represented in the hourly time increment model.
The effective precipitation rate, \( i_e \), (that which occurs after interception is satisfied) is expressed by the following equations:

\[
\begin{align*}
i_e &= 0, \quad \text{for } i \leq i_c \quad (3.4) \\
i_e &= i (1 - e^{-P/S_d}), \quad \text{for } i > i_c
\end{align*}
\]

Most of the moisture accumulated in interception storage is lost through evaporation; however, little evaporation occurs during short duration storms.

**Infiltration**

Infiltration loss is represented in the model as a function of time in accordance with the form proposed by Horton and used by Narayana et al. (1969).

\[
f = f_c + (f_o - f_c) e^{-k_f t} \quad \quad (3.5)
\]

in which

\[
\begin{align*}
f_c &= \text{instantaneous potential infiltration rate} \\
t &= \text{time measured from the beginning of the infiltration period} \\
f_c &= \text{constant infiltration rate which } f \text{ approaches asymptotically with time} \\
f_o &= \text{initial infiltration rate at } t = 0 \\
k_f &= \text{positive coefficient depending upon the soil characteristics}
\end{align*}
\]

The actual rate of infiltration, \( f_a \), is the smaller of either 1) the rate of water supply, \( i_e \), and 2) the potential infiltration rate given by Equation 3.5. Thus,

\[
f_a = i_1, \quad \text{for } i_2 < f
\]

and

\[
f_a = f, \quad \text{for } i_2 > f \quad \quad (3.6)
\]

The actual infiltration rate, \( f_a \), follows the effective precipitation hyetograph, \( i_1 \), as long as precipitation rates are less than the potential infiltration rate curve. When precipitation exceeds potential infiltration, actual infiltration rate is limited to \( f \). The initial infiltration rate \( f_o \) depends on the prevailing soil moisture status at the beginning of the storm event.

**Surface Depression Storage**

The capacity rate of inflow into depression storage is expressed by the equation

\[
\Delta c = i_2 e^{-\frac{(P_1 - F)}{S_d}} \quad \quad (3.7)
\]

in which

\[
i_2 = (i_1 - f) = \text{net rate of precipitation after satisfying interception and infiltration}
\]

\[
P_1 = \text{accumulated rainfall having satisfied interception storage}
\]

\[
F = \text{accumulated infiltration loss}
\]

\[
S_d = \text{total volume of available depression storage (expressed as mean depth over the entire catchment area)}
\]

\[
\Delta c = \text{capacity rate of inflow into depression storage}
\]

The actual rate of inflow into depression storage, \( \Delta c \), at any time is expressed in accordance with limiting conditions as follows:

\[
\Delta c = i_2, \quad \text{for } i_2 \leq \Delta c
\]

and

\[
\Delta c = \Delta c, \quad \text{for } i_2 > \Delta c \quad \quad (3.8)
\]

**Hydrograph of Rainfall Excess**

The hyetograph of rainfall excess is computed by sequentially deducting the losses due to interception, infiltration, and depression storage from the hyetograph of precipitation in compatible, finite, time increments (Figure 3.5).

**Overland-Channel Routing**

Narayana et al. (1969) adopted the linear procedure of "storage routing" wherein the storage effects (overland and channel components) of the catchment area are accounted for by using the characteristic time of the catchment area.

The general continuity equation for any linear storage system is given as follows:

\[
P_e \cdot Q = \frac{dS_t}{dt} \quad \quad (3.9)
\]

in which

\[
P_e = \text{rainfall excess rate} \\
Q = \text{runoff rate} \\
S_t = \text{catchment area storage (overland and channel components)}
\]

Catchment area storage is considered as being directly proportional to the outflow rate. Thus,

\[
S_t = t_R Q \quad \quad (3.10)
\]

in which

\[
t_R = \text{a proportionality factor approximated by the hydrograph rise time}
\]

The equation derived by Espey et al. (1965), for 30-minute unit hydrographs of urban watersheds, expressed the time of rise as a function of the channel length and the mean slope of the catchment area. Hence,
The runoff rate, \( Q \), at the outlet of a single catchment area is obtained by solving the differential Equation 3.11.

Channel Routing

The outflow hydrographs at the discharge point of each subzone are generated by applying the urban watershed model. The computed discharge for a particular zone is then routed and combined with the discharge from the adjacent downstream zone, and the procedure is continued until the outlet of the watershed is reached. A channel routing technique was devised by Evelyn et al. (1970) to combine subzone discharges to produce the outflow hydrograph from the entire basin. The method is based on the assumption that the channel or storm drain is a linear storage reservoir. Hence,

\[
P_e \cdot Q = t_R \frac{dQ}{dt}. \quad \therefore \quad (3.11)
\]

in which

- \( Q_1 \) = rate of inflow into the section at the upstream boundary between subzones
- \( Q_o \) = rate of outflow from the section at the boundary with the adjacent downstream subzone
- \( S_c \) = instantaneous volume of channel storage
- \( T_L \) = proportionality factor between \( S \) and \( Q_o \) which represents the time lag of water flowing between upstream and downstream channel sections

Substituting Equation 3.13 into Equation 3.12 gives:

\[
P_i \cdot Q_o = T_L \frac{dQ_o}{dt}. \quad \therefore \quad (3.14)
\]

Use of the linear storage system analogy for channel routing necessitated derivation of an expression for the characteristic lag time, \( T_L \), in Equation 3.14. This lag time represents the time required for flow to move

---

Figure 3.5. Schematic flow chart for obtaining hydrograph of rainfall excess.
through a channel of length, \( L \). In order to simplify the analysis, a rectangular channel cross-section was assumed. Appropriate parameters of width and depth of flow can be substituted to represent a particular storm drainage system. If \( b \) is assumed to represent channel width and \( y \) the depth of flow, the cross-sectional area of flow, \( A \), is given by:

\[
A = by \quad \ldots \ldots \ldots \ldots \quad (3.15)
\]

and the wetted perimeter, \( p \), is

\[
p = b + 2y = b \quad \ldots \ldots \ldots \ldots \quad (3.16)
\]

Manning’s open channel flow equation is

\[
Q = VA = 1.49 \frac{AR^{2/3} S^{1/2}}{n} \quad \ldots \ldots \ldots \ldots \quad (3.17)
\]

in which

- \( Q \) = discharge in cfs
- \( S \) = channel slope in ft/ft
- \( n \) = Manning’s roughness coefficient
- \( R \) = hydraulic radius = \( A/P \)
- \( R^{2/3} = (A^{2/3})/(P^{2/3}) = y^{2/3} \)

Therefore,

\[
Q = 1.49 \left( \frac{by}{n} \right) y^{2/3} S^{1/2} = 1.49 \frac{bS^{1/2}}{n} \quad (y^{5/3}) \quad \ldots \ldots \ldots \ldots \quad (3.18)
\]

Solving for \( y \) as function of \( Q \),

\[
y = f(Q) = \left( \frac{n}{1.49 \ b S^{1/2}} \right)^{3/5} Q^{3/5} \quad \ldots \ldots \ldots \ldots \quad (3.19)
\]

\[
y = KQ^{3/5} \quad \ldots \ldots \ldots \ldots \quad (3.20)
\]

in which

\[
K = \left( \frac{n}{1.49 \ b S^{1/2}} \right)^{3/5} \quad \ldots \ldots \ldots \ldots \quad (3.20)
\]

\( T_L \) can then be estimated as a function of instantaneous discharge by the computer program as:

\[
T_L = \frac{\text{distance}}{\text{velocity}} = \frac{L A}{Q} \ 	ext{Lby} \quad \ldots \ldots \ldots \ldots \quad (3.21)
\]

Substituting Equation 3.19 into Equation 3.21 yields

\[
T_L \ = \ L \frac{b K Q^{0.6}}{Q} = L b K Q^{-0.4} \quad \ldots \ldots \ldots \ldots \quad (3.22)
\]

\( T_L \) is thus given in terms of readily obtained channel or storm drain design dimensions. Dividing Equation 3.22 by 60 gives \( T_L \) in minutes.

By assuming a linear distribution of inflow into the channel or the storm drain system along its length, the added \( Q \) within a subzone is

\[
Q_l + Q_o \quad \ldots \ldots \ldots \ldots \quad (3.23)
\]

\( Q_l \) and \( Q_o \) are the discharge within the subzone and the upstream storm drain, respectively. Narayana et al. (1969) did not use a lag time concept in their study because a single watershed area was assumed and routing was not required. The Evelyn et al. (1970) study utilized a subzone approach and a lag time parameter which was reduced to a constant based on subzone characteristics and peak discharge rates from individual storm events. The discharge for each subzone was assumed proportional to the area drained. The lag time parameter for each subwatershed therefore was expressed in terms of the peak discharge at the outflow point of the most downstream subzone. The method (Evelyn et al., 1970) gave satisfactory results. This lag time parameter, in essence, had an attenuation effect on the outflow hydrographs and increased the recession time. The time of the peak discharge was not shifted, however.

In this study, discharge rates are determined for each subzone and used to calculate the lag time parameter. The lag time parameter is applied to calculate the time shift due to channel routing effects by dividing the lag time parameter into the time scale and then rounding to the nearest integer. In routing the upstream hydrograph is delayed by the calculated number of time units. This process is continued for each subzone until the outflow hydrograph is computed for the entire watershed area.

Model Verification

Computer Synthesis

The computer model was produced by programming the mathematical relationships and logic functions described above. The model is analogous to the prototype to the degree that the mathematical relationships represent real world conditions. A mathematical function which describes a basic process, such as evapotranspiration, is applicable to many different hydrologic models. A simulation model incorporates general equations of the various basic processes which occur within the system. The result, therefore, is free of the geometric restrictions characteristic of network analyzers and physical models. The model is applied to a particular prototype system by establishing, through a calibration procedure appropriate values for the "constants" of the equations used.

Model Verification

Hydrologic models require verification. Verification is performed in two steps, namely calibration, or system identification, and testing (described in a
later section). Data from the prototype system are required in both phases. Model calibration involves adjustment of the values used for the variable model parameters until a close fit is achieved between observed and computed output functions. It, therefore, follows that the accuracy of predictions from the model cannot exceed that provided by the historical data from the prototype system.

Estimation of the model parameters can be either by trial and error or by a computerized search. In this study, the computerized pattern-search procedure described by Hill et al. (1970) was used. Each parameter is assigned an initial value, an upper and lower bounds, and a number of increments to cover the range between the assigned bounds. The first selected variable is varied through the specified range while all other variables remain at their initial value. A measure of the difference between the recorded and the synthesized flows for each value of the variable is printed, and the value which produced the minimum is stored. The first variable is reset to its initial value, and the second variable is taken through the same procedure. After all parameters have been varied, the set of values which produced each local minimum becomes the new set of initial values and the procedure is repeated. The process is continued until a reasonable match is achieved between computed and observed outflows. Because it is the objective of the program to minimize the difference between the observed and the computed plots, the measure of the difference is termed the "objective function." In the case of this program the objective function is computed by summing the squares of the differences at specific time points between the two traces.

It should be noted that the range of values tested for a given parameter is based on the judgment and experience of the programmer. However, selection is tempered by the experience gained from during the process. Thus, calibration effectively uses all previous experience, including that gained during the procedure.

Model Calibration for the Rural Watersheds

The runoff from the rural portions of the study area was simulated by means of both a daily model and an hourly time increment model (Figures 3.3 and 3.4), with the hourly model being used to simulate the high flow rates from rapid-runoff producing events. The basic precipitation data available for the study area are daily totals from the non-recording gages (Figure 2.7) and data published in the form of "Hourly Precipitation Data" by the U. S. Department of Commerce for the recording gage. The daily information from the non-recording gages was then distributed hour by hour over the day proportional to the observed data from the recording gage by assuming the time distribution of precipitation at the recording gage represents that over the watershed as a whole. It is recognized that this might not be true, especially during convective storms.

As indicated by Figure 1.1, Mill, Big Cottonwood, and Little Cottonwood Creeks are each gaged at the canyon mouth. This point represents outflow from the rural portion of each drainage and inflow to the urbanizing portion. Because adequate streamflow records are not available farther upstream for either the Big or the Little Cottonwood Creeks, it was necessary to model the rural watershed areas for these two streams as a single space increment. However, for Mill Creek, a stream-gaging station situated at Mill Creek Canyon (Number 1698) enables the rural portion of the Mill Creek watershed to be modeled in two space increments.

The application of the daily and the hourly time increment models to both gaged and ungaged areas of the three watersheds is illustrated by the following discussion of Mill Creek (gaged) and Neff's Canyon (ungaged). Similar procedures were followed elsewhere.

Daily time increment model.

Because no surface runoff records were available for the Neff's Canyon, the model was calibrated first for the two subwatersheds of Mill Creek, using data for the water years 1962 and 1963. A study was conducted to examine the influence or effects on the value of the output function of changing each parameter. This kind of study is termed a sensitivity analysis, and those parameters which cause major changes in the output are said to be sensitive. The calibrated parameter values for the two watersheds are shown by Table 3.1 in order of decreasing sensitivity, or relative importance to system response characteristics. In other words, the model suggested that the parameter which has the most influence on the outflow hydrograph to be the available moisture storage capacity of the soil at the beginning of the storm event. Thus, antecedent soil moisture conditions (or the soil moisture levels at the beginning of a runoff producing event) were found to have considerable influence on the ensuing hydrograph.

Table 3.1 also indicates the values of the watershed parameters selected for Neff's Canyon. These values were determined on the basis of experience and information gained in the calibration of the two nearby Mill Creek subwatersheds. The basins have similar topography, elevation, aspect, soil types, and vegetation and are adjacent to one another and subject to the same climatological patterns.
Table 3.1. Optimized parameter values\(^a\) for the upper and lower subwatersheds of Mill Creek (after Shih et al., 1976).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFC</td>
<td>Field capacity of soil (inches)</td>
<td>MillCreek Upper Subwatershed 6.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 5.0</td>
</tr>
<tr>
<td>TBF</td>
<td>Base flow decay constant (day(^{-1}))</td>
<td>MillCreek Upper Subwatershed .004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .005</td>
</tr>
<tr>
<td>GLL</td>
<td>Ground water storage level above which sub-surface outflow occurs (inches)</td>
<td>MillCreek Upper Subwatershed 4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 5.0</td>
</tr>
<tr>
<td>TGW</td>
<td>Interflow decay constant (day(^{-1}))</td>
<td>MillCreek Upper Subwatershed .04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .03</td>
</tr>
<tr>
<td>QK</td>
<td>The fraction of outflow from soil moisture that becomes interflow</td>
<td>MillCreek Upper Subwatershed .15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .20</td>
</tr>
<tr>
<td>SMR</td>
<td>Snow melt rate (inches/day F)</td>
<td>MillCreek Upper Subwatershed .11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .07</td>
</tr>
<tr>
<td>ETF</td>
<td>Evapotranspiration factor</td>
<td>MillCreek Upper Subwatershed .59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .50</td>
</tr>
<tr>
<td>TAUSW</td>
<td>Surface runoff decay constant (day(^{-1}))</td>
<td>MillCreek Upper Subwatershed .30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .50</td>
</tr>
<tr>
<td>SI</td>
<td>Upper limit of interception storage (inches)</td>
<td>MillCreek Upper Subwatershed .40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .40</td>
</tr>
<tr>
<td>FC</td>
<td>Minimum value of infiltration (inches/day)</td>
<td>MillCreek Upper Subwatershed 2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 1.0</td>
</tr>
<tr>
<td>DKT</td>
<td>Infiltration decay constant</td>
<td>MillCreek Upper Subwatershed 2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 1.5</td>
</tr>
<tr>
<td>SS</td>
<td>Saturated soil level (inches)</td>
<td>MillCreek Upper Subwatershed 12.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 13.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 13.0</td>
</tr>
<tr>
<td>WILT</td>
<td>Wilting point of the soil (inches)</td>
<td>MillCreek Upper Subwatershed 1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 1.0</td>
</tr>
<tr>
<td>ROS</td>
<td>Factor related to snow melt by rain</td>
<td>MillCreek Upper Subwatershed .01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .01</td>
</tr>
<tr>
<td>TRAIN</td>
<td>Temperature above which all precipitation falls as rain</td>
<td>MillCreek Upper Subwatershed 35.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed 35.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon 35.0</td>
</tr>
<tr>
<td>CPF</td>
<td>Channel precipitation factor</td>
<td>MillCreek Upper Subwatershed .003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .003</td>
</tr>
<tr>
<td>FNGM</td>
<td>Factor related to ground melt in snow pack</td>
<td>MillCreek Upper Subwatershed .02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .023</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .02</td>
</tr>
<tr>
<td>TFWFBN</td>
<td>Decay constant for drainage of free water from snow pack (day(^{-1}))</td>
<td>MillCreek Upper Subwatershed .10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Subwatershed .18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neff’s Canyon .15</td>
</tr>
</tbody>
</table>

Mean value of the objective function (inches per unit area) 1.53 3.24 NA

Mean annual stream flow (inches per unit area) 6.97 10.15 NA

Ratio of mean objective function to mean annual streamflow .22 .32 NA

\(^a\) Parameters are shown in decreasing order of sensitivity.

The transfer of parameter values from one watershed to another is not an ideal procedure but can be used when one has no other suitable runoff records for calibration. Factors favoring this method in this case are listed above; however, there are differences in the geology of the Mill Creek and Neff’s Canyon watersheds. Some information on these differences (taken by Calvin G. Clyde (1974) in a geology class some years ago at the University of Utah) is summarized below.

In 1948, some measurements were made by Salt Lake County of water flow rates from Neff’s Canyon. A geologic survey of the canyon at that time also indicated the presence of glacial moraine and two faults. The Mt. Olympus Spring Company had submitted an application to direct water from Neff’s Canyon, and County officials were concerned that perhaps these waters supplied the Spring Creek, Castro, and Dry Creek Springs which are situated on the lower slopes of Mt. Olympus above the urbanizing area of the cove. In 1950 three students from the University of Utah discovered a cave in Neff’s Canyon. It was found that the limestone cavern extended a distance of 1,170 feet from the portals to a point where water blocked the way. It was speculated that this water leaves the stream bed at the fault lines and flows through the cavernous limestone to the three springs mentioned above. To confirm this speculation, dye was placed in the waters of Neff’s Canyon at a point upstream from the fault lines. This dye appeared at the springs 27 hours later and persisted for four days. During the spring runoff period of 1948 the total surface discharge from the Neff’s Canyon drainage was measured at 330 acre feet per square mile. It was estimated that if the flows from the three springs during this same period were added to this figure, the total runoff from the watershed would be 1,800 acre feet per square mile. This figure is consistent with precipitation on the watershed during the winter of 1948 as estimated from snow survey data.

On the basis of the geologic differences between the Mill Creek and Neff’s Canyon watersheds the unit surface runoff might be expected to be less from Neff’s Canyon than that from Mill Creek, all other factors being equal. For this reason, the parameters on Table 3.1 for Neff’s Canyon might overestimate the surface runoff from the watershed.
Nevertheless, the results for Neff's Canyon are comparable with those obtained in an independent analysis made by the Corps of Engineers (1969b). The Corps study predicts the peak flow at the mouth of Neff's Canyon for a "100-year" storm to be 1500 cfs. This model predicts 1490 cfs, at an antecedent soil moisture level of 11 inches.

**Hourly-time-increment model.**

It was also necessary to calibrate the hourly model on Mill Creek and to transfer the resulting parameter values, with appropriate adjustment, to the drainage areas of Neff's Canyon. The lower Mill Creek subwatershed was selected for this calibration process.

Some parameter values for the hourly-time-increment model were taken to be the same as those found for the daily time increment model. For example, soil field capacity remains unchanged for both time increments. Other parameters, such as the interflow time delay constant, are a function of the model time increment. Such parameter values were selected from the results of the simulation of the lower Mill Creek subwatershed on an hourly basis. The same calibration procedure was used for both the daily and hourly models.

The size of the Mill Creek watershed is not suitable for simulation on an hourly basis. Given the existing data network for hourly precipitation, it is difficult to say what proportion of the watershed is covered by the storm, and is, therefore, contributing to the gaged watershed outflow.

In transferring parameter values from Mill Creek to Neff's Canyon, and later to the urbanizing area of Olympus Cove, the effects of differences in areas were taken into account, where necessary. Parameter values, such as the time delay constant in the surface water routing equation were adjusted for the decrease in size of the watershed. The finalized parameter values used for the hourly time increment simulation of the rural portions of the study area (Figure 1.1) are shown in Table 3.2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>Saturated soil level (inches)</td>
<td>13.0</td>
</tr>
<tr>
<td>SFC</td>
<td>Field capacity of soil (inches)</td>
<td>6.0</td>
</tr>
<tr>
<td>FO</td>
<td>Maximum infiltration capacity rate (inches/hr)</td>
<td>1.0</td>
</tr>
<tr>
<td>FC</td>
<td>Minimum infiltration capacity rate (inches/hr)</td>
<td>.20</td>
</tr>
<tr>
<td>DKT</td>
<td>Decay constant in infiltration equation (hr)</td>
<td>2.0</td>
</tr>
<tr>
<td>TAUSW</td>
<td>Decay constant in surface water routing (hr/hr)</td>
<td>.50</td>
</tr>
<tr>
<td>TGW</td>
<td>Decay constant in interflow routing (hr/hr)</td>
<td>.01</td>
</tr>
<tr>
<td>QK</td>
<td>The fraction of outflow from soil moisture storage that becomes interflow</td>
<td>.30</td>
</tr>
<tr>
<td>SI</td>
<td>Upper limit of interception and depression storage (inches)</td>
<td>.20</td>
</tr>
</tbody>
</table>

**Daily time increment model.**

Following calibration for the two subwatersheds of Mill Creek, the parameter values given by Table 3.1 were used to simulate five years of record at each of the two stations. Sample comparisons with observed hydrographs are shown by Figures 3.6 and 3.7 for the upper and lower subwatersheds, respectively. At the bottom of Table 3.1, the mean value (over the five years of simulation) of the objective function is given for the two Mill Creek subwatersheds. The table also includes the ratio of the mean yearly objective function to mean yearly streamflow, a quantity termed the relative objective function.

While without data it was not possible to test the model for Neff's Canyon, the runoff predictions were comparable with those of the lower Mill Creek and are shown by Figure 3.8. Runoff is computed at the points of discharge indicated on Figure 1.1.

**Hourly time increment model.**

This model was tested by generating runoff hydrographs associated with several short duration, high intensity rainfall events on the lower Mill Creek subwatershed. The computed and observed hydrographs for two of these events are shown by Figure 3.9.

**Model Calibration for the Urban Watersheds.**

As previously indicated, the time increment adopted for the urban model is 30-minutes. As for the rural models, the precipitation data available for calibrating the urban model are daily total from non-recording gages and data from a recording gage (Fig...
Figure 3.6. Hydrographs of observed and computed streamflow at Gaging Station No. 1698 on Mill Creek for the water year 1964.
Figure 3.7. Hydrographs of observed and computed streamflow at Gaging Station No. 1700 on Mill Creek for the water year 1964.
Figure 3.8. Hydrograph of computed runoff from Neff's Canyon for the water year 1964.
Figure 3.10. Isohyetal lines for the event of May 22-23, 1968.

ure 2.7) published as "Hourly Precipitation Data" by the U.S. Department of Commerce. By interpolation from the hourly data estimates were made of the 30-minute precipitation quantities of the recording gage. The daily information from the non-recording gages was distributed in time on the same basis as the observed data from the recording gage. The 30-minute precipitation thus computed at each gage location was spatially distributed in accordance with the Thiessen network of Figure 2.7. Some questions might be raised on the use of the Thiessen procedure rather than isohyetal lines. For illustrative purposes, Figure 3.10 shows isohyetal lines and the precipitation station totals for a single storm event. This procedure of spatially distributing point precipitation measurements is generally regarded as more accurate, but it is also more difficult to implement in a computer. Some isohyetal charts for specific events were developed, and significant differences were not detected between the results of the isohyetal and the Thiessen weighing methods. Because it is readily implemented on the computer, the Thiessen technique was adopted for this study.

Calibration of the urban model was based on prototype data from three storms. Model output was compared to measured flow by using the sum of the squared deviations as the objective function for the pattern search procedure described previously. The three storms gave varying values for the five parameters, and an average value was selected to provide the closest agreement between predicted and observed hydrographs for the three storms.

In order to vary watershed parameter values with urbanization it was necessary to relate the para-
meters to urbanization characteristics. The equations used were of the form:

\[ S_f = a + bC_f + cL_f \]  \hspace{1cm} (3.24)

in which

- \( S_f \) = the volume of the interception storage capacity (Equation 3.2)
- \( C_f \) = the percentage impervious cover on the watershed (Chapter II)
- \( L_f \) = the characteristic impervious length factor (Chapter II).

The coefficients \( a \), \( b \), and \( c \) are determined for each watershed parameter from each of the three storms. For example, for \( S_f \):

\[ S_{f1} = a + bC_{f1} + cL_{f1} \] \hspace{1cm} (3.25)

\[ S_{f2} = a + bC_{f2} + cL_{f2} \]

\[ S_{f3} = a + bC_{f3} + cL_{f3} \]

\( S_f \) for each storm event (Equation 3.25) is determined by calibration and the three equations are solved for the three unknowns \( a \), \( b \), and \( c \). A similar set of equations was solved for the depression storage capacity, \( S_d \), the initial infiltration rate, \( f_o \), and the equilibrium infiltration capacity rate, \( f_c \). Each of these watershed parameters was thus expressed as a function of the two urban parameters, percentage impervious cover, \( C_f \), and characteristic impervious length factor, \( L_f \). From these relationships, values of the model parameters \( S_f \), \( S_d \), \( f_o \), and \( f_c \) were calculated as needed for particular values of the urban parameters (which characterize the degree of urbanization). A fifth watershed parameter, the hydrograph rise time, \( t_r \), was estimated as a function of the drainage area. The five equations thus established were:

\[ S_f = 0.272 - 0.203C_f + 0.222L_f \] \hspace{1cm} (3.26)

\[ f_o = 0.793 - 0.451C_f - 0.040L_f \] \hspace{1cm} (3.27)

\[ S_d = 0.113 + 0.072C_f + 0.168L_f \] \hspace{1cm} (3.28)

\[ f_c = 0.277 - 0.247C_f - 0.168L_f \] \hspace{1cm} (3.29)

\[ t_r = 0.144A \] \hspace{1cm} (3.30)

The above parameters for the entire area were used to calculate a combined runoff hydrograph from Big and Little Cottonwood Creeks for one storm. This hydrograph was then subtracted from the total recorded hydrograph to isolate the hydrograph for the third watershed (Mill Creek) for the chosen storm (say, storm number one). Then the model was calibrated to match this hydrograph, and a set of watershed parameters thus was determined Mill Creek for storm number one. Using the total watershed parameters for Big Cottonwood Creek and those just determined for Mill Creek, a combined hydrograph for these two watersheds was computed. By subtracting this hydrograph from the total hydrograph, the Little Cottonwood Creek hydrograph was isolated and used to estimate watershed parameters for the Little Cottonwood Creek. Finally, using the Mill Creek and the Little Cottonwood Creek parameters for the respective areas, a combined hydrograph was calculated and subtracted from the total watershed hydrograph. The resulting hydrograph was assumed to be the Big Cottonwood Creek and was used to determine values for the watershed parameters for that subwatershed. This procedure was repeated for the second and third storms, except that the order of subbasin selection was altered to prevent a bias from the order in which the storms were selected.

The above procedure was followed to estimate individual runoff hydrographs for three storms corresponding to each of the three watersheds within the study area. For each runoff event, the values of the watershed parameters \( S_f \), \( S_d \), \( f_o \), and \( f_c \) were determined from the model calibration procedure. The sets of equations of the form given by Equation 3.25 were solved for each parameter, and thus the coefficients \( a \), \( b \), and \( c \) were evaluated to produce equations for each of the three watersheds similar to those of Equations 3.26 through 3.29. The data covered a fairly broad spectrum of values for \( C_f \) and \( L_f \); for example, \( C_f \) varied between 10 and 50 percent. A fourth storm event (May 23, 1968) was used to test the equations. Figure 3.11 gives a comparison of the observed and computed total discharge rates on the Jordan River at stations 1705 and 1710 for this storm. Flow from Mill Creek at this time (station 1700) was negligible and not included in the calculations. Obviously, the results would have been better had the individual watershed outputs been gaged, but the method provides flood peak estimates for various levels of urbanization.

These equations could be used to estimate stream flow under all conditions of urbanization. Watershed data and precipitation data (U. S. Army Corps of Engineers, 1969a) for the desired return periods were used in the model to graph the peak discharge resulting from specified degrees of urbanization by frequency as shown in Figures 3.12, 3.13, and...
3.14. The predicted runoff rates from the urban areas of the watersheds for the precipitation events of various return periods are shown in Table 3.3. These flood peaks are estimated from precipitation events of assigned frequency, not from historical data, and represent the application of the model to the individual watersheds and a summation of the results for the entire drainage area.

Figure 3.11. A comparison between observed and computed outflow hydrographs from the study area in the Jordan River for the storm event of May 23, 1968.
Figure 3.12. Peak discharge rate for Mill Creek as a function of return frequency at different levels of urbanization.

Figure 3.13. Peak discharge rate for Big Cottonwood Creek as a function of return frequency at different levels of urbanization.

Figure 3.14. Peak discharge rate for Little Cottonwood Creek as a function of return frequency at different levels of urbanization.

Table 3.3. Precipitation and associated computed runoff rates corresponding to rainfall events or specific frequencies within the urban portion of the study area.

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Return Period</th>
<th>Duration of Precipitation Event</th>
<th>Precipitation Rate (inches)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 years</td>
<td>30 min.</td>
<td>.41</td>
<td>.52</td>
</tr>
<tr>
<td>Measurable</td>
<td>5 years</td>
<td>1 hr.</td>
<td>.60</td>
<td>.70</td>
</tr>
<tr>
<td>Precipitation</td>
<td>10 years</td>
<td>2 hr.</td>
<td>.75</td>
<td>.90</td>
</tr>
<tr>
<td>Pattern</td>
<td>25 years</td>
<td>3 hr.</td>
<td>.85</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>50 years</td>
<td>6 hr.</td>
<td>1.00</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>100 years</td>
<td>12 hr.</td>
<td>1.15</td>
<td>1.30</td>
</tr>
</tbody>
</table>

A. Precipitation in inches

B. Discharge in cubic feet per second (cfs)

<table>
<thead>
<tr>
<th>Stream and Station Number (see Figures 1.1 and 2.7)</th>
<th>Little Big Jordan River Little Cottonwood Creek Big Cottonwood Creek Mill Creek Jordan River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff</td>
<td>1673 1677 1685 1700 1705</td>
</tr>
<tr>
<td>Return</td>
<td>200 2100 1000 200 2500</td>
</tr>
<tr>
<td>Period</td>
<td>2 years 5 years 10 years 25 years 50 years 100 years</td>
</tr>
<tr>
<td>Discharge Rate</td>
<td>900 1300 1700 2100 2400 2700</td>
</tr>
<tr>
<td>Discharge Rate</td>
<td>100 600 900 1200 1400 3000</td>
</tr>
</tbody>
</table>

From records published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.
CHAPTER IV
CONCEPTUAL MODEL OF THE FLOOD CONTROL DECISION SOCIAL SYSTEM

The sociological system like the hydrologic system, is modeled by identifying its basic elements and developing linkage functions among them. The assumptions made to do so must be plausible without introducing extreme complexity. The conceptual model is shown in Figure 4.1. The public opinion stage includes general societal or cultural values as well as values specific to flood behavior. The governmental agencies act in rational goal orientation, coordinative and mission functions. Finally, the conceptual model includes the participative functions of the public within a wide diversification of interest groups, local communities and mass media.

The mathematical model was built through a pragmatic, descriptive, linear, systems approach. The elements in the system were derived from interviews with officials in public agencies, individuals from private engineering firms, and individuals selected randomly to represent the public.

Developing the Conceptual Model

Designing a Flow Chart of the Conceptual Model

Figure 4.1 diagrams in more detail the broad subsystems in the preliminary chart of Figure 1.4. Figure 4.1, however, is still a simplification of the real world as it represents the flow of action from one behavioral process to another and of linkages between the sociological and hydrologic components of the total system. Some processes may occur simultaneously and some agencies may perform more than one of the functions shown; however, all elements of the process occur, and they are illustrated in the figure in a logically sequential order. Interruption of the process produces a recycling or feedback.

Basic Model Elements in Flood Control

An examination of the basic elements of non-emergency flood control actions shows seven key evaluation considerations:

1. Flood control ability and the hydrologic system characteristics
2. Cost
3. Aesthetics
4. Recreation
5. Ecology
6. Acceptance of an action by other agencies than the one acting
7. Acceptance of an action by relevant populations and interests.

The first five of these factors are concerned with the characteristics of the proposal for remedial action and the last two are concerned with attitudes. Each factor is discussed below.

"Flood control ability," an engineering and hydrologic factor, includes: 1) The degree to which a particular action provides a total solution to a flood problem, and 2) the duration of the solution. When combined, these two elements consider the flood control potential of a particular project under given hydrologic and other conditions and also include implications for both the present and the future. Both the dynamics of return probabilities and of continuing land use changes must be considered.

"Cost" needs to be estimated with respect to each agency in order to determine agency differences in considering economic aspects of projects. A limitation may exist on the time, dollars, or other resources available during a certain period preventing certain potential solutions. Benefit-cost ratios are often used in planning, but the factors considered as benefits and costs vary with the agency and the perceptions of its officials.

"Aesthetics" refers to values associated with the appearance of the proposed flood control solution and also its effects on the aesthetics of other objects or areas.

"Recreation" includes both recreation provided by a proposed solution and the effect of the proposal on other recreation.
Figure 4.1. Flow chart of the conceptual model of the sociologic-hydrologic system.
"Ecology" refers to the effect that a project has on the balance of nature or in other words on the relationships between organisms and their physical environment.

The remaining variables, "acceptance of an action by other agencies" and "acceptance of an action by relevant populations and interests," refer to the attitudes of "significant others" about the action. A "significant other" is defined in this context as any group whose attitudes influence the attitude of the first group concerned toward the object being evaluated.

For a particular flood control proposal to be acceptable to any group or agency, the value of each characteristic and attitude must meet certain minimum levels. If a proposal is sufficiently negative on any important function, it will be stopped. These minimum requirements are based on: 1) Standards set by outside sources, such as laws and regulations; 2) policy set within the planning or decision agency; 3) judgment of agency officials and administrators; and 4) influences from other groups. If public or agency attention is focused on negative aspects of a project, the chances of acceptance are decreased.

Elements of an Open System Model

In addition to the possibility of different agencies performing more than one function is more than one stage of the decision-making process there is also the possibility of several functions occurring within a stage. These functions provide for either an open system model or one which permits feedback for outside systems to impact the system at different stages. Figure 4.2 illustrates this for the first three stages and shows where public hearings and other external or internal inputs may occur. These sub-processes may or may not open up the system at all levels depending upon the methods used by the relevant agencies.

Figure 4.1 illustrates a traditional or nearly closed system approach to public agency planning, but the recent trend has been toward a greater public role in planning. This change has helped the agencies to adjust their system of decision-making to place greater emphasis on public input.

The model assumes that once a "need" has been identified and inserted into the public agency decision track that an agency will behave as a direction-oriented system to bring about a decision on that need. This is a theoretical problem of complex organization and includes both "structural" and "interactionist" concepts of a social system. "Social conflict theory" can also be useful in the analysis of the actions among various publics, special interests, and mission-oriented agencies in a public decision.

Elements of the Conceptual Model

Figure 4.1 is divided into six stages of human behavior in a public flood control decision. The model, as represented by these six sections, contains: 1) The state of public opinion, public perceptions of flooding and level of information about these problems; 2) the decision and planning agencies that are involved in the earliest stages of the decision that a plan is needed and develop the first plan; 3) the decision agency making the decision about the initial plan, or the structure for analysis and adoption of a plan; 4) the public reaction through an acceptance, adjustment or rejection process; 5) the making of the final decision with a subcycle for alternative actions; and 6) implementation. These six stages provide an organizational framework for the conceptual model. Difficulties were encountered in modeling some of these social components. As further insights into the system are developed, both the conceptual and mathematical models can be improved.

Section One: Public Opinion

The primary variable in the first stage of the flow chart is perception of a need for improved flood control in the local area. This was also identified as "general concern about flooding." This concern is expected to be directly affected by personal flooding experience and the extent to which a respondent is informed of local flooding problems. Assuming this expectation is correct, concern is directly linked to the hydrologic system. The frequency of occurrence and extent of flooding, and therefore the likelihood of personal experience with flooding problems, are largely functions of the hydrologic system.

A widespread perception among the public of a need for improved flood control would be expected to culminate into a consensus of a need for a plan by the flood-control decision agency since more people are likely to put pressure on the agency to control flooding. Experience within the study area has shown this to be true. Whenever people perceived that the likelihood of flooding was high, they tended to call the local County Flood Control Department to request action. This relationship should be true of long term dangers as well as immediate ones as long as the exposed population is aware of the situation. An attitude without overt behavior by people will exert little or no influence on a planning agency because the agency has no way of knowing that the attitude exists.

---

1 This would be under normal conditions. A strong enough anxiety over flooding could overcome other considerations and would be reflected in the public perception and need for flood control. This would occur in crisis situations where flooding is actually or potentially extremely serious.
I. Public Opinion stage

| Condition or general state of the public? degree of awareness, concern and interest or opposition | Emergence of a concern point, i.e., a party that acts as initiator for stating a need | Initiation action taken by either an agency, a group or an individual and moved to the formal decision tracks to a decision agency |

II. Early decision and planning agencies stage

<table>
<thead>
<tr>
<th>Discussion by agency planners</th>
<th>Decision Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>may include inputs of others, i.e., specific publics or experts</td>
<td>Problem identification by technicians</td>
</tr>
<tr>
<td></td>
<td>Need identified</td>
</tr>
</tbody>
</table>

Need High Enough By Public and Decision Agency

Yes

Planning Agency Activated

Technical Plan developed

Internal Planning Revisions

Plan Proposed

III. Initial plan decision stage

<table>
<thead>
<tr>
<th>Decision Agency Initial Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review consultation with reference groups and some elements of the public</td>
</tr>
</tbody>
</table>

IV. Public reaction stage

General Public Evaluation

V. Final decision stage

Decision Agency Final Evaluation and Review of Alternative

VI. Action stage

Final Action Implementation

Figure 4.2. Functions within each step of the decision-action process.
This variable of "general concern about flooding" is used in the model as an input to the public reaction stage which occurs after announcement of a flood control plan to the public. The perceived need affects the dependent variable in that section which is in turn fed back to the decision agency and affects its evaluation of a flood control plan.

Section Two and Three: Decision and Planning Agencies

The second and third stages of the conceptual model deal with functions of the decision and planning agencies. The second stage represents the initial official response as to whether action is needed and the initiation and formation of a preliminary plan for dealing with the problems. The third section represents the evaluation of the proposed plan and the decision to adopt it by the decision agency and the announcement to the public of the decision.

The manner in which the various agencies concerned with flood control in the Salt Lake test area were found to function is discussed in several parts: 1) Characteristics of the agencies responsible for flood control; 2) the role of social power in agency actions; 3) characteristics of the planning agencies; 4) planning and decision functions; 5) the manner in which agencies identify flooding problems; and 6) strategies used by agencies for evaluating possible solutions. Finally, the problem of distortions in evaluation is dealt with.

Characteristics of decision agencies

The decision agency, as specified in Figure 4.1, for the Salt Lake County study area was the County Flood Control Department. While many diverse individuals and groups hold property rights in the watershed, state law provides that county government has primary decision power on flood control activities and the powers to implement nonstructural programs through rules and regulations and to use the right of eminent domain to obtain land for structural measures. In the study area, the active county agencies are the County Flood Control Department, the County Planning and Zoning Department, and the Board of County Commissioners.

Through its enabling legislation, the Salt Lake County Flood Control Department has been given the charge to:

Assist the Board of County Commissioners in the discharge of responsibility for the gathering, control and disposal of storm drainage and flood water; for the conservation of such water for beneficial and useful purposes, and for the protection of personal property, public highways, and waterways within the county from damage resulting from such water.

The ordinance further states that the department, "shall administer all County ordinances pertaining to flood problems." (Revised Ordinances of Salt Lake County, Section 7/2/1.) Thus, the County Flood Control Department has broad responsibilities for water control activities in Salt Lake County and is considered to be the principal agency related to flood control.

The Salt Lake County Planning and Zoning Department, which in water related issues works with the County Flood Control Department, has authority to control land use changes within the tributary watershed. Watershed characteristics, such as the degree and rate of urbanization, are greatly affected by decisions of the County Planning and Zoning Department.

The County Flood Control and the Planning and Zoning Departments, subject to guidance and direction from the Salt Lake County Board of Commissioners, are the primary governmental sources of decisions for changes that affect the urban watershed within the study area. Under existing ordinances and rules directing the two agencies, decisions are made in close cooperation in the area being modeled. Because of this coordination, county government is treated as one decision agency in the model; neither the County Planning and Zoning Department nor the County Board of Commissioners is represented separately. Divisions of this nature could be introduced as needed in subsequent development of the model.

The supervisory role played by the Salt Lake County Board of Commissioners is important since the board not only provides general direction, but may also change the characteristics of the decision agencies themselves. In addition, at the local level, other municipal commissioners, mayors and associated agencies can have input and may be considered.

The role of social power in agency action

In order to determine the functional role of the various government agencies in flood control planning, several characteristics were examined which involve relationships between agencies and between agencies and other organizations, groups, and individuals. Included within these relationships were factors related to social power held by agencies or persons.

The power of an agency encompasses both authority and influence. Authority is power intrinsic to the agency and given to it to accomplish the tasks which the agency has been assigned. Influence is the ability to affect the behavior of other agencies, groups, or individuals without formal authority. As illustrations of these two types of power in Salt Lake County, the County Flood Control Department has the authority to decide whether a particular flood control meth-
od will be applied or not, but another agency that has either technical or financial resources necessary to the project may be able to affect a decision made by its power to control or withhold its resources. This ability to affect a decision indirectly is as important a type of power as authority.

Agency actions also are influenced by agency administrators who may view exactly the same situation in different ways. For this reason an effort was made to obtain information on both the perceptions held by the various agency administrators and the stated policies of the agency.

**Characteristics of planning agencies**

Planning agencies at the federal, state, and local levels also influence decisions made within the county. These agencies act primarily in a planning capacity while the county has the major decision-making power on what policies are implemented. This view is simplified but was adequate in developing the model.

Several agencies can act in a planning capacity. On the federal level, the Army Corps of Engineers plans for flood control. Provision has also been made in the model to consider inputs from private groups and consultants. The master storm drainage plan for the Salt Lake County area was designed by a private engineering firm engaged by the County Flood Control Department. The influence of various private citizen groups on the planning function can also be included in this section of the model.

**Planning and decision functions**

The planning and decision functions are performed by the model, Figure 4.1 within Sections Two and Three, respectively. Planning and decisions may be made by the same or by separate agencies, or several agencies may share responsibility for a single function and these functions may be conducted either sequentially or simultaneously or both. In the current version of the model, only one decision agency is identified, the County Flood Control Agency.

The impact of Section Three is decisions that are based on the evaluations made of the planning actions in Section Two. At this point, potential actions which might be supplied by the planning agencies are screened in order to reduce the number to be evaluated in Section Three. After screening, the decision agency evaluates each potential action by much the same procedure followed in the planning agency evaluation.

The second or planning section and the third or decision section of the model are designed to function in much the same way. As indicated by Figure 4.1, feedback from Section Three is sent to prior sections of the model. Output is the "preferred solution or solutions" to flooding and water control problems as determined by decision agency evaluations. In the case of favorable solutions mutually exclusive, the one with the largest positive evaluation is assumed to be chosen by the decision agency.

**Identifying flooding problems**

In the model represented by Figure 4.1, the section titled, "Planning Agencies" represents functioning bureaucracies whose missions are to define and solve urban flooding problems. These functions are performed within the limits of their organizational characteristics and responsibilities. An agency may be alerted to a flooding problem by either hydrologic information from that component of the model or by public perception of flood probabilities. Under normal conditions, a planning agency will continue to search for flooding problems by studying the hydrologic system. This is because it is characteristic of any bureaucracy to develop work in its area of responsibility and thereby maintain itself or grow in fulfilling its mission (Selznick: 25); this work must be within the prescribed legal and social limits of the bureaucracy.

The pressure exerted through public opinion may vary. When the public concern about flooding is high, the agency will seek changes to the hydrologic system which would reduce public concern. Public concern may be lowered through 1) feedback of "expert knowledge and opinion" which indicates a less serious flooding condition than originally supposed or, 2) through action to alleviate flooding conditions and by the subsequent feedback of this information from the hydrologic system (present condition of the physical system) to the Public Opinion section of the sociological model.

The Planning Agency section of the model is connected to the first part through the "pressure" described above. Even though the pressure or public perception of need for flood control is general, agencies may behave differently because some agencies are more sensitive to public pressure than others. This varying sensitivity and other differences are noted through differences in the characteristics of the particular agencies simulated in the model.

After a flooding problem is recognized, the agencies involved must decide whether or not action is needed to protect endangered property or persons. The decision depends upon 1) an evaluation of the conditions and factors in the hydrologic system, 2) the degree of development within the endangered area, and 3) the "pressure" coming from the first, or public, section of the model. If flooding occurs, an agency may feel pressured to get on an emergency basis, and an emergency decision process would be
used. Although the emergency situation is shown in Figure 4.3, it will not be considered further in a model designed to apply to flood control plans formulated under normal conditions.

_Evaluating non-emergency flooding solutions_

After examining government agencies in the study area, steps in their decision process were identified as shown in Figure 4.3, but the specific sequence may vary. The steps are described by Table 4.1. The major points are identification of important factors that determine agency action, all of which must be positive to some degree for action to occur. Resolution of problems will occur if no function is negative; otherwise, no action or an alternative action will occur.

Alternative actions to decrease the seriousness of a flooding problem are often possible. However, the solutions available to a particular agency are limited by the technological, economic, policy, and other capabilities that constrain the agency. In addition to these constraints, a solution selected for implementation is also a result of social factors. These social factors may be organizational, individual, or public.

Action decisions are made under internal and external controls and constraints. Internal constraints are due to the characteristics of the agency, and external constraints come from other social systems and existing agency relationships with those systems. Social power is important since a strong external influence can greatly affect the decisions which are made by a particular agency.

Agency characteristics or modes of thinking (Reich, 1962) act as a screen which eliminates certain solutions from potential use in controlling flooding and water problems. For this reason, the assumption is made in the model that each agency has a finite repertoire of solutions available for use. The number of solutions considered for each flooding problem is limited by the characteristics of the agencies seeking solutions.

_Distortion Factors (DF)_

A discrepancy between an actual value of a characteristic or attitude and what a group perceives it to be is referred to as a "Distortion Factor." "Distortion Factors" (DF) provide for differences between actual situations and the perception of these situations by officials of an agency. These biases or differences occur because of incomplete knowledge and because perception of information is distorted. If it could be assumed that an agency or other group had perfect knowledge about the attitudes of the public

<table>
<thead>
<tr>
<th>Table 4.1. Components of a decision in flood control action shown by Figure 4.3.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision blocks:</strong></td>
</tr>
<tr>
<td>1. Is emergency action needed to protect endangered property, person, highways, waterways?</td>
</tr>
<tr>
<td>2. Can the action be technologically implemented in the situation?</td>
</tr>
<tr>
<td>3. Will the action provide a solution to the current flooding problem?</td>
</tr>
<tr>
<td>4. Will the action prevent future problems (flood control potential)?</td>
</tr>
<tr>
<td>5. Is the action economically acceptable?</td>
</tr>
<tr>
<td>6. Is the action acceptable from aesthetic, recreational, and ecological standpoints?</td>
</tr>
<tr>
<td>7. Is the action the best usable solution under existing conditions?</td>
</tr>
<tr>
<td>8. Is action in harmony with the key authorizing agency, i.e., no action-blocking conflict with key government authority exists?</td>
</tr>
<tr>
<td>9. Is action in harmony with other agencies, i.e., no action-blocking conflict of other government agencies exist?</td>
</tr>
<tr>
<td>10. Is action in harmony with the public, i.e., no action-blocking conflict from the population exist?</td>
</tr>
</tbody>
</table>

| **Emergency actions:** |
| 11. Can the agency technologically implement the action? |
| 12. Will the action protect property, person, highways, waterway for the emergency period? |
| 13. Is the action the best usable solution under existing conditions? |
| 14. Are there no action blocking conflicts (economic, technological, aesthetic, recreational, or ecological)? |

and of other agencies and about the characteristics of proposed flood control actions, there would be no need for a Distortion Factor. However, since no agency has perfect knowledge, an agency may misinterpret the situation and make decisions that become non-acceptable to those with more complete knowledge. The means to account for these distortions is built into the model.

**Section Four: Public Reaction**

This section models the public reaction to the plan proposed and "recommended" by the decision agency. Public attitudes toward flood control proposals are thought to be based on similar considerations to those of agencies; although, often with very different importance attached to these considerations. These considerations are as before flood control ability, cost, aesthetics, recreation, ecology and the attitudes of significant others. The most "significant other" in this case (i.e. group or person influencing the public attitude) is believed to be the decision agen-
Figure 4.3. Steps or components of the agency decision process.
The announced attitude of the decision agency toward a proposal is an important variable in determining the attitude of the public.

Perceived vs. real characteristics of a proposal

Agencies are assumed to have a more realistic view of the characteristics of proposals than the public because of their access to technical information. The information used in the model to predict public attitudes toward a proposal are the "perceived" characteristics of the proposal. These perceptions are qualitative and vary because complete information is not available to the public and because perceptions are influenced by personal factors and interests.

James et al. (1971: 28-29) studied the decision choices made by people who chose to move into a flood plain area. They explored the attitudes and perceptions characteristic of people who would or would not choose to locate in a flood plain, they did not analyze public choices of means of flood control. They assumed that, "Perceived flood hazard must be distinguished from scientifically measured flood hazard in order to model successfully human response to flooding." This distinction is also used in this model as the basis for the Distortion Factors.

Function of predisposed public attitudes

Factors other than the characteristics of a particular flood control proposal may also influence people favorably or negatively toward flood control in general. In such a case, a particular project proposal would have to overcome this influence in order to be rejected or accepted, as the case may be. Experience with flood control, for instance, might influence one favorably toward a flood control proposal, but a person without such experience might still be predisposed to be favorable toward a project he perceives as "doing something" to solve flood problems which is doing something "good."

Non-proposal related factors affecting attitudes

Other personal factors and demographic characteristics also can influence attitude toward flood control actions. From preliminary surveys, 22 additional factors from Table 2.1 were statistically significant. These are shown in Table 4.2. Most of these are not directly related to the proposal for flood control.

It is believed that because of the weight a decision has within an agency once it is approved, and the legitimacy that agencies have in public affairs that the attitudes of the general public could be negative to a moderate degree and that a proposal previously approved by the decision agency would still be implemented. Opposition would need to be strong enough to overcome favorable agency factors of approval.

Table 4.2. Significant variables for attitudes toward flood actions

| 1) Knowledge of local flood control projects | 2) General concern about flooding |
| 3) Length of residence in present home | 4) Condition of home, yard and neighborhood |
| 5) Social class | 6) Natural feature beauty score |
| 7) Group membership | 8) Perceived level of local taxes |
| 9) Income | 10) Occupation |
| 11) Discussed flooding problems with others | 12) Stream proximity |
| 13) Knowledge of recent flooding | 14) Education |
| 15) Perceived likelihood of flooding at present residence | 16) Daily newspaper received |
| 17) Man-made feature beauty score | 18) Home ownership |
| 19) Main source of information | 20) Length of residence in local area |
| 21) Perceived adequacy of local parks | 22) Awareness of local flooding problems |

Since, as indicated by the surveys in this research, the average person has little knowledge and limited interest in flood control proposals in non-crisis conditions, the attitude of the general public is not considered likely to be either strongly negative or positive. Rather persons and groups with particular concerns, "special interest groups," are more likely to have strong feelings, voice their opinions, and consequently influence the final decision.

For example, the data gathered for this study described a project proposal which would channelize and line certain streams to reduce future flood damage. Being technically feasible the proposal was recommended by the planning agency and approved by the decision agency. When particular individuals in the public learned of the proposal, their latent personal interest was actuated and they actively opposed it on the basis of a perceived adverse effect upon the aesthetic qualities of the area. This attitude of individuals expanded into an organized effort to influence the decision agency. The effort was successful, and another proposal, not nearly as effective for flood control but acceptable on aesthetic grounds, was proposed and accepted. In other words, the additional information from the population indicated by the feedback loop in the flow chart changed the evaluation of the project by the decision agency. The conceptual model assumes that the decision agency is
affected by public opinion as was true for the agency in this example.

This is also an example both of how the system is dynamic and of the reciprocal influence of some parts of the system upon others. In this case, public opinion was of little or no importance in the evaluations of the initial plan and of the first evaluation of this plan by the decision agency. In fact, the public attitude was a latent factor until the decision was made public. However, after announcement of the plan, the aesthetic interests of people in the area became threatened which motivated them to respond and a segment of public opinion became strongly negative, moved to action, and thereby influenced the agency to reject the plan.

Section Five: The Final Decision and Alternative Actions

If the opposition is ineffective or nonexistent then a final acceptance decision can be made. If, however, Section Four of the model, Public Reaction, indicates that the opposition to a particular action is successful, other alternative actions or potential solutions are considered in a search for acceptable solutions. Alternative actions are assumed to be introduced one at a time in this conceptualization. This is a simplification, but multiple proposal can be considered sequentially; so this is not a serious limitation. This process continues until either one of the proposed actions is found acceptable in Section Four and the model is thus able to move to the implementation section (Section Six) or no additional actions remain for consideration.

In the case where no acceptable solutions are found, the process would either stop or begin again from Section One using any changes which may have occurred in the initial or starting conditions. As indicated by Figure 4.1, a similar return to Section One can occur at the end of the initial decision stage (Section Three) if no action plans had been developed which were satisfactory to the decision agency.

Section Six: Implementation of the Action Plan

Following project approval, the last stage is implementation of the plan. This last stage of the model also indicates the effects of the social decisions upon both the hydrologic system and the public. The physical effects would relate to the watershed and its drainage characteristics by altering the hydrologic parameters. The effects of these modifications to the hydrologic system are examined through operation of the hydrologic component of the model. If the project is satisfactory, it will end the current problem. As this information disseminates to the public, the public perception of a need for flood control represented in the first stage of the model will change, and the public will not consider further action necessary.

At this point, one sequence of steps will have ended. However, the hydrologic system is continually functioning, and events can occur which will cause problems for the public and again place pressure on the agencies. In addition other social factors and the desires of flood control agencies for achieving their mission objectives will cause additional proposals to be made, and the process outlined by the flow chart in Figure 4.1 will occur again. The process continues indefinitely.

The Decision Process and Some Important Theoretical Concepts

The linear regression analysis method was used to mathematically model the six-stage process. The method assumes additivity of relationships and linearity of terms. This last assumption, however, does not preclude some other interactions which are vital in understanding this process.

Social Theoretical Aspects of Modeling the Decision Process

In addition to the linearity assumption, there are certain underlying assumptions on sociological structural development which are made in modeling the decision system. Certain causal elements are assumed to underly a "structural-interactional system." These would affect the main system as well as its subsystems.

The system is established to provide a means for action that fulfills the beliefs or needs of a population. There are three aspects to this construct.

1. The ideological aspect: belief in something that has meaning for the believers. It may be a quality of life factor, an aesthetic interest, etc.

2. The awareness aspect: where a number of people have an awareness of a common interest, belief or need.

3. The structural aspect: development of an organized system to express or take action to achieve the common interests or beliefs.

These elements underly any decision or action system.

One of the great difficulties in predicting human behavior is in the problem of representing the subtle and latent subjective elements that influence what
people choose to do. Individual elements are not evident, and many combinations of elements may come together at any one point in time to affect each other. Sociological measurement has been entirely too gross to measure these conditions. It is probable that some subtle factors are stronger than others and function as gatekeepers and regulators, or provide the means for predicting behavior, or cause an ordering of actions when the gatekeepers combine with other elements. In the process of developing the steps and elements into a functional model, some mechanisms were discovered to mathematize and standardize some of these causal interactional behavior factors in ways that add to the conceptual refinement of element measurement.

From the standpoint of sociological theory, the sociological decision system in this model has both structural and interactional elements briefly outlined as follows:

A. Structural elements of the system:
   1. There are numerous organized systems that are interacting in the total process as subsystems as well as the public which functions as a general system in terms of normative behavior and in relation to rating activity.
   2. The conceptual model has several subparts and a feedback system.
      a. The model has six stages in a linear flow system.
      b. The social structures within each stage are arranged in a logical sequence in relation to the process.

B. Interaction elements of the system:
   1. The people impact the system with their own subjective values which become effect factors. These factors are part of the individual's behavior system, but may also become group behavior patterns when many have an attitude in common.
   2. Several basic elements are introduced into the model as implementing mechanisms. These effect factors that can be mathematically modeled for simulation and sensitivity analysis purposes are:
      a. Distortion Factors, which account for the difference between perception and reality.
      b. Importance Factors, which input the degree of importance or strength of feeling of those involved.
      c. Acceptance Functions, a judgment decision of the worth of a specific characteristic of a proposal. An Importance Factor combined with an important characteristic of a proposal results in an Acceptance Function.
      d. Expansion Effect, where interest or concern moves from a latent state reflecting low concern or unimportance to a state of high importance and action.
      e. Threshold Level, the level of concern necessary to trigger the expansion effect specified as a minimum level of the Acceptance Function.

These interaction elements require subjective value involvement of the participants in the system.

The concepts outlined are necessary to understand the conception of the total decision process. They function in the model as implementing elements. They are connectors at important junctures in the process. They provide explanatory values for subjective causalities that have not been accounted for before. The concepts are defined and discussed in relation to how they work in the modeling scheme.

Importance Factors

An "Importance Factor" (IF) is the degree of importance placed on a characteristic or feature of a proposed flood control program. The model reacts to Importance Factors for the seven types of important considerations or variables discussed earlier; flood control ability, cost, aesthetics, recreation, ecology, acceptance by other agencies, and acceptance by relevant populations. The importance of a given variable depends on the characteristics of the group reacting to the flood control program.

Different groups may have different interpretations of the importance associated with these variables. For example, some agencies may feel aesthetic or recreational values have secondary importance when compared with others such as flood control or economic considerations. If the attitudes of the public are important to a decision-making agency, the agency can be greatly influenced by public sentiment. The reaction, however, depends on the influence and power of the public group involved. If an agency chooses to ignore the desires of a public group, then feedback can result in further public resistance and the agency is staking its success on the strength of its position as opposed to the degree of importance the action has for the public involved.

The differences in the ways groups place values on the major variables are conceptualized as differences in the Importance Factor scores used in the model as multipliers. The numerical value of each IF factor can range from zero upward. The maximum value

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for a particular IF factor is determined by the scale used to measure it. A large value of the IF factor associated with cost, IF_c, means that the group considers cost very important.

Power relationships affect the value of the Importance Factor (IF). For example, one agency was sensitive to the desires of the governing board to which it was responsible, and the elected governing board was sensitive to the desires of public groups. If public opposition to a project is made known, IF evaluations may be changed for the board which can influence the agency in its decision. The project may thus become unacceptable although it had been previously approved by the agency.

Conflict resolution may result in changes in criteria and behavior patterns. Since groups vary in values, an agency cannot satisfy all of them. The importance which an agency places on different factors must also satisfy the functional requirements of the agency; in other words, enable the agency to do its job.

All of these forces influence the criteria by which the agency judges possible solutions. The criteria are programmed as IF statements in the model. They may be conceived as indicators of a steady state which may be changed by alteration of any of the forces affecting it. Normally, these forces are well-established, and the criteria are therefore stable. A large change in social concern or physical circumstances may be necessary to modify them. Conflict resolutions would result in a new equilibrium between opposing forces, but the change would probably be small.

Acceptance Functions

A perceived characteristic of a proposal is not considered to affect a proposal evaluation until a judgment decision, subconscious or conscious, is made of the worth of that characteristic. Combining an Importance Factor value or IF level with the value of an important variable associated with a flood control proposal results in an "Acceptance Function." The Acceptance Function is conceived as a simple product of the value of the variable and the associated Importance Factor. For example, if IF_1 expresses the importance which a particular group attaches to the ability of a flood control project to control flooding and f_1 is the measured value of that variable as perceived by that group, then multiplying IF_1 by f_1 gives the Acceptance Function for that variable by that group for a particular flood control proposal. Thus, the Acceptance Function F_1 equals IF_1 \cdot f_1.

For any particular group or population, the opinion of significant others about a proposal has a very important influence upon an evaluation. Such influence is multiplied by a numerical expression of the other group's evaluation to obtain an Acceptance Function for the influence of the other group.

After an initial evaluation, the decision of an agency is influenced by preceding judgments. This is accounted for in the model by Acceptance Function terms reflecting the influence of other agency evaluations. In the last evaluation made by the decision agency, an Acceptance Function is also included for the evaluation of the public.

It should be noted that Acceptance Functions vary from proposal to proposal, because of differences in proposal characteristics. Variations in characteristics of a proposal also affect the acceptance terms which include the evaluations of "significant others." Public evaluation also contains an acceptance term reflecting the prior evaluation of the decision agency, and this also may vary from group to group.

Total Evaluation of a Proposal

In addition to the Acceptance Function, terms which reflect specific characteristics of a flood control plan, some general attitudes will consistently in-

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2Assumptions of linearity in the method used here need not necessarily be retained in future applications of the model. See Chapter VIII and the section on suggested improvements.

3In this context, a group may be an agency, social organization, population, special interest group, or individual.

4In this project, proposal characteristics as perceived by agencies are considered to be the same as the engineering estimates of these parameters. This assumption is not made for the public, and perceived proposal characteristics are used in public or population acceptance functions. In both instances (agencies and public), it is assumed that evaluations by significant others are perceived accurately.

5A preceding evaluation by an agency has a large effect on subsequent evaluation, and this could be reflected in an Acceptance Function with the value of the preceding evaluation as an input. This was not done for two reasons: 1) The consistency of judgment reflecting the effect of a previous assessment would be accounted for by similarity of the calibrated equations for the two evaluations, 2) the inclusion of such an Acceptance Function would obscure the relationships between other factors and an evaluation. This is because the Acceptance Functions for the effect of a preceding evaluation would include the effect of other variables as they influenced the preceding evaluations to the extent the effects are the same in the preceding and present evaluations. It can be expected for social and bureaucratic reasons that judgments and justifications tend to be consistent and consequently for the effect of this type of Acceptance Function to be strong.

In summary, Acceptance Functions for preceding evaluations by the same agency were not included because clarity and interpretability would be seriously impaired if they were and because there is no loss in effectiveness of prediction by omission of these terms.

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fluence evaluation of flood control proposals. The effect of these factors is to bias a group for or against flood control proposals and establish a general underlying tendency to approve or reject them. If the attitude were negative a proposal would have to overcome this generalized conditioned response, or attitude, or be rejected. If, for example, people with urban backgrounds, or home ownership, or some other characteristic were likely to approve a flood control proposal without specific knowledge about it, this tendency or predisposition would be an example of a biasing factor. Such a factor may have a separate effect and also be useful in an Acceptance Function. For instance, two variables used in this study were experience with flooding and proximity of flood experience to present residence. Either of these may cause a tendency for favoring control measures and may alter the respondents' perception of the effectiveness of a particular flood control method.

The relative importance of either of these two variables may also depend on the evaluation judge's knowledge of the proposal. For example, a person who tends to be in favor of flood control because he perceived a need may reject a particular proposal when he learns that it is less efficient than another method. A "labeling" phenomenon, or conditioned response to a symbol, may occur because of the name "flood control." This type of response may be removed with sufficient knowledge. 6

The evaluation of a flood control proposal is determined by adding the effect of predisposing characteristics and the Acceptance Functions discussed in the preceding section. 7 as shown in Figure 4.4. This diagram illustrates the conceptualization behind the equation applied to every agency and the public in the model.

For example, suppose a project would actually cost $3,000,000 and add a tax of $150 per taxpayer in the affected area. The perceived cost by members of the population, however, would not necessarily be this dollar cost; in fact, the perceived cost may not be in dollars. 9 The perceived cost would be "high" to "low" depending on a person's circumstances and background. What is considered "low" by one group may be considered "high" by another. The perceived characteristics were measured by scales of "low" to "high" in calibrating the main equation developed in this report.

The Distortion Factors in Figure 4.4 reflect the differences between the designed characteristics of a proposal and the perceived characteristics. The agency perceptions are assumed to be the same as those of the designer because of information exchange during the design of a proposal. Distortion Factors should perhaps be used to account for 1) an agency's perception of other agency's proposals, and 2) the public's evaluation of a flood control proposal, but this is not done in the present model. Since the public's perception of flood control proposal characteristics was directly measured, any distortion is already included. The assumption that the agency opinion is correctly perceived is justified on the basis of the publicity given to flood-control decisions by an agency.

The variables shown in Figure 4.4 are not exhaustive. Other considerations such as safety and generality of benefit may be included (see Andrews, and Geertsen, 1974a: 33-35). Also effects on numerous "other groups" may be usefully represented in the model. Acceptance Functions for other groups affected can be as many as there are groups whose opinions are significant. The model can be expanded by repeated application of the basic equation based on this conceptualization of the decision process with groups being connected to each other through Acceptance Functions of this last type. The model can be made as complicated as desired by adding more interactions as they are observed.

Special Interest Group Functions

In applying the equations based on the conceptualization of the decision process shown in Figure 4.4, a problem develops in that the results predict the average attitude of the public, and people in unusual situations have a disproportionate influence on the outcome of the total process. Special interest groups act to block or promote changes. They are vocal and may be influential.

Expansion Effect

A concern or value is latent and unimportant until it is threatened, when its importance is suddenly expanded. When this value becomes a group concern, whether by an existing group or one newly organized, its public role is expanded greatly. The resulting "expansion effect" is psychological, cognitive, and emotional and often becomes a "cause" for a special interest group. This latent-expansion phenomena needs to be identified and represented in a social system for decision-making. In an ecological special interest group, for example, potential effects on an ecological
Figure 4.4. Conceptualization of the decision process equation: Evaluation of Proposal A by Group I.
element would cause greater concern than elsewhere. The weightings of that factor in influencing the evaluation by that group would be much greater. Coupled with this value, a threat to it would bring about far greater sensitivity and a concomitant expansion of action.

Threshold Level

The interest of the public or of a special interest group may not be stirred until an effect reaches a certain "threshold level." This level needs to be reached before a group cares enough to act.

The phenomena of expansion effect and threshold level for special interest groups are handled in the model by setting minimum values on each of the Acceptance Functions associated with proposal characteristics in the equation for public evaluation. It is assumed that an action will not be blocked unless the value characteristic falls below a certain threshold level. The setting of these levels, one for each factor about which special interest opposition may develop, is part of model calibration from experience data.

The assumption that an agency plan would not be blocked unless sufficient opposition occurs is not theoretically in accord with multiple objective planning where alternative plans are also evaluated. But it is functional since alternate infers a best or preferred plan. Threshold values could also be established to indicate promotion of a plan by a special interest group. This might reinforce the previous positive evaluation of a proposal by the decision agency, but it would not change the basic direction of approval or rejection nor remove a deleterious effect on some other factor about which strong opposition may focus. Such an additional disapproval may be sufficient to cause rejection. Acceptance is a function of the degree of opposition and degree of favorability. Concentration was placed on opposition by setting minimum levels of acceptability on the Acceptance Function.
CHAPTER V
MATHEMATICAL MODEL OF THE SOCIAL SYSTEM

Introduction of the Basic Elements of the Model

Purpose and Approach

The major objective of this study is to translate the system in the conceptual model shown in Figure 4.1 into a mathematical model for a computer. The equations reflect the fundamental processes and complex interactions involved in the real world system. The chapter describes the process and derives a general form of the equations which may be applicable to any area. This general equation is shown as the summarization of the chapter. Succeeding chapters present the actual computer model, and Table 6.1 shows the equations as calibrated for the Salt Lake County study area.

The model is based on using a multiple step regression technique to derive a general equation which represents a decision process in regard to a proposal by any group, whether the group be an agency or the public. Any group may be included in the model by calibrating the equation for that group. Thus the model may be enlarged to as complex a system as that illustrated in Figure 4.1 once appropriate data are collected on the additional groups.

The model is viewed as an experimental attempt to mathematically model a human behavior system and thus to provide a useful simulation tool for planning based upon realistic behavioral data. The model includes complex multi-related variables and provides trade off conditions with respect to them. Although problems remain, the system worked rather well in simulating behavior. It is expected that further testing and application would improve it for more general use and similar equations could be adapted to many planning uses.

Equations in the model could be applied at earlier stages in the process and could give different results because the various values of the dependent variables may vary through time. The basic assumption for the validity of the equations is that the relationships between the factors contained in the equations and the dependent variables is consistent and not that the values of these variables do not change.

1 Other equations may also have to be adjusted because influences of the additional groups within the system would then be explicitly included.
Figure 5.1. Flow chart of mathematical sociologic-hydrologic model.
through time or during the process of project determination. It is true, however, that in order to predict the results at the end of the evaluation process, some way of predicting values at that point must be used; this is ideally done by the use of dynamic equations for the variables or by the assumption that the values of relevant variables will remain the same or change in a predetermined way.

The blocks on the right of Figure 5.1 identify specific equations which are used in the model. These equations are developed later in this chapter. As indicated by the equation numbers within the blocks, the same equation may be used in two steps in some instances (see blocks 4 and 6 and 7 and 8). This means that values for an agency in one of these steps were also used later. In the event that a social occurrence (such as the ecology movement) alters basic public values, the equations would need to be recalibrated. At two points in the flow chart (blocks 5 and 12) the user of the model must provide values for the parameters to depict local conditions.

The decision agency decides that a plan is needed and asks the planning agency for a plan or for alternate plans. Plans are then formulated by the planning agency and a decision made as to whether it is feasible. If so, the planning agency would forward it on to the decision agency.

Equation I (5.4) and Equation II (5.6) and IF statement A (5.7) are the only mathematical formulas used in the model that are not applications of the basic conceptual equation of the decision process of a group regarding a flood control proposal.

Detailed Development of the Mathematical Model

Concepts in Formulations of the Mathematical Model

The mathematical model of the institutional response to flood problems was formulated in terms of representing the interaction of four principal types of components. They are:

1. Social characteristics of the general public and other populations (including organized interest groups) in the area concerned.
2. Agency characteristics of both action and planning agencies.
3. Physical characteristics of the proposed flood control methods.
4. Hydrologic system characteristics.

The first two sets of characteristics are essentially social, and the second two are essentially physical. Interactions within and between subsets need to be defined and represented in order to model the sociologic response to hydrologic problems.

A linear form of relationships within the model is generally easier to work with, therefore, it is desirable to use a linear model. However, appropriate limits of applicability need to be set (Narayana et al., 1970).

Equations representing a subsystem can be calibrated using measurements of the pertinent variables. Five major variables selected from previous tests to be significant in the initial selection of a proposed project plan are:

1. Flood control ability.
2. Cost per capita.
3. Outdoor aesthetics provided or destroyed.
4. Recreation provided or destroyed.
5. Ecological impact (disturbance or improvement of natural conditions).

Values for these five variables are used by the computer model to determine the acceptability of a possible plan. The variables in the equations (i.e., the sets of characteristics) need to be operationally defined for alternative flood control proposals to be compared on the same basis. A method was developed for assigning numerical values to the perceived significant characteristics of flood control proposals and of pertinent social groups to form scales that may be treated as interval or ratio data, a necessary level of measurement for modeling purposes.

As consistent measures are established, they can be used in regression analysis to predict effects from causes. Coefficients for the equations can be deter-

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2 A basic need expressed in Chapter VIII is to develop equations for the perceived characteristics of proposals.
3 An analysis of the measured variables may indicate which variables would have to change in value in order to alter the results of a decision process or if change is even possible.
4 Almost any plan could be submitted by the planning agency for evaluation in the model. The computer program could be modified so that the highest positively rated plan would be submitted first. If this plan were rejected subsequently, the second highest rated plan could be submitted, and so on. Also, the system could be established so that plans are submitted in order of priority so long as a constraint is not exceeded. An example would be a financial limitation, in which case alternate plans would be submitted so long as the total costs does not exceed a specified amount.

5 The planning and action agencies may be the same. The categories of characteristics for the various types of agencies involved will be largely the same, but appropriate values of these characteristics need to be determined.

6 Ordinal data with a reasonably large number of response categories over the range of the variable may be treated as interval data with approximately correct results (Labovitz, 1970, Baker et al., 1971).
dined by considering factors individually and collectively (Narayana et al., 1970; Namboodiri et al., 1975). Single variable relationships are readily established with limited data. Multivariable relationships are more complicated, and the complexity increases with the number of variables. When the equations are specified, they can be combined into a mathematical model. The model can then be improved by comparison of the simulation to reality and correcting the model for a better fit.

The Basic Equations for the Social Model

The parameters in all the equations except 5.4 and 5.6 were estimated by calibrating general equations representing the decision processes for a flood control proposal. Differences are manifest in the values of the parameters which vary with the groups and stages for which the equations were calibrated. The dependent variable in the first basic equation is the evaluation of a flood control proposal by a particular agency or defined population.

The terms shown in Equation 5.1 are simplified. For instance, although only simple linear relations are expressed in the first three terms, data often contain complex nonlinear relationships which could be reflected in a computer model. Some of the necessary terms may be more complex than those shown in Equation 5.1.

Classification of terms in the general equations

Four types of terms are included in Equation 5.1.

Type I Terms are those in which only factors describing the population or agency occur and no interaction occurs among them (such as \( b_1 X_{10} \)). These terms represent factors in populations, agencies, or proposals which influence reaction to a flood control proposal but whose effect is independent of the measured values for any other factors. This type of term would have the same influence on attitude toward a flood control proposal regardless of the proposal being evaluated and may be considered as reflecting a tendency to accept or reject flood control proposals in general.

Type II Terms are those in which more than one variable describing the population or agency occurs in the same term of the equation. Terms of this type happen when a variable has an effect on evaluation only when and to the extent that another variable is also present; in other words, a contingent relationship occurs such as if high education had an effect only if high income were also present. An example of this type is the term beginning with \( b_4 \) in Equation 5.1.

Variables from the agency or population which do not account for differences between groups in perceptions of particular flood control proposals can be combined in expression:

\[
Y = b_0 + b_1 X_{10} + b_2 X_{20} + b_3 X_{30} + b_4 X_{40}
\]

The subscripting procedure used in Equation 5.1 is designed to indicate the term number in which the variable appears and also its location within the term. For example, in the term \( b_5 X_{50} X_{51} \), the subscript 51 designates that the variable \( X_{51} \) appears in the sixth position on the right side of the equation \((0 + 5)\) and that it is the record X-variable used in the term \((0 + 1)\).
vary from individual to individual and from group to group. It can be seen from this that if the amount of variance explained by Equation 5.2 is increased that the absolute value of $b_o$ in Equation 5.1 can be decreased, provided that the scales of the variables in Equation 5.2 are such that their zero points are the same as that of $Y$. If this is true, then the values of the terms including the coefficients will be such that their effects will tend to make $b_o$ go to zero. This occurs because the value of a term with its sign will then vary directly with the value of $Y$ and because the weightings given to each variable or combination of variables in Equation 5.2 keep these values within reasonable bounds. If there were no explanatory terms in 5.2, $b_o$ and $b'_o$ would be the same; it is the addition of these terms that partially explains $b'_o$ and consequently can reduce $b_o$. As one adds additional significant factors to Equation 5.2 this would be increasingly true.

Another implication of the preceding is that the model can be calibrated without knowing the values of the variables contained only in terms of types 1 or 2. This could be done by using Equation 5.3 which contains none of these terms.

**Type III Terms** are those in which a factor from a proposed project and a factor from the population or agency interact in the same term, $(b_3 - b_8)$ in Equation 5.1. The presence of the project factors means that these terms reflect differences in characteristics between flood control proposals. The $z$ factors should be measurable descriptors of perceived features of flood control proposals which make a difference in the way individuals or groups react to the proposals. The $X$ factors are values or attitudes which affect the people respond to the $z$ factors; in general, the related attitudes are considered to be the importance attached to the respective factors by the population. For a given population or agency these are set at a particular time. The differences in reactions among flood control proposals can be seen by inserting the values for the different $z$ factors in the equations.

Interaction terms containing both $x$ and $z$ are called "Acceptance Functions." A minimum value may have to be obtained for each of these (regardless of the total value of the equation) to achieve acceptance. The acceptance functions and related values could also be graphed separately (see Appendix G) and should have value for the planner particularly when the relationships between these terms are known; these relationships could be determined from the regression equation involving these terms.

The perceived characteristics of proposals are multiplied respectively by the measures of importance factors in order to account for variations in the weightings of the proposal elements by groups and individuals and thereby allow the development of an equation that may be applicable to different groups and individuals. Weightings for each factor in the equation could be obtained for each respondent by regression analysis, but then the equation would need to be recalibrated for each evaluator. Conceptually, the method used is believed to be correct since the effect of a factor is dependent on its importance which varies within a group and from group to group. Empirically, it also seems to be verified since the predictability of evaluations by an equation including acceptance functions is much greater than when the factors are included in an equation alone without the importance factors or when the importance factors and perceived proposal characteristics are entered separately into an equation.

Ideally, the perceived factors should completely describe all differences in flood control proposals which make a difference in people's reactions to them. For this research project, it was decided that the factors of effectiveness, cost, aesthetics, recreation, and ecology would be used (Appendix B). Numerical values for various flood control proposals for perceived values of each of these five factors provide data for use in equations of this type. Another way of describing the function of these proposal characteristics is that just as the differences in reaction specific to a proposal depends on the differences between populations, the differences in reaction of a particular population depends on the differences between proposals. Both types of differences must be described mathematically to develop a model sensitive to proposal and group variations. One can also for a given proposal insert various $X$ values in equations of type (5.1) to determine differences in reaction to the same proposal by different populations.

**Type IV Terms** portray the interaction between factors describing the population and factors describing outside influence ($X$ and $V$); there can and probably will be more than one of these terms in equations of the model. These terms represent the relationships between the attitudes of a population or agency and the opinions of "significant others" toward a proposal. For example, a flood control agency may favor or approve a proposal and, thereby, influence the opinion of the population or another agency toward the proposal. The value for $V_1$ could be the dependent variable of another equation representing the reaction for that agency or group. The reactions of the parts of a system are linked to its reaction as a whole, and vice-versa.

A Type IV term that includes a factor that may change from proposal to proposal may be considered an acceptance function. Such a situation occurs when an evaluation of the proposal by one group influences another group. Omission of significant terms of this type would lead to serious errors of prediction.
Equation 5.1 is diagrammed in Figure 5.2. Equations similar to Equation 5.1 were prepared for each population and agency needed for modeling the system.

**Equations in the Model**

The specific equations derived for the model are presented in numerical order as outlined in Figure 5.1, except for Equation 5.21 which is explained together with the other agency equations and is followed following the section on Equation IV. The discussion of IF statement A will be given with Equation II. IF statements B₁ - B₃ are mentioned in a section after the application of Equation III to the decision agency. IF statements C₁ - C₅ are discussed following Equation V. For a particular step, see the section on the equation representing that step.

The square of the correlation coefficient is calculated for each equation calibrated from available data. The interpretation varies from equation to equation, and appropriate comments will be made in the discussion of an equation. Also where meaningful, both the unstandardized and standardized versions (see Chapter II) of an equation are given.

Emphasis in development of the model was placed on those parts involving evaluation (i.e., from Equation III onward). Particular effort was expended on the public acceptance equation (Equation V), because it has the greatest potential utility for planners. Equations I and II are preliminary formulations which need additional refinement. These initial formulas did allow, however, the completion of the model of the social system and, in combination with the hydrologic system, the closing of the main loop in Figure 5.1. All variables used in the equations may be seen in a summary listing with their symbols in Table 6.1. The title given to an equation refers to the dependent variable. Independent variables are listed in associated tables.

The regression analysis using the data for perception of need for flood control for the study area yielded the coefficients for Equation I. The variables in Equation I are indicated by Table 5.1. The $r^2$ of Equation I is quite low, .194. Adding more variables increased the $r^2$ slightly, by about .03, but reduced the significance of the variables already in the model to unacceptable levels. In the above equation most variables are significant at the .05 level and all are significant at the .10 level. A multiplicative power func-

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7The $r^2$ for the standardized and unstandardized forms of an equation is the same since one form is a transformation of the other.
Table 5.1. Variables in Equation I: public concern.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Schedule Item</th>
<th>Possible Range of Unstandardized Scores a</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCL</td>
<td>Perception of Need (in sample) for Improved Flood Control in a Local Area (CONCL)</td>
<td>(Appendix B)</td>
<td>9.44 to 43.8c</td>
</tr>
<tr>
<td>X1</td>
<td>Number of Types of Sources of Information About Flooding (NSORSE)</td>
<td>(9)</td>
<td>0 to 6</td>
</tr>
<tr>
<td>X2</td>
<td>Perceived Likelihood of Flooding at Personally Owned Property in the Area (KPERFL)</td>
<td>(2-A)</td>
<td>0 to 100</td>
</tr>
<tr>
<td>X3</td>
<td>Length of Years of Awareness of Neighborhood Flooding Problems (LNEIGH)</td>
<td>(7-A)</td>
<td>0 to 99</td>
</tr>
<tr>
<td>X4</td>
<td>Closeness of Groups of Persons With Whom They Discussed Flooding Problems (KLOSGR)</td>
<td>(9-D)</td>
<td>0 to 3</td>
</tr>
<tr>
<td>X5</td>
<td>Number of Young Children (NYONGC)</td>
<td>(119)</td>
<td>0 to 3</td>
</tr>
<tr>
<td>X6</td>
<td>Willingness to Pay for Government Expenditures (PAYL-6)d</td>
<td>(Appendix B)</td>
<td>0 to 24</td>
</tr>
<tr>
<td>X7</td>
<td>Attitude Toward Effect of Man-Made Objects Upon the Beauty of Nature (MANL-4)</td>
<td>(Appendix B)</td>
<td>0 to 16</td>
</tr>
<tr>
<td>X8</td>
<td>Leisure Orientation (LEIL-4)</td>
<td>(Appendix B)</td>
<td>0 to 16</td>
</tr>
<tr>
<td>X9</td>
<td>Proximity of Flooding Experience (KLOSF)</td>
<td>(8)</td>
<td>0 to 3</td>
</tr>
<tr>
<td>X10</td>
<td>Cost of Damage from Flooding to the respondent (ICOSTF)</td>
<td>(2)</td>
<td>0 to 999</td>
</tr>
</tbody>
</table>

\[(X_9 X_{10} = 0 \text{ to } 2997)\]

a For a definition of the meaning of the scores, refer to Appendix A.

b Scales used to measure the dependent variable, CONCL and the variables PAYL, MANL, and LEIL are listed in Appendix B. The values of the items in these scales may be the fact in the weights given for each question as shown in Appendix A.

c The range of the dependent variables is the minimum to maximum that could be obtained from extreme values of the independent variables.

d James et al. (1971:37) investigated a similar variable for willingness to spend personal money, but in a different context. They were measuring willingness to pay for relief from flood damage by taxes or flood insurance.

The coefficients of the standardized form (Equation 5.5) should only be used to compare the relative importance of terms presently in the equation. They should not be considered as reflective of the weights of these factors in the "real world." When the proportion of explained variance is low, the sizes of the coefficients are very unstable and could, almost literally, disappear with the addition or change of variables in the equation (Gordon, 1968; Schoenberg, 1971).

Equation I: Perception of need (or concern) for flood control in a local area (CONCL)\(^8\)

Unstandardized form:

\[ \text{CONCL} = \frac{1}{n} \sum_{i=1}^{n} (10.8 + .506X_{1i} + .128X_{3i} + .30X_{4i} - .453X_{6i} + .146X_{7i} + .230X_{8i} + .0012 (X_9 X_{10}) ) \]

Standardized form:

\[ \text{CONCL} = \frac{1}{n} \sum_{i=1}^{n} (.163X_{1i} + .142X_{2i} + .180X_{3i} ) \]

\(^9\) The presentation of Equations 5.4 and 5.5 are technically correct. It should be remembered that in calculation of coefficients by regression analysis, the values of variables are considered individually and the best match made over all cases. The mean value signs matter in the case of product terms since the product of the means is not generally equal to the mean of the products. However, it is cumbersome to write the summation and mean value signs continually henceforth they will be omitted for simplicity of presentation. "n" as used here represents the sample size and the used calibration by the regression program.

\(^8\) Also called concern for flooding: hence the acronym, CONCL.
A simulation model is used.

However, as compared to an input of ten and reduced the value of \( C \) in the model.

Hence, the variables reflecting public concern and attitudes had values that precluded any need for flood control. These would be circumstances, for example, where little or no communication occurred regarding flooding problems or the perception of flood probabilities became very low. The value chosen for \( C_1 \) was -37. Since \( M, \text{CONCL}, \) and \( \text{PAYL} \) are all greater than zero, the only way that \( N \) can be less than zero is for the absolute value of \( C_1 \) to be larger than the combined values of the other terms, and for \( C_1 \) to be opposite in sign. It is this relationship of \( C_1 \) to the other terms that allows the calibration of this equation by assigning an appropriate number to \( C_1 \).

Inserting the values of the constants in Equation 5.6 gives:

\[ N = -37 + 2M + \text{CONCL} + \text{PAYL} \]  

Willingness to pay for government expenditures (PAYL) was placed in the equation because it is thought that less willingness to pay might reduce the demand for flood control in situations where the concern about flooding is low. The coefficient of \( \text{PAYL} \) was positive since a higher value of \( \text{PAYL} \) means a greater willingness to pay.

IF statement A provides a point for the model to end its analysis. If there is enough concern over the flooding problem to cause establishment of a flood control agency, it is unlikely that the problem will ever be so completely solved that no more effort will be needed or that public concern about flooding will become so low as to oppose all further plans for flood control. An \( N \) greater than zero signifies circumstances that allow an agency to consider flood control proposals. All of the rest of the social model consists of one group or another doing this.

C2, C3, and C4 adjust the weightings of \( M, \text{CONCL}, \) and \( \text{PAYL} \) in Equation II (5.6) and are always positive since these variables are considered to vary directly with \( N \). \( C_1 \) is used to adjust Equation II so that IF statement A is true. Since \( M, \text{CONCL}, \) and \( \text{PAYL} \) are never negative, this means that \( C_1 \) must be less than zero under the constraint caused by IF statement A in order for the system ever to be able to stop planning flood control solutions (i.e. make \( N \leq 0 \)).

The value of \( M \) was defined as varying from zero to ten and was arbitrarily set at five or a median position on the scale. CONCL is the output of Equation I and \( \text{PAYL} \) is one of the independent population variables. \( \text{CONCL} \) and \( \text{PAYL} \) are both used as independent variables in Equation II. All of the values plus the \( C \) values and the value of \( N \) can be printed out when the simulation model is used.

C2 was set at two, and C3 and C4 were given values of one. C2 was given a greater value than the other coefficients because it was felt from experience that variation over the small range of \( M \), agency mission factor, as compared to \( \text{CONCL} \) and \( \text{PAYL} \) would otherwise underplay an important factor. \( M \) was weighted more to compensate for the smaller range and thus more accurately represent the theory behind the equations, although in this case \( M \) never varied during use of the model. \( C_2 M \) thus became essentially a constant of ten and reduced the value of \( C_1 \) that would be required.

### Agency Evaluation Equations

**Equation III: Initial evaluations**

Unstandardized form:

\[
Y = .241X_1 - .305X_2 - .0695X_3X_9 + 843X_2 (1/X_10) \\
+ .00568X_3X_{11} + .136X_4X_{12} + .228X_5X_{13} 
\]  

10 Should flooding problems be nearly completely solved, the function of a flood-control agency may change to some other public works activity, or perhaps large parts of the staff would be transferred to another agency.
Table 5.2. Variables for agency equations (Equation III, IV, and VI).

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variables</th>
<th>Possible Range of Score*</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y )</td>
<td>Evaluation by a particular agency of a flood control proposal at a point in time. (IAGEEV-3)</td>
<td>0 to 9</td>
</tr>
</tbody>
</table>

| \( X_1 \) | Presence of a flood control problem (IFPROB) | 0 to 9 |
| \( X_2 \) | Agency concern to include low cost in flood control project (IACCOS) | 0 to 4 |
| \( X_3 \) | Agency concern to include effectiveness in flood control project (IACEFF) | 0 to 4 |
| \( X_4 \) | Agency concern to include pleasing aesthetics in flood control project (IACAES) | 0 to 4 |
| \( X_5 \) | Agency concern to include recreation in flood control proposal (IACREC) | 0 to 4 |
| \( X_6 \) | Agency concern to include least detrimental environmental effect in flood control project (IACEO) | 0 to 4 |
| \( X_7 \) | Importance of other agency opinion to agency (AGEAGE) | 0 to 4 |
| \( X_8 \) | Importance of public opinion to agency (PUBAGE) | 0 to 4 |
| \( X_9 \) | Benefit-cost ratio of flood control proposal (based on engineering criteria) (BECORA) | 0 to (9.99) |
| \( X_{10} \) | Cost of proposal (COSPRO) (actual ÷ 1,000,000) | -3 to +3 |
| \( X_{11} \) | Average annual flood control benefit in dollars (AVEBEN) (actual ÷ 10,000) | -3 to +3 |
| \( X_{12} \) | Judges' estimate of aesthetics effect of flood control proposal (OJEAES) | -3 to +3 |
| \( X_{13} \) | Judges' estimate of recreational effect of flood control proposal (OJEREC) | -3 to +3 |
| \( X_{14} \) | Judges' estimate of ecological effect of flood control proposal (OJEOC) | -3 to +3 |
| \( X_{15} \) | Other agency evaluation of proposal (OTHEVE-3) | -2 to +2 |
| \( X_{16} \) | Mean public evaluation of proposal (PUBPRO-3) | -2 to +2 |

*For a definition of the meaning of the scores, refer to Appendix A.

bComputed within computer program from COSPRO (\( X_{10} \)) AVEBEN (\( X_{11} \)), and Years of Flooding Controlled (YRSCON) (See section on IF statements B1-B3).

Standardized form:

\[
Y = -.231X_1 - .634X_2X_9 + .363X_2 (1/X_{10})
\]

\[
+ 1.13X_3X_{11} + .291X_4X_{12} + .549X_5X_{13}
\]  \( (5.10) \)

The independent variables of Equation III (5.9) are included also in Equations IV (5.16) and VI (5.21) with different coefficients.\(^{11}\) The variables used in all the agency equations are listed in Table 5.2 and the terms in Table 5.3. Note that the numbers in parentheses above the terms of Equation III (5.9) refer to the identification of the terms listed in Table 5.3; the same is also true of Equations IV and V.

The \( R^2 \) of Equation III is .662. The significance levels of the terms are (1) .0222; (2) .0074; (3) .0125; (4) .0001; (5) .1277; and (6) .0001. The F test for the whole equation was highly significant, beyond .0001.

Term 3 (Table 5.3), in the agency equations, unlike the other interaction terms, contains the recipro-

\(^{11}\)See footnote 15.
of the proposal. Consequently, the signs of the interaction terms would theoretically be positive.13

Anomalies such as the negative signs of the first two terms in Equation III (5.9) can occur for any of several reasons. Among the possible causes are omission of important variables, poor measurement, inadequate sample, and an incorrect form of the model. Assuming the relationships for these terms are correct, this leaves the first three possibilities of which the first may be the most cogent in this case.

One problem may be that the conceptual model of the decision process (Chapter IV) was not followed exactly in measuring of variables. As signified by the name, "Importance Factors," the companion variables to the characteristics of proposals in Type III terms and to the evaluations by other groups in Type IV terms, should measure the importance of the companion factors in evaluation of flood control proposals. As such, they would have no effect direct or indirect, on evaluation except in relation to the characteristics and evaluations. If a factor had a direct relationship with the dependent variable, then the term would also. If a factor had an inverse relationship with the evaluation, regression analysis would produce a negative coefficient automatically. There would be no need to predetermine the direction of the interacting variables.14 Assessing the importance factors would have been easier than measuring the variables used. However, this assessment of importance factors was not done as directly as could have been. Attitudes were measured rather than the direct importance of a characteristic in flood control proposal evaluation and the amount of that characteristic present in the proposal being considered. Direct measurements would require a straight rating technique or ratio scaling. As it is, acceptance functions are interactions between various attitudes and expected impacts of a proposal.

The coefficients when Equation III (5.9) is applied to a planning agency would not have the same effects as when the equation is applied for the initial evaluation by the decision agency. This is because the values of the coefficients shown are multiplied by

<table>
<thead>
<tr>
<th>Table 5.3. Terms of agency equationsa (Equations III, IV, and VI).</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Presence of a Flood Control Problem (IFPROB)</td>
</tr>
<tr>
<td>(2) Agency Concern to Include Low Cost in Flood Control</td>
</tr>
<tr>
<td>Project (IACCOS) by Benefit-Cost Ratio of Flood Control</td>
</tr>
<tr>
<td>Proposal (BECORA)</td>
</tr>
<tr>
<td>(3) Agency Concern to Include Low Cost in Flood Control</td>
</tr>
<tr>
<td>Project (IACCOS) by One over the Cost of the Proposal (1/COSPRO)</td>
</tr>
<tr>
<td>(4) Agency Concern to Include Effectiveness in Flood Control</td>
</tr>
<tr>
<td>Proposal (IACEFF) by Average Annual Benefit of Flood Control</td>
</tr>
<tr>
<td>Proposal in Dollars (AVEBEN)</td>
</tr>
<tr>
<td>(5) Agency Concern to Include Pleasing Aesthetics in Flood</td>
</tr>
<tr>
<td>Control Proposal (IACAES) by Original Judges Estimate of</td>
</tr>
<tr>
<td>Aesthetics Effect of Flood Control Proposal (OJEAES)</td>
</tr>
<tr>
<td>(6) Agency Concern to Include Recreation in Flood Control</td>
</tr>
<tr>
<td>Proposal (IACREC) by Original Judges Estimate of Recreatonal</td>
</tr>
<tr>
<td>Effect of Flood Control Proposal (OJERC)</td>
</tr>
<tr>
<td>(7) Agency Concern to Include Least Detrimental Environmental</td>
</tr>
<tr>
<td>Effect of Flood Control Proposal (IACECO) by Original Judges</td>
</tr>
<tr>
<td>Estimate of Ecological Effect of Flood Control Proposal</td>
</tr>
<tr>
<td>(OJEECO)</td>
</tr>
<tr>
<td>(8) Importance of Other Agency Opinion to Agency</td>
</tr>
<tr>
<td>(AGEAGE) by Other Agency Opinion of Proposal (OTHEYE-3)</td>
</tr>
<tr>
<td>(9) Importance of Public Opinion to Agency (PUBAGE)</td>
</tr>
<tr>
<td>by Mean Public Evaluation of Proposal (PUBPRO-3)</td>
</tr>
</tbody>
</table>

Terms consist of one or more variables.

12 The values of 1/COSPRO are not as small as would be expected because the figures entered for COSPRO were costs in millions of dollars.

13 The desire to have all acceptance function positive resulted in difficulties both in the agency and population evaluation equations with the cost acceptance function. In the future, the companion variable should be measured such that COSPRO can be entered without modification into the evaluation equations. See discussion of IF statement C5.

14 The reason for establishing importance factor values rather than letting the regression analysis specify regression coefficients on the factors alone is in the hope of making the equation more general. Importance factors vary from person to person and from group to group. Establishing an equation with set importance factors would preclude generality. The concept of acceptance functions accounts for the variability. See discussion of Type III terms in this chapter and decision process section of Chapter IV.
the values of agency variables to create separate equations for the different agencies. Each of the coefficients in the case of terms of Types III and IV would be equal to the product of a coefficient in Equation III and the appropriate value of the parameters of the agency which are in the equation. This procedure, however, is applicable only to the nonstandardized form of the equation because the transformation required for the standardized form is on the product of the variables in the interaction terms and there is no way to separate the effects of the transformations on the respective variables without considerable information on the distributions of the variables involved. The use of means always distorts the equation from the results with direct calibration. Therefore, the derived equations should be considered approximations.

In spite of the difficulties caused by limited data and approximate procedures, the results appeared adequate. The coefficients and signs of the agency equations may not be stable because of the data base problem; however, four of the five acceptance functions in Equation III relate in the way one would expect to the dependent variable. The measures of agreement, the r squares, for the evaluation equations were reasonably high. For the purposes of system simulation, the developed equations seem to work fairly well.

Construction of agency equations

The coefficients of the agency equations are calibrated from data reflecting a judgment of the agency evaluation of a flood control proposal and estimates from engineering data and expert judges of the characteristics of these proposals. The mean values of the agency characteristics used for calibration are shown in Table 5.4, and the means and ranges of the other variables are listed in Table 5.5. The set of data used to establish the agency regression equations consisted of the values estimated by a judge for variables Xf.

Table 5.4. Mean values for agency variables in Equations III, IV, and VI.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Planning Agency</th>
<th>Decision Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>IACCOs (X2)</td>
<td>1.750</td>
<td>3.250</td>
</tr>
<tr>
<td>IACEFF (X3)</td>
<td>3.750</td>
<td>2.875</td>
</tr>
<tr>
<td>IACEES (X4)</td>
<td>0.625</td>
<td>2.125</td>
</tr>
<tr>
<td>IACREC (X5)</td>
<td>0.625</td>
<td>2.000</td>
</tr>
<tr>
<td>IACFECO (X6)</td>
<td>0.500</td>
<td>1.625</td>
</tr>
<tr>
<td>AGEAGE (X7)</td>
<td>1.800</td>
<td>2.000</td>
</tr>
<tr>
<td>PUBAGE (X8)</td>
<td>2.300</td>
<td>3.800</td>
</tr>
</tbody>
</table>

Table 5.5. Mean values and range of proposal characteristics (X9 - X14) and other variables used in calibrating Equations III, IV and VI.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Value</th>
<th>Score Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BECORA (X9)</td>
<td>3.89</td>
<td>0.08 to 9.58</td>
</tr>
<tr>
<td>COSPRO (X10)</td>
<td>20.23 (X10^6)</td>
<td>181.0 (X10^6) to 22.10 (X10^4)</td>
</tr>
<tr>
<td>AVEBEN (X11)</td>
<td>100.0 (X10^6)</td>
<td>14.8 (X10^4) to 196.7 (X10^4)</td>
</tr>
<tr>
<td>OJEAES (X12)</td>
<td>-0.223</td>
<td>-2.17 to 1.67</td>
</tr>
<tr>
<td>OJEREC (X13)</td>
<td>-0.053</td>
<td>-2.33 to 2.50</td>
</tr>
<tr>
<td>OJEECO (X14)</td>
<td>-0.223</td>
<td>-2.17 to 1.83</td>
</tr>
<tr>
<td>IFPROB (X15)</td>
<td>4.50</td>
<td>3.00 to 6.00</td>
</tr>
<tr>
<td>OTHEVE (X16)</td>
<td>3.87</td>
<td>1.50 to 4.83</td>
</tr>
<tr>
<td>PUBPRO (X17)</td>
<td>3.83</td>
<td>2.85 to 4.51</td>
</tr>
</tbody>
</table>

- Variable labels are taken from Table 5.2.
- Computed within computer model from other variables (see Chapter VI).
- Significant figures are those not in parentheses. Only these were entered into computer figures. The numbers in parentheses are provided to inform the reader of the amount of the actual engineering estimates.

The values of X9 through X6, estimates by engineers X10 and X11 for the proposal involved; means of the judged values for X7, X9, and X12 to X15 for that proposal; and the actual mean public evaluation of that proposal as estimated from the sample taken in the second stage of this study, X16. All but the first group are constant from judge to judge for the same proposal and agency.

The values of characteristics of proposals and of other group evaluations of a given proposal were held constant partly because of two assumptions mentioned in Chapter IV. These are that agencies perceive the characteristics of flood control plans "correctly" or factually in the way the designer does, and that they were cognizant of public and other agency attitudes toward the plan. The proposal characteristics estimated from engineering data (X9, X10, X11) and that derived from the population data (X16) are considered intrinsically stable for a proposal at a given time. Pooling the results of the judges' estimates of the remaining characteristics (X12, X13, X14, X15) was done partly to help stabilize the values obtained.

As can be inferred from the values of variables X2 to X6 in Table 4.5 (all are divisible by one over the number of judges, in this case .125), integer values were assigned by eight judges to these variables; this was also true for variable X1. The values of X2 and X9 are based on four judgments. Six judges were used for the remaining variables; X12, X13, X14, and X15. Another reason for using mean values when possible was to reduce the effect of cognitive consistency discussed below. Mean values of all variables could not be used, however, because this would not leave enough
cases to establish a regression equation. If regression techniques are to be applied to an agency, some treatment of multiple estimates as separate cases appears to be required in the absence of data on the same agency for many proposals.

The preceding was explained to show how sufficient cases for regression analysis were obtained. By combining data from two agencies and three proposals for eight judges, 48 cases were obtained. Separating the two agencies would have resulted in 24 degrees of freedom, an insufficient number. Had the judges' data all been pooled for each proposal and agency, there would have only been a total of six data sets. The best way to avoid having to do this is to gather data on many proposals for an agency in an area.

Because of the method by which the data were obtained, it cannot be determined what proportion of comparatively high correlation coefficients of the agency equations results from real association and what proportion is from a tendency toward cognitive consistency or internal mental agreement by each judge. Adjustment toward consistency is not the only adaptive mechanism for matching experience and perceptions, but it may be common. To the degree that judges achieve consistency at the sacrifice of accurate representation, a misleading result could occur. Hopefully, judges can provide reasonably accurate data when other sources are not available. The problem discussed here applies only when one person must judge another's values. What matters in application is the ability to correctly predict the evaluation of flood control proposals by a particular group.

**Evaluation by the planning agency (PAEV)**

Equation III (5.9) is needed for predicting the evaluation by the planning agency of a flood control proposal idea. If a plan is evaluated favorably and approved by the planning agency, it is considered as proposed to the decision agency.

Since this is an initial evaluation, no Type IV interaction terms are used to reflect the influence of a previous judgment on the plan, as the last two terms, #8 and #9 in Table 5.3, are Types IV terms. Term #7 reflects the ecological consequence of the proposal if enacted and was not included in Equation III because its significance was too low. With the data used, ecology did not have an appreciable effect other than through its relationship to aesthetics. Term #7 did not enter an agency evaluation this early in the planning process.

The values of the agency variables which would be absorbed into the coefficients of Equation III (5.9) can be substituted for those variables in the non-standardized form of the equation. These variables are $X_2$ through $X_5$ for Equation II (5.9). The values of these variables are in Table 5.2. Substituting the values listed there are the planning agency, in the un-standardized form of Equation III (5.9) results in the following:

$$Y = -0.241 - 0.305X_1 - 0.0695(1.75)X_9 + 8.43(1.75)/X_{10} + 0.00568(3.75)X_{11} + 0.136(6.25)X_{12} + 0.228(6.25)X_{13} - 0.241 - 0.305X_1 - 0.122X_9 + 14.753/X_{10} + 0.021X_{11} + 0.085X_{12} + 0.143X_{13}$$

Equation III is also applied to predict the initial evaluation by the decision agency under the model assumptions that no important evaluative input from another group enters in at this point and that the planning agency is considered as recommending the plans it proposes. The second assumption is justified by the logic that the planning agency would not propose a plan that it did not favor and that the attitude of the agency would be relatively stable in a favorable direction and thus tend to have a consistent influencing effect. Also, a planning agency and a decision agency often work together closely enough to develop congruent perspectives toward types of flood control proposals. If these assumptions are true, separate inclusion of the planning agency evaluation would tend to dominate the effect of other variables in a regression analysis that accounts for much of the same variation as already considered. Omission of a decision agency acceptance function for the planning agency evaluation would consequently allow the effects of the other variables to be more closely seen through the equation.

Equation III further distinguishes the initial decision agency evaluation from the revised evaluation (Figure 5.1). Even if Equation IV were used both places, the results would still be different as the output from the planning agency is different than that from the decision agency, but the similarity of the agency evaluation values in the model would be greater. If the planning agency evaluation has a significant differential effect upon the initial decision agency evaluation from proposal to proposal, then Equation IV could be used in place of Equation III. When the
planning agency and decision agency functions are performed by the same organization, inclusion of an acceptance function for the planning evaluation in the initial decision agency evaluation would mean that the other terms of the equation would only be needed to account for changes in the evaluations by that organization. Such changes may be reused by different review processes or time-lags between the evaluations.

In the model, rejection of a plan at any point requires that the planning agency develop another plan ("No" arrows to the left on Figure 5.1). "Yes" indicates acceptability, and the process of evaluation continues.17

An equation just calibrated for an initial evaluation by the decision agency is obtained by substituting the mean values listed in Table 5.4 of the decision agency for variables $X_2$ to $X_5$ into the unstandardized Equation III as follows:

$$
Y = -0.241 - 0.305X_1 - 0.0695 (3.25)X_9 + 8.43(3.25/X_{10}) + 0.00568(2.875)X_{11} + 0.136(2.125)X_{12} + 0.228(2.0)X_{13} + 0.00568(2.875)X_{11} + 0.136(2.125)X_{12} + 0.228(2.0)X_{13}
$$

The results can be compared with Equation 5.11.

**IF statements B1 to B3**

The only way that a plan can be rejected at this point is for subsequent evaluation to become negative. However, a plan can have some undesirable characteristics with respect to flood control and still be approved if other characteristics are strong enough. In order to identify the strong and weak aspects of a proposal, it is desirable to stipulate criteria and test whether a flood-control proposal meets them. This is the function of IF statements $B_1$, $B_2$, and $B_3$.

IF statement $B_1$ (for cost of proposal):

$$
IF \ X_{10} \leq C_m \ continue \ . \ . \ . \ . \ . \ . \ (5.13)
$$

where

$$X_{10} = \text{the cost of the proposal}$$

$$C_m = \text{maximum acceptable cost of a proposal}$$

IF statement $B_2$ (for effectiveness of proposal):

$$
IF X_{17} \geq F_s \ continue \ . \ . \ . \ . \ . \ (5.14)
$$

where

$$X_{17} = \text{the flood recurrence interval in years used in the proposed design}$$

$$F_s = \text{the lowest flood recurrence interval acceptable in a flood control plan}$$

IF statement $B_3$ (for benefit-cost ratio):

$$
IF X_9 \geq B_s, \ continue \ . \ . \ . \ . \ . \ (5.15)
$$

where

$$X_9 = \text{the benefit-cost ratio of the flood control proposal}$$

$$B_s = \text{the smallest benefit-cost ratio acceptable in a flood control proposal (normally 1.0)}$$

The benefit-cost ratio is figured internally in the model from information required for IF statements $B_1$ and $B_2$ and from the present value of the average annual flood control benefit.

**Equation IV: Intermediate evaluations**

- Unstandardized form:

$$
(1) \ (2) \ (3)
Y = -0.206X_1 - 0.00585X_2X_9 + 1.85X_2(1/X_{10}) + 0.00125X_3X_{11} + 0.108X_4X_{12} - 0.0189X_5X_{13} + 0.442X_7X_{15} \ . \ . \ . \ . \ . \ (5.16)
$$

- Standardized form:

$$
(1) \ (2) \ (3)
Y = +0.491 - 0.156X_1 - 0.0533X_2X_9 + 0.0795X_2(1/X_{10}) + 0.248X_3X_{11} + 0.231X_4X_{12} - 0.0455X_5X_{13} + 0.777X_7X_{15} \ . \ . \ . \ . \ . \ (5.17)
$$

The $r^2$ of Equation IV (5.16) is .823. Tables 5.2 and 5.3 define the variables and terms.

The only difference in the terms of this and Equation III is in the addition of the interaction term (#8 in Table 5.5), "Importance of Other Agency Opinion and Other Agency Opinion of a Proposal." This Type IV term attempts to account for the effect of the evaluation of another agency on the agency whose evaluation is being predicted and turns out to be far the most important single term in Equation 5.16. It is important to note the elastic effect which the addition of this influence had on the other coefficients because of the great importance of this variable and because of an overlapping causal relationship with the other factors in the equation. The prominence of the Type IV term can be ascertained immediately.

17The mean public evaluation may be slightly negative and the process continue.
from the standardized form of the Equation 5.17. It is much larger than any other found in this form because of the obliterating effect of an important single summarizing variable as discussed under the section on Equation III.

All six terms in Equation III were retained for the regression run creating this equation so that the coefficients in Equation IV could be compared with the same terms in Equation III under conditions where every term is the same except for the new one added (term 8 in Equation 5.16). Terms #2, #3, and #6 of this same equation could have been removed since their removal only reduced the \( r^2 \) from .823 to .819. However, even though these three terms have little effect in this particular application, they might have significant impacts on another situation, and therefore, should be retained for future analyses. Without terms #2, #3, and #6, and unstandardized form of the equation is:

\[
Y = -.0466 + .491 - .206X_1 - .0102X_9 + 3.24X_{10} + .00469X_{11} + .0675X_{12} - .0118X_{13} + .769X_{15} \\
\]

Revised decision agency evaluation (DARE)

"The revised decision agency evaluation" is the second of three evaluations by this agency as a proposal moves through the system (Figure 5.1). If the decision resulting from this second evaluation is positive, the plan is announced to the general public. In the model, the revised decision agency evaluation also is given by an application of Equation IV, and the previous decision agency evaluations are input to term #8 (Equation 5.16) in this application. The previous decision agency evaluations have a significant effect on the revised agency evaluation through interaction with the other agency evaluation. This would be characteristic of real life since a person or agency usually tends toward consistency of viewpoint, especially in an area about which the group or person is familiar and has taken a public stand. Inserting the decision agency values from Table 5.4 in the unstandardized form of Equation IV (5.16) gives the following equation which is an approximation of that which would have been obtained had this equation been directly calibrated to the decision agency.

\[
Y = +.491 - .206X_1 - .0190X_9 + 6.01X_{10} + .00359X_{11} + .216X_{12} - .0307X_{13} + .884X_{15} \\
\]

Equation VI: Final agency evaluation (DAFE)

The regression on the data for this evaluation was based on the same data as before but with terms #7 and #9 added. The results are:

Unstandardized form:

\[
Y = -.0466 - .210X_1 + .00522X_9 + .419X_{10} + .00213X_{11} + .0988X_{12} - .0699X_5X_{13} \\
\]

18This representation could be incorrect under certain circumstances. The output of the other agency goes to the decision agency for consideration in its revised evaluation of the flood control plan. As the model is now constructed, this occurs only when the output of the agency evaluation is positive. However, it is conceivable that an objection could be ignored. In this case, the response from the agency would still have an effect which would be accounted for by the Type IV term in Equation IV.

19See discussion under Agency Evaluation Equations.
(7) + (8) + (9) + .0205X6X14 + .400X7X15 + .150X8X16

Standardized form:

Y = - .159X1 + .0476X2 + .0181X2(1/X10) + .421X7X12 + .0168X5X13 + .0367X6X14 + .704X7X15 + .262X8X16

The r² is .827, only slightly more (.004) than without terms #7 and #9. The variables are defined in Table 5.2, and the terms are identified in Table 5.3.

The only coefficients significant at the .05 level are those for terms 1 and 8; those for terms 4 and 5 are significant at a level between .10 and .20. Eliminating variables until all those remaining are significant at the .05 level results in Equation 5.16. The added terms in Equation 5.21 add little to the predictive ability.

Term 9, a Type IV term for the influence of public opinion, was the third most important term as judged by the coefficients of the standardized form (5.22). This term may be more significant than indicated in the previous paragraph because of the high multicollinearity of the equation. High multicollinearity means that much of the variance that would be explained by one term could be accounted for by other terms in the equation and consequently the sizes of the coefficients are smaller (Johnston, 1972; Theil, 1970) and unstable (Gordon, 1968). Therefore, the values of the coefficients of this equation should not be relied on, but the output of the equation could still be relatively stable because fluctuations in some coefficients would be compensated by opposite fluctuations in others.

The results of using Equation 5.21 in the model appear reasonable. The influence of the previous decision agency evaluation dominates, and the sign of Term 9 representing the influence of the public's evaluation is in the direction expected. A favorable public evaluation reinforces the rating by the decision agency. This direct relationship may be offset some by the smaller value of the regression constant in Equation VI (5.21) compared to Equation IV (5.16), meaning that the other terms would have to be more positive to have the same output value of the equation than in Equation IV.

The relative influence of public and previous agency evaluation terms is more than apparent from the coefficients of Equation IV (5.16). This is because the public and previous agency's evaluations are weighted by variables X7 and X8. When the values of the decision agency as listed in Table 5.4 are substituted in Equation VI, the following equation is derived:


The coefficients of X15 and X16 are much more equal in value in Equation 5.23 than are those of the corresponding terms #8 and #9 in Equation 5.21. X15 and X16 are the outputs of other equations in the model. For Equation 5.21, X15 is input from Equation 5.16 applied to the decision agency. X16 comes from the public evaluation equation discussed below.

Population Evaluation Equation

Equation V(a): Population evaluation equation - continuous form

Unstandardized form:


Standardized form:


The variables in Equations 5.24 and 5.25 are identified in Table 5.6. The terms are listed in Table 5.9. This equation has an r² of .492 for the sample and flood control proposals used. The significance levels of the terms (denoted by bracketed numbers) are: (1) .005; (2) .003; (3) .015; (4) .02; (5) .07; (6) .0001; (7) .006; (8) .0627; (9) .02; (10) .05; and (11) .02.

All the terms in Equation 5.25 were reasonably significant, and the r² was fair by social science stand-
Table 5.6. Variable list for the population evaluation equation (Equations Va and Vb.)

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Definition</th>
<th>Scheduled Item #</th>
<th>Possible Score Range*</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>Number of Types of Groups with Whom TheyDiscussed Flooding Problems (KTYPE)</td>
<td>(5-A)</td>
<td>0 to 4</td>
</tr>
<tr>
<td>X2</td>
<td>Proximity of Flooding Experience to Present Residence (KLOSF)</td>
<td>(8)</td>
<td>0 to 3</td>
</tr>
<tr>
<td>X3</td>
<td>Proportion of Single Unit Structures in a Block (KSINUN)</td>
<td>(135)</td>
<td>0 to 1</td>
</tr>
<tr>
<td>X4</td>
<td>Willingness to Follow Government Agencies (AGENL-4) Recommendations or Advice</td>
<td>(App. B)</td>
<td>0 to 16</td>
</tr>
<tr>
<td>X5</td>
<td>Knowledge of Local Flood Control Proposals (KNOWL)</td>
<td>(5)</td>
<td>0 to 4</td>
</tr>
<tr>
<td>X6</td>
<td>Perception of Need for Improved Flood Control in the Local Area (CONCL-8)</td>
<td>(59)</td>
<td>0 to 32</td>
</tr>
<tr>
<td>X7</td>
<td>Attitude Toward the Effect of Man-Made Objects Upon the Beauty of Nature (MANL-4)</td>
<td>(App. B)</td>
<td>0 to 16</td>
</tr>
<tr>
<td>X8</td>
<td>Outdoor Recreation Orientation (RECL-6)</td>
<td>(App. B)</td>
<td>0 to 24</td>
</tr>
<tr>
<td>X9</td>
<td>Ecological Orientation (ECOLL-8)</td>
<td>(App. B)</td>
<td>0 to 32</td>
</tr>
<tr>
<td>X10</td>
<td>Willingness to Pay for Government Expenditures (PAYL-6)</td>
<td>(App. B)</td>
<td>0 to 24</td>
</tr>
<tr>
<td>X11</td>
<td>Willingness to Follow Experts Recommendations or Advice (EXPTL-6)</td>
<td>(App. B)</td>
<td>0 to 24</td>
</tr>
<tr>
<td>X12</td>
<td>Perceived Effectiveness of a Proposal (IERFF)</td>
<td>(95-C, 97-C, 98-C)</td>
<td>-2 to +2</td>
</tr>
<tr>
<td>X13</td>
<td>Perceived Aesthetic Effect of a Proposal (IRAES)</td>
<td>(95-E, 97-E, 98-E)</td>
<td>-2 to +2</td>
</tr>
<tr>
<td>X14</td>
<td>Perceived Recreational Effect of a Proposal (IRREC)</td>
<td>(95-D, 97-D, 98-D)</td>
<td>-2 to +2</td>
</tr>
<tr>
<td>X15</td>
<td>Perceived Ecological Effect of a Proposal (IRECO)</td>
<td>(95-F, 97-F, 98-F)</td>
<td>-2 to +2</td>
</tr>
<tr>
<td>X16</td>
<td>Perceived Cost of a Proposal (IRCOS)</td>
<td>(95-B, 97-B, 98-B)</td>
<td>-2 to +2</td>
</tr>
<tr>
<td>X17</td>
<td>Evaluation by Government Decision Agency of a Proposal (IDAGEN)</td>
<td></td>
<td>-2 to +2</td>
</tr>
</tbody>
</table>

*For a definition of the meaning of the scores, refer to Appendix A.

An effect of measurement error is to weaken real relationships; consequently, the appearance of expected relationships despite measurement problems indicates the plausibility of the underlying construct. The direction of the relationships in Equation 5.24 with the dependent variables are as hypothesized.

A recently developed method of measurement appears to be similar and more effective for this type of application (Hamblin, 1971; 1974; Stevens, 1966).
The validity of these results is reinforced by multicollinearity analysis (Appendix I). For an equation with 11 terms and 17 social science variables, the intercorrelation between the independent variables is quite low. Of the 55 bivariate relationships, only six are significant at the .20 level and most are not significant at .10. Even the multiple $r^2$’s from linear multiple regressions, using all the other terms except the dependent variable as predictors, are comparatively low with the majority between .05 and .12 and the highest three between .36 and .38. This low multicollinearity is important because coefficients are so unreliable when multicollinearity is severe that even changes in signs of important variables may occur (Gordon, 1968; Darlington, 1968; Schoenberg, 1971; Johnston, 1972; Wonnacott and Wonnacott, 1972; Duncan and Goldberger, 1973). Low multicollinearity is a necessary, although not sufficient, condition of valid coefficients.

Figure 5.3 illustrates the formulation of the terms used in Equation 5.24. This chart can be compared to Figure 5.2 in order to see how a general conceptualization was applied to obtain a working equa-

Table 5.7. Terms of the population evaluation equation (Equation V).

<table>
<thead>
<tr>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Number of Types of Groups With Whom Discussed Flooding Problems.</td>
</tr>
<tr>
<td>(2) Proximity of Flood Experience to Present Residence.</td>
</tr>
<tr>
<td>(3) Proportion of Single Unit Structures in Block</td>
</tr>
<tr>
<td>(4) Willingness to Follow Government Agencies</td>
</tr>
<tr>
<td>(5) Knowledge of Local Flood Control Proposals</td>
</tr>
<tr>
<td>(6) Perception of Need for Improved Flood Control in Area</td>
</tr>
<tr>
<td>(7) Attitude Toward the Effect of Man-made Objects upon the Beauty</td>
</tr>
<tr>
<td>(8) Outdoor Recreation Orientation</td>
</tr>
<tr>
<td>(9) Ecological Orientation</td>
</tr>
<tr>
<td>(10) Willingness to Pay for Government Expenditures</td>
</tr>
<tr>
<td>(11) Willingness to Follow Experts</td>
</tr>
</tbody>
</table>

22 These three were the aesthetics, recreation, and ecology terms and did cause some difficulties.
The difference between Figures 5.2 and 5.3 is that specific groups, variables, and coefficients are provided in Figure 5.3. The boxes are labeled in the diagram, the variables are defined in Table 5.8, and the arrows show how information is directed to Equation 5.24.

The variables in the terms of the equation were assigned values in such a way that a larger number indicated a greater level of the variable or combination of variables as defined in Table 5.8. This means that a positive sign indicates a direct relationship with the dependent variable and vice-versa. In particular, all the acceptance functions (Terms # 6 through # 11) were deliberately constructed so that a higher value would mean greater acceptability of a project proposal. This required defining all the variables in the acceptance functions in such a way that a higher value meaning greater acceptability would be true of each of these variables also.

**Single variable terms**

All the terms of Equation 5.24 are positively related to public support for the flood control plan (the dependent variable) except for Terms 1 and 3. Term 1 "Number of types of groups with whom they discussed flooding problems," may be negative because of opposition of some groups to a proposal for stream channelization. Owners of homes along the streams organized and vehemently protested the destruction of the aesthetic aspects of the streams in their backyards. In general, people were sympathetic to the importance of aesthetics and to the streamside owners' viewpoints, and the proposal was revoked. This could explain an inverse relationship for this variable in this application of the basic equation.

The negative sign of Term 3, "Proportion of Single Unit Structures in a City Block," is harder to interpret. "Length of Time Lived in the Area," while not used in this equation, was also negatively related to the evaluation of flood control proposals. Perhaps a person in a situation for a longer time becomes used to and therefore less concerned about dangers in his environment, particularly if these threats do not occur frequently as in the case of serious floods. Since persons who own their own homes are more likely to live in single dwellings than are those who do not, and a person who lives in an area longer is more likely to become a homeowner, this effect may cause the negative sign for variable X₃. Additionally, a homeowner pays property taxes and therefore may be more aware of the cost of government projects.

| Table 5.8. Categories of independent terms for Equation 5.28. |
|-----------------|---|---|---|---|---|---|---|---|---|---|---|---|
| Z               | C  | N  | Z  | C  | N  | Z  | C  | N  | Z  | C  | N  |
| 1.1 0           | 136| 4.1| 6-8| 26 | 7.1| -22-10| 16 | 10.1| -36-25| 18 |
| 1.2 1           | 47 | 4.2| 9-11| 109| 7.2| -9-1| 20 | 10.2| -24-18| 32 |
| 1.3 2           | 34 | 4.3| 12-14| 116| 7.3| 0| 170| 10.3| -17-11| 88 |
| 1.4 3           | 33 | 4.4| 15-17| 24 | 7.4| -1-9| 41 | 10.4| -10-1| 89 |
| 1.5 4           | 25 | 5.1| 28 | 7.5| 10-24| 28 | 10.4| -10-1| 89 |
| 2.1 0           | 164| 5.2| 63 | 7.6| -45-| 11 | 10.5| 0| 33 |
| 2.2 1           | 42 | 5.3| 2| 7.7| -1-9| 19 | 10.6| 1-32| 15 |
| 2.3 2           | 35 | 5.4| 3| 7.8| -1-9| 19 | 10.7| 0-0| 0 |
| 2.4 3           | 34 | 5.5| 51 | 8.1| -1-5| 11 | 11.1| -32-25| 43 |
| 3.1 0-.39       | 15 | 6.1| -50-21| 7 | 8.2| 0| 136| 11.2| -21-1| 42 |
| 3.2 0-.59       | 31 | 6.2| -20-1| 14 | 8.3| 136| 11.2| -21-1| 42 |
| 3.3 0-.79       | 52 | 6.3| 0| 19 | 8.4| 136| 11.2| -21-1| 42 |
| 3.4 0-.89       | 52 | 6.5| 16-30| 146| 8.5| 136| 11.2| -21-1| 42 |
| 3.5 0-.99       | 62 | 6.6| 31-50| 28 | 8.6| 136| 11.2| -21-1| 42 |
| 3.6 1.0         | 83 | 9.2| -1-5| 11 | 9.3| 0| 105| 9.4| 1-22| 114 |
|                |    | 9.5| 23-40| 23 |    |    |    |    |    |    |

aZ refers to the subscript of Z in Equation 5.28. The first number identifies the term defined in Table 5.7. The number to the right of the decimal point indicates a range of values. The C column specifies the values each range contains. N is the number of observed values in a range. For example 15 values of Term 3 range between 0.00 and 0.39. The total number of observed values is 275.
The "Proportion of Single Unit Structures in the City Block," may be important because of social interaction effects. An individual is influenced by the opinions of his associates and neighbors, especially those whom he feels share his situation. Therefore, a single residence occupant in an area of apartment type multiple dwellings can be hypothesized to be more likely to be positive on a flood control issue than single residence inhabitants in a neighborhood dominated by single residents.

The first term related positively to the dependent variables is Term 2 (variable X2), "Proximity of Flood Experiences to Present Residence." If a person has actually experienced flooding and particularly in the place in which he lives, he is expected to be more likely to favor a flood control proposal. Variable X4, "Willingness to Follow Government Agencies," would also be expected to be positively related to support for flood control since most flood control proposals (all those considered in calibration of the model) are government recommendations.

Term 5 or variable X5, "Knowledge of Local Flood Control Proposals," turned out to be positively related to the evaluation of flood control proposals for the cases tested but may not be generalizable to other areas or circumstances. The positive relationship in Equation 5.24 may be because the strong effect of negative factors on the evaluation of a proposal is largely accounted for by the acceptance functions. A positive relationship would be reduced to the degree that the extra knowledge centers on negative factors. The sign and value of the coefficient of X5 needs further testing by calibrating the general equation for each population to which the model is applied.

The population variables may be much more important in predicting differences in the reactions of different populations to the same proposal than in the present application of predicting differences within the same population to different proposals. This is because a variable must fluctuate to be studied. Consequently, data from a homogenous population may cause population variables which are important determinants to be underrated. The matter can only be resolved by applying the general equation to substantively different populations.

Interaction terms

The interaction terms in the Equation 5.24 are the heart of this equation and this model. They link the separate equations together and also account for most of the variance in the evaluation equations. In fact, the general equation could be calibrated using the interaction terms alone, and most of the variance accounted for by Equation 5.24 would be included.

An indication of the approximate relative importance of the terms of the equation can be seen from the sizes of the coefficients in standardized form (see Chapter II). Although the coefficients are large for the interaction terms, the r2 without the single variable terms would almost certainly be larger than that estimated from the ratio of the sum of the coefficients of the standardized interaction terms to that of the sum of the standardized single variable terms. This is because of variance which would be explained by other variables if a term were removed. The measurement error in some cases is greater for variables in the interaction terms; and this would result in underestimation of the real effect of terms of which those variables are part.

In all the interaction terms the scale score was reduced by the number of items in the scale (Appendix C) in order to make the minimum score equal zero. There is an implied assumption in this procedure that all attitudes are unidirectional in effect. Setting the zero point at one end of the scale means that there can be no opposites in sign. This means that the directional effect of an interaction with another variable depends entirely on the magnitude of the other variable. Unsigned variables are consistent with the idea of importance functions for which function scale scores were used in the interaction terms in the mathematical model. Importance normally is thought of as more or less, not negative or positive. In most cases, as applied in this model, this is reasonable.

It may not be tenable for the Type IV term for the effect of a revised decision agency evaluation on the public's attitude.

The quantity three was subtracted from the perceived judgment score used in each of the Type III terms, called acceptance functions, so that "neutral" received a value of zero. This was done because of the substantive meaning of these interaction terms. The effect of a positive attitude about recreation, for example, would be the reverse if the proposal would lessen the quality or quantity of recreation than if

Condominiums may be an exception because they are owned by the occupant.

There is about one chance in fourteen that the positive relationship is spurious for the sampled population. This is the weakest significance level of terms in the equation.

It may be impossible to predict the sign and magnitude of X5 from the social and hydrologic conditions of an area. This interesting and worthwhile task, however, would be a major undertaking.

It is assumed that almost no one will be against ecology, aesthetics, recreation, or effectivenss of a flood control proposal.

Quality and quantity were not distinguished in asking the perception of the effect of a proposal. This may be a distinction for some variables such as recreation.
it increased the supply of recreation. Consequently, in order to have the interaction terms affect the dependent variable consistently, this adjustment was made. The perceived cost of a proposal in addition had its value reversed so that a higher number indicated lower cost. Since all the perceived judgments were five point scales running from one to six, a scale value could be reversed by subtracting from six. Doing this and subtracting three is equivalent to subtracting the score of the perceived judgment from three.

The first interaction term, the effectiveness acceptance function \( X_6 X_{12} \) is indicated (e.g., 5.25) to be the most influential on public evaluation of flood control proposals. The two variables are probably better measured than most others, both because of the relatively high reliability and internal consistency of the CONCL scale, "Perception of Need for Improved Flood Control in a Local Area," and because the concept of flood control has a comparatively stable and consistent definition. CONCL is interacted with "Perceived Effectiveness of a Proposal." Therefore, the effect of this factor is probably less undervalued than some others. The other problems dealing with measurement which have been mentioned do not appear to apply as strongly in this case as in most cases.

The second interaction term is the aesthetic acceptance function \( X_7 X_{13} \). The scale measured "Attitude Toward the Effect of Man-Made Objects Upon Beauty of Nature," MANL. The basic idea needing to be measured, however, was the importance of aesthetics in a flood control proposal. The MANL variable does not measure this specific important aspect, although it does measure an aesthetically related attitude, and the two seem to be correlated.

The third interaction term \( X_8 X_{14} \) is the recreation acceptance function RECL, "Outdoor Recreation Orientation." This does not have the measurement difficulties of the aesthetic term, but the coefficient (e.g., 5.25) is only about half that of the aesthetics acceptance function. An interpretation of this result could be that a large part of the recreational enjoyment associated with flood control relates to the beauty of the surroundings in which recreation occurs; and, since the aesthetics acceptance function is more directly related to this aspect of recreation, that term absorbed much of the variance that would otherwise be included in the recreation term.

Some support for this interpretation is found in a regression run where each of the terms in Equation 5.24 is added until the total equation is specified. Before any other variables were added, in other words, in relation to the total variance of the dependent variable, the mean square indicated for the recreation acceptance function term was nearly equal to that for the aesthetics acceptance function. But with the aesthetics acceptance function in the model, the mean square of the recreation acceptance function dropped considerably. The correlation between recreation and ecology terms was measured as 0.3453, the highest of any bivariate relationships among the terms in the model. Although the significance of the recreation acceptance function was second lowest of all the terms in the equation, it is recommended that this term be included in future analyses.

Two of the three flood control methods, channelization and retention basins, used in the calibration have a major effect on recreation, the first negative and the other positive; and in both cases aesthetic aspects are a principal part of the recreation effected. Channels detract from scenic surroundings in back yards and reservoirs provide parks. The beauty of the locality may affect the choice of a location for water-oriented recreation. Perhaps with data on recreation activities without a strong aesthetic aspect, the coefficient of the recreation acceptance function will be increased.

Ecology is the focus of the fourth acceptance function included in Equation 5.24, Term 9. This term worked fairly well. The ECOL or "Ecological Orientation Scale" does not appear to have serious problems although it is likely not unidimensional. As with recreation, the coefficient of the ecological acceptance function term might be substantially larger if the aesthetics term were absent. For many laymen, the most meaningful aspect of ecology might be the visual part primarily since this is what is most appar-

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30 The mean square is the mean of squares divided by the degrees of freedom. For an individual independent term in regression analysis, the degree of freedom is one; and the sum of squares is the total of the squared deviations of the measured from the predicted values of the dependent variable. Initially, the mean of the dependent variable is used as the best prediction; and all the variance in the dependent variable is unaccounted for. Consequently, the greater the mean square at that time, the greater the ability of that independent variable to alone explain the variation in the dependent variable.

31 The mean square with no independent variables in the model was 58.46 for the term for aesthetics and 53.71 for the recreation term.

32 Upon addition of the aesthetics term to the model the mean square of the recreation acceptance function, which was not in the model at that time, reduced from 29.064 to 8.146. The reason it can drop is that the part of the variance of the dependent variable not explained by the model to that point is used in the calibration.

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29 The revised decision agency evaluation which is used as an input to the Type IV interaction term has the neutral point already adjusted to zero in the model.
ent to the senses. Similar evidence to that described for the relationships of the recreation and aesthetics terms was manifested for the ecological and aesthetics terms; the calculated correlation coefficient in this case was not quite as high, 0.2345. Despite any attenuation or weakening caused by correlation with other variables, this term is shown by Equation 5.25 as being one of the more important. Certainly, the interest in ecology warrants inclusion of such a term in analyses of the merits of flood control proposals.

The results of analysis of the term interrelating the "Willingness to Pay for Government Expenditures Scale," PAYL, and "Perceived Cost of a Project" indicated Term 10 to be the least important. The cost acceptance function had the lowest standardized coefficient of any of the interaction terms in Equation 5.25. The scale score PAYL for willingness to pay had the second highest reliability of any of the scales (Appendix D). This would indicate that concern about flood control cost is not as great a concern as other aspects of a project. The general public may usually assume a proposal is affordable if it is proposed by an official agency and costs are not direct; they may also expect officials who oversee the flood control decision to be responsible for keeping costs down. If this is true, monetary considerations will be very important to an agency, especially the decision agency, in determination of acceptable flood control proposals. Such a result is suggested by Equation III, but requires further testing. 33 In any case, a cost acceptance function term should be included in all studies, whether it be an agency or public group being analyzed, until further testing indicates specifically when and where it is unimportant.

The correlation between the "Ecological Orientation Scale," ECOL, and MANL was computed as 0.3745. It is interesting also that use of leisure orientation, LEIL, in place of MANL in this acceptance function term (Term 7 of Equation 5.21) results in a slightly more effective equation which is entered into this term in the model. This point is illustrated by replacing (MANL4) by (LEIL-6) (see Appendix D) in Equation 5.24. The resulting equation in unstandardized form is:

$$\text{POPEVE} = 0.381 - 0.124X_1 + 0.124X_2 + 0.480X_3 + 0.049X_4$$

$$+ 0.063X_5 + 0.023X_6X_12 + 0.032X_1$$

In standardized form is:

$$\text{POPEVE} = -0.172X_1 + 0.134X_2 - 0.107X_3 + 0.108X_4$$

$$+ 0.087X_5 + 0.339X_6X_12 + 0.196X_7X_13$$

$$+ 0.111X_8X_14 + 0.124X_9X_15 + 0.081X_10X_16$$

$$+ 0.19X_11X_17$$

The $r^2$ of Equation 5.26 or 5.27 is 0.490.

Equation 5.26 was not used instead of Equation 5.24 because of the slightly smaller value of the coefficient in Term 7 and slight reduction in $r^2$. The results would have been easier to explain had this last equation been used on the hypothesis that leisure orientation and outdoor aesthetics orientation are correlated. All that can be expressed with certainty at this stage of development is that the aesthetics acceptance function is important and must be included for realistic analysis of public flood control proposal evaluations. What the actual value of the coefficient will be in this context with satisfactory measurements of the variables remains for further study.

The last term in Equation 5.24, the only Type IV term in the equation, accounts for the influence of the County Flood Control Division agency. It is the predicted value of that agency's revised evaluation which is entered into this term in the model. The companion variable is measured by the "Willingness to Follow the Advice of Experts," EXPTL. The scale was slightly more effective in this interaction than the "Willingness to Follow Government Agencies Scale," AGENL, Term IV; this could partly be because of the higher reliability and longer length of this scale (see Appendix C). 34 This type of relationship should always be included in any attempt to predict actual reaction to proposals by the public. It may be useful to add more acceptance functions of this kind with each one representing the effect upon the public's evaluation of some significant group.

In summary, all the acceptance functions included in this population analysis seem reasonable.

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33Equation IV and VI do not indicate strong importance of cost factors because the effect of monetary considerations is largely absorbed by the Type IV term for the influence of previous agency evaluations. The effect of the cost factors is probably underrated even in Equation III because of the fact that it appears in both Terms 2 and 3 (see Gordon, 1968).

34The fact that a variable is used as a Type I variable did not prevent its selection for a Type IV term. The selection of the variables for the interaction terms was done before the addition of other variables to an equation.
for future analyses of public evaluation of flood control proposals. Because of measurement difficulties and real differences, the coefficients can be expected to vary substantially from those specified in Equation 5.24. Much variation can be eliminated by improved measurement of the variables and by more data for calibration. If this was done, the predictive ability of the equation should increase and the correlation coefficient attained would be considered high by traditional standards of nonexperimental research in social science.

**Equation V(b): Population evaluation equation - categorized form**

In cases where relationships are nonlinear, the predictive capability of equations designed to reflect these relations can be improved by incorporating the nonlinear effects. Thus, the predictive capability of Equation V(a) (5.24) can be improved by allowing for nonlinear relationships. However, the inclusion of nonlinear terms in an equation complicates its development, calibration, and use. A way of accounting for nonlinearities in an equation without having nonlinear terms is to stratify or categorize the independent variables into relatively homogeneous groups and to formulate linear "sub-relationships" for each group. The resulting equation produces a series of connecting but discontinuous straight lines which in effect form a quasi curvilinear function. The categorized form of the unstandardized version of Equation V (5.24) is as follows:

Unstandardized form: 35

\[
\text{POPEVE} = 3.30 + .152\psi_{1.1} + .224\psi_{1.2} + .227\psi_{1.3} - .493\psi_{1.4} - .110\psi_{1.5} - .134\psi_{1.1} - .084\psi_{2.1} + .136\psi_{2.2} + .082\psi_{2.4} + .344\psi_{3.1} + .026\psi_{3.2} + .022\psi_{3.3} - .173\psi_{3.4} - .114\psi_{3.5} - .105\psi_{3.6} - .0464.1 - .076\psi_{4.2} - .005\psi_{4.3} + .127\psi_{4.4} - .144\psi_{5.1} - .221\psi_{5.2} - .013\psi_{5.3} + .140\psi_{5.4} + .238\psi_{5.5} - .638\psi_{6.1} - .592\psi_{6.2} - .006\psi_{6.3} + .313\psi_{6.4} + .368\psi_{6.5} + .555\psi_{6.6} - .651\psi_{7.1} - .243\psi_{7.2} - .241\psi_{7.3} - .235\psi_{7.4} + .435\psi_{7.5} - .587\psi_{8.1} - .175\psi_{8.4} + .067\psi_{8.3} + .002\psi_{8.4} + .006\psi_{8.5} + .671\psi_{9.6} - .288\psi_{9.1} - .359\psi_{9.2} + .283\psi_{9.3} + .170\psi_{9.4} + .194\psi_{9.5} - .034\psi_{10.1} - .336\psi_{10.2} - .166\psi_{10.3} + .093\psi_{10.4} + .281\psi_{10.5} + .162\psi_{10.6} - .112\psi_{11.1} - .134\psi_{11.2} + .034\psi_{11.3} + .215\psi_{11.4} - .003\psi_{11.5} \quad (5.28)
\]

The independent or \( \psi \) variables in this equation are defined in Table 5.8. The first number of each \( \psi \) subscript refers to a term in Table 5.7. The second number in each subscript is the number of a category encompassing a range of values for that item shown in Table 5.8. Each range has been numbered in sequence from smaller to larger values.

The regression using this categorization of continuous variables increased \( r^2 \) to 0.602. The increase was not spurious. Since there were 275 observations, dividing them into five or six categories still leaves many degrees of freedom. The cutting points dividing categories were chosen to give sufficient observations in each category for stable statistics. Negative and positive values were not permitted in the same category, and each category was nearly equal in range. The number of observations in each category is as shown in Table 5.8.

The pattern of the values of the coefficients of the \( \psi \) variables in Equation 5.28 suggests a direct relationship with the dependent variable in cases where the coefficients for a given term increase with the number of the category. The opposite trend suggests an inverse relationship. Fluctuations in the pattern suggest a nonmonotonic relationship. 36 Most of the values of the coefficients for a given term in Equation 5.28 are consistent; indeed, they must be for the term to be significant in a linear equation such as 5.24.

Another attempt to increase the predictive ability of Equation 5.27 used a multiplicative power function with the same variables. 37

Unstandardized form:

\[
\text{POPEVE} = e^{-0.31X_1} \cdot 0.49X_2 \cdot 0.53X_3 \cdot 39X_5 - 0.16X_{12} \cdot 41(X_4X_7) \cdot 0.72(X_9X_{15}) \cdot 0.17(X_{10}X_{16}) \cdot 0.041 \quad (5.29)
\]

36 The coefficients of the category terms add to one because a dummy variable coding using 0's and 1's was used. If there were equal numbers of cases in each category, each coefficient would be equal to the differences between the mean of a given group assigned 1's and the group assigned 0's throughout, (Kerlinger and Pedhazur, 1973: 108). This is because the best single predictor for a subject is a score equal to the mean of the group of values in which the subject's real value occurs.

37 All the variables in Equation 5.27 and listed in Table 5.8 were entered singly in development of the multiplicative power function and, in addition, all the interaction terms were tried.
The $r^2$ equals .548 with all terms significant at the .05 level. Equation 5.29 was not used in the model because it is more difficult to interpret\textsuperscript{38} and because Equation 5.28 had a higher $r^2$.

The $r^2$ of Equation 5.28 was greater than that of Equation 5.27 because the categorization of terms accounted for nonlinearity in the relationships.\textsuperscript{39} Equation 5.28 was the one used in the model to predict public response to a flood control proposal. Unlike the agency evaluation equations, public response could be slightly negative and still not cause rejection of a proposal. The value set for rejection in the model is -.5.

\textit{IF statement $C_1$ to $C_5$}

The next step in the model is to check for special interest opposition to the flood control proposal with five IF statements. The statements are set to mirror the ability of special interest groups to block projects which adversely affect aspects about which they are concerned. They specify limits of acceptability of factors such as cost, effectiveness, and ecology.

Acceptance functions are used in these checks rather than the perceived characteristics because a negative response by a special interest group to a proposal would meet more success if that factor was also considered important by the general population. The acceptance functions reflect this interactive interrelationship. A negative value for a factor of a proposal in the acceptance function can become more negative if either the importance factor (IF) increases or a proposal is considered worse because of the factor. If a factor is unimportant, a severe adverse effect would be required to cause a large enough negative value of the acceptance function for the flood control proposal to be rejected. If the factor were perceived as very important, even a small negative value on the perceived project characteristic would block adoption.

For some factors, the minimum acceptable value will be positive. This kind of factor would be one with respect to which the flood control proposal must actually improve conditions in order to be accepted. For flood control proposals, one such factor would be the ability of the proposal to control flooding.

The relationships used by the model in the $C$ IF functions are:

\begin{equation}
\text{IF statement } C_1 \text{ for recreation:} \quad \text{Reject If } X_8 X_{14} \leq -3.0 \quad \ldots \quad (5.30)
\end{equation}

\begin{equation}
\text{IF statement } C_2 \text{ for ecology:} \quad \text{Reject If } X_9 X_{15} \leq -5.0 \quad \ldots \quad (5.31)
\end{equation}

\begin{equation}
\text{IF statement } C_3 \text{ for aesthetics:} \quad \text{Reject If } X_7 X_{13} \leq -1.0 \quad \ldots \quad (5.32)
\end{equation}

\begin{equation}
\text{IF statement } C_4 \text{ for effectiveness:} \quad \text{Reject If } X_6 X_{12} \leq 4.0 \quad \ldots \quad (5.33)
\end{equation}

\begin{equation}
\text{IF statement } C_5 \text{ for cost:} \quad \text{Reject If } X_{10} X_{16} \leq -20.0 \quad \ldots \quad (5.34)
\end{equation}

The variables are those defined in Table 5.6. The values of the limits should not be compared with each other as a common scale of measurement was not used.

The values of the acceptance functions for IF statements $C_1$ to $C_5$ used as threshold acceptability levels are established by system simulation. They are adjusted to values just below those that historically caused plans to be rejected and just above those for proposals that were accepted. This is done by examining historical records for the reasons, especially in the actions of special interest groups, and adjusting the appropriate acceptance function threshold levels.

These IF functions generally worked well. However, IF function $C_5$ (5.34) gave unrealistic responses to cost in some cases because of the way in which one of the variables in the population acceptance function was handled. In an attempt to achieve consistency in this term, willingness to pay, PAYL, and the reciprocal of perceived cost were used together\textsuperscript{41} in the population evaluation equation. This means that the value of the cost acceptance function goes up with willingness to pay if the perceived low cost is positive and down if it is negative. An increase in PAYL should always make a proposal more acceptable. It would have been better, in this case only, to have not subtracted

---

\textsuperscript{38}Standardization of this type of equation is not very meaningful since the factors are not in separate terms. A power function equation is best interpreted by remembering that the exponents are weightings of the logarithms of the variables in relation to the log of the dependent variable.

\textsuperscript{39}Another way of accounting for nonlinearity is by specifying the non-functional form more precisely; however, actual ratio level data are required for this to be done with confidence. Recently, this has become possible in sociology (footnote 31), and a few analyses have achieved $r^2$ values prior to those obtained in the applied physical sciences (see Hamblin, 1974). Stimulus-attitude relationships appear to often have a power-function relationship as do physical-stimulus responses (Hamblin, 1974).

\textsuperscript{40}The converse is used in the computer program for $C_1, C_2, C_3,$ and $C_4$ accept when the acceptance function is greater than the value. This is exactly equivalent.

\textsuperscript{41}See discussion on Interaction Terms.
three from the values of perceived low cost, but instead have exclusively positive numbers.

If the value of the perceived cost of a proposal is placed directly into the acceptance function, IF function $C_S$ would have to have a maximum rather than a minimum for acceptability. The companion variable would have to be changed in that case also, either by reversing PAYL so that it became unwillingness to pay or by use of another variable such as importance of lost cost in a flood control proposal. If this model is followed, it would be unnecessary to worry about the sign of the term as regression analysis would set the sign according to the relationship of the term with public evaluation. The sign would probably be negative when perceived cost figures are directly inserted into an evaluation equation. As evidenced above, it is necessary to be concerned about zero points of variables in interaction terms. In future research, it is recommended that both in the public and agency evaluation equations, the perceived cost of a proposal be entered into the equation without transformation and IF statement $C_S$ be modified accordingly. This would have been done with this model except the equations and systems had been calibrated and some sensitivity analyses performed before the problem was found, and it was not feasible to change the equations at that point. The model can still be assessed with this problem present if interpretations are adjusted appropriately.

In the model, C IF statements are do or die mechanisms. They all must be met or the flood control proposal fails and the process begins anew with another proposal. An alternate approach would be to have a deficient level of a function trigger a second evaluation equation. This evaluation equation would be for a special interest group whose concern is the same as that of the IF statement that triggered the use of the equation. The factor under consideration would then be expanded greatly for that group in the general population. The degree of opposition by the group could then be calculated. Rejection of a plan could hinge on a combination of the different special interest groups and/or mean public evaluations reaching a certain negative level. This scheme would include more of the dynamics and also allow for the cumulative effects of different evaluations within the public.

The possibility described above is another illustration of how the model can be extended to cover different and more complex situations. The discussion of this mathematical model has been thorough and candid, and the errors and consequent problems have been presented. This frankness should not be held against either the equations or the system as a whole. The model did well, usually simulating reactions in a realistic way and providing insight into the reverberations which a change in one or two variables can make. Interrelationships among parts of the model, translation of the social system model into a computer model, and the results of sensitivity and simulation analyses are discussed in the next chapters.

**Summary of the General Equations of the Model**

Table 5.9 summarizes the general equations in unstandardized form derived from application of the theory and methodology of this study. The model is designed to permit use of several values for the variables in order to identify possible reactions to flood control proposals. This chapter explains development of the equations used in the mathematical model for the various stages of the process.

Table 5.9 brings together the various mathematical relationships proposed for representing institutional and public response to flood control plans by quantifying the social variables and functions of a complex system. The deductive conceptual model of Figure 4.1 was mathematized by the inductive process of the discovery and identification of significant dependent and independent variables. After these variables were specified, their numerical values were determined, and relationships among them were specified. This required specifying different types of variables and factors influencing those variables. Once these elements were developed into a mathematical model, it was possible to simulate the decision process.

The model is not expected to provide precise predictions of human behavior, but it is capable of providing important insights to planners and those making decisions in communities. Because it indicates sensitivities, the model enhances an understanding of the relationships between the needs, interests, intensities of feelings, and possible reactions to various conditions and proposed changes. In particular, the model illuminates the interactions between factors and relationships in the system. With further development, this tool should help reduce poor choices and the time for making decisions and thus reduce the social and economic costs of flood control planning.
Table 5.9. A summarization of the general equations for the sociologic-hydrologic model (unstandardized form which may be applied for any geographic area).

Equation I  Perception of need for flood control in the local area:

\[ CONCL = 10.8 + 0.506X_1 + 0.353X_2 + 0.26X_3 + 0.308X_4 - 0.453X_5 + 0.146X_6 + 0.230X_8 + 0.0012 (X_9X_{10}) \]

Variables in Equation I are defined in Table 5.1

Equation II and IF statement a: decision agency need:

\[ N = C_1 + C_2M + C_3 CONCL + C_4 PAYL \]

IF Statement A IF \( N > 0 \), continue

Variables in Equation II and IF Statement A are defined in section on Equation II.

Equation III  Initial agency evaluations

\[ Y = -.241 - .305X_1 + 0.695X_2X_9 + 8.43X_2/X_{10} + 0.0568X_3X_{11} + 1.36X_4X_{12} + 0.228X_5X_{13} \]

Variables in Equation III are defined in Table 5.2

IF statements B1 to B3

IF statement B1 for cost of proposal:

if \( X_{10} \leq C_m \), continue

IF statement B2 for effectiveness of proposal:

if \( X_{17} \geq F_y \), continue

IF statement B3 for benefit-cost ratio:

if \( X_9 \geq B_y \), continue

Variables in IF statements B1 through B3 are defined in Table 5.2

Equation IV: Intermediate agency evaluations

\[ Y = .491 - .206X_1 - 0.00585X_2X_9 + 1.85X_2 (1/X_{10}) + 0.0125X_3X_{11} + 0.108X_4X_{12} - 0.0189X_5X_{13} + 0.442X_7X_{15} \]

Variables in Equation IV are defined in Table 5.2

Equation V(a)  Population Evaluation Equation

\[ POPEVE = .645 - 1.129X_1 + 1.29X_2 - .947X_3 - .047X_4 + .060X_5 + .024X_6X_{12} + .033X_7X_{13} + .085X_8X_{14} - .0081X_9X_{15} - .0090X_{10}X_{16} + .0062X_{11}X_{17} \]

Variables in Equation V(a) are defined in Table 5.6

IF statement C1 - C5

IF statement C1 for recreation.

Reject if \( X_8X_{14} \leq R_m \)

IF statement C2 for ecology:

Reject if \( X_9X_{15} \leq N_m \)

IF statement C3 for aesthetics.

Reject if \( X_7X_{13} \leq A_m \)

IF statement C4 for effectiveness:

Reject if \( X_6X_{12} \leq E_m \)

IF statement C5 for cost:

Reject if \( X_{10}X_{16} \leq M_m \)

81
Table 5.9. Continued.

Variables in IF statements $C_1 - C_5$ are defined in Table 5.6.

$R_m$, $N_m$, $A_m$, $E_m$, and $M_m$ are set values of the respective acceptance function which a proposal must meet to be acceptable.

Equation VI: Final agency evaluation

\[
y = 0.0446 - 0.210x_1 + 0.00522x_2x_9 + 0.419x_2(1/x_10) + 0.00213x_3x_{11} + 0.988x_4x_{12} - 0.0699x_5x_{13} + 0.0205x_6x_{14} \\
+ 0.400x_7x_{15} + 0.150x_8x_{16}
\]  

Variables in Equation VI are defined in Table 5.2
CHAPTER VI

COMPUTER MODEL OF THE SOCIAL SYSTEM

Introduction

Once the equations are calibrated and interrelated through common variables, translation into a computer model consists of programming the calculations indicated by the formulas, entering the data and constants used to adjust the model to a particular system, and constructing a user manual. Afterwards, simulation and sensitivity analyses can be performed. The ability to do these analyses is one of the main benefits of a system model as it is used to develop a better understanding of key relationships.

Outline of Computer Model

The computer model (see right side column of Figure 5.1) is programmed from the mathematical model presented in the last chapter. The solid lines indicate various paths followed, given the particular response estimated by an equation within the computer program. The second numbers to the right refer to the labeled sections of the computer program and output discussed later in this chapter. The program is listed in Appendix F. The particular equations used to model the study area were derived by a calibration procedure from the general equations of Table 5.9. The equations applied are summarized in Table 6.1. The variables are defined in Table 6.2.

Most of the blocks within the center column of Figure 5.1 are rectangular. These boxes represent equations which, with one exception (Section 2), have been calibrated before insertion within the model and cannot be changed by the model operator. The two triangles, on the other hand, represent IF statements whose threshold levels are established by operation of the model and which can stop continuation of the evaluation process or, in other words, cause a proposal to be rejected.

Another set of IF statements provides additional information but is not shown separately on the flow chart. These act at the same time as the initial decision agency evaluation, but cannot stop the process within the model. Rather they are used to signal some deficiency in a desired characteristic of a flood control proposal. They occur in Section 5 in Figure 5.1 as discussed in Chapter V for IF statements B1 to B3.

Interrelationship of Physical and Social Systems

The block on the left of Figure 5.1 represents the hydrologic system. The lines going to the block represent the effects of the social system on the hydrologic system, and the lines coming from this block represent the effect of the hydrologic system upon the social system. These effects may be direct or indirect. The solid line going to the hydrologic system from the "Action by the Implementation Agency," depicts that the parameters of the hydrologic system are affected by flood control action. The broken lines coming from the hydrologic system box mean that at least one variable in each of the equations to which they lead is affected by the hydrologic system. In this case, this connection is primarily with public flood experience related variables.

Dashed-line relationships show connections for which explicit equations have not yet been developed but lead to equations in the social model some of whose variables reflect differences in the hydrologic situation. Each of the rectangular boxes has either a solid or broken line leading from the hydrologic system to it.

The sociological and hydrologic components of the total system cannot be separated from each other without giving a distorted picture because the parameters of one are changed by the other. The interrelationship of urban sprawl and runoff is an example. Urban sprawl is related to population growth and geography as well as other physical and social factors such as the availability and cost of transportation, water supply, etc. The cost and benefit of flood control proposals given the same physical conditions also varies with the social environment.

Computer Programs

The computer program for modeling the social system is written in Fortran IV. One version of the program was used for sensitivity analysis, and another was used for simulation. The sensitivity analysis program is in Appendix F. The introduction of that appendix explains differences between the two versions. Use of the computer program of the social system en-
Table 6.1. Sociological equations used to model the Salt Lake County area.\textsuperscript{a}

BLOCKS IN FIGURES 5.1

Block 1: Public Concern About Flooding (CONCL):

\[
\text{CONCL} = 10.8 + 0.506X_1 + 0.033X_2 + 0.128X_3 + 0.300X_4 + 0.453X_5 + 0.148X_6 + 0.146X_7 + 0.230X_8 + 0.0012(X_9X_{10})
\]

Variables in Equation 5.4 are defined in Table 5.3

Block 2: Decision Agency Need For Plan (N):

\[
N = -37 + 2M + \text{CONCL} + \text{PAYL}
\]

Variables in Equation 5.8 are defined in section on Equation II.

Block 3: Need High Enough?

IF \(N > 0\), continue

\(N\) is defined as decision agency need for plan

Block 4: Planning Agency Evaluation (PAEV):

\[
Y = -0.241 - 0.305X_1 - 0.122X_9 + 14.753/X_{10} + 0.021X_{11} + 0.085X_{12} + 0.143X_{13}
\]

Variables in Equations 5.12 through 5.15 are defined in Table 5.4

Block 5: no equation (see text)

Block 6: Decision Agency Initial Evaluation (DAIE):

\[
Y = -0.241 - 0.305X_1 - 0.0695(3.25)X_9 + 8.43(3.25/X_{10}) + 0.00568(2.875)X_{11} + 0.136(2.125)X_{12} + 0.228(2.0)X_{13}
\]

IF statement B\textsubscript{1} for cost of proposal:

\(\text{if } X_{10} \leq 300,000,000 \text{ continue} \)

\(\text{if } X_{17} \geq 10 \text{ continue} \)

Variables in Equation 5.19 are defined in Table 5.2

Block 7: Intermediate Review Agency Evaluation (IMEV):

\[
\text{IMEV} = +0.491 - 0.206X_1 - 0.0102X_9 + 3.24/X_{10} + 0.00469X_{11} + 0.0675X_{12} + 0.0018X_{13} + 0.796X_{15}
\]

Variables in Equation 5.19 are defined in Table 5.4

Block 8: Decision Agency Revised Evaluation (DARE)

\[
Y = +0.491 - 0.206X_1 - 0.0190X_9 + 6.01/X_{10} + 0.00359X_{11} + 0.216X_{12} - 0.030X_{13} + 0.884X_{15}
\]

Variables in Equation 5.20 are defined in Table 5.4

Block 9: General Public Evaluation (POPEVE)

\[
\text{POPEVE} = 3.30 + 0.152z_{1,1} + 0.224z_{1,2} + 0.277z_{1,3} - 0.493z_{1,4} - 0.110z_{1,5} - 0.134z_{2,1} - 0.084z_{2,2} + 0.136z_{2,3}
\]

\[
+ 0.082z_{2,4} + 0.344z_{3,1} + 0.262z_{3,2} + 0.022z_{3,3} - 0.173z_{3,4} - 0.114z_{3,5} - 0.105z_{3,6} - 0.0464,1 - 0.767z_{4,2}
\]

\[
- 0.005z_{4,3} + 0.127z_{4,4} - 0.144z_{5,1} + 0.221z_{5,2} - 0.013z_{5,3} + 0.140z_{5,4} + 0.238z_{5,5} + 0.638z_{6,1}
\]

\[
- 0.592z_{6,2} + 0.006z_{6,3} + 0.313z_{6,4} + 0.368z_{6,5} + 0.555z_{6,6} + 0.651z_{7,1} - 0.243z_{7,2} + 0.241z_{7,3}
\]

\[
+ 0.235z_{7,4} + 0.435z_{7,5} - 0.567z_{8,1} + 0.175z_{8,2} + 0.067z_{8,3} - 0.002z_{8,4} + 0.006z_{8,5} + 0.671z_{8,6}
\]
Table 6.1. Continued.

\[-.288z_{9.1} + .359z_{9.2} + .283z_{9.3} + .170z_{9.4} + .194z_{9.5} + .034z_{10.1} + .336z_{10.2} + .166z_{10.3} + .093z_{10.4} + .281z_{10.5} + .162z_{10.6} + .112z_{11.1} + .134z_{11.2} + .034z_{11.3} + .215z_{11.4} - .003z_{11.5} = 0 \] \hspace{1cm} (5.28)

The first number in the subscript of each of the terms in Equation 5.28 is the term number in Table 5.7. Variables in each of the terms are written there. The category number of a term is indicated by the second number of the subscript; i.e., the number to the right of the period. Category ranges are listed in Table 5.8

Block 10: Public and Special Interest Opposition

- IF statement C₁ for Recreation
  - Reject if \( X_8X_{14} \leq -3.0 \) \hspace{1cm} (5.30)
- IF statement C₂ for Ecology
  - Reject if \( X_9X_{15} \leq -5.0 \) \hspace{1cm} (5.31)
- IF statement C₃ for Aesthetics
  - Reject if \( X_{10}X_{13} \leq 1.0 \) \hspace{1cm} (5.32)
- IF statement C₄ for Effectiveness
  - Reject if \( X_6X_{12} \leq 4.0 \) \hspace{1cm} (5.33)
- IF statement C₅ for Cost
  - Reject if \( X_{10}X_{16} \leq -20.0 \) \hspace{1cm} (5.34)

Variables in IF statements C₁ to C₅ are defined in Table 5.6

---

**Table 6.2. Variables with acronyms as used in the social model**

<table>
<thead>
<tr>
<th>Order No.</th>
<th>Equation No. Where Used</th>
<th>Acronym</th>
<th>A. Public and Population Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V</td>
<td>AGENL</td>
<td>Willingness to follow government agencies recommendations or advice</td>
</tr>
<tr>
<td>2</td>
<td>1, V</td>
<td>CONCL</td>
<td>Concern about flooding or perception of need for improved flood control in a local area</td>
</tr>
<tr>
<td>3</td>
<td>V</td>
<td>ECOL</td>
<td>Ecological orientation</td>
</tr>
<tr>
<td>4</td>
<td>V</td>
<td>EXPTL</td>
<td>Willingness to follow experts recommendations or advice</td>
</tr>
<tr>
<td>5</td>
<td>I</td>
<td>ICOSTF</td>
<td>Cost of damage from flooding</td>
</tr>
<tr>
<td>6</td>
<td>V</td>
<td>IDAGEN</td>
<td>Evaluation by a government decision agency of a proposal</td>
</tr>
<tr>
<td>7</td>
<td>V</td>
<td>IRAES</td>
<td>Perceived aesthetic effect of a proposal</td>
</tr>
<tr>
<td>8</td>
<td>V</td>
<td>IRCOS</td>
<td>Perceived cost of a proposal</td>
</tr>
<tr>
<td>9</td>
<td>V</td>
<td>IRECO</td>
<td>Perceived ecological effect of a proposal</td>
</tr>
<tr>
<td>10</td>
<td>V</td>
<td>IREFF</td>
<td>Perceived effectiveness of a proposal</td>
</tr>
<tr>
<td>11</td>
<td>V</td>
<td>IRREC</td>
<td>Perceived recreational effect of a proposal</td>
</tr>
<tr>
<td>12</td>
<td>1, V</td>
<td>KLOSF</td>
<td>Proximity of flooding experience to present residence</td>
</tr>
<tr>
<td>13</td>
<td>I</td>
<td>KLOSGR</td>
<td>Closeness of groups of persons with whom discussed flooding problems</td>
</tr>
<tr>
<td>14</td>
<td>V</td>
<td>KNOWL</td>
<td>Knowledge of local flood control proposals</td>
</tr>
<tr>
<td>15</td>
<td>I</td>
<td>KPERFL</td>
<td>Perceived likelihood of flooding at personally owned property in the area.</td>
</tr>
</tbody>
</table>

---

aA computer listing of the sociological model is given in Appendix F.
bEquation numbers refer to equations developed in Chapter V under the heading "Equations in the Model"
<table>
<thead>
<tr>
<th>Order No.</th>
<th>Equation No. Where Used</th>
<th>Acronym</th>
<th>A. Public and Population Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>V</td>
<td>KSINUN</td>
<td>Proportion of single unit structures in a city block 6, 7</td>
</tr>
<tr>
<td>17</td>
<td>V</td>
<td>KTYPE</td>
<td>Number of types of groups with whom discussed flooding problems 6, 7</td>
</tr>
<tr>
<td>18</td>
<td>I</td>
<td>LEIL</td>
<td>Leisure orientation 1</td>
</tr>
<tr>
<td>19</td>
<td>I</td>
<td>LNEIGH</td>
<td>Length of years of awareness of neighborhood flooding problems 1</td>
</tr>
<tr>
<td>20</td>
<td>I, V</td>
<td>MANL</td>
<td>Attitude toward the effect of man-made objects upon the beauty 1, 6, 7</td>
</tr>
<tr>
<td>21</td>
<td>I</td>
<td>NSORSE</td>
<td>Number of types of sources of information about flooding 1</td>
</tr>
<tr>
<td>22</td>
<td>I</td>
<td>NYONGC</td>
<td>Number of young children 1</td>
</tr>
<tr>
<td>23</td>
<td>I, V</td>
<td>PAYL</td>
<td>Willingness to pay for government expenditures by the public. 1, 6, 7</td>
</tr>
<tr>
<td>24</td>
<td>V</td>
<td>POPEVE</td>
<td>Population evaluation of flood control proposal 6</td>
</tr>
<tr>
<td>25</td>
<td>V</td>
<td>RECL</td>
<td>Outdoor recreation orientation 6, 7</td>
</tr>
<tr>
<td>1</td>
<td>III, IV, VI</td>
<td>AGEAGE</td>
<td>Importance of other agency opinion to agency 2</td>
</tr>
<tr>
<td>2</td>
<td>III, IV, VI</td>
<td>AVEBEN</td>
<td>Average annual flood control benefit in dollars 2, 3</td>
</tr>
<tr>
<td>3</td>
<td>III, IV, VI</td>
<td>BECORA</td>
<td>Benefit-cost ratio of flood control proposal (based on engineering criteria). 2, 3</td>
</tr>
<tr>
<td>4</td>
<td>III, IV, VI</td>
<td>COSPRO</td>
<td>Cost of proposal 2, 3</td>
</tr>
<tr>
<td>5</td>
<td>III, IV, VI</td>
<td>DAFE or FE</td>
<td>Decision agency final evaluation</td>
</tr>
<tr>
<td>6</td>
<td>III, IV, VI</td>
<td>DAIE</td>
<td>Decision agency initial evaluation</td>
</tr>
<tr>
<td>7</td>
<td>III, IV, VI</td>
<td>DARE or FE</td>
<td>Decision agency revised</td>
</tr>
<tr>
<td>8</td>
<td>III, IV, VI</td>
<td>IACAES</td>
<td>Agency concern to include pleasing aesthetics in flood control project. 2, 3</td>
</tr>
<tr>
<td>9</td>
<td>III, IV, VI</td>
<td>IACCOS</td>
<td>Agency concern to include low cost in flood control project. 2, 3</td>
</tr>
<tr>
<td>10</td>
<td>III, IV, VI</td>
<td>IACECO</td>
<td>Agency concern to include least detrimental environmental effect in flood control project. 2, 3</td>
</tr>
<tr>
<td>11</td>
<td>III, IV, VI</td>
<td>IACEFF</td>
<td>Agency concern to include effectiveness in flood control project 2, 3</td>
</tr>
<tr>
<td>12</td>
<td>III, IV, VI</td>
<td>IACRFC</td>
<td>Agency concern to include recreation in flood control proposal 2, 3</td>
</tr>
<tr>
<td>13</td>
<td>III, IV, VI</td>
<td>IAGEEV</td>
<td>Evaluation by a particular agency of a flood control proposal at a point in time (includes PAEV, DAIE, IMEV, DARE*, and DAFE***) 2</td>
</tr>
<tr>
<td>14</td>
<td>III, IV, VI</td>
<td>IFPROB</td>
<td>Presence of a flood control problem 2, 3</td>
</tr>
<tr>
<td>15</td>
<td>III, IV, VI</td>
<td>IMEV</td>
<td>Implementation agency evaluation</td>
</tr>
<tr>
<td>16</td>
<td>II</td>
<td>M</td>
<td>Agency mission: tendency to want plan in order to perpetuate function</td>
</tr>
<tr>
<td>17</td>
<td>I</td>
<td>N</td>
<td>Decision agency need for a plan</td>
</tr>
<tr>
<td>18</td>
<td>III, IV, VI</td>
<td>OJEAES</td>
<td>Judges' estimate of aesthetic effect of flood control proposal 2, 3</td>
</tr>
<tr>
<td>19</td>
<td>III, IV, VI</td>
<td>OJEICO</td>
<td>Judges' estimate of ecological effect of flood control proposal 2, 3</td>
</tr>
<tr>
<td>20</td>
<td>III, IV, VI</td>
<td>OJERE</td>
<td>Judges' estimate of recreational effect of flood control proposal 2, 3</td>
</tr>
<tr>
<td>21</td>
<td>III, IV, VI</td>
<td>OTHEVE</td>
<td>Other agency evaluation of proposal 2, 3</td>
</tr>
<tr>
<td>22</td>
<td>III, IV, VI</td>
<td>PAEV</td>
<td>Planning agency evaluation</td>
</tr>
<tr>
<td>23</td>
<td>III, IV, VI</td>
<td>PUBAGE</td>
<td>Importance of public opinion to agency 2, 3</td>
</tr>
<tr>
<td>24</td>
<td>III, IV, VI</td>
<td>PUBPRO**</td>
<td>Mean public evaluation of proposal 2, 3</td>
</tr>
<tr>
<td>25</td>
<td>III, IV, VI</td>
<td>YRSCON</td>
<td>Flood years controlled by a proposal</td>
</tr>
</tbody>
</table>

*IDAGEN is similar to DARE referred to in Chapter VII. The difference is that IDAGEN are the values of this variable used to calibrate the population equation. DARE refers to the values of this variable as predicted by Equation IV, i.e., IDAGEN is a measured value, and DARE is a hypothetical value.

**PUBPRO refers to the mean public evaluation as measured and used in calibrating the population equation. POPEVE or EV refers to the same variable when it is to be predicted as the dependent variable using the equation after calibration.

***DAFE is sometimes referred to as FE.

aVariables 8 through 12 are different for each agency in the model.

bIf n is the number of agency evaluations included in a model, there are n-1 possible values of variable 21.
tails entering values of the characteristics of various groups and proposals. These are put by the program into the proper places. Some of these inputed values are printed along with the output of the sociological model.

**Computer Model Input**

Tables 6.3 through 6.6 provide the details for supplying data to the model. The ordering of all the data cards is presented in Table 6.3 along with information to control printing and to supply values for Equation II and the IF statements. It is recommended the option to print input data on Cards 2 and 9 be set at zero. When there is a large number of values, this setting can avoid pages of output. The means and standard deviations of the dependent variables in Equation I and V will always be printed.

**Computer Program Output**

An example output from the computer model is presented as Table 6.7. Numbers on the left side reference output sections indicated on the right side of Figure 6.1. Each section will be discussed in turn. Many of the more meaningful variables are labeled on the print-out.

Section 1 shows the data and the evaluation of public concern about flooding. If the number in Col-

---

**Table 6.3. Data ordering for simulation deck.**

<table>
<thead>
<tr>
<th>Card No. (in sequence)</th>
<th>Type of Information</th>
<th>Column(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proposal name</td>
<td>1-30</td>
</tr>
<tr>
<td>2</td>
<td>Print of input data(^a) for population</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0 = no, 1 = yes</td>
<td>2-5</td>
</tr>
<tr>
<td>3</td>
<td>Sample size</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Equation I (5.4) Section 1</td>
<td>See Table 6.4</td>
</tr>
<tr>
<td>5</td>
<td>Input data for population concern</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Equation II (5.6) Section 2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Input data for Equation II and IF statement A(^b)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C(_1)</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>C(_2)</td>
<td>5-10</td>
</tr>
<tr>
<td></td>
<td>C(_3)</td>
<td>11-15</td>
</tr>
<tr>
<td></td>
<td>C(_4)</td>
<td>16-20'</td>
</tr>
<tr>
<td></td>
<td>Equation III (5.11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agency Mission</td>
<td>21-25</td>
</tr>
<tr>
<td>8</td>
<td>Section 3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Input data for planning agency</td>
<td>See Table 6.5</td>
</tr>
<tr>
<td>10</td>
<td>IF statements B(_1) to B(_3) criteria for proposal:</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cost Maximum(^c) (actual (\times 1,000,000))</td>
<td>1-4</td>
</tr>
<tr>
<td>12</td>
<td>Effectiveness Minimum(^c) (in flood years controlled)</td>
<td>5-8</td>
</tr>
<tr>
<td>13</td>
<td>Benefit - Cost Ratio Minimum(^d)</td>
<td>9-12</td>
</tr>
<tr>
<td>14</td>
<td>Equation III (5.12-5.15) Sections</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Input data for decision agency</td>
<td>See Table 6.5</td>
</tr>
<tr>
<td>16</td>
<td>Equation IV (5.19) Section</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Input data for intermediate review agency</td>
<td>See Table 6.5</td>
</tr>
<tr>
<td>18</td>
<td>Equation V (5.28) Section</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Print of input data for population evaluation</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0 = no, 1 = yes</td>
<td>1-5</td>
</tr>
<tr>
<td>21</td>
<td>Sample size</td>
<td>2-5</td>
</tr>
<tr>
<td>22</td>
<td>Input data for population evaluation</td>
<td>See Table 6.6</td>
</tr>
<tr>
<td>23</td>
<td>IF statements C(_1) to C(_5)(^b)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C(_1) - Recreation</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>C(_2) - Ecology</td>
<td>6-10</td>
</tr>
<tr>
<td></td>
<td>C(_3) - Aesthetics</td>
<td>11-15</td>
</tr>
<tr>
<td></td>
<td>C(_4) - Effectiveness</td>
<td>16-20</td>
</tr>
<tr>
<td></td>
<td>C(_5) - Cost</td>
<td>21-25</td>
</tr>
</tbody>
</table>

\(^a\)Whole number (integers) only.

\(^b\)Decimal point in each set of five columns is after fourth place.

\(^c\)Decimal point may be punched.

\(^d\)Decimal point is to right of second space.
Table 6.4. Input data for public concern Equation (1).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Item</th>
<th>Col.</th>
<th>Range as Measured</th>
<th>Formata,b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of types of sources of information about flooding (NSORSE)</td>
<td>1-6</td>
<td>0.00 to 6.00</td>
<td>F6.2b</td>
</tr>
<tr>
<td>2</td>
<td>Perceived likelihood of flooding at personally owned property in area (KPERFL)</td>
<td>7-12</td>
<td>0.00 to 100.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>3</td>
<td>Length of years of awareness of neighborhood flooding problems (LNEIGH)</td>
<td>13-18</td>
<td>0.00 to 99.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>Closeness of groups of persons with whom discuss flooding problems (KLOSGR)</td>
<td>19-24</td>
<td>0.00 to 3.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>5</td>
<td>Number of young children (NUMC)</td>
<td>25-30</td>
<td>0.00 to 3.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>6</td>
<td>Willingness to pay for government expenditures (PAY-6)</td>
<td>31-36</td>
<td>6.00 to 30.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>7</td>
<td>Attitude toward effect of man-made objects upon beauty of nature (MANI-4)</td>
<td>37-42</td>
<td>6.00 to 30.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>8</td>
<td>Leisure orientations (LEIL-4)</td>
<td>43-48</td>
<td>4.00 to 20.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>9</td>
<td>Proximity of flooding experience (KLOSF)</td>
<td>49-54</td>
<td>0.00 to 3.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>10</td>
<td>Cost of damage from flooding (ICOSTF)</td>
<td>55-60</td>
<td>0.00 to 99.0</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

a All data should be keypunched without decimal point. Example: If variable 1 = 5.00, then "500" would be keypunched on Col. 4 to Col. 6.

b F6.2 indicates that the decimal point is after the fourth column in the field. A field is an area allowed for the value of a variable.

If a proposal does not meet the desired criteria, the reason for the deficiency can be seen. The evaluation process continues in any case.

Sections 5, 6, and 7 all have the same format. In each case, the model estimate of the agency evaluation of the flood control proposal is printed. If this is greater than zero, the proposal process continues, and a message is printed so stating. If not, a negative message is written, and computations terminate. For the sensitivity analysis program, the model continues.

Section 8 for the public evaluation of a flood control proposal contains more information than do the agency evaluation sections in a format similar to the section on evaluation of public concern. (See Section 1.) The printing of the values from Card 10 in Section 8 differs between the sensitivity and simulation programs. Because of space limitation on one line, only four spaces were allowed for printing each variable and only one space is allotted to the right of the decimal point. It can be seen from the sample output (a sensitivity run) that the values run together. For this reason, the format in the simulation program was altered to print only the whole number part of the values.

The next six numbers which follow on the same line after the population input data are respectively
the values of the effectiveness, aesthetics, recreation, ecology, cost acceptance functions for the individual respondent, and an acceptance function for the respondent of the previous decision agency evaluation. The final number in this line, the individual score, is estimated by the model from inserting the data to the left in Equation V. If the option on input Card 9 is set at zero, the output described so far for this section will not be printed. Only the mean and the standard deviation of the evaluation scores will be printed. The value of mean public evaluation of a flood control proposal can be as low as -.5, and the model evaluation process will still continue. The result of this determination is written as the last line of this section.

The results of the tests of IF statements C1 through C5 are presented in Section 9. Labels for the respective acceptance functions are printed on the first line. The second line lists the requirement for each acceptance function. The values under these requirements are the mean values attained by the acceptance functions in the sample. Should a proposal be rejected at this time as indicated by a statement on the next printed line, inspection of these pairs of values will reveal the cause.

Section 10 prints the predicted final evaluation by the decision agency in the model as based on the same data used in Sections 5 and 7 with the addition of the value for public evaluation from Section 8. The number calculated from placing these values in Equation VI is printed. If the result is positive, it is considered that the plan could be implemented. A final message indicates whether the proposal exceeds or fails to exceed minimum requirements for enactment.

Table 6.5. Input data for agency equations (III, IV and V).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Item</th>
<th>Col.</th>
<th>Range Measured</th>
<th>Formata,b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Presence of a flood control problem (IFPROB)</td>
<td>1-3</td>
<td>1.00 to 9.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>2</td>
<td>Agency concern to include low cost in flood control project (IACCOS)</td>
<td>4-6</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>3</td>
<td>Agency concern to include effectiveness in flood control project (IACEFF)</td>
<td>7-9</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>4</td>
<td>Agency concern to include pleasing aesthetics in flood control project (IACAES)</td>
<td>10-12</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>5</td>
<td>Agency concern to include recreation in flood control proposal (IACREC)</td>
<td>13-15</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>6</td>
<td>Agency concern to include least detrimental environmental effect in flood control project (IACECO)</td>
<td>16-18</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>7</td>
<td>Importance of other agency opinion to agency (AGEAGE)</td>
<td>19-21</td>
<td>0.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>8</td>
<td>Importance of public opinion to agency (PUBAGE)</td>
<td>22-24</td>
<td>4.00 to 4.00</td>
<td>F 3.2</td>
</tr>
<tr>
<td>9</td>
<td>Benefit cost ratio of flood control proposal based on engineering criteria (BECORA)</td>
<td>25-25</td>
<td>0.00 to 9.99</td>
<td>F 3.2</td>
</tr>
<tr>
<td></td>
<td>Normally computed from 10, 11, and 15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Cost of proposal in hundred of thousands of dollars (COSPRO)</td>
<td>28-32</td>
<td>Up to 999.99</td>
<td>F 5.2</td>
</tr>
<tr>
<td>11</td>
<td>Average annual flood control benefit in dollars (AVEBEN)</td>
<td>33-36</td>
<td>0.00 to 999.9</td>
<td>F 4.1</td>
</tr>
<tr>
<td>12</td>
<td>Judges estimate of aesthetic effect of flood control proposal (OJEAES)</td>
<td>37-40</td>
<td>-3.00 to 3.00</td>
<td>F 4.2</td>
</tr>
<tr>
<td>13</td>
<td>Judges estimate of recreational effect of flood control proposal (OJERREC)</td>
<td>41-44</td>
<td>-3.00 to 3.00</td>
<td>F 4.2</td>
</tr>
<tr>
<td>14</td>
<td>Judges estimate of ecological effect of flood control proposal (OJERCO)</td>
<td>45-48</td>
<td>-3.00 to 3.00</td>
<td>F 4.2</td>
</tr>
<tr>
<td>15</td>
<td>Benefit - years of flood control proposal (YRSCON)</td>
<td>49-52</td>
<td>up to 999.1</td>
<td>F 4.1</td>
</tr>
</tbody>
</table>

aFORTRAN format statement. F indicates numerical data with a possible decimal point. The number to the left of the decimal point is the number of columns on the card allowed for the number. The number to the right side of the period indicates the number of columns in the field to the right of the decimal point. If a decimal point is punched, the placement of the decimal point dictated by the format statement is overridden.
bAll data should be keypunched without decimal point. Example: If var. 4 = 5.00, then 500 would be keypunched on Col. 10 to Col. 12.
cIf the statement in the program calculating the benefit-cost ratio (the one following statement 4) is removed, the value of benefit cost ratio is read from columns 25-27 and variable 15 may be omitted. If the benefit-cost ratio is computed internally in the program, the field for benefit-cost ratio is ignored.
Table 6.6. Input data for public evaluation Equation (V).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Item</th>
<th>Col.</th>
<th>Range as Measured</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of types of groups with whom discussed</td>
<td>1-4</td>
<td>0 to 4</td>
<td>F 4.2</td>
</tr>
<tr>
<td></td>
<td>flooding problems (KTYPE)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Proximity of flooding experience to present residence</td>
<td>5-8</td>
<td>0 to 3</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>(KLOSF)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Percent of single unit structures in block (KSINUN)</td>
<td>9-12</td>
<td>0 to 100</td>
<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>Willingness to follow government (AGENL)</td>
<td>13-16</td>
<td>0 to 16</td>
<td>&quot;</td>
</tr>
<tr>
<td>5</td>
<td>Knowledge of local flood control proposals</td>
<td>17-20</td>
<td>0 to 5</td>
<td>&quot;</td>
</tr>
<tr>
<td>6</td>
<td>Perception of need for improved flood control in area(a) (from Equation IB) (CONCL)</td>
<td>21-24</td>
<td>8.00 to 40.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>7</td>
<td>Attitude toward effect of man-made objects upon beauty of nature (MANL)</td>
<td>25-28</td>
<td>40 to 20.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>8</td>
<td>Outdoor recreation orientation (RECL)</td>
<td>29-32</td>
<td>6.00 to 30.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>9</td>
<td>Ecological orientation (ECOL)</td>
<td>33-36</td>
<td>8.00 to 40.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>10</td>
<td>Willingness to pay for government expenditures (PAYL)</td>
<td>37-40</td>
<td>6.00 to 30.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>11</td>
<td>Willingness to follow experts (EXPTL)</td>
<td>41-44</td>
<td>6.00 to 30.00</td>
<td>&quot;</td>
</tr>
<tr>
<td>12</td>
<td>Perceived effectiveness of proposal (IREFFP)</td>
<td>45-48</td>
<td>1 to 5</td>
<td>&quot;</td>
</tr>
<tr>
<td>13</td>
<td>Perceived aesthetics effect of proposal (IRAESP)</td>
<td>49-52</td>
<td>1 to 5</td>
<td>&quot;</td>
</tr>
<tr>
<td>14</td>
<td>Perceived recreation effect of proposal (IRRECP)</td>
<td>53-56</td>
<td>1 to 5</td>
<td>&quot;</td>
</tr>
<tr>
<td>15</td>
<td>Perceived ecological effect of proposal (IRECOP)</td>
<td>57-60</td>
<td>1 to 5</td>
<td>&quot;</td>
</tr>
<tr>
<td>16</td>
<td>Perceived cost of proposal (IRCOSP)</td>
<td>61-64</td>
<td>1 to 5</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

\(a\)Read in for simulation deck. See Appendix D.

\(b\)Computed in sensitivity analysis deck from output of Equation I according to formula \(Z(6) = 17.914 + [5(Pub) - 17.014]\). See Appendix D.
Table 6.7. Sample computer output of the social model.

<table>
<thead>
<tr>
<th>SOCIAL MODEL FLOOD CONTROL PROPOSAL = OJEAES = O IRAESP = 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Evaluation of Public Concern INPUT DATA SAMPLE SIZE = 1</td>
</tr>
<tr>
<td>1.39 9.78 2.52 0.85 0.47 10.27 6.24 9.04 0.08 32.45</td>
</tr>
<tr>
<td>PUBLIC CONCERN = 17.014 STANDARD DEVIATION = NOT CALCULABLE</td>
</tr>
<tr>
<td>2 - IF STATEMENT A</td>
</tr>
<tr>
<td>C(1) C(2) C(3) C(4) AM CONCL PAYL S</td>
</tr>
<tr>
<td>-37.00 2.00 1.00 1.08 5.00 17.014 10.268 0.242</td>
</tr>
<tr>
<td>NEED FOR PLAN CONTINUE EVALUATION</td>
</tr>
<tr>
<td>3 - EVALUATION OF PLANNING AGENCY</td>
</tr>
<tr>
<td>Planning Agency Evaluation = 0.918 The Evaluation is Greater than 0.0 Continue Evaluation</td>
</tr>
<tr>
<td>4 - IF STATEMENT B COST(DOLLAR$) BENEFIT(YRS) BENEFIT COST RATED</td>
</tr>
<tr>
<td>Desired Proposal</td>
</tr>
<tr>
<td>L = T = 300000000 G E 10.0 G T 1.00</td>
</tr>
<tr>
<td>20230000 53.3 2.63</td>
</tr>
<tr>
<td>PROPOSAL MEETS THE DESIRED CRITERIA</td>
</tr>
<tr>
<td>5 - INITIAL EVALUATION BY DECISION AGENCY</td>
</tr>
<tr>
<td>Decision Agency Initial Evaluation 0.759 The Evaluation is greater than 0.0 Continue Evaluation</td>
</tr>
<tr>
<td>6 - EVALUATION BY INTERMEDIATE REVIEW AGENCY*</td>
</tr>
<tr>
<td>Evaluation = 0.770 Intermediate Review Agency The Evaluation is greater than 0.0, Continue Evaluation</td>
</tr>
<tr>
<td>7 - REVISED EVALUATION BY DECISION AGENCY</td>
</tr>
<tr>
<td>Decision agency revised evaluation - 0.854 The Evaluation is greater than 0.0, Continue Evaluation</td>
</tr>
<tr>
<td>8 - EVALUATION BY PUBLIC INPUT DATA SAMPLE SIZE = 1</td>
</tr>
<tr>
<td>1.1 0.8 82.11.5 2.217.9 8.615.018.810.514.4 0.9-1.0 0.3 0.4-1.0 16.3 -8.6 5.0</td>
</tr>
<tr>
<td>6.8 - 10.4 12.3 INDIVIDUAL SCORE = 0.493</td>
</tr>
<tr>
<td>PUBLIC EVALUATION = 0.493 STANDARD DEVIATION = NOT CALCULABLE THE EVALUATION IS GREATER THAN -0.5, then Continue Evaluation</td>
</tr>
<tr>
<td>9 - IF STATEMENT C</td>
</tr>
<tr>
<td>RECREATION ECOLOGY AESTHETICS EFFECTIVENESS COST</td>
</tr>
<tr>
<td>G.T. -3.0 G.T. -5.0 G.T. -1.0 G.T. 4.0 G.T. -20.0 Requirement</td>
</tr>
<tr>
<td>4.96 6.77 =8.64 16.30 -10.36 Acceptance</td>
</tr>
<tr>
<td>Function</td>
</tr>
<tr>
<td>STOP EVALUATION</td>
</tr>
<tr>
<td>10 - FINAL EVALUATION BY DECISION AGENCY</td>
</tr>
<tr>
<td>Final Evaluation = 0.626</td>
</tr>
<tr>
<td>THE PROJECT EVALUATION EXCEEDS MINIMUM REQUIREMENTS</td>
</tr>
</tbody>
</table>

*The Intermediate Review Agency was also an implementing agency in this application.
Figure 6.1. Schematic diagram of the computer model of the social system model.
CHAPTER VII
SENSITIVITY AND MANAGEMENT STUDIES

Sensitivity Studies

A sensitivity analysis is performed by changing one variable while holding the others constant and noting changes in the output. If small changes in an input variable induce large changes in the output, the system is said to be sensitive to that parameter. Thus, through sensitivity analyses it is possible to establish the relative importance of various system processes and input functions. This information is useful for system management, system modeling, and the assignment of priorities in the collection of field data. Sensitivity analyses were conducted with both the hydrologic and the sociologic components of the model, and the results are discussed briefly in this chapter.

Hydrologic Sensitivity Analyses

The Olympus Cove and Neff's Canyon portions of the Mill Creek drainage (Figure 1.1) were selected to study the effects of model parameter changes on the shape of the outflow hydrograph. Typical simulated hydrographs from the hourly model at an assumed antecedent soil moisture level of 8.5 inches and storm recurrence intervals of 10, 25, 50, and 100 years are shown by Figure 7.1. Similar curves for an antecedent soil moisture level of 11 inches are given by Figure 7.2. The marked influence of antecedent soil moisture on peak runoff rates is seen in that for a 25-year storm event and an antecedent moisture level of 8.5 inches the peak runoff rate is estimated at 500 cfs, whereas at the 11-inch antecedent level the peak is nearly 700 cfs.

Figure 7.3 summarizes the peak runoff rates from the Neff's Canyon drainage for various storm recurrence intervals and for antecedent soil moisture levels of 4.0 inches, 8.5 inches, and 11.0 inches. As could be expected, Figure 7.3 clearly shows that the runoff amount is most sensitive to antecedent soil moisture in the small or frequent storm range. For larger storms, the peak runoff rate becomes less influenced by antecedent soil moisture.

Precipitation data for storms of various recurrence intervals were input to the hourly hydrologic model of the 0.61 square mile Olympus Cove urbanizing area. The effect of urbanization on runoff hydrographs is illustrated by Figure 7.4 where runoff from the Olympus Cove urbanizing area is plotted for a 25-year storm at various degrees of urbanization. An antecedent soil moisture of 4.0 inches was used because measurements indicate that it is the most likely

Figure 7.1. Simulated hydrographs from Neff's Canyon from storms of various recurrence intervals and antecedent soil moisture of 8.5 in.

Figure 7.2. Simulated hydrographs of runoff from Neff's Canyon from storms of various recurrence intervals and 2.5 m of 11.0 in.
level during the period of maximum cloudburst storm activity along the Wasatch Front (Butler and Marsell, 1972). Figure 7.4 suggests also that watershed runoff characteristics are very sensitive to degree of urbanization (refer also to Figures 3.13, 3.14, and 3.15).

Simulated hydrographs also were generated for 10- and 50-year storm recurrent intervals. The results are plotted on Figure 7.5 which shows the rate of increase in peak runoff rate with increasing degree of urbanization for each of three selected storm recurrence intervals (10, 25, and 50 years). The plots show how for a 10-year storm an increase in urbanization of from 0 to 40 percent more than doubled the peak rate of surface runoff. On the other hand, for a 50-year storm, the increase is only 2 or 3 percent. Like the trend noted for Figure 7.3, this situation results because large runoff producing events, such as a 50-year storm, cause high runoff rates whether under natural or urban conditions, so that in this case the effects of urbanization are relatively less important. This same explanation applies to the decreasing sensitivity of the hydrologic system to antecedent soil moisture with increasing storm size.

In concluding this brief discussion of hydrologic sensitivity, surface runoff characteristics were found to be highly sensitive to the magnitude of the runoff producing event, the degree of urbanization, and the level of soil moisture (antecedent soil moisture) at the time of the storm. However, the sensitivity to antecedent soil moisture and degree of urbanization decreases with increasing magnitude of the runoff producing event.

Figure 7.3. Graph of peak runoff against the causative storm recurrence interval for Neff's Canyon watershed.

Figure 7.4. Simulated hydrographs of runoff from the study area of Olympus Cove for various degrees of urbanization.

Figure 7.5. Graph relating peak runoff to degree of urbanization for the study area of Olympus Cove.
Sociologic Sensitivity Analyses

The sensitivity of the model to the sociologic variables was studied by varying through specific ranges the variables contained in each of the sociologic equations. Sensitivity studies conducted, together with the ranges of values used for each parameter, are shown by Table 7.1. The complete results are in Appendix H; however, some results are highlighted here.

Figure 7.6(a) indicates the sensitivity (runs I-A of Table 7.1) of three variables "Concern For Flooding" (CONCL), "Decision Agency Need for a Plan" (N), and "Population Evaluation" (POPEVE) to the years of awareness of neighborhood flooding problems (LNEIGH). Provided the scales are the same, the steeper the slope of the line (positive or negative), the more sensitive the dependent variable is to changes in the independent variable. A horizontal line indicates no dependence (and thus no sensitivity). Figure 7.6(b), one of the runs under sensitivity test I-C (Table 7.1), indicates that the population evaluation of a flood control proposal (POPEVE) is relatively insensitive to changes in the number of sources of information about flooding (NSORSE).

Not all of the sensitivity runs produced linear relationships, as indicated by the plots of Figure 7.6(d) which correspond to test IV B. The population evaluation (POPEVE) and the decision agency evaluation (DAFE) are very sensitive to changes in concern for flooding (CONCL) in the low range of these two variables. However, for larger values, the sensitivity to

### Table 7.1. Examples of sensitivity studies using the sociological model

<table>
<thead>
<tr>
<th>Variables in Equation I - Population Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. A. LNEIGH 0 to 50</td>
</tr>
<tr>
<td>CONCL = 16.69 to 23.09</td>
</tr>
<tr>
<td>N = -.040 to 6.360 (would stop)</td>
</tr>
<tr>
<td>POPEVE = .735 to .977</td>
</tr>
<tr>
<td>FE = .666 to .697</td>
</tr>
<tr>
<td>I. C. LNEIGH = 0 and NSORSE 0 to 6</td>
</tr>
<tr>
<td>CONCL = 15.99 to 19.02</td>
</tr>
<tr>
<td>N = -.745 to 2.291</td>
</tr>
<tr>
<td>POPEVE = .735 to .790</td>
</tr>
<tr>
<td>FE = .666 to .697</td>
</tr>
<tr>
<td>IV. B. CONCL 5 to 28</td>
</tr>
<tr>
<td>POPEVE = -.170 to .790**</td>
</tr>
<tr>
<td>FE = .150 to .697</td>
</tr>
<tr>
<td>**NOTE: Evaluation stops when CONCL = 5 or 12 due to Effectiveness acceptance function.</td>
</tr>
<tr>
<td>IV. D. IREFFP = 2, CONCL 5 to 28</td>
</tr>
<tr>
<td>POPEVE = .735 to -.170**</td>
</tr>
<tr>
<td>FE = .666 to .150</td>
</tr>
<tr>
<td>NOTE: Proposal never acceptable because of lack of effectiveness</td>
</tr>
</tbody>
</table>

*Definitions of symbols in Table 6.2.
CONCL decreased markedly. These results suggest that at the higher levels of CONCL considerable care should be exercised in estimating this parameter. Conversely, for tests VID [Figure 7.6(c)] the sensitivity is very high for the smaller values of the cost of the proposal (COSPRO).

The results of the sensitivity plots in Appendix H are summarized in Table 7.2. The intent is to indicate the sensitivity of the model to various ranges of the parameters. The results are helpful in all phases of modeling activity, including data collection, model improvement, and model application.

Management Studies

Using the model, 36 possible approaches or plans to flood control projects were examined. The projects are defined in terms of how they are perceived by experts and the public in terms of various model

Figure 7.6(b). Results of sensitivity studies within Test I.C.

Figure 7.6(c). Results of sensitivity studies within Test VID.

Figure 7.6(d). Results of sensitivity studies within Test IV.B.

96
parameters (defined on Table 6.2) as shown by Table 7.3. The model evaluation of the projects are summarized below for each project by number.

Plan 1. The plan would not be desirable because of a low benefit-cost ratio. If chosen, it would be approved until it reaches the population where it would be rejected due to lack of perceived effectiveness. Evaluation by agencies are all medium high (around one).

Plan 2. This plan is not approved by the planning agency.

Plan 3. This plan is approved by the planning agency and barely approved by other agencies until announced to the public. The plan is not desirable because of a very low benefit-cost index. The plan is rejected when it reaches the public due to high perceived cost and low perceived effectiveness. Evaluation by the public is negative. Decision agency evaluation would become negative due to public reaction.

Plan 4. This proposal does not meet the desired criteria and is rejected by the decision agency (barely). The planning agency evaluation is medium and implementation agency about neutral. The plan would be rejected by the public due to high perceived cost.

Plan 5. Medium high approval by the planning agency. The plan does not meet desired criteria because of the benefit-cost ratio. There is high approval by other agencies and the public, but rejected when it reaches the public because of very high cost. If not rejected, final approval by the decision agency would be very high.

Plan 6. Approved by the planning agency. It meets desired criteria. Medium high approval by agencies. Very high approval by the public and very high final approval by the decision agency. Enacted.

Plan 7. Proposal not proposed. Would be strongly rejected throughout the model.

Plan 8. Proposal would not be considered and would be very strongly rejected.

Plan 9. Proposal would not be made, and if made, would be very negatively rated.

Plan 10. Proposal approved by the planning agency. Easily meets desired criteria. Medium high approval by agencies until it reaches the public. Very high approval by the public results in very high final approval by the decision agency.

Plan 11. Medium high approval by the planning agency, but does not meet desired criteria because of high cost and limited flood control resulting in a very low benefit-cost index. High positive social effects result in high ratings by other agencies. Medium approval by the general public. However, rejected when it reaches the public because of high cost and low effectiveness.

Plan 12. Medium high rejection by the planning agency. Would be strongly rejected thereafter, but plan would never be proposed.

Plan 13. Plan earns medium high approval throughout, but might not be selected if another plan met the desired benefit-cost ratio criteria which this proposal does not. Also, it may be rejected by a concerned citizen's group because the plan is perceived as not being effective.

Plan 14. Approved throughout, but blocked due to negative ecology.

Plan 15. Would be approved except for poor ecological effect which causes rejection when plan reaches the public.

Plan 16. Strong approval if selected initially but probably wouldn't be due to a low benefit-cost ratio. Also blocked in the model by the effectiveness acceptance function.

Plan 17. High approval throughout early phases despite inadequate benefit-cost ratio. However, rejected due to poor perceived ecology.

Plan 18. Would be barely approved if selected (benefit-cost ratio low) except for rejection due to poor recreation.

Plan 19. Medium approval by planning agency. Meets desired criteria. However, rejected thereafter anywhere in the model. Poor perceived aesthetics and ecology also would cause rejection in themselves according to the model.

Plan 20. If selected, would be approved throughout except for high perceived cost by the public.

Plan 21. Would never be proposed; and if proposed, would never be selected.

Plan 22. Medium approval by planning agency. Slight rejection by other agencies. Ecology too poor and cost too much to obtain public approval.

Plan 23. Low acceptability to planning agency. Medium high rejection would occur by agencies and public if proposed.

Plan 24. Medium approval by planning agency, but rejected thereafter.
Plan 25. Would be strongly approved throughout by agencies and public. Easily meets desired criteria. Would be implemented if objection to limited perceived flood control by a segment of public could be overcome.

Plan 26. Would be extremely strongly approved except for poor ecology acceptance function.

Plan 27. Extreme strong approval by some segments and would be done except for possible rejection because of cost and negative ecology.

Plan 28. Strong approval except perceived as ineffective.

Plan 29. Extreme strong approval by some segments and would be done except for possible rejection because of cost and negative ecology.

Plan 30. Would be approved except for poor perceived ecological effect.


Plan 32. Would be accepted except for possible rejection due to extremely high perceived cost.


Plan 34. Rejected by public because of negative ecological effect and very high cost.

Plan 35. Proposal rejected by general public. Recreation, ecology, aesthetics, and cost all not acceptable.

Plan 36. Rejected by general public. Recreation and aesthetics of proposal too negative.

In addition to the 36 project studies, the model was used to consider the effects of various population attitudes upon the acceptance of a particular project. The assumed population attitudes and corresponding values for various social parameters are indicated on the left half of Table 7.4. Corresponding results, including some specific output values for dependent parameters, are shown to the right. For comparison purposes, for the study site in Salt Lake County, the model predicts that the proposed project would be acceptable to the public and could be constructed.

Table 7.2. Summary of sensitivity studies using the sociologic model.

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Test No.</th>
<th>Independent Variable(^b)</th>
<th>Dependent Variable(^b)</th>
<th>Relationship(^c)</th>
<th>Sensitivity(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
<td>LNEIGH</td>
<td>CONCL</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td>I</td>
<td>B</td>
<td>NSORSE</td>
<td>CONCL</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>L</td>
<td>Low</td>
</tr>
<tr>
<td>I</td>
<td>C</td>
<td>NSORSE</td>
<td>CONCL</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>L</td>
<td>Low</td>
</tr>
<tr>
<td>I</td>
<td>D</td>
<td>NSORSE</td>
<td>CONCL</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>L</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>L</td>
<td>Nil</td>
</tr>
<tr>
<td>I</td>
<td>E</td>
<td>All direct flood related</td>
<td>CONCL</td>
<td>NL</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>variables</td>
<td>N</td>
<td>NL</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>NL</td>
<td>Medium</td>
</tr>
<tr>
<td>II</td>
<td>A</td>
<td>LEIL</td>
<td>CONCL</td>
<td>L</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>L</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POPEVE</td>
<td>L</td>
<td>Medium</td>
</tr>
</tbody>
</table>

\(^a\)Refer to Appendix H.

\(^b\)See Table 6.1 for definition of all variables.

\(^c\)Linear or nonlinear.

\(^d\)High, medium, or low. Sensitivity results are relative and are dependent upon the model itself and the input data. Thus, the characteristics of the model, of the sample, and of the measurement processes all will influence the results of sensitivity analyses.
<table>
<thead>
<tr>
<th>Run No.</th>
<th>Test No.</th>
<th>Independent Variable&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Dependent Variable&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Relationship&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Sensitivity&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High Range</td>
<td>Low Range</td>
</tr>
<tr>
<td>II</td>
<td>B</td>
<td>MANL CONCL</td>
<td>L</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>II</td>
<td>C</td>
<td>MANL CONCL</td>
<td>L</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>III</td>
<td>A</td>
<td>IRAESP POPEVE</td>
<td>NL</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>III</td>
<td>B</td>
<td>MANL POPEVE</td>
<td>L</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>III</td>
<td>C</td>
<td>MANL POPEVE</td>
<td>L</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>III</td>
<td>D</td>
<td>MANL LEIL</td>
<td>POPEVE</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>III</td>
<td>E</td>
<td>MANL LEIL</td>
<td>POPEVE</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>IV</td>
<td>A</td>
<td>IPEFFP POPEVE</td>
<td>NL</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>IV</td>
<td>B</td>
<td>CONCL POPEVE</td>
<td>NL</td>
<td>Low</td>
<td>Very High</td>
</tr>
<tr>
<td>IV</td>
<td>C</td>
<td>CONCL POPEVE</td>
<td>NL</td>
<td>Very High</td>
<td>Low</td>
</tr>
<tr>
<td>IV</td>
<td>D</td>
<td>CONCL POPEVE</td>
<td>L</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>IV</td>
<td>E</td>
<td>CONCL POPEVE</td>
<td>L</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>IV</td>
<td>F</td>
<td>CONCL POPEVE</td>
<td>NL</td>
<td>High</td>
<td>Nil</td>
</tr>
<tr>
<td>V</td>
<td>A</td>
<td>All variables CONCL</td>
<td>NL</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>V</td>
<td>B</td>
<td>All variables CONCL</td>
<td>NL</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>VI</td>
<td>A</td>
<td>YRSCON PAEV</td>
<td>L</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>VI</td>
<td>B</td>
<td>COSPRO PAEV</td>
<td>NL</td>
<td>Very High</td>
<td>Very Low</td>
</tr>
<tr>
<td>VI</td>
<td>C</td>
<td>AVEBEN PAEV</td>
<td>L</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>VI</td>
<td>D</td>
<td>COSPRO PAEV</td>
<td>NL</td>
<td>Very High</td>
<td>Very Low</td>
</tr>
<tr>
<td>VI</td>
<td>E</td>
<td>COSPRO PAEV</td>
<td>NL</td>
<td>Very High</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

<sup>a</sup>Refer to Appendix H.

<sup>b</sup>See Table 6.1 for definition of all variables.

<sup>c</sup>Linear or nonlinear.

<sup>d</sup>High, medium, or low. Sensitivity results are relative and are dependent upon the model itself and the input data. Thus, the characteristics of the model, of the sample, and of the measurement processes all will influence the results of sensitivity analyses.
<table>
<thead>
<tr>
<th>Run No.</th>
<th>Test No.</th>
<th>Independent Variable&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Dependent Variable&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Relationship&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Sensitivity&lt;sup&gt;d&lt;/sup&gt;</th>
<th>High Range</th>
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<sup>a</sup> Refer to Appendix H.
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<sup>c</sup> Linear or nonlinear.
<sup>d</sup> High, medium, or low. Sensitivity results are relative and are dependent upon the model itself and the input data. Thus, the characteristics of the model, of the sample, and of the measurement processes all will influence the results of sensitivity analyses.
Table 7.2. Continued.

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^aRefer to Appendix H.
^bSee Table 6.1 for definition of all variables.
^cLinear or nonlinear.
^dHigh, medium, or low. Sensitivity results are relative and are dependent upon the model itself and the input data. Thus, the characteristics of the model, of the sample, and of the measurement processes all will influence the results of sensitivity analyses.
Table 7.3. *Simulated flood control projects using the hydrologic-sociologic model.*

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<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td># 14</td>
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<td>0</td>
<td>3</td>
<td>3</td>
<td>4</td>
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</tr>
</tbody>
</table>

*Definition of symbols in Table 6.2.*
### Table 7.3. Continued.

<table>
<thead>
<tr>
<th>Project #</th>
<th>Cost, Control</th>
<th>Aesthetics</th>
<th>Ecology</th>
<th>Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Low, Med.</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Slightly</td>
</tr>
<tr>
<td>16</td>
<td>Med., Low</td>
<td>Positive</td>
<td>Neutral</td>
<td>Positive</td>
</tr>
<tr>
<td>17</td>
<td>High, High</td>
<td>Positive</td>
<td>Negative</td>
<td>Slightly</td>
</tr>
<tr>
<td>19</td>
<td>Low, Med.</td>
<td>Negative</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>20</td>
<td>High, High</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Slightly</td>
</tr>
</tbody>
</table>

- **COSPRO** = 500
- **YRSCON** = 250
- **OJEAES** = +1.5
- **OJEECO** = -1.5
- **OJEREC** = +3
- **IRCOS** = 5
- **IREFF** = 5
- **IRAES** = 4
- **IRECO** = 2
- **IRREC** = 5

*Definition of symbols in Table 6.2.*
Table 7.3. Continued.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Simulated Project # 24</th>
<th>Low Cost, Med. Control; Negative Aesthetics Neutral Ecology Negative Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSPRO = 20</td>
<td>YRSCON = 50</td>
</tr>
<tr>
<td>OJEAES = -1.5</td>
<td>OJEECO = 0</td>
</tr>
<tr>
<td>OJEREC = -1.5</td>
<td>IRAES = 2</td>
</tr>
<tr>
<td>IRCOS = 1</td>
<td>IRECO = 3</td>
</tr>
<tr>
<td>IRCOS = 5</td>
<td>IRREC = 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulated Project # 25</th>
<th>Med. Cost, High Control; Positive Aesthetics Neutral Ecology Positive Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSPRO = 100</td>
<td>YRSCON = 50</td>
</tr>
<tr>
<td>OJEAES = +1.5</td>
<td>OJEECO = 0</td>
</tr>
<tr>
<td>OJEREC = +1.5</td>
<td>IRAES = 4</td>
</tr>
<tr>
<td>IRCOS = 3</td>
<td>IRECO = 3</td>
</tr>
<tr>
<td>IRCOS = 5</td>
<td>IRREC = 4</td>
</tr>
<tr>
<td>AVEBEN = 999.9</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulated Project # 26</th>
<th>Med. Cost, High Control; Positive Aesthetics Negative Ecology Positive Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSPRO = 100</td>
<td>YRSCON = 250</td>
</tr>
<tr>
<td>OJEAES = +1.5</td>
<td>OJEECO = -1.5</td>
</tr>
<tr>
<td>OJEREC = +1.5</td>
<td>IRAES = 3</td>
</tr>
<tr>
<td>IRCOS = 3</td>
<td>IRECO = 3</td>
</tr>
<tr>
<td>IRCOS = 5</td>
<td>IREFF = 3</td>
</tr>
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\textsuperscript{a}Definition of symbols in Table 6.2.
Table 7.3. Continued.a

IRAES = 4
IRECO = 2
IRREC = 4
AVEBEN = 999.9

Simulated Project #27
Low Cost, Med. Control; Neutral Aesthetics
Slightly Negative Ecology
Slightly Positive Recreation
COSPRO = 20
YRSCON = 50
OJEAES = 0
OJEECO = -0.5
OJEREC = +0.5
IRCOS = 1
IREFF = 3
IRAES = 3
IRECO = 2.5
IRREC = 3.5
AVEBEN = 999.9

Simulated Project #28
Med. Cost, Low Control; Positive Aesthetics
Neutral Ecology
High Positive Recreation
COSPRO = 100
YRSCON = 10
OJEAES = +1.5
OJEECO = 0
OJEREC = +3
IRCOS = 3
IREFF = 1
IRAES = 4
IRECO = 3
IRREC = 5
AVEBEN = 999.9

Simulated Project #29
High Cost, High Control; Positive Aesthetics
Negative Ecology
High Positive Recreation
COSPRO = 500
YRSCON = 250
OJEAES = +1.5
OJEECO = -1.5
OJEREC = +3

Simulated Project #30
Med. Cost, Med. Control; Neutral Aesthetics
Negative Ecology
Neutral Recreation
COSPRO = 100
YRSCON = 50
OJEAES = 0
OJEECO = -1.5
OJEREC = 0
IRCOS = 3
IREFF = 3
IRAES = 3
IRECO = 2
IRREC = 3
AVEBEN = 999.9

Simulated Project #31
Low Cost, Med. Control
Negative Aesthetics
Neutral Ecology
Negative Recreation
COSPRO = 20
YRSCON = 50
OJEAES = -1.5
OJEECO = 0
OJEREC = -1.5
IRCOS = 1
IREFF = 3
IRAES = 2
IRECO = 3
IRREC = 2
AVEBEN = 999.9

Simulated Project #32
High Cost, High Control
Neutral Aesthetics
Neutral Ecology
Slightly Positive Recreation
COSPRO = 500
YRSCON = 250
OJEAES = 0
OJEECO = 0
OJEREC = +0.5

---

aDefinition of symbols in Table 6.2.
Table 7.3. Continued.\textsuperscript{a}

<table>
<thead>
<tr>
<th>IRCOS</th>
<th>5</th>
<th>Simulated Project #35</th>
<th>High Cost, High Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>IREFF</td>
<td>5</td>
<td></td>
<td>Negative Aesthetics</td>
</tr>
<tr>
<td>IRAES</td>
<td>3</td>
<td></td>
<td>High Negative Ecology</td>
</tr>
<tr>
<td>IREC</td>
<td>3.5</td>
<td></td>
<td>Negative Recreation</td>
</tr>
<tr>
<td>AVEBEN</td>
<td>999.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Simulated Project #33

<table>
<thead>
<tr>
<th>IRCOS</th>
<th>3</th>
<th>Simulated Project #36</th>
<th>Low Cost, Med. Control;</th>
</tr>
</thead>
<tbody>
<tr>
<td>IREFF</td>
<td>2</td>
<td></td>
<td>Negative Aesthetics</td>
</tr>
<tr>
<td>IRAES</td>
<td>1</td>
<td></td>
<td>Neutral Ecology</td>
</tr>
<tr>
<td>IREC</td>
<td>2</td>
<td></td>
<td>Negative Recreation</td>
</tr>
<tr>
<td>IRCOS</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IREFF</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRAES</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IREC</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVEBEN</td>
<td>999.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Definition of symbols in Table 6.2.
Table 7.4. The results of typical simulation runs to examine the effects of population attitudes within the study area upon predicted project acceptance.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Population Attitudes (Inputs to the Model)a</th>
<th>Predicted Population Characteristics and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Values</td>
<td>Description</td>
</tr>
<tr>
<td></td>
<td>The description and mean values for all input parameters are given by Appendix C. Those values are those for the study area.</td>
<td>Proposal accepted and could be enacted.</td>
</tr>
<tr>
<td></td>
<td>Means for the county population within the study area.</td>
<td>Even though concern about flooding and the need for a plan are increased (from mean values), the changes are not sufficient to affect acceptance of the plan.</td>
</tr>
<tr>
<td>1</td>
<td>NSORSE = 5.0</td>
<td>Flood threat publicized</td>
</tr>
<tr>
<td></td>
<td>KPERFL = 60.0</td>
<td>CONCL = 20.990</td>
</tr>
<tr>
<td></td>
<td>KLOSGR = 2.5</td>
<td>NEED = 4.258</td>
</tr>
<tr>
<td></td>
<td>KNOW = 2.0</td>
<td>POPEVE = .790</td>
</tr>
<tr>
<td></td>
<td>ICOSTF = 400</td>
<td>DAFE = .697</td>
</tr>
<tr>
<td>2</td>
<td>NSORSE = 5.5</td>
<td>Serious flooding occurred recently</td>
</tr>
<tr>
<td></td>
<td>KPERFL = 68</td>
<td>CONCL = 22.798</td>
</tr>
<tr>
<td></td>
<td>KLOSGR = 2.7</td>
<td>NEED = 6.066</td>
</tr>
<tr>
<td></td>
<td>KLOSF = 2.6</td>
<td>POPEVE = .943</td>
</tr>
<tr>
<td></td>
<td>ICOSTF = 400</td>
<td>DAFE = .784</td>
</tr>
<tr>
<td>3</td>
<td>PAYL = 27</td>
<td>-High willingness to pay</td>
</tr>
<tr>
<td></td>
<td>ECOL = 36</td>
<td>CONCL = 19.893</td>
</tr>
<tr>
<td></td>
<td>RECL = 28</td>
<td>NEED = 13.893</td>
</tr>
<tr>
<td></td>
<td>MANL = 18</td>
<td>POPEVE = .620</td>
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<tr>
<td></td>
<td>LEIL = 15</td>
<td>DAFE = .600</td>
</tr>
<tr>
<td>4</td>
<td>PAYL = 8</td>
<td>-High ecological concern</td>
</tr>
<tr>
<td></td>
<td>ECOL = 30</td>
<td>CONCL = 16.193</td>
</tr>
<tr>
<td></td>
<td>MANL = 15</td>
<td>NEED = -8.807</td>
</tr>
<tr>
<td></td>
<td>RECL = 24</td>
<td>POPEVE = .735</td>
</tr>
<tr>
<td></td>
<td>MANL = 18</td>
<td>DAFE = .666</td>
</tr>
<tr>
<td>5</td>
<td>CONCL = 18</td>
<td>-High recreation concern</td>
</tr>
<tr>
<td></td>
<td>MANL = 10</td>
<td>CONCL = 17.223</td>
</tr>
<tr>
<td></td>
<td>ECOL = 18</td>
<td>NEED = -3.777</td>
</tr>
<tr>
<td></td>
<td>RECL = 24</td>
<td>POPEVE = 1.049</td>
</tr>
<tr>
<td></td>
<td>MANL = 18</td>
<td>DAFE = .845</td>
</tr>
<tr>
<td>6</td>
<td>CONCL = 40</td>
<td>-Low concern about flooding</td>
</tr>
<tr>
<td></td>
<td>MANL = 10</td>
<td>CONCL = 16.686</td>
</tr>
<tr>
<td></td>
<td>ECOL = 24</td>
<td>NEED = -.046</td>
</tr>
<tr>
<td></td>
<td>RECL = 24</td>
<td>POPEVE = 735</td>
</tr>
<tr>
<td></td>
<td>MANL = 18</td>
<td>DAFE = .666</td>
</tr>
<tr>
<td>7</td>
<td>PAYL = 12</td>
<td>-Very high concern about flooding</td>
</tr>
<tr>
<td></td>
<td>AGENL = 8</td>
<td>CONCL = 16.382</td>
</tr>
<tr>
<td></td>
<td>EXPTL = 12</td>
<td>NEED = -4.618</td>
</tr>
<tr>
<td></td>
<td>AGENL = 16</td>
<td>POPEVE = 1.079</td>
</tr>
<tr>
<td></td>
<td>EXPTL = 24</td>
<td>DAFE = .862</td>
</tr>
<tr>
<td>8</td>
<td>PAYL = 24</td>
<td>-Low willingness to pay, to follow agencies, and to follow experts</td>
</tr>
<tr>
<td></td>
<td>AGENL = 16</td>
<td>CONCL = 18.158</td>
</tr>
<tr>
<td></td>
<td>EXPTL = 24</td>
<td>NEED = 9.158</td>
</tr>
<tr>
<td></td>
<td>EXPTL = 24</td>
<td>POPEVE = 1.004</td>
</tr>
<tr>
<td></td>
<td>EXPTL = 24</td>
<td>DAFE = .819</td>
</tr>
</tbody>
</table>

aExcept where indicated in this table, mean values for all input parameters (see Appendix C) are used.
CHAPTER VIII
SUMMARY AND RECOMMENDATIONS

Summary

This study was directed toward development of a general technique for joint consideration of the hydrologic and social dimensions of formulating a structural program for urban flood control. The chosen methodology was to employ simulation for integrating these dimensions into the logic of a decision-making process (Andrews et al., 1973:1).

Many of the steps necessary to accomplish these goals have been performed. Relevant variables and concepts have been defined, expressed in quantitative relationships, and placed in respective models of the sociological and hydrologic systems for a Salt Lake study area. A basic conceptual model and equations have been created to facilitate expansion to include additional groups in a more complex model. Simulation and sensitivity analyses using the models have been successfully run for a study area.

However, the linkage of the two models is not yet complete. A more direct method of obtaining agency evaluations of proposed plans needs to be perfected, and the list of variables needs to be made interchangeable and extended for other watersheds. Strengths and weaknesses of the model and suggestions for improvements in the present model are discussed in this chapter.

The models were formed by identifying important variables, analyzing system response to them, and describing the relationship of the resultant input variables to relevant output variables with equations integrated to form a model. Integration is done through a chain of dependent variables or common independent variables or both. The major dependent variable in the hydrologic model is the peak runoff from a designated area. The major dependent variable in the sociological model is the evaluation of a project proposal by a particular group such as the decision agency or by a defined population. Calibration of certain parameters and refinements of others occur after a model is formed by combining the equations to represent a system.

Brief Overview of Chapters

Chapter I and II explain the need for and methodologies used in this study. Theoretical foundations are explained in Chapters III and IV for the hydrologic and sociologic systems, respectively. The conceptual and applied models of the sociologic and hydrologic systems are represented by flow diagrams in Chapters III through VI. Figures 3.1, 3.2, 3.3, 3.4, 3.6, outline the hydrologic system, and Figures 4.1, 4.2, 4.3, 5.1 diagram the sociological systems. In Chapter V and VI the fundamental decision process and general equation which is applied repeatedly in the social model are illustrated by Figures 5.2 and 5.3. Lists of the variables used in the sociologic and hydrologic models are in Tables 6.1 and 6.2 in Chapter VI. The charts in Chapter VI show the workings of both models. Social data were collected by interviews with random samples of the public, depth interviews with officials, planners and managers, and secondary data from records. The hydrologic data came from records from various agencies. The data on the variables were tested for statistical significance as a screening step, and multiple regression analysis was used for calibration.

The Hydrologic Model

The conceptual model used for hydrologic analyses is stated in equations representing the system process in a structure shown by Figures 3.3 and 3.4. The equations follow system processes from precipitation to runoff and evapotranspiration. The model distinguished differences between rural and urban conditions and between hourly and daily time increments for applications to varying degrees of urbanization and magnitudes of other important hydrologic system parameters.

For any watershed within the study area, the hydrologic model predicts runoff from both the rural and urban drainages, combines flows, and routes them downstream. The model also is capable of predicting changes in the hydrologic responses and flooding patterns associated with various management practices, such as urbanization and the development of flood control structures.
The Social Conceptual Model

Chapter IV describes a conceptual model of behavioral elements that function in the process of complex public decision-making. It then identifies theoretical elements for inclusion in a mathematical model which can be used for simulation purposes. Figure 4.1 is an expansion of the main elements of the real social process from the greatly simplified version illustrated in Figure 1.4. It shows six stages, each represented by a separate section of the model, charting the typical process for public resource decision-making. It shows how at any point the process may be either stopped and returned to an earlier stage or continued on to succeeding stages.

The process may be interpreted as a sequence of agency decisions reaching a public stage at Section IV. However, Figure 4.2 also shows how the decisions may be opened to public, agency or other group participation at each level. The pattern, dependent upon the choice of the agency, may be open or closed. The degree of openness, however, does not affect the modeling process. The model will handle either pattern or a mixture of them.

The conceptual model was derived in two parts. The first part was deductive thinking from the experience of the project staff who identified the structure of decisions with the steps in the process. This was followed by inductive refinement from which interactional aspects of the process were identified and conclusions about the system were drawn. By this method a conceptual framework of the process was formed.

The result was to show that several theoretical constructs are necessary to account for social interactional elements. These are developed in six sections or stages. In Section One on Public Opinion, the concern is for attitudes of members of the public, the perceptions of these individuals regarding flood control measures, and how these attitudes and perceptions affect their interaction or behavior in the decision system. The model provides for inputs on these social psychological factors. Sections Two and Three, Agency Planning and Decision Functions, represent the behavior of government agencies in the decision process and how that behavior is influenced by social power comprising both authority and influence. The seven basic elements involved in planning for flood control are perceptions and evaluations of behavior concerning flood control, cost, aesthetics, recreation, ecology, and acceptance by other agencies and other populations. The concept of distortion factors was introduced to account for differences between actual situations and the perception of these situations by agency officials in planning activity. This concept assisted in determining what effect the difference between perceptions and reality has on public decision-making behavior. Section Four, Public Reaction to Planning, analyzed public attitudes, perceptions, public predispositions and the personal and demographic characteristics affecting action. Section Five dealt with alternative decisions. Section Six relates the process to completion of action and its relationship to new public attitudes and effects on the hydrologic system.

Some additional concepts were developed to deal with decision-making in this complex organizational system and were discussed in conjunction with the decision process.

Importance Factors (IF) measure the degree of importance placed on each of the basic characteristics of a flood control proposal by different groups. Weighting these factors provides a gate-keeping mechanism for the social variables that were deterministic in the model. They provided a means for determining what factors, agencies, groups and individuals were basing their decision behavior on. They show the differences between groups in the values they emphasize and how these emphases vary as power elements come into play and conflicts are solved. All these factors result in setting criteria by which agencies judge possible solutions.

The concept of the acceptance function was developed to depict the relationship between importance function weightings and the values of each of seven basic characteristic variables associated with a proposal. These relationships tell the degree of acceptance the proposed flood control has in relation to the seven basic variables.

Overall proposal evaluation is then based on the sum of these acceptance functions and indicates acceptance or rejection. Figure 8.1 illustrates how functions of the model may be displayed by showing point scores on a scale of 0 to 10 for each proposal for each function. Line $B_a$ shows score values for aesthetics, and lines $B_r$ and $B_e$ show values for recreation and ecology. This could be done for any factor included in the acceptance functions in the model as illustrated by $B_f$ where $f$ stands for any other factor. Similar graphs could be constructed for the acceptance functions, the perceived quantities, and other related quantities. Other elements deserving consideration are general tendencies or conditions for favoring or opposing proposals, general attitudes of the public or attitudes in agencies that are conditioned predispositions to respond.

The behavior of special interest groups has particular importance and is a fundamental problem that must be considered. To depict this phenomenon, the concept of an expansion effect was developed to account for stimulation of a latent concern that triggers a high level of social power action. The related concept of threshold level was developed to quantify the
idea that the concern must rise to a minimum level before action will become significant.

These concepts provide the basic theoretical structure necessary in order to relate variables to measurement so that a mathematical model could be developed.

Characteristics of the Social Model

The development of the model of social components of the sociologic-hydrologic systems has been a pioneering effort. No previous effort is known. Since it is a new approach, many problems took considerable effort and time to overcome; in fact in some cases, these have not yet been completely resolved. The ones that have may be considered points of accomplishments.

One of the chief goals of the study was to identify sensitive variables influencing flood control decision-making. The results of this score are detailed in Table 7.2. In order to advance to this point, significant and important variables had to be identified and relationships among them hypothesized. This was partly done in earlier work (Andrews and Geertsen, 1973) and continued in the flow charts and theoretical constructs of this project.

The central developments of this project are the conceptualization and the expression in mathematical form of the decision process. These two steps formed the basis for the equations in the present model for evaluating flood control systems and may have wide applicability to other types of institutional decision-making. The model uses an analysis of the components of possible projects and represents the components as terms in an equation. From the equation, individual terms can be varied to study the special effects of variables or combinations of variables such as was done with the model to determine the effect of special interest groups in the total flood-control proposal evaluation scheme.

The values of $r^2$ reached for the principal equations of the model were good for a first try, but the improved methods learned during this research would permit substantial improvement. The $r^2$ of Equation II as an example, is nearly the maximum that could be achieved considering the reliability of the measurements utilized. The experience gained from this study and the use of recently developed techniques can reasonably be expected to improve the results substantially.

The construction of the model also accomplished other goals:

1. Relating agency and official policy and decision action to public behavior and reaction by combining public input and other social factors along with physical considerations in a single equation.
2. Demonstrating the use of content analysis of interviews to assign numerical values for agency characteristics.
3. Showing how regression analysis can be used to relate variables in an intertwining relationship and to establish primary, secondary, tertiary, etc., relationships among these variables. The effects of one variable upon others can thereby be traced.
4. Using the decision process conceptualization to develop a mathematical formulation for predicting evaluation of a flood control proposal. This may be the most useful equation of the system due to its utility in project planning.

---

1Equation 5 in Chapter V ($r^2 = 0.49$).

2A primary relationship is one in which a variable appears as an independent variable in an equation to estimate the dependent variable. A secondary relationship occurs if a variable is an independent variable in an equation which has one of the independent variables in a primary equation as its dependent variable. A tertiary relationship is one in which a variable helps predict a variable which predicts another variable which in turn predicts a variable in a primary equation for the dependent variable concerned. A fourth-order relationship would be defined similarly and so on. Obviously, a variable will have different relationships with different variables. Multiple order relationships may also occur by which a variable effects directly or indirectly more than one term of an equation.
5. Developing a theory on the possible expansion effect of some variables within special interest and other groups and also of the related concept of the threshold level.

6. Successfully using the system for simulating response to different projects for the same conditions but for similar projects under altered conditions such as increased flood experience, increased environmental orientation, etc. The model may thus be used either to choose the most feasible project for an area or to choose the most feasible location for a project.

Possibly the most important accomplishment of the model was the integration of different types of variables into one scheme each for evaluating agency and public response to project proposals. The indicators range through demographic characteristics, attitudes toward flood-related experiences, agency evaluation, and perceptions of the physical characteristics of flood control proposals. Socially perceived hydrologic characteristics and social psychological characteristics are incorporated in one equation. This interconnecting is increased by coupling each equation to the others.

The primary weakness at this point is in the linkage between the social and hydrologic characteristics of the two models. Some variables in the social model relate to characteristics of the hydrologic system, but the relationship cannot be directly obtained through operation of a single model. The users of the sociologic model must apply the hydrologic model, interpret the results, and change appropriate variables accordingly. Judgment must also be made of how the public will perceive physical characteristics of a proposal for the modeler to avoid running a survey for each proposal to be considered. The more direct linking of the hydrologic and sociologic models would greatly facilitate operations.

A more direct connection between the social-behavioral and physical elements would contribute hypotheses relating social and natural ecologic phenomena and add evidence to theoretical ideas in this area. Social and hydrologic variables are related in various ways. The frequency of flooding relates to public consciousness of flooding problems; degree of flooding is related to damage and injury; experience with flooding is expected to be related to public attitudes, knowledge, and readiness to act. The hydrologic model also can provide physical facts on actual conditions that can be compared to perceived conditions and interest group positions.

Time is only an implied variable in the present model. The model is static rather than dynamic in the technical sense, and the system is assumed to be in equilibrium. This means that the parameters are considered constant during the evaluation process. This is not as restrictive as it appears as parameters of the model can be varied to simulate altered conditions; indeed, this is a main purpose of simulation. This assumption does mean that the conditions determined by exogenous variables, that is, by variables which obtain their value from outside the system model, are considered unchanged during a given run. Explicit time variation of the variables would be very difficult because the status of some variables depend on the occurrence of meteorological events and because longitudinal knowledge of social behavior is insufficient at present to allow formulation of the requisite equations.

Use of the Model

Simulation and Sensitivity Analyses

The use and advantages of the model for simulation and sensitivity analyses have been explained (Chapter I) and demonstrated (Chapter VII). The most salient advantages of computer simulation are:

1. Identification of the most attractive alternatives. For flood control these would be the proposals most effective for controlling flooding and acceptable to the responsible agencies and the people in the area affected. Acceptability is important particularly to allow quick implementation of a plan and to minimize solution costs.

2. Identification of sensitive variables. This process allows one to gauge the effect of fluctuations in the values of variables on the system. One is then better able to specify the design parameters of possible projects so as to emphasize important qualities that will expedite implementation of solutions to flood control problems. Also, measures may be shown by the model to affect specific social factors which relate strongly to project acceptance.

3. Increased understanding of the system. Both construction of the model and its use in sensitivity analyses provide better understanding of the system. This occurs as one hypothesizes and tests relationships believed to be important. Investigation of relevant factors and their interrelationships in the real-world system are required, and data needs to be collected on components of the system.

Understanding is probably the most important benefit from a model as it allows one to judge real
world systems more realistically and hence accurately. Actually, it is hoped that enough insight is gained through construction of a model that needed additions and possible errors requiring further research can be detected or sensed by the creator when the model is used. For these reasons, it would also be useful for managers to be involved in creating a simulation model of their systems.

Decision Analysis

The model is also useful in considering the outputs of separate sections of the model as inputs to be weighted by the planner. These separate outputs then serve as additional information by which a planner may better specify the probabilities of various results of a possible decision.

Figure 8.2 shows a way the model at its present level of development may be used to help formulate a decision regarding a flood control recommendation. This chart shows the outputs of the hydrologic system and how each of the decision sections of the social model can be considered separately. It also indicates that the present model includes interactions between social groups, but that the connections between the

Figure 8.2. A conception of model utility. A variety of groups can be included and a choice of proposals compared.
hydrologic and sociological components are through variables which are interpretations of physical factors or effects. The main effect of improving the completeness of the model would be to reduce repetitious measurement of variables, thereby making the model easier to apply. However, provided the measurements are accurate, the results should be the same, and these are what are important to the planner.

Inclusion of Additional Inputs

The dashed lines in Figure 8.2 indicate where social groups and agencies may be added as needed to represent the real-life system. For instance, although the present model does not include public input at the planning stage, an extension of the present model such as that indicated by Figure 4.2 to include significant public input to the planning agency or decision agency in its initial evaluation could be done fairly easily.

Among other possible model expansions, public or other groups could be added to the model by calibrating the basic decision process Equation 5.1 for each particular group desired. The only difference besides coefficient values of the equations for different groups, would be in representing interactions between (type four terms). Both the number of type four terms and other groups represented by each of these will vary from group to group. An additional type four term would have to be added to the planning agency evaluation equation for each public group which is considered at this stage and the equation calibrated.5

The type four terms which account for the influence of one group's opinion upon another's evaluation must also be reviewed in adopting the model to another area. The organizational and other social arrangements within different areas vary, although often they will be similar. Variations in the order of steps, the number of agencies involved, etc. can all be handled by applying the general equation to the steps and agencies in a manner analogous to that done for the simplified system model constructed in this initial research. It is anticipated for sociological reasons (Chapter IV) that equations for generic types of groups in culturally similar areas will be consistent. After creation of a few models of this sort, insight will be gained into what future applications will produce.

The use of interaction terms may be expanded to include physical effects of a project proposal other than those included in the present formulation of the equations. Interaction between physical characteristics of a project and social characteristics could also be added. Safety, for example, could be added to the formulation and used in calibration of equations for a model.

Effects of social change on the values which people place on different aspects of a project could be accounted for by the same procedure of adding type three terms if the factors were not already included in the equation formulation. The relative importantances of the factors included in the equation are assessed by regression analysis and reflected in the coefficients of the terms of the calibrated equations. In addition, social movements may produce new special interest groups which need to be included in the system representation by use of type four terms. For these reasons, a system model needs to be recalibrated in the event of a major social movement or other major social change.6

The factors representing impacts of a project proposal in a model formulation such as this must be specific enough to be identifiable consistently to the groups concerned and distinguishable from each other. Consequently, a concept such as "social well-being" can be used, but only when it is broken down into components which can be connected to physical characteristics of projects. It is these components which occur in the model equations and which can be pulled out and considered separately in the assessment. Suggestions for the use of "acceptance functions" for this purpose, including graphing, are made in the last appendix. About any factor desired or that might be included in a social impact assessment may be used, but the factors must be expressed in terms which are meaningful to the people whose responses are being sought.7

It should be mentioned that the same formulation used in this model for flood control proposals would also be applicable to many other land-use proposals by altering the referent for "effectiveness" to the type of project concerned. Effectiveness as used in a type three term in this report refers to ability to control flooding. For other land-use project proposals, it would refer to the ability to accomplish the principal purpose of that type of project. Multiple purposes would be reflected in multiple type three terms. The hydrologic system model would have to be replaced by models representing the relevant physical components which can be connected to social conceptions.

5If any of the same public groups evaluations are also put in to any other equations in the model, at least these equations should be recalibrated also.

6Recalibration of a model under altered social conditions may be difficult since sufficient data under the changed conditions may not be available. The Delphi or some other judgmental technique using experts in the field may be necessary in this situation. Experience gained through previous applications of similar models would be particularly useful.

7This is not a major limitation. It simply is stating implicitly that a concept must be defined specifically before it can be quantitatively assessed.
cal conditions affecting other kinds of effectiveness which will probably require different equation formulations for other processes. The social system model construction, however, would be relatively unaffected since the output of most of the equations in the model would be the same, i.e. an evaluation by a group of a proposal. This possibility of expanded applicability of the basic social modeling methodology increases the importance of developing and refining the model.

Recommendations

The contributions of this model would be made even greater by overcoming the weaknesses which have been pointed out in this report and by expanding the model to more closely represent reality. The suggestions below are designed to accomplish these objectives.

Suggested Improvements

1. Development of formulas for predicting perceived characteristics of flood control or other similar land-use proposals.

Probably the most important practical improvement in the model would be the development of formulas for predicting perceived characteristics of flood control projects as well as other land-use projects by population groups. In terms of the conceptualization presented in Chapter IV, the formulas would predict distortion factors. This would be a major step as it would allow implementation of a model simulation (taking only that part of the model) without requiring 1) judgments as to what the perceived effects of a project would be by a particular group, or 2) a sample survey of the population for each type of project which one is interested in testing.

Equations for predicting perceptions could be achieved by the same techniques used to create most of the equations in the present model, e.g. data collection and system investigation, theoretical analysis and formulations, and calibration using regression analysis.

The independent variables in the developed equations can reasonably be expected to include physical characteristics of possible projects, social variables related to cultural definitions, and psychological factors derived from experience. A thorough investigation of the interrelationships of these factors would have additional benefits in the human ecology-resource management field because of consequent increased comprehension of physical-human factor interaction.

2. Longitudinal analysis of flood control and related social factors and processes.

The companion variables to perceived characteristics of a proposal in the acceptance function terms of evaluation equations are called importance factors. Unlike the perceived characteristics, the importance factors are considered stable from proposal to proposal. This conceptualization does not preclude these varying through time, but it does limit the validity of a calibration to periods of stable attitudes. Changes in attitudes caused by a social movement or other factors would necessitate recalibration.

Recalibration requirements can be reduced if one knows how importance factors vary with other factors. For example, the importance of flood control may be an inverse waning exponential function of time since the last flooding, modified by the seriousness and proximity of the flooding. To establish whether this hypothesis is true, a continuing study must be made of people’s attitudes on flooding, and how these attitudes are influenced by events or in the case of no pertinent events. This type of study would allow one to establish the data points to form realistic mathematical expressions for importance and other attitudinal factors through time. Inclusion of these equations with time as a variable would then make the social model explicitly dynamic.

Longitudinal analysis would also have other benefits and advantages. The processes of flood control development and evaluation could be repeatedly followed as they occur. Measurements could be taken of the factors as they exist at the time they affect the system. The necessity of after-the-fact judgments, whether by the participants or others, would be eliminated. If data were collected over a number of years, the number of proposals on which the calibration of the system could be based would be considerably larger, thereby contributing significantly to the accuracy and comprehensiveness of model equations.

3. Application of ratio scaling techniques to variables in the social model.

The above suggestions and most of those that follow depend for their effectiveness on the measurement of the dependent variable being analyzed. Techniques have been developed which allow the measurement of social-psychological variables at the ratio level. These techniques are justified on the basis that people can consistently make point allocations between pairs to express "mental ratios" (Stevens, 1960, and Garms, 1968). What this means is that a person can reliably state numbers to indicate the importance

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8"Longitudinal" refers to a study made over an extended period of time.
of one factor relative to another or the extent to which a characteristic is present and that these judgments match with each other at the ratio level.\textsuperscript{9}

A technique which may be used to determine the relative importance of various factors is the general allocation technique in which the respondent allocates a fixed number of points over a small number of factors according to their effects (Metfessel, 1947). This has been recently shown to be effective in this type of application (see Gum, 1974; Masteller et al., 1976).

A more general psychometric technique is called "ratio scaling." This social measurement method is based on the discovery that:

\[ y = cx^k \] (called a power function) by which \( y \) can be known when \( x \) is known. Ratio scaling conventionally has \( k = 1 \). A decibel scale is an example of a nonlinear \((k \neq 1)\) physical scale. Effectively, this makes no difference in the evaluation equation. This is because when \( y = cx^k \) is substituted in \( zy \), it becomes \( cxy \) which would no longer be considered a linear term in regression analysis.\textsuperscript{12} (For further discussion see Masteller, 1977: Chapter VII.)

5. Development of evaluation equations for agencies and populations from reactions to hypothetical project proposals.

One of the principal problems which had to be overcome was the few types of flood control proposals on which recent historical data were available. This limitation affected mostly the calibration of the agency equations. Practically, data may not permit expansion of the model for the real world. The longitudinal analysis recommended earlier may provide sufficient data to prevent this difficulty. An alternative would be to submit a reasonably large number of varied types of proposals to high managerial personnel of agencies and also possibly to a population sample to ascertain their reactions.\textsuperscript{13} Such a procedure would provide more accurate weights for the various project-related factors (Type III Terms).

This suggested procedure may have limited utility for evaluation of the influence of others' opinions (Type IV Terms) as such influences may be relatively difficult to convey to a respondent. The assessment of this kind of Type IV Term may therefore have to depend on more limited information from the real world system operation.

6. Refinement of the influence of special interest groups in the system model.

In the present model, the influence of special interest groups is reflected in threshold level values set on IF C statements. Instead, the outputs of prediction equations similar to the population evaluation equation, but calibrated for the special interest groups involved could be used. A term which reflects the concern of a special interest group may not have much effect on the initial model prediction but it would al-

\textsuperscript{9}Ratio level in this context means a relationship of the form \( Y = cx^k \) (called a power function) by which \( y \) can be known when \( x \) is known. Ratio scaling conventionally has \( k = 1 \). A decibel scale is an example of a nonlinear \((k \neq 1)\) physical scale. Effectively, this makes no difference so long as \( k \) is constant (Stevens, 1966; Hamblin, 1971).

\textsuperscript{10}Other measurement methods should not be abandoned until ratio level methods have been demonstrated to be successful in this application (see Masteller et al., 1976: 179). The other techniques may be surprisingly effective, even if simple (Taylor and Parker, 1964). Also as discussed in Chapter II, ordinal measured data may approximate interval level data (Labovitz, 1970).

\textsuperscript{11}A multiple factor equation may be used; i.e., \( y = cx^kmh^n \).

\textsuperscript{12}An efficient algorithm for least-square estimation of a class of nonlinear models which includes that which would result from insertion of this type term in the basic equation of the social model has been discussed by Gutman, Pereira, and Skolnick (1973).

\textsuperscript{13}A group of questions for obtaining a respondent's attitude toward each of a comprehensive list of specific flood control methods was included in this research (Appendix A, variables 146-165). Twenty-two flood control methods were pretested to determine if people distinguished between the various methods. Analysis of pretest results indicated that all but two of the flood control methods had distinct evaluations.
low a proposal to be so positive on other things that the deficiency would be overcome even within that special interest group.

A special interest group evaluation equation may also be useful when the IF C statement does not signal probable rejections by a special interest group. A high positive value may be used to indicate active promotion of a proposal by that group. Also, the combination of scores from assorted special interest groups may be used to assess the effects of opposing sentiments or reinforcing conditions. Perhaps the special group evaluation equations in combination would determine the outcome of the flood control decision process in the public sector, provided that the general public sentiments were not too negative toward the proposal.

Expansion of the model should emphasize special interest groups. The conceptualization of this research provides a basis for investigating the behavior of such groups. From the resulting understanding, a manager may not be able to avoid conflict, but he should be better able to minimize it.

7. Formulation of equations to establish an improved linkage between the social and hydrologic models.

The expression of relationships of the variables in the hydrologic model to the variables within the sociologic model would more closely link the two. In the present model, the assessment of hydrologic effects on the sociologic system is largely based upon the background flooding experience of the people in the area.

A model combining the two systems may be accomplished by analyzing the response to one system to information about the other. For example, relationships might be developed between historical flood records and sociologic reactions. Determination of how they are related would supply important variables for an equation connecting the hydrologic and sociologic systems. On the other hand the hydrologic situations may not be stable due to changing social conditions such as, for instances, when an area grows in population resulting in a greater percentage of impervious surface or when alterations in types of agricultural land use occur. This example shows how prediction of the behavior of one system without consideration of the other is not feasible. Formulation of 1) equations relating changes in flood hazard to variables reflecting social trends and other factors, and 2) equations relating flood control concern to variables reflecting the hydrologic situation would be valuable.

Recommendations for Further Research

The primary recommendation for research is a major effort consisting of a sequence of research projects or stages of works to specifically implement the improvements that have been suggested previously. Each stage would build upon the work of this research project and on any previous stages completed to produce a more applicable and meaningful model. Five specific recommendations are presented.

1. Investigation of the factors of flood control project perception.

The first stage would be to investigate and analyze the factors in flood control perception. This comprehensive investigation would provide a more refined basis for expressing the relationships needed to eliminate what was described in the preceding section as the most important practical deficiency in application of the present model.

This study has assumed that the principal factors the public considers important in evaluating a flood control plan are effectiveness, cost, aesthetics, ecology, and recreation. The components of flood control perception could be more scientifically determined by using the semantic differential (Osgood, Suci, and Tannenbaum, 1957) or other factor analytic techniques. The list of factors may be modified or lengthened. Once these determinants of flood control perception are verified, the factors which generate and change these perceptions must be understood so that the relations between physical and social characteristics can be specified more clearly.

2. Investigation of responses of special interest groups.

Special interest groups are a very important component of public reaction to flood control proposals because of their roles in opposition or advocacy to proposals and as instigators of public opinion. The action patterns of these groups by stimuli should be analyzed. Emphasis should be placed on determining the components of reactions to proposals. Psychological and sociological theory will need to be applied. It can be expected that most of the data analyzed would be historical; however, several cases of action and reaction need to be examined as they occur.

3. Formulation of an improved model and its application to a specific site for testing purposes.

This research stage involves integrating the additional knowledge obtained in stage 1 and 2 into the current model to form a more complete and comprehensive model. Data from a study site should be used to test the validity of the individual equations and of the model as a whole. Emphasis on practical application must be made in formulation of the model to help insure the usefulness of the result.
4. Application of the modeling process to multiple sites and dissemination of information.

The largest payoff from the research is in application of the information acquired to other areas to determine acceptable and effective flood control solutions in problem areas. This phase would include at least three types of activities:

1. Construction of models for various areas similar to those previously created.

2. Instruction of planners and other flood-control related personnel in the use of the model.

3. Presentation of methodology and results.

Models constructed for other locations would use the same type of formulation. Probably the same basic equations can be applied, although at least some equations will need to be recalibrated. The basic equation of the social model can be used for as many groups as needed and expanded to include additional factors.

Model modification and recalibration should become easier with each new formulation. With experience, coefficients for generic types of groups may be estimated as they can now for hydrologic conditions. Involvement of officials in model construction is important in making them cognizant of the mechanisms and consequently the benefits and limitations of the methodology.

5. Establishment of an information center to collect longitudinal data for water resource management.

The establishment of a center for flood control information would provide both a means of supplying managers with relevant information and a base for collection of data on a continuing basis. It would serve as a general information gathering and dissemination center for material on water resource management. Managers would then know where to get help with these problems based on the experience of others in similar situations and obtain expert assistance to meet their needs. Such a center could both reduce data difficulties such as encountered in this research and also provide knowledge on which time series analyses and other refinements of the present model could be based.

The analyses suggested here may benefit those making any land or water use decisions. The only important difference in the basic equation of the social model would be in the definitions of effectiveness and in the specific flood related variables. The measure of effectiveness for a project where the main purpose is to provide water for irrigation is obviously different than one which is principally designed for flood control. Continued research could provide a methodology of wide applicability. Persons and organizations interested in effective land and water planning therefore have reason to pursue this modeling of social decision-making.

Conclusions

The results presented in this report show that the goals of this study were largely met. Successful computer models of both the social and the hydrologic systems were created. The social model was the first known successful effort to portray decision-making in water resources planning.

It is recommended that research to improve the model continue and that the model be applied to different areas. Even closer integration of the sociological and hydrologic computer system models is important. These analyses should be disseminated to planners so that they may use them to improve the planning process by including a greater number of significant variables in their decisions, provide better public participation, predict with better likelihood of proposing acceptable, effective, and more quickly implementable flood control plans.

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14 Some of the Type I and Type II Terms may also be different. When considering proposals affecting the same population, those are relatively less important than Type III and Type IV Terms.

15 Multiple Type III Terms could be included in the same equation for multiple purposes.
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Kostelnik, B. L., R. N. Harlow, M. Karlins, and R. Pargament. 1968. Predicting group status from member’s cognitions. Sociometry, 31:64-76.


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APPENDIX A

QUESTIONS AND PUNCH CARD CODE FOR THE INTERVIEW SCHEDULE

The number to be punched in the column is also the weight of the scale item when the question has a graduated scale for an answer, examples for Item 3 and Item 4.

CODEBOOK FOR MODELING PROJECT CDOO

Deck 1

<table>
<thead>
<tr>
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<tr>
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<tr>
<td>3-5</td>
<td>Schedule Number</td>
</tr>
<tr>
<td>6</td>
<td>Closeness of information</td>
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<tr>
<td></td>
<td>0 = 000</td>
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<td></td>
<td>1 = 001</td>
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<tr>
<td></td>
<td>2 = 002, 013, 037, 004, 035, 040, 003</td>
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<tr>
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<td>3 = 005, 012, 046, 051, 058, 023, 006, 017, 021, 024, 033, 053, 10, 045</td>
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<td></td>
<td>4 = 007, 018, 041, 047, 050, 008, 027, 028, 030, 057, 031, 036</td>
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<tr>
<td></td>
<td>5 = 009, 011, 014, 015, 016, 019, 020, 022, 025, 026, 029, 032, 034, 038</td>
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<tr>
<td></td>
<td>039, 042, 043, 044, 048, 049, 052, 054, 055, 056</td>
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7 1. Have you ever experienced damage or inconvenience due to flooding (in your lifetime, at any place)?
   0 = None
   1 = Inconvenience only
   2 = Damage
   3 = Both 1 and 2
   (IF NONE, SKIP TO QUESTION #2)

8-9 A. Where did this occur?
   00 = DNA
   01 = Outside of Salt Lake area
   02 = Property other than a residence in Salt Lake area
   03 = Another residence(s) in Salt Lake area
   04 = At present home
   05 = 3, 4
   06 = 1, 3
   07 = 1, 4
   08 = 2, 4
   09 = 1, 2

10-11 (1) In which of the above places did you receive the most inconvenience or damage?
   CODE SAME AS 1A.
(IF DAMAGED) What would you estimate the cost of the damage that you experienced from flooding to be in current dollars? (in all areas)

Round to nearest $10 and code by dropping the last 0.999. $10,000 or more damage.

What do you feel is the likelihood that you will experience flooding at your present residence or other personally owned property in the Salt Lake area in the next five years? Could you please give this in percentage of likelihood where:

0% is no likelihood of flooding and 100% is absolutely sure of flooding.

Refused to answer = 08

What do you feel is the main source (or sources) of flooding threat to your residence or other personal property?

00 = DNA
01 = Snowmelt
02 = Flash flood rains
03 = Long heavy rains
04 = Rain and snowmelt
05 = Stream or creek
06 = Other (specify)
07 = 2,3
08 = 1,2,3,4,5
09 = 2,5
10 = 3,4
11 = 1,3
12 = 4,5
13 = 5,6
14 = 1,2,3,4

What would you say is the degree of concern or worry you have about flooding in general in the Salt Lake area?

0 = None
1 = Low
2 = Moderate
3 = High
4 = DK
<table>
<thead>
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<tbody>
<tr>
<td>21</td>
<td>4.</td>
</tr>
<tr>
<td>0</td>
<td>Only those who receive damage from floods</td>
</tr>
<tr>
<td>1</td>
<td>District within the country</td>
</tr>
<tr>
<td>2</td>
<td>City or town</td>
</tr>
<tr>
<td>3</td>
<td>County government</td>
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<tr>
<td>4</td>
<td>Multicounty district</td>
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<td>5</td>
<td>State government</td>
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<tr>
<td>6</td>
<td>Federal government</td>
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<tr>
<td>7</td>
<td>Other (specify)</td>
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<td>8</td>
<td>5, 6</td>
</tr>
<tr>
<td>9</td>
<td>DK</td>
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</table>

| 22     | 5.   | In the past year have you heard anything about flooding problems or flood control projects in the Salt Lake City or County area? |
| 0      | No   |
| 1      | Yes  |

| 23-25  | A.   | From what source or sources did you hear about this? |
| 000    | DNA  |
| 001    | TV, Radio |
| 002    | Newspaper |
| 003    | Official source |
| 004    | Meeting |
| 005    | Work associates |
| 006    | Friends not in neighborhood |
| 007    | Friends in neighborhood |
| 008    | Family members |
| 009    | Personal observations |
| 010    | Other (specify) |
| 011    | 1, 2, 6, 7, 8, 9 |
| 012    | 2, 5 |
| 013    | 1, 2 |
| 014    | 1, 2, 5, 9 |
| 015    | 2, 5, 7, 9 |
| 016    | 1, 2, 9 |
| 017    | 2, 5, 6 |
| 018    | 1, 2, 4, 5, 7 |
| 019    | 1, 9 |
| 020    | 2, 5, 9 |
| 021    | 1, 2, 6 (combine with 033 and 045) |
| 022    | 1, 2, 5, 7, 9 |
| 023    | 1, 2, 5 |
| 024    | 1, 6 |
| 025    | 1, 2, 6, 9 |
| 026    | 2, 6, 9 |
| 027    | 1, 2, 6, 8 |
| 028    | 1, 2, 8 |
| 029    | 1, 2, 3, 5, 9 |
| 030    | 1, 4, 5, 6, 8 |
| 031    | 1, 2, 6, 7, 8 |
| 032    | 2, 9 |
| 033    | 1, 2, 6, 12, 6, 13, 9 (Duplicate) |
| 034    | 1, 3, 9 |
| 035    | 3, 4 |
| 036    | 3, 7 |
| 037    | 2, 3 |
| 038    | 1, 2, 5, 6, 8, 9 |
| 039    | 1, 6, 9 |
| 040    | 1, 2, 4 |
| 041    | 1, 2, 5, 7 |
| 042    | 1, 2, 7, 9 |
| 043    | 5, 9 |
| 044    | 1, 2, 5, 6, 9 |
| 045    | 1, 2, 6, 12, 6, 13, 9 (Duplicate) |
| 046    | 1, 2, 3, 4, 5 |
| 047    | 1, 2, 5, 6, 7 |
| 048    | 1, 2, 6, 7, 9 |
| 049    | 1, 5, 6, 9 |
| 050    | 1, 2, 3, 6, 7 |
| 051    | 3, 5 |
| 052    | 1, 2, 6, 8, 9 |
| 053    | 2, 6 |
| 054    | 5, 6, 9 |
| 055    | 7, 9 |
| 056    | 1, 5, 7, 8, 9 |
| 057    | 1, 2, 5, 6, 8 |
| 058    | 1, 5 |
| 125    |  |
6. How serious do you feel flooding problems are in the Salt Lake area?
   0 = None
   1 = Not serious
   2 = Moderately serious
   3 = Very serious
   4 = DK

7. Have you ever been aware of flooding problems in your neighborhood?
   0 = No
   1 = Yes

7A. How long (in years have you been aware of flooding problems in your neighborhood?

8. How serious do you feel flooding problems are in your neighborhood?
   0 = None
   1 = Not serious
   2 = Moderately serious
   3 = Very serious
   4 = DK

9. Some people discuss flooding problems with other persons. Do you discuss flooding problems with others?
   0 = No
   1 = Yes

32-33 A. With whom do you discuss flooding problems?

<table>
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34 B. With whom do you discuss flooding problems most frequently?

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<td>2</td>
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<td>4</td>
<td>Family and close relatives</td>
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<tr>
<td>5</td>
<td>Other (specify)</td>
</tr>
</tbody>
</table>
10. What daily newspapers do you regularly receive?
   0 = None
   1 = Tribune
   2 = Deseret News
   3 = Other (specify)
   4 = 1,2
   5 = 1,2,3
   6 = 1,3

11. Do you live adjacent to or within two blocks of a stream?
   0 = No
   1 = Within two blocks
   2 = Adjacent

12. Do you feel that the number of public parks in Salt Lake City and County (not including mountain canyons) is adequate or not adequate?
   0 = Not adequate
   1 = Adequate
   2 = DK

A. Do you visit public parks in Salt Lake City or County?
   0 = No
   1 = Yes
   2 = NA

B. Are the public parks in this area satisfactory to you?
   0 = No
   1 = Yes
   2 = NA

C. Is there any particular reason why the public parks are not satisfactory?

13. I am going to read a short list of outdoor recreation activities. As I read each one would you please indicate the approximate number of times you participated in it during the past twelve (12) months.

Code the number of days in three columns

1. Picnicking  40-42
2. Walking  43-45
3. Horseback riding  46-48
4. Cycling-motor or bike  49-51
5. Boating  52-54
6. Fishing  55-57

We have a series of statements on which we would like to have your opinion. They are about several different factors related to flooding and different aspects of flood control. As I read the statements, please tell me how you feel about each one according to the categories shown on card 11: strongly agree, agree, undecided disagree, or strongly disagree. After you reply to each question, please tell me how hard it was for you to make your judgment on the statement. The possible responses are also shown on card 11. They are: very hard, hard, easy, very easy
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<th>Column</th>
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<tbody>
<tr>
<td>58</td>
<td>14. The problem of flooding is one of the most pressing problems that faces people in the Salt Lake area.</td>
</tr>
<tr>
<td></td>
<td>A. Do you strongly agree, agree? Are you undecided or neutral? Do you disagree, or strongly disagree? (Scale Weights for these are the numbers associated with each answer.)</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td>4 = A</td>
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<td>3 = U</td>
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<td>1 = SD</td>
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<td></td>
<td>0 = NA</td>
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<tr>
<td>59</td>
<td>B. How hard was it for you to answer this question? Was it very hard, hard, easy, or very easy?</td>
</tr>
<tr>
<td></td>
<td>1 = VH</td>
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<td>2 = H</td>
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<tr>
<td></td>
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<tr>
<td>60</td>
<td>15. Flood control in the Salt Lake area is an excellent investment.</td>
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<tr>
<td>61</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>62</td>
<td>B. 0 = NA 1 = VH 2 = H 3 = E 4 = VE</td>
</tr>
<tr>
<td>63</td>
<td>16. Recommendations by government agencies are often wrong.</td>
</tr>
<tr>
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<td>A. 0 = NA 1 = SA 2 = A 3 = D 4 = SD</td>
</tr>
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<td>65</td>
<td>B. 0 = NA 1 = VH 2 = H 3 = E 4 = VE</td>
</tr>
<tr>
<td>66</td>
<td>17. People should follow the advice of experts more.</td>
</tr>
<tr>
<td>67</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = D 4 = SD 5 = SD</td>
</tr>
<tr>
<td>68</td>
<td>B. 0 = NA 1 = VH 2 = H 3 = E 4 = E 5 = VE</td>
</tr>
<tr>
<td>69</td>
<td>18. The environment must be modified to meet the needs of man.</td>
</tr>
<tr>
<td>70</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD</td>
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<tr>
<td>71</td>
<td>B. 0 = NA 1 = VH 2 = H 3 = E 4 = E 5 = VE</td>
</tr>
<tr>
<td>72</td>
<td>19. There is real danger of serious flood damage in the Salt Lake area in the next five years.</td>
</tr>
<tr>
<td>73</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>74</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
</tr>
</tbody>
</table>
20. Agencies are much better able to make correct decisions in the fields of their responsibility such as flood control than anybody else.

<table>
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<th>Column</th>
<th>Item</th>
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<tr>
<td>70</td>
<td>A. $5 = SA$ $4 = A$ $3 = U$ $2 = D$ $1 = SD$ $0 = NA$</td>
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<td>71</td>
<td>B. $0 = NA$ $1 = VH$ $2 = H$ $4 = E$ $5 = VE$</td>
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21. Outdoor recreation activities are the most enjoyable activities anyone can do.

<table>
<thead>
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<th>Column</th>
<th>Item</th>
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<tbody>
<tr>
<td>72</td>
<td>A. $5 = SA$ $4 = A$ $3 = U$ $2 = D$ $1 = SD$ $0 = NA$</td>
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<td>73</td>
<td>B. $0 = NA$ $1 = VH$ $2 = H$ $4 = E$ $5 = VE$ $6 = NR$</td>
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For Question 2B Groupings into yes or no, i.e. groups of answers indicating there is a flood threat from this source or not.

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<td>74</td>
<td>Perception of snowmelt as a flooding threat $0 = 00, 02-07, 09, 10, 12, 13, 14-20$ no $1 = 01, 08, 11, 14, 21$ yes</td>
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<tr>
<td>75</td>
<td>Perception of flash flood rains as a flooding threat $0 = 00, 01, 03-06, 10-13, 16, 20$ no $1 = 02, 07, 08, 09, 14, 15, 17, 18, 19, 21$ yes</td>
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<tr>
<td>76</td>
<td>Perception of long heavy rains as a flooding threat $0 = 00-02, 04-06, 09, 12, 13, 15, 18, 21$ no $1 = 03, 07, 08, 10, 11, 14, 16, 17, 19, 20$ yes</td>
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<td>77</td>
<td>Perception of rain and snowmelt as a flooding threat $0 = 00-03, 05-07, 09, 11, 15, 16, 19-20$ no $1 = 04, 08, 10, 12, 13, 14, 17, 18, 21$</td>
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<tr>
<td>78</td>
<td>Perception of stream or creek as flooding threat $0 = 00-04, 06, 07, 10, 11, 14, 15, 17-21$ no $1 = 05, 08, 09, 12, 13, 16$</td>
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<tr>
<td>79</td>
<td>Perception of other flooding threat to residence or other personally owned property in the Salt Lake area. $0 = 00-05, 07-12, 14, 16-18, 21$ no $1 = 06, 13, 15, 19, 20$ yes</td>
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Number of Sources for Questions 5A (groupings)

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<tr>
<td>80</td>
<td>0 = 000 $1 = 001, 002, 003, 004, 005, 006, 007, 008, 009, 010$ $2 = 012, 013, 019, 024, 032, 035, 036, 037, 043, 051, 053, 055, 058$ $3 = 016, 017, 020, 021, 023, 026, 028, 033, 034, 039, 040, 054, 045$ $4 = 014, 015, 025, 027, 041, 042, 049, 018, 022, 029, 030, 031, 038, 044, 046, 047, 048, 050, 052, 056, 057, 011$</td>
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22. People who rely a lot on experts are generally people who can't think for themselves.

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23. Flooding is not really a serious problem in the Salt Lake area.

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24. Taxes in Salt Lake County are very high.

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25. Not nearly enough is being done to protect our environment.

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26. Experts know considerably more than the average person.

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27. I would like to participate in much more outdoor recreation.

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28. Man generally improves the appearance of areas.

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29. Government projects are too expensive.

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30. Nothing makes a trip into the wilderness more enjoyable than a well paved road.

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<td>Column</td>
<td>Item</td>
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<td></td>
</tr>
<tr>
<td>31.</td>
<td>The beauty of nature is <strong>not</strong> destroyed by the presence of man made objects.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>Flood control management in the Salt Lake area is very adequate.</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>33.</td>
<td>Much more land should be preserved in its natural state.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>If people were outdoors more, they would <strong>not</strong> be much better off.</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>35.</td>
<td>The government cares how much of my money it spends.</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>36.</td>
<td>Most people don't spend enough time just e-joying themselves.</td>
<td></td>
</tr>
<tr>
<td>35.</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>37.</td>
<td>The only way government won't waste money is if it doesn't have money to waste.</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>38.</td>
<td>Being in harmony with nature is extremely important.</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>39.</td>
<td>More control by the people is needed over the decisions of government agencies.</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
<tr>
<td>40.</td>
<td>People should play more and work less.</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE</td>
<td></td>
</tr>
</tbody>
</table>
41. Experts are wrong nearly as often as they are right.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

42. I wouldn't participate in outdoor recreation if someone weren't with me.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

43. Only emergency flood control work should be done in the Salt Lake area.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

44. People should spend much more of their recreation time outdoors.
A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

45. Taxes should be raised if necessary to cover the cost of better protection for the public.
A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

46. Buildings near an outdoor recreation area ruin the beauty of the area.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

47. Generally speaking, the main satisfaction I get out of life is working.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

48. Industrial growth is as important as preserving natural areas.
A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

49. Flood control and similar projects destroy the beauty of the areas in which they are located.
A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

50. Stronger laws are needed to protect our environment.
A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA
B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE
51. I generally feel guilty when I enjoy leisure for more than a short time except when on vacations.

   Column | Item
   65
   A. 0 = NA  1 = SA  2 = A  3 = U  4 = D  5 = SD
   B. 0 = NA  1 = VH  2 = H  4 = E  5 = VE

52. Major decisions in fields such as flood control should be left to the government agency responsible.

   Column | Item
   67
   A. 5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA
   B. 0 = NA  1 = VH  2 = H  4 = E  5 = VE

53. Not enough emphasis is placed on the opinion of experts.

   Column | Item
   69
   A. 5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA
   B. 0 = NA  1 = VH  2 = H  4 = E  5 = VE
54. Additional government services are worth additional taxes.

A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA

B. 0 = NA 1 = VH 2 = H 4 = E % = VE

55. People should form more of their own opinions rather than listen to experts.

A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD

B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

56. Indoor activities are as much fun as outdoor activities.

A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD

B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

57. The control of flooding in the Salt Lake area is adequate.

A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD

B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

58. Developed areas are more enjoyable than undeveloped area.

A. 0 = NA 1 = SA 2 = A 3 = U 4 = D 5 = SD

B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE

59. Something definitely needs to be done to further control flooding in the Salt Lake area.

A. 5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA 6 = DK

B. 0 = NA 1 = VH 2 = H 4 = E 5 = VE 6 = DK

How do you feel about:

70. A small earth dam (50 feet wide or less)

5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA

71. Cleaning and deepening of a river

5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA
<table>
<thead>
<tr>
<th>Column</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>72. A developed streamside park</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>22</td>
<td>73. A high <em>concrete</em> bank or dike over 3 feet in height</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>23</td>
<td>74. A small reservoir</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>24</td>
<td>75. Straightening of a stream</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>25</td>
<td>76. A large wide <em>earth</em> dam more than 50 feet wide</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>26</td>
<td>77. A streamside area left undeveloped</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>27</td>
<td>78. A rock lining in a stream</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>28</td>
<td>79. A large reservoir</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>29</td>
<td>80. A high <em>earth</em> bank more than 3 feet in height along a stream</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA 6 = DK</td>
</tr>
<tr>
<td>30</td>
<td>81. Stream bank protection at critical points</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA 6 = DK</td>
</tr>
<tr>
<td>31</td>
<td>82. An underground storm sewer</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>32</td>
<td>83. A small <em>concrete</em> dam up to 50 feet high</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
<tr>
<td>33</td>
<td>84. A low <em>concrete</em> bank or dike under 3 feet or less in height</td>
</tr>
<tr>
<td></td>
<td>5 = SA 4 = A 3 = U 2 = D 1 = SD 0 = NA</td>
</tr>
</tbody>
</table>
column 34
85. An unlined or dirt canal
5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA

86. Concrete lining in a stream
5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA

87. A low earth bank or dike 3 feet or less in height along a stream
5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA

88. A concrete lined canal
5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA

89. A large concrete dam more than 50 feet in height
5 = SA  4 = A  3 = U  2 = D  1 = SD  0 = NA

PLANS FOR FLOOD CONTROL

Have you heard of any of these plans? If so, which ones?

39 90. Retention Basin Parks
     0 = No, has not heard
     1 = Yes, has heard

40 91. Jordan River Parkways Plan (i.e., a riverside park)
     0 = No, has not heard
     1 = Yes, has heard

41 92. Master Storm Sewer Drain System
     0 = No, has not heard
     1 = Yes, has heard

42 93. Concrete or rock lining of lower sections of Millcreek, Big Cottonwood, and Little Cottonwood Creeks.
     0 = No, has not heard
     1 = Yes, has heard

43 94. Straightening and dredging of the Jordan River
     0 = No, has not heard
     1 = Yes, has heard

(IF RESPONDENT HAS NOT HEARD OF ANY PLANS, SKIP TO QUESTION 100)

We would like to know how you feel about each plan(s) and certain aspects of the plan(s) about which you have heard.
<table>
<thead>
<tr>
<th>Column</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.</td>
<td>RETENTION BASIN PARKS</td>
</tr>
<tr>
<td>A.</td>
<td>How do you feel about Retention Basin Parks</td>
</tr>
<tr>
<td>44</td>
<td>5 = SG 4 = MF 3 = U 2 = M0 1 = SO 6 = Applicable but no answer</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td>45</td>
<td>B. The cost of Retention Basin Parks would be</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = Very inexpensive</td>
</tr>
<tr>
<td></td>
<td>2 = Inexpensive</td>
</tr>
<tr>
<td></td>
<td>3 = Neither inexpensive nor expensive</td>
</tr>
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<td></td>
<td>4 = Expensive</td>
</tr>
<tr>
<td></td>
<td>5 = Very expensive</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
</tr>
<tr>
<td>46</td>
<td>C. Retention Basin Parks would be</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = Very ineffective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>2 = Ineffective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>3 = Neither ineffective or effective</td>
</tr>
<tr>
<td></td>
<td>4 = Effective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>5 = Very effective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
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<tr>
<td>47</td>
<td>D. Retention Basin Parks would be</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = Very detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>2 = Detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>3 = Have no effect on outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>4 = Beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>5 = Very beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
</tr>
<tr>
<td>48</td>
<td>E. Retention Basin Parks would be</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = Very ugly</td>
</tr>
<tr>
<td></td>
<td>2 = Ugly</td>
</tr>
<tr>
<td></td>
<td>3 = Neither ugly nor beautiful</td>
</tr>
<tr>
<td></td>
<td>4 = Beautiful</td>
</tr>
<tr>
<td></td>
<td>5 = Very beautiful</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
</tr>
<tr>
<td>49</td>
<td>F. Retention Basin Parks would have</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = A very detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>2 = A detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>3 = No ecological effect</td>
</tr>
<tr>
<td></td>
<td>4 = A beneficial ecological effect</td>
</tr>
<tr>
<td></td>
<td>5 = A very beneficial effect</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
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<tr>
<td>Column</td>
<td>Item</td>
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</tbody>
</table>
| 50     | G. Finally, how do you think Retention Basin Parks would control flooding?  
|        | 0 = Incorrect answer given  
|        | 1 = Correct answer given  |

96. The Jordan River Parkway

A. How do you feel about the Jordan River Parkway

| 51 | B. The cost of the Jordan River would be:  
|    | 0 = DNA  
|    | 1 = Very inexpensive  
|    | 2 = inexpensive  
|    | 3 = neither inexpensive nor expensive  
|    | 4 = expensive  
|    | 5 = very expensive  
|    | 6 = applicable, but no answer  |

| 52 | C. The Jordan River Parkway would be:  
|    | 0 = DNA  
|    | 1 = very ineffective in controlling flooding  
|    | 2 = ineffective in controlling flooding  
|    | 3 = neither ineffective nor effective  
|    | 4 = effective in controlling flooding  
|    | 5 = very effective in controlling flooding  
|    | 6 = applicable but no answer  |

| 53 | D. The Jordan River Parkway would be:  
|    | 0 = DNA  
|    | 1 = very detrimental to outdoor recreation  
|    | 2 = detrimental to outdoor recreation  
|    | 3 = have no effect on outdoor recreation  
|    | 4 = beneficial to outdoor recreation  
|    | 5 = very beneficial to outdoor recreation  
|    | 6 = applicable but no answer  |

| 54 | E. The Jordan River Parkway would be:  
|    | 0 = DNA  
|    | 1 = very ugly  
|    | 2 = ugly  
|    | 3 = neither ugly nor beautiful  
|    | 4 = beautiful  
|    | 5 = very beautiful  
<p>|    | 6 = applicable but no answer  |</p>
<table>
<thead>
<tr>
<th>Column</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>F. The Jordan River Parkway would have:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = a very detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>2 = a detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>3 = no ecological effect</td>
</tr>
<tr>
<td></td>
<td>4 = a beneficial ecological effect</td>
</tr>
<tr>
<td></td>
<td>5 = a very beneficial effect</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
<tr>
<td>57</td>
<td>G. Finally, how do you think the Jordan River Parkway would control flooding?</td>
</tr>
<tr>
<td></td>
<td>0 = Incorrect answer given</td>
</tr>
<tr>
<td></td>
<td>1 = Correct answer given</td>
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<td></td>
<td>6 = NR</td>
</tr>
</tbody>
</table>

**97. MASTER STORM SEWER DRAIN SYSTEM**

<table>
<thead>
<tr>
<th>Column</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>A. How do you feel about the Master Storm Sewer Drain System:</td>
</tr>
<tr>
<td></td>
<td>6 = Applicable but no answer</td>
</tr>
<tr>
<td></td>
<td>2 = MO</td>
</tr>
<tr>
<td></td>
<td>5 = SF</td>
</tr>
<tr>
<td></td>
<td>1 = SO</td>
</tr>
<tr>
<td></td>
<td>4 = MF</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>3 = U</td>
</tr>
<tr>
<td>59</td>
<td>B. The cost of the Master Storm Sewer Drain System would be:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = very inexpensive</td>
</tr>
<tr>
<td></td>
<td>2 = inexpensive</td>
</tr>
<tr>
<td></td>
<td>3 = neither inexpensive nor expensive</td>
</tr>
<tr>
<td></td>
<td>4 = expensive</td>
</tr>
<tr>
<td></td>
<td>5 = very expensive</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
<tr>
<td>60</td>
<td>C. The Master Storm Sewer Drain System would be:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = very ineffective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>2 = ineffective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>3 = neither ineffective nor effective</td>
</tr>
<tr>
<td></td>
<td>4 = effective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>5 = very effective in controlling flooding</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
<tr>
<td>61</td>
<td>D. The master Storm Sewer Drain System would be:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = very detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>2 = detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>3 = have no effect on outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>4 = beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>5 = very beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
</tbody>
</table>
E. The Master Storm Sewer Drain System would be:
0 = DNA
1 = very ugly
2 = ugly
3 = neither ugly nor beautiful
4 = beautiful
5 = very beautiful
6 = applicable but no answer

F. The Master Storm Sewer Drain System would have:
0 = DNA
1 = a very detrimental ecological effect
2 = a detrimental ecological effect
3 = no ecological effect
4 = a beneficial ecological effect
5 = a very beneficial effect
6 = applicable but no answer

G. Finally, how do you think the Master Storm Sewer Drain System would control flooding?
0 = Incorrect answer given
1 = Correct answer given

98. CONCRETE OR ROCK LINING OF STREAMS

A. How do you feel about Concrete or Rock lining of streams?
6 = Applicable but no answer
5 = SF
4 = MF
3 = U
2 = MO
1 = SO
0 = DNA

B. The cost of Concrete or Rock lining of streams would be:
0 = DNA
1 = very inexpensive
2 = inexpensive
3 = neither inexpensive nor expensive
4 = expensive
5 = very expensive
6 = applicable but no answer

C. Concrete or rock lining of streams would be:
0 = DNA
1 = very ineffective in controlling flooding
2 = ineffective in controlling flooding
3 = neither ineffective nor effective
4 = effective in controlling flooding
5 = very effective in controlling flooding
6 = applicable but no answer
<table>
<thead>
<tr>
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<th>Item</th>
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<tbody>
<tr>
<td>68</td>
<td>D. Concrete or rock lining of streams would be:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = very detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>2 = detrimental to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>3 = have no effect on outdoor recreation</td>
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<tr>
<td></td>
<td>4 = beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>5 = very beneficial to outdoor recreation</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
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<tr>
<td>69</td>
<td>E. Concrete or rock lining of streams would be:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = very ugly</td>
</tr>
<tr>
<td></td>
<td>2 = ugly</td>
</tr>
<tr>
<td></td>
<td>3 = neither ugly nor beautiful</td>
</tr>
<tr>
<td></td>
<td>4 = beautiful</td>
</tr>
<tr>
<td></td>
<td>5 = very beautiful</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
<tr>
<td>70</td>
<td>F. Concrete or rock lining of streams would have:</td>
</tr>
<tr>
<td></td>
<td>0 = DNA</td>
</tr>
<tr>
<td></td>
<td>1 = a very detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>2 = a detrimental ecological effect</td>
</tr>
<tr>
<td></td>
<td>3 = no ecological effect</td>
</tr>
<tr>
<td></td>
<td>4 = a beneficial ecological effect</td>
</tr>
<tr>
<td></td>
<td>5 = a very beneficial effect</td>
</tr>
<tr>
<td></td>
<td>6 = applicable but no answer</td>
</tr>
</tbody>
</table>
G. Finally, how do you think concrete or rock lining of streams would control flooding?
0 = Incorrect answer given
1 = Correct answer given

99. STRAIGHTENING AND DREDGING OF THE JORDAN RIVER

A. How do you feel about straightening and dredging of the Jordan River?
6 = Applicable but no answer
2 = MO
5 = SF
4 = MF
3 = U

B. The cost of straightening and dredging of the Jordan River would be:
0 = DNA
1 = very inexpensive
2 = inexpensive
3 = neither inexpensive nor expensive
4 = expensive
5 = very expensive
6 = applicable but no answer

C. Straightening and dredging of the Jordan River would be:
0 = DNA
1 = very ineffective in controlling flooding
2 = ineffective in controlling flooding
3 = neither ineffective nor effective
4 = effective in controlling flooding
5 = very effective in controlling flooding
6 = applicable but no answer

D. Straightening and dredging of the Jordan River would be:
0 = DNA
1 = very detrimental to outdoor recreation
2 = detrimental to outdoor recreation
3 = have no effect on outdoor recreation
4 = beneficial to outdoor recreation
5 = very beneficial to outdoor recreation
6 = applicable but no answer

E. Straightening and dredging of the Jordan River would be:
0 = DNA
1 = very ugly
2 = ugly
3 = neither ugly nor beautiful
4 = beautiful
5 = very beautiful
6 = applicable but no answer
F. Straightening and dredging of the Jordan River would have:
   0 = DNA
   1 = a very detrimental ecological effect
   2 = a detrimental ecological effect
   3 = no ecological effect
   4 = a beneficial ecological effect
   5 = a very beneficial effect
   6 = applicable but no answer

G. Finally, how do you think straightening and dredging of
   the Jordan River would control flooding?
   0 = Incorrect answer given
   1 = Correct answer given

100. Have you or your spouse attended a meeting or public
      hearing since 1965 in which flood control projects or
      problems were the main topic discussed? (IF YES) Who
      attended?
      0 = No
      1 = Yes, Spouse only
      2 = Yes, respondent only
      3 = Yes, both

A. (IF YES) How many meetings did you or your spouse attend?
   Code with number of meetings:
   00 = DNA
   99 = 99 or more meetings attended

B. What group(s) sponsored the meetings?

C. When were the meetings held?

101. Since 1965 have you or your spouse belonged to a citizen
      group or other organization that was mainly interested
      in flood control projects? (IF YES) who belonged?
      0 = No
      1 = Yes, Spouse only
      2 = Yes, respondent only
      3 = Yes, both

A. (IF YES) Which groups have you or your spouse belonged to?

B. (IF A CITIZEN GROUP) Who are the leaders?
102. Have you or your spouse worked to promote any flood control proposals or ideas since 1965 by petitioning, calling on people, writing letters, or by other means? (IF YES) Who worked?

0 = No
1 = Yes, Spouse only
2 = Yes, Respondent only
3 = Yes, both

A. (IF YES) Which proposal(s) or idea(s)? (SPECIFY S-spouse, R-Respondent, B-Both)

00 = DNA
01 = Retention Basin Parks
02 = Jordan Parkways
03 = Master Storm Sewer Drain System
04 = Rock and concrete Channelization of lower sections of Big and Little Cottonwood and Millcreek streams
05 = Straightening and dredging of the Jordan River
06 = Watershed Management
07 = Flood Plain Zoning restrictions
08 = Other (Specify)
09 = 3,7

B. What did you or your spouse do? (SPECIFY S-Spouse, R-Respondent, B-Both)

0 = DNA
1 = Petition
2 = Letter
3 = Vocal protest
4 = Other (Specify)
5 = 1,3
6 = 1,2,3
7 = 3,4
8 = 1,3,4

103. Have you or your spouse opposed any flood control proposals or ideas since 1965 by petitioning, writing letters, vocal protests, or other means? (IF YES) who?

0 = No
1 = Yes, spouse only
2 = Yes, respondent only
3 = Yes, both

A. (IF YES) Which proposal(s) or idea(s)? (SPECIFY S-Spouse, R-Respondent, B-Both)

00 = DNA
01 = Retention Basin Parks
02 = Jordan River Parkway
03 = Master Storm Sewer Drain System
04 = Rock and concrete channelization of lower sections of Big and Little Cottonwood and Millcreek streams
05 = Straightening and dredging of the Jordan River
06 = Watershed management
07 = Flood Plain Zoning restrictions
08 = Other (Specify)
B. What did you or your spouse do? (SPECIFY S-Spouse, R-Respondent, B-Both)
0 = DNA
1 = Petitioning
2 = Letter
3 = Local protest
4 = Other (Specify)
5 = 1, 2, 3
6 = 3, 4

104. To what groups, clubs or organizations do you belong? I need this information for you only and not your family.
Code 1 point for each organization
plus 1 point for 1/4 participation
or 2 points for 1/2 participation
or 3 points for 3/4 participation
plus 1 point for each committee or office held

105. To what extent do you feel that the local citizens have control over what happens in this community?
0 = DK
1 = No control
2 = Little control
3 = Some control
4 = Quite a bit of control
5 = Almost complete control

106. A number of government agencies have been established to regulate and monitor different forms of air, water and land pollution. In general, how strict do you feel the standards set by these agencies are?
0 = Much too strict
1 = Too strict
2 = About right
3 = Too lenient
4 = Much too lenient
5 = NA or undecided

107. Do you know of any governmental agencies in this area whose main purpose is flood control?
0 = Respondent did not mention either the Corps of Engineers or the Salt Lake County Flood Control Department
1 = Respondent mentioned the Corps of Engineers but not the Salt Lake County Flood Control Department
2 = Respondent mentioned the Salt Lake County Flood Control Department but not the Corps of Engineers
3 = Respondent mentioned both the Corps of Engineers and the Salt Lake County Flood Control Department.
108. In the last four years have you written or talked to your Congressman or any other public official to let him know what you would like him to do on a public issue in which you were interested?
   0 = No
   1 = Yes

109. In the last four years have you worked for the election of any political candidate by doing things like distributing circulars or leaflets, making speeches, or calling on voters?
   0 = No
   1 = Yes

110. In the last four years have you contributed money to a political party or to a candidate for a political office?
   0 = No
   1 = Yes
   2 = NR

111. Have you voted in either of the last 2 elections? (Includes election at the local level)
   0 = No
   1 = Yes
   2 = Was underage or noncitizen

112. There is no way other than voting that people like me can influence actions of the government.
   0 = Agree
   1 = Disagree
   2 = NA

113. Sometimes politics and government seem so complicated that I can't really understand what's going on.
   0 = Agree
   1 = Disagree
   2 = NA

114. People like me don't have any say about what the government does.
   0 = Agree
   1 = Disagree
   2 = NA

115. I believe public officials don't care much what people like me think.
   0 = Agree
   1 = Disagree
   2 = NA
116. Approximately how long have you lived in your present home?
(Code to the nearest year)

117. How long have you lived anywhere in Salt Lake County, including Salt Lake City?
(Code to the nearest year)

118. Please give me the year of your birth.
(Code the last two digits only)
00 = NA

119. How many children do you have?
0 = None
1 = One
2 = Two
3 = Three
4 = Four
5 = Five
6 = Six
7 = Seven or more
8 = DNA (includes never married, etc.)

A. (IF CHILDREN) How many of these live at home at least 8 months of the year
(Code same as 119)

B. (IF CHILDREN) How many of these are under 6 years of age?
(Code same as 19)

120. What is your present marital status?
0 = Never married
1 = Separated or divorced
2 = Widowed
3 = Married

121. What is the principle kind of work that you do?
A. Respondent's major occupation
   Job title __________________________
   Brief Description ____________________
   Industry __________________________
000 = NA
001 = Student
002 = Retired
003 = Housewives
004 = Laborers, except farm and mine
005 = Farm laborers and farm foreman
006 = Service workers, except private household
007 = Private household workers
008 = Operative and kindred workers
009 = Craftsman, foreman, and kindred workers
010 = Sales workers
011 = Clerical and kindred workers and other military
012 = Managers, officials, proprietors, except farm
013 = Farmers and farm managers
014 = Professional, technical and kindred workers includes commissioned officers in armed services

(SEE APPENDIX FOR CATEGORY BREAKDOWN)

67-69 122. What is the principal kind of work that your spouse does?
A. Spouse's major occupation
   Job title ____________________________
   Brief Description ___________________
   Industry ____________________________

   (Code same as 121)
   000 = Not married
   080 = Deceased
123. What was the last grade of school that you completed?
   00 = None
   01 = One year
   02 = Two years
   03 = Three years
   04 = Four years
   05 = Five years
   06 = Six years
   07 = Seven years
   08 = Eight years
   09 = Nine years - 1 year H.S.
   10 = Ten years - 2 years H.S.
   11 = Eleven years - 3 years H.S.
   12 = Twelve years - 4 years H.S.
   13 = 1 year of college
   14 = 2 years of college
   15 = 3 years of college
   16 = 4 years of college
   17 = Masters
   18 = Doctorate

124. What was the last grade of school that your spouse completed?
   (CODE SAME AS 123)
   80 = Not married

125. Are you buying or renting your home?
   0 = Renting
   1 = Buying or own home
   2 = NA

126. Taking into consideration all sources of income for you and your spouse which category on this card best represents your total income before taxes in 1972?
   00 = $0-999
   01 = $1,000-1,999
   02 = $2,000-2,999
   03 = $3,000-3,999
   04 = $4,000-4,999
   05 = $5,000-5,999
   06 = $6,000-6,999
   07 = $7,000-7,999
   08 = $8,000-8,999
   09 = $9,000-9,999
   10 = $10,000-11,999
   11 = $12,000-13,999
   12 = $14,000-15,999
   13 = $16,000-17,999
   14 = $18,000-19,999
   15 = $20,000-23,999
   16 = $24,000-29,999
   17 = $30,000 or over
   18 = NA

127. Are there any other ideas or comments that you would like to make concerning anything we have discussed.

128. Sex of respondent
   0 = Female
   1 = Male
15

129. Type of structure in which family lives.
   0 = None, DNA
   1 = Rooming house
   2 = Apartments in partially commerical structure
   3 = Apartment house (4+ units)
   4 = Row houses (4+ units)
   5 = Apartment house (2-3 units)
   6 = Condominium
   7 = Trailer or mobile home
   8 = Detached single family house

16-22

130. Describe conditions of respondent's home, yard, and neighborhood compared to typical residence in Salt Lake County.
The following are the criteria being compared:
   1. Overall
   2. Lawns
   3. Flower gardens
   4. Shade and ornamental trees
   5. House exterior
   6. House interior
   7. Neighborhood rating

   CODE AS FOLLOWS:

   0 = None
   1 = Poor or low
   2 = Fair
   3 = Average
   4 = Good or above average
   5 = Very good or high
   6 = No answer

131. Thumbnail sketch

132. Other notes
Not to be completed by interviewer, obtain from census tracts.

<table>
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<tr>
<th>Column</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-25</td>
<td>133. Percent in block under 18 (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>26-28</td>
<td>134. Percent in block over 62 (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>29-31</td>
<td>135. Percent of structures that are one unit in block (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>32-34</td>
<td>136. Percent in structures of ten or more units in block (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>35-37</td>
<td>137. Percent of housing units which are owned by resident in block (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>38-42</td>
<td>138. Mean value of house in block (CODE ACTUAL AMOUNT IN DOLLARS FROM $0 to $99,999)</td>
</tr>
<tr>
<td>43-45</td>
<td>139. Percent of housing units which are rented in block (CODE ACTUAL PERCENT)</td>
</tr>
<tr>
<td>46-50</td>
<td>140. Average contract rent of rental units in block (CODE ACTUAL AMOUNT IN DOLLARS FROM $0 to $99,999)</td>
</tr>
<tr>
<td>51-53</td>
<td>141. Percent of one person household in block (CODE PERCENT TO NEAREST TENTH FROM 0.00 to 99.9)</td>
</tr>
<tr>
<td>54-56</td>
<td>143. Percent of housing units in block with female head of household (CODE PERCENT TO NEAREST TENTH FROM 0.0 to 99.9)</td>
</tr>
</tbody>
</table>
APPENDIX B

VALUES FOR THE EIGHT MEASUREMENT SCALES FROM THE SECOND PHASE SCHEDULE

Each respondent was asked to state on a five point scale the degree of his agreement or disagreement to a number of statements within each of eight categories (or scales). The responses to the questions within each category are summed to form scale scores for the respondent. The reasons for summing the individual scores are at least twofold: 1) to try to keep an idiosyncratic answer to a single item from being too misleading, and 2) to amplify the distinctions among respondent attitudes by providing a wide range of possible scores. This procedure can more accurately assess the desired attitude than can a single question. Summed scores of this type for several individual questions are called Likert scales.

Some of the questions in a scale may appear inappropriate and might seem to be asking the opposite of that which is intended. This is a deliberate procedure to reduce response bias produced by habit patterns, such as a tendency to agree with whatever statement is made. Before summing the values of the response categories for the scale, the response categories are numbered in such a way that there is consistency in the meaning of a higher number in relation to the variable being measured. This is done by reversing the numbering of the response categories for those items which are phrased such that they convey a meaning which is opposite to that of the other questions in the scale.

The reliability for each scale was computed using Cronbach’s alpha (Cronbach, 1951; Guilford, 1954:385). The reliabilities of the measurements in an equation constitute a theoretical upper limit on the possible predictive ability as measured by the correlation coefficient of an equation. Also, a factor measured by a scale with higher reliability is more likely to appear as important in an equation since the factor would appear as being more consistent. Cronbach’s alpha for each of the eight population attitude scales used as inputs to the model is as follows:

Concern for flooding, (CONCL): .8356
Attitude toward effect of man-made objects upon beauty of nature, (MANL): .3774
Leisure orientation, (LET): .4134

Outdoor recreation orientation, (RECL): .5748
Willingness to pay (PAYL): .6632
Ecological orientation (ECOL): .6389
Willingness to follow experts, (EXPTL): .6598
Willingness to follow agencies, (AGENL): .5074.

The statements which fall within the eight categories (or scales), and which were used to develop the range of values for each scale are as follows. Correlation coefficients also are indicated for each statement or question. The significance levels of each correlation coefficient is at least the 0.001 probability.

I. CONCERN FOR FLOODING AS A PROBLEM IN THE RESPONDENTS AREA (CONCL)

1. The problem of flooding is one of the most pressing problems that faces people in the Salt Lake area (Question 14) \( r = .5518 \).
2. Flood control in the Salt Lake area is an excellent investment (Question 15) \( r = .5470 \).
3. There is danger of serious flood damage in the Salt Lake area in the next five years (Question 19) \( r = .7024 \).
4. Flooding is not really a serious problem in the Salt Lake area (Question 23) \( r = .7237 \).
5. Flood control management in the Salt Lake area is very adequate (Question 32) \( r = .6695 \).
6. Only emergency flood control work should be done in the Salt Lake area (Question 43) \( r = .4644 \).
7. The control of flooding in the Salt Lake area is adequate (Question 57) \( r = .7269 \).
8. Something definitely needs to be done to further control flooding in the Salt Lake area (Question 59) \( r = .7622 \).
II. ATTITUDE TOWARD EFFECT OF MAN-MADE OBJECTS UPON BEAUTY OF NATURE (MANL)

1. Man generally improves the appearance of areas (Question 28) \( r = .5482 \).
2. The beauty of nature is not destroyed by the presence of man-made objects (Question 31) \( r = .6757 \).
3. Buildings near a recreational area ruin the beauty of the area (Question 46) \( r = .6113 \).
4. Flood control and similar projects destroy the beauty of the areas they are in (Question 49) \( r = .4738 \).

III. LEISURE ORIENTATION (LEIL)

1. Most people don't spend enough time just enjoying themselves (Question 36) \( r = .4618 \).
2. People should play more and work less (Question 40) \( r = .6250 \).
3. Generally speaking, the main satisfaction I get out of life is working (Question 47) \( r = .6664 \).
4. I generally feel guilty when I enjoy leisure for more than a short time except when on vacations (Question 51) \( r = .5689 \).

IV. OUTDOOR RECREATION ORIENTATION (RECL)

1. Outdoor recreation activities are the most enjoyable activities one can do (Question 21) \( r = .6178 \).
2. I would like to have much more recreation outdoors (Question 27) \( r = .6249 \).
3. If people were outdoors more, they would not be much better off (Question 34) \( r = .5195 \).
4. I wouldn't participate in outdoor recreation if someone weren't with me (Question 42) \( r = .4856 \).
5. People should spend much more of their recreation time outdoors (Question 44) \( r = .5413 \).
6. Indoor activities are as much fun as outdoor activities (Question 56) \( r = .6607 \).

V. WILLINGNESS TO PAY FOR GOVERNMENT EXPENDITURES (PAYL)

1. Taxes in Salt Lake County are very high (Question 24) \( r = .6011 \).
2. Government projects are too expensive (Question 29) \( r = .5799 \).
3. The government cares how much of my money it spends (Question 35) \( r = .5535 \).
4. The only way government won't waste money is if it doesn't have money to waste (Question 37) \( r = .4877 \).
5. Taxes should be raised if necessary to cover the cost of better protection for the public (Question 45) \( r = .6465 \).
6. Additional government services are worth additional taxes (Question 54) \( r = .6178 \).

VI. ECOLOGICAL ORIENTATION (ECOLL)

1. The environment must be modified to meet the needs of man (Question 18) \( r = .4372 \).
2. Not nearly enough is being done to protect our environment (Question 25) \( r = .6213 \).
3. Nothing makes a trip into the wilderness more enjoyable than a well paved road (Question 30) \( r = .5392 \).
4. Much more land should be preserved in its natural state (Question 33) \( r = .5841 \).
5. Being in harmony with nature is extremely important (Question 38) \( r = .3397 \).
6. Stronger laws are needed to protect our environment (Question 50) \( r = .5470 \).
7. Developed areas are more enjoyable than undeveloped areas (Question 58) \( r = .5351 \).

VII. WILLINGNESS TO FOLLOW ADVICE OF EXPERTS (EXPTL)

1. People should follow the advice of experts more (Question 17) \( r = .6218 \).
2. People who rely a lot on experts are generally people who can't think for themselves (Question 22) \( r = .5945 \).
3. Experts know considerably more than the average person (Question 26) \( r = .5972 \).
4. Experts are wrong nearly as often as they are right (Question 41) \( r = .6642 \).
5. Not enough emphasis is placed on the opinion of experts (Question 53) $r = .5479$.

6. People should form more of their own opinions rather than listen to experts (Question 55) $r = .6480$.

VIII. WILTINGNESS TO FOLLOW GOVERNMENT AGENCIES (AGENL)

1. Recommendations by government agencies are often wrong (Question 16) $r = .5887$.

2. Agencies are much better able to make correct decisions in the fields of their responsibility such as flood control than anybody else (Question 20) $r = .6723$.

3. More control by the people is needed over the decisions of government agencies (Question 39) $r = .4718$.

4. Major decisions in fields such as flood control should be left to the government agency responsible (Question 52) $r = .7371$. 
This appendix is included to provide information on the values, variations, and other characteristics of variables from the sample used in calibrating the population evaluation equation included in the model. (Equation 5.24) These values were also used unless otherwise specified in sensitivity and simulation analysis runs.

These figures represent the original data. When inputed to the equation three is subtracted from each perceived project factor and for project evaluation in order to have neutral as zero; perceived project factors are identified by the code name for the variable beginning with I. The minimum possible value for each Likert scale was subtracted from the value of the scale; the Likert-scale code words all end in L. The minimum value for CONCL and ECOLL was eight, for RECL, PAYL, and EXPTL, six, and for AGENL and MANL, four.\footnote{\textsuperscript{1,2}}

There were in all cases two hundred seventy-five valid observations.

\footnote{\textsuperscript{1}When any of these variables were used in Equation 1 of the social model, no transformations were made.  
\textsuperscript{2}See Appendix B.}
VALUES USED IN CALIBRATION OF POPULATION EVALUATION EQUATIONS*

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<th>EVALUATION LOCAL FLOOD CONTROL PROPOSAL</th>
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<tr>
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<td>3.98909</td>
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<td>0.66776</td>
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*See Table 6.2 for definition of variables.
<table>
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<th>PERCEIVED RECREATION EFFECT OF PROPOSAL</th>
<th>PERCEIVED AESTHETICS EFFECT OF PROPOSAL</th>
<th>PERCEIVED ECOLOGICAL EFFECT OF PROPOSAL</th>
<th>JUDGED LOCAL DECISION AGENCY EVALUATION</th>
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<tr>
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<td>3.90909</td>
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<td>3.09818</td>
<td>3.36364</td>
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<td>0.04927</td>
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<td>0.28018</td>
</tr>
<tr>
<td>STD DEV</td>
<td>0.79397</td>
<td>0.81699</td>
<td>0.67906</td>
<td>0.82753</td>
<td>1.24045</td>
<td>4.64623</td>
</tr>
</tbody>
</table>

| Mean | 0.63039 | 0.66747 | 0.46113 | 0.68480 | 1.53872 | 21.58747 |
| STD ERROR | 3.46548 | 0.93972 | 1.06398 | 0.84879 | -1.25541 | -0.51295 |
| STD DEV  | 0.79397 | 0.81699 | 0.67906 | 0.82753 | 1.24045 | 4.64623 |
| KURTOSIS | -1.54638 | -0.27169 | -0.54267 | -0.91564 | -0.53135 | -0.32813 |
| SKEWNESS | 0.63039 | 0.66747 | 0.46113 | 0.68480 | 1.53872 | 21.58747 |
| Range  | 4.00000 | 5.00000 | 4.00000 | 4.00000 | 3.30000 | 23.00000 |
| MINIMUM | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 1.50000 | 13.00000 |
| MAXIMUM | 5.00000 | 5.00000 | 5.00000 | 5.00000 | 4.80000 | 36.00000 |
### Variable: ECOLI - Ecological Orientation

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<th>Skewness</th>
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<tr>
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### Variable: PAIL - Willingness to Pay

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<th>Skewness</th>
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<tbody>
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<tr>
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### Variable: MANL - Perceived Effect: Man-Made Objects Nature

<table>
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### Variable: LEIL - Leisure Orientation

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### Variable: RECL - Outdoor Recreation Orientation

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### Variable: EXPTL - Willingness to Follow Experts

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APPENDIX D
MULTICOLLINEARITY ANALYSIS OF POPULATION EVALUATION EQUATION OF SOCIAL SYSTEM MODEL (EQUATION V (a))

The following is the result of a multicollinearity analysis of the independent variables in Equation V of the social system model or the population evaluation equation. The values in the first column are the values of the squared multiple correlation coefficients for the relationship of the independent variable to all other independent variables of the equation. The figures to the right of the vertical double line are the squared bivariate correlation coefficients between the variables indicated.

MULTICOLLINEARITY MATRIX *a

<table>
<thead>
<tr>
<th>Term</th>
<th>No. in Table 5.7*</th>
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<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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</tr>
</tbody>
</table>

*See Table 5.7 for list of terms.

*It was unnecessary, of course, to write the whole matrix since upper and lower triangular matrices contain the same values (Vij = Vji). This was done for convenience.
The two versions of the computer program used to analyze social elements are written in Fortran IV. The main differences between them is that the "simulation" version stops upon rejection of a plan while the "sensitivity" version does not. The simulation program stops because in real life evaluation of flood control proposals ceases once the proposals are rejected. The sensitivity program continued to show the hypothetical results of evaluation of flood control proposals by the various groups even if a proposal were rejected at a prior stage. The sensitivity deck also facilitates the exploration of interrelationships between the various stages and groups. Only the sensitivity version is listed.

The other differences between the two versions are that the simulation deck 1) prints integer values of the variables entered into Equation VI, the population evaluation equation, and 2) requires the value of CONCL, Population Concern about Flooding in the Local Area, be read for use in Equation 5. The first of these variations allows easier reading of the variables since they are printed separately by single spaces. The sensitivity deck prints the variable values to one more decimal place which runs the numbers into each other but provides additional information. CONCL is taken in the sensitivity deck as the output of Equation I because of runs that may be desired for which no data may be available. On the other hand, since Equation I had the lowest correlation coefficient of any of the regression equations, the actual value of CONCL should be used in simulation.

The formula used for inputing the output of Equation I to Equation V in the sensitivity analysis deck is \( Z(6) = 17.914 + (5\text{PUB} - 17.014) \) where \( Z(6) \) is the value of CONCL inserted into Equation V and PUB is the result of Equation I. This equation was derived from the mean values of CONCL of the general population sample used for Equation I and the values used in calibration of Equation V. It is designed to adjust for the differences in those means and to compensate for the reduction in variance caused in regression analysis by the low \( r^2 \) of the predicted values of Equation I compared to the actual values (see Chapter V).
The sociologic sub-model (sensitivity version).

DIMENSION(X(15),Y(20),Z(20),C(15),B(15),U(15),T(15),Y(20))
READ(S10)NAME,HEM,PROPOSAL
10 FORMAT(*65)
WRITE(*65)NAME,HEM,PROPOSAL
20 FORMAT(1X,2X,SOCIAL MODEL,7X,FLOOD CONTROL PROPOSAL...SA6)

EVALUATION OF PUBLIC CONCERN READ(S1)NEED,NSP
1 FORMAT(1X,19)
WRITE(*65)NAME,HEM,NSP
2 FORMAT(1X,3X,1-EVALUATION OF PUBLIC CONCERN)
IF(NFEO<11000.999,958
958 FORMAT(6X,4X,INPUT DATA*IN_SAMPLE SIZE=1.9=6X,INDIVIDUAL SC
10RC5)
959 SQ=0.0
TPI=0.0
TPAT=0.0
DO 100 M21,NSP
READ(S2,X(1),I=1,10)
2 FORMAT(1D6.2)
X(1)=X(1)+0.3
W(1)=W(1)+0.1
IF (W(1)<0.0.15) GO TO 750
100 CONTINUE

111 FORMAT(1X,3X,REND,10X,STANDARD DEVIATION=NOT C
112 FALUCABLE
GO TO 996
996 WRITE(4997)CONC
997 FORMAT(1X,10X,PUBLIC CONCERN=+.8X7X+STANDARD DEVIATION=+.96
131
IF STATEMENT A
998 WRITE(450)
52 FORMAT(10X,3X,1,IF STATEMENT A)
READ(S3,X(1),I=1,4,AM
3 FORMAT(5F5.1)
...}

PLANNING AGENCY EVALUATION
MUST INITIALIZE IMPLEMENTATION AGENCY
121 GO TO 500.M=1.3
READ(S1,Y(11),I=1,15)
...}

FORMAT(9F3.2,F4.1,3F4.2,F1.1)
...}

Y(1)=Y(11)/11+110
Y(2)=Y(11)/11
Y(3)=Y(11)/11
Y(4)=Y(11)/11
Y(5)=Y(11)/11
Y(6)=Y(11)/11
...}

IF(NFEO<1001,303
303 WRITE(4551)PA
55 FORMAT(10X,3X,1-EVALUATION BY PLANNING AGENCY=+.7X,PLANNING AGENCY EVALUATION=+.8X)
B(1)=10.1
B(1)=10.1
B(1)=10.1
...}
GO TO 320
310 WRITE(4551)PA
56 FORMAT(10X,3X,S=INITIAL EVALUATION BY DECISION AGENCY=+.8X7X+DE
...}

枋(1)=.0185+Y513
FE=0.0185+Y513
...}

WRITE(1011)PP
300 IF(X=1.3) GO TO 1500
333 WRITE(4557)
57 FORMAT(10X,3X,4-IF STATEMENT B
...}

WRITE(4573)
73 FORMAT(*10X,2X,COST(DOLLAR),2X,BENEFIT(TRANS),2X,BENEFIT COST
...}

WRITE(4574)
74 FORMAT(*10X,DESIRED,10X,6X.,7X,.,6X,5X,6X,7X,5X,7X,5X,7X,5X,7X,7X,7X,7X,7X)
...}

IF(NFEO<1500,140)
150 IF(X=1.3) GO TO 1500
155 IF(X=1.3) GO TO 1500
160 WRITE(4558)
50 FORMAT(*10X,PROPOSAL MEETS THE DESIRED CRITERIA*)
...}

WRITE(4559)
60 GO TO 300
59 FORMAT(*10X,PROPOSAL MEETS THE DESIRED CRITERIA*)
...}

WRITE(4529)
69 GO TO 300
315 ATAO(+1,1,1,1,0.00585*Y29+1.00562*Y311+0.1084*Y94
...}

CONTINUE
992 IF (Ev > 0.5) 380, 380, 385
990 WRITE (6, 643)
996 FORMAT ('0.7X, 'THE EVALUATION IS EQUAL TO OR LESS THAN -0.5, STOP
990 EVALUATION')
GO TO 390
385 WRITE (6, 645)
395 FORMAT ('0.7X, 'THE EVALUATION IS GREATER THAN -0.5, CONTINUE EVALUATION')
C IF STATEMENT C
390 WRITE (6, 663)
63 FORMAT ('0.7X, '9, IF STATEMENT C)
-- 15 FORMAT (5FS, 1) WRITE (6, 321)
32 FORMAT ('0.25X, 'RECREATION, ', 7X, 'ECOLOGY, ', 6X, 'AESTHETICS, ', 3X, 'EFFEC
32 TIVENESS, ', 6X, 'CONT')
WRITE (6, 401) (DIJ = 1, 1)
80 FORMAT ('0.7X, 'REQUIREMENT, ', 5(6X, 'G. T++, FS. 1))
 READREC/PNS
ECO/ECS/PNS
AEST/ECS/PNS
EFF/ECS/PNS
COS/COS/PNS
WRITE (6, 633) READREC, ECS, EFF, COS
33 FORMAT ('0.7X, ACCEPTANCE FUNCTION, ', 5(8X, 'F, 2))
  IF (REC - D(1)) 210, 215, 215
210 IF (ECO - D(2)) 210, 220, 220
215 IF (AEST - D(3)) 210, 225, 225
  220 IF (EFF - D(4)) 210, 230, 230
  225 IF (COS - D(5)) 210, 240, 240
  230 IF (ECO - D(2)) 210, 220, 220
  210 WRITE (6, 636)
34 FORMAT ('0.7X, 'STOP EVALUATION')
GO TO 1001
240 WRITE (6, 665)
35 FORMAT ('0.7X, 'STOP EVALUATION')
GO TO 1001
FINAL EVALUATION BY DECISION AGENCY
1001 WRITE (6, 666)
36 FORMAT ('0.7X, 'FINAL EVALUATION BY DECISION AGENCY')
  EV = REC + 0.100 + (19) * AIA + 0.150 * (120); EV
WRITE (6, 371) EV
37 FORMAT ('0.7X, 'FINAL EVALUATION', 'F, 3)
  IF (EV < 0.998, 699)
  699 WRITE (6, 735)
999 FORMAT ('0.7X, 'THE PROJECT EVALUATION FAILS TO EXCEED MINIMUM REQ
999 UIREMENT')
GO TO 1000
998 WRITE (6, 961)
961 FORMAT ('0.7X, 'THE PROJECT EVALUATION EXCEEDS MINIMUM REQUIREMENT
961 15')
1000 STOP
The following are examples of outputs of the computer program for social variables related to three types of proposed flood control methods. The three methods are retention basins, master storm drainage systems and lining straightening of streams. Each of the three proposals evaluated was actually considered in the study area. The use of these proposals provided a check on the validity of the model as the results of the analyses were compared with the actual experiences.

The system model as a whole was calibrated using the IF statements on the basis of earlier computer runs examining these proposals. See Chapter VI for further details regarding the output format and Chapter VII for information on the results of runs using the program.

Integer values are printed in these runs for the values of variables used in the population evaluation equation Section 8. This was done for clarity. (See Appendix E).

EXAMPLE I

RETENTION BASIN PARKS

\footnote{Flood control retention basins retain excess water beyond the capacity of the stream to carry it away. In addition, these areas are developed into municipal parks for use in non-flooding periods.}
EXAMPLE II:
MASTER STORM DRAIN SYSTEM

SOCIAL MODEL

FLUID CONTROLS PROPOSAL: MASTER STORM DRAIN SYSTEM

1. EVALUATION OF PUBLIC CONCERN

PUBLIC CONCERN = 17,043

STANDARD DEVIATION = 1.939

2. IF STATEMENT A

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>A</th>
<th>CONCL</th>
<th>PAYL</th>
<th>N</th>
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<tr>
<td>7.00</td>
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<td>4.00</td>
<td>16.043</td>
<td>10.246</td>
<td>11.311</td>
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NEED FOR PLAN, CONTINUE EVALUATION

3. EVALUATION BY PLANNING AGENCY

PLANNING AGENCY EVALUATION = 0.678

THE EVALUATION IS GREATER THAN 0.5, CONTINUE EVALUATION

4. IF STATEMENT B

COST(DOLLARS) BENEFIT(YRS.) BENEFIT COST RATIO

DESERED

L.T.300000000 0.5, 10.0 0.7, 1.00

PROPOSAL

221000000 50.0 2.00

PROPOSAL MEETS THE DESIRED CRITERIA

5. INITIAL EVALUATION BY DECISION AGENCY

DECISION AGENCY INITIAL EVALUATION = 0.420

THE EVALUATION IS GREATER THAN 0.5, CONTINUE EVALUATION

6. EVALUATION BY IMPLEMENTATION AGENCY

IMPLEMENTATION AGENCY EVALUATION = 0.431

THE EVALUATION IS GREATER THAN 0.5, CONTINUE EVALUATION

7. REVISED EVALUATION BY DECISION AGENCY

DECISION AGENCY REVISED EVALUATION = 0.671

THE EVALUATION IS GREATER THAN 0.5, CONTINUE EVALUATION

8. EVALUATION BY PUBLIC

PERCEPTION OF PROPOSAL CHARACTERISTICS

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<tr>
<th>MECHANIZATION</th>
<th>ECOLOGY</th>
<th>AESTHETICS</th>
<th>EFFECTIVE</th>
<th>COST</th>
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<tbody>
<tr>
<td>MEAN</td>
<td>0.33</td>
<td>0.40</td>
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<td>STANDARD DEVIATION</td>
<td>0.617</td>
<td>0.697</td>
<td>0.429</td>
<td>0.576</td>
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PUBLIC EVALUATION = 1.048

STANDARD DEVIATION = 0.146

THE EVALUATION IS GREATER THAN 0.5, CONTINUE EVALUATION

9. IF STATEMENT C

MECHANIZATION | ECOLOGY | AESTHETICS | EFFECTIVE | COST |

| REQUIREMENTS | 0.1, 3.0 | 0.7, -1.0 | 0.6, -1.0 | 0.6, 4.0 | 0.6, -2.0 |

ACCEPTANCE FUNCTION

4.75 7.04 0.53 20.44 -12.64

CONTINUE EVALUATION

10. FINAL EVALUATION BY DECISION AGENCY

FINAL EVALUATION = 0.558

THE PROJECT EVALUATION EXCEEDS MINIMUM REQUIREMENTS
Example of Sensitivity Deck Output #1

INPUT DATA

SAMPLE SIZE: 100

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<td>0.980</td>
<td>1.020</td>
<td>1.060</td>
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<td>0.980</td>
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<td>1.060</td>
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</tbody>
</table>

Individual Score: 1.000
Example of Sensitivity Deck Output #2
APPENDIX G

SENSITIVITY STUDIES

The following sensitivity studies are given as examples of the analyses performed by the model. Some anomalies may occur in these relationships because of small numbers of proposals and inaccuracies of measurement. The sensitivity of the system to particular variables can be surprisingly large as the effect of a small change is compounded because of the interactions and partial dependencies in the system. Also, the effect which a change in variables has is often dependent on the extent of presence of another factor.

Despite the use of linear regression analyses, curved lines sometimes occur. One reason is interaction with another factor such as exists for the acceptance functions. The second reason is that variables may be multiplied by other variables in the terms of the equations in which they appear. A direct case is when a variable is contained in more than one term either itself or as part of an index; cost is an example of this. An indirect case occurs because a factor which influences another variable will have an indirect effect through the inclusion of that other variable in another equation. The factor is to some extent doubly entered into that equation. Usually an indirect influence occurs through an acceptance function reflecting the influence of another group's evaluation of a proposal. Tables 6.1 defines the variables shown in these analyses.

<table>
<thead>
<tr>
<th>Table G. Sensitivity studies using the sociologic model</th>
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</thead>
<tbody>
<tr>
<td>Variables in Equation I 1 - Population Concern</td>
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<tr>
<td>I. A. LNEIGH 0 to 5</td>
</tr>
<tr>
<td>CONCL 16.69 to 23.09</td>
</tr>
<tr>
<td>N - .040 to .636 (would stop)</td>
</tr>
<tr>
<td>POPEVE .735 to .977</td>
</tr>
<tr>
<td>FE .666 to .697</td>
</tr>
<tr>
<td>B. NSORSE 0 to 6</td>
</tr>
<tr>
<td>CONCL 16.31 to 19.35</td>
</tr>
<tr>
<td>N - .423 to 2.613</td>
</tr>
<tr>
<td>POPEVE .735 to .790</td>
</tr>
<tr>
<td>FE .666 to .697</td>
</tr>
<tr>
<td>C. LNEIGH 0 and NSORSE 0 to 6</td>
</tr>
<tr>
<td>CONCL 15.99 to 9.02</td>
</tr>
<tr>
<td>N = .743 to 2.291</td>
</tr>
</tbody>
</table>

1For definitions of social variables refer to Table 6.1.

POPEVE = .735 to .790
FE = .666 to .697

D. LNEIGH = 50 and NSORSE 0 to 6
CONCL = 22.39 to 25.42
N - 5.655 to 8.691
POPEVE .977 always
FE = .804 always

E. All direct flood related variables from very low to high
CONCL = 15.39 to 27.557
N = -1.341 to 10.825
POPEVE = 1.35 to .977
FE = .666 to .804

II. A. LEIL 6 to 20
CONCL 15.394 to 18.614
N - 1.358 to 1.882
POPEVE .735 to .790
FE .666 to .697

B. MANL 6 to 20
CONCL 16.102 to 18.146
N - .630 to 1.414
POPEVE .735 to .790
FE .666 to .697

C. LEIL: 6 to 20 and MANL 6 to 20
CONCL 14.482 to 19.746
N - 2.250 to 3.014
POPEVE = .735 to .790
FE .666 to .697

Variables in Equation V - Population Evaluation

III. A. IRAESP 1 to 5
POPEVE = .096 to .990
FE .192 to .811

B. IRAESP = 1, MANL 6 to 20
CONCL 16.102 to 18.146
N - .630 to 1.414
POPEVE = .257 to -.095*
FE .393 to .192
*Note: Evaluation always stops because of poor aesthetics

C. IRAESP = 5, MANL 6 to 20
CONCL 16.102 to 18.146
POPEVE .735 to .990
FE .666 to .811

D. IRAESP = 1, MANL, LEIL 6 to 20
CONCL = 14.482
N = 2.250
POPEVE = .25 and -.096
FE = .393 and .666
*Note: Evaluation stops in case where IRAESP = 1 due to acceptance function.

E. IRAESP = 5, MANL, LEIL 6 to 20
CONCL = 19.746
N = 3.014
POPEVE = .735 to .990
FE = .192

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Table G. (Continued)

IV. A. \( \text{IREFFP} = 1 \text{ to } 5 \),
\[ \text{POPEVE} = .216 \text{ to } .977^* \]
\[ \text{FE} = .124 \text{ to } .804 \]
*Note: Evaluation always stops due to acceptance function when proposal is non-affective or ineffective.

B. \( \text{CONCL} = 5 \text{ to } 28 \)
\[ \text{POPEVE} = -.170 \text{ to } .790^* \]
\[ \text{FE} = .150 \text{ to } .697 \]
*Note: Evaluation stops when \( \text{CONCL} = 5 \text{ or } 12 \) due to effectiveness acceptance function.

C. \( \text{IREFFP} = 1, \text{CONCL} = 5 \text{ to } 28 \)
\[ \text{POPEVE} = .735 \text{ to } -.216^* \]
\[ \text{FE} = .666 \text{ to } .124 \]
*Note: Except in case where no importance is attached to flood control (in which case proposal would never be considered), proposal always rejected because of ineffectiveness.

D. \( \text{IREFFP} = 2, \text{CONCL} = 5 \text{ to } 28 \)
\[ \text{POPEVE} = .735 \text{ to } -.170^* \]
\[ \text{FE} = .666 \text{ to } .150 \]
*Note: Proposal never acceptable because of lack of effectiveness.

E. \( \text{IREFFP} = 4, \text{CONCL} = 5 \text{ to } 28 \)
\[ \text{POPEVE} = -.170 \text{ to } .790^* \]
\[ \text{FE} = .150 \text{ to } .697 \]
*Note: Proposals not acceptable because of effectiveness acceptance function when \( \text{CONCL} = 5 \text{ or } 12 \)

F. \( \text{IREFFP} = 5, \text{CONCL} = 5 \text{ to } 28 \) (11)
\[ \text{POPEVE} = .977^2 \text{ to } .977^* \text{ (.735)} \]
\[ \text{FE} = .804^2 \text{ to } .804 \text{ (.666)} \]
*Note: Proposal rejected when \( \text{CONCL} \) very low (=5)

Using Equation 1 to Obtain \( \text{CONCL} \)

V. A. \( \text{IREFFP} = 1, \) All direct flood related variables from very low to high.
\[ \text{CONCL} = 15.391 \text{ to } 27.557 \]
\[ N = -1.341 \text{ to } 10.825 \]
\[ \text{POPEVE} = -.216 \text{ always}^* \]
\[ \text{FE} = .124 \text{ always} \]
*Note: Proposal always rejected because of poor effectiveness.

B. \( \text{IREFFP} = 5, \) All direct flood related variables from very low to high.
\[ \text{CONCL} = 5.391 \text{ to } 27.557 \]
\[ N = -1.341 \text{ to } 10.825 \]
\[ \text{POPEVE} = .790 \text{ to } .977 \]
\[ \text{FE} = .697 \text{ to } .804 \]

\( \text{IREFFP} \) is deviant case. Probably result of scale (or response) problems.
APPENDIX H

CONCEPTS BASED ON ACCEPTANCE FUNCTIONS
THAT MAY BE USEFUL IN PROJECT PLANNING

The concepts based on the use of acceptance functions may be useful in comparing the desirability of alternative proposals for a given location or in analyzing the social benefits of similar proposals in different locations. Each acceptance function may be graphed, and a display made of the results. The particular values to use will depend on the preferences of the planner. The potential application of each is mentioned in the following discussion.

One way of identifying values for flood control proposal factors is to use an operationally defined set of perceived characteristics of a proposal that is related to a set of values in the population. This is done in the model by acceptance functions. Assuming the definitions of the factors are consistent so that different proposals can be compared, the following concepts may be useful in planning and assessing projects for various areas. As an example, the general variable, recreation will be used.

\[ R_{np} = Q_{nr} \cdot K_{rp} \]  

\[ \text{where} \]

\[ R_{np} \] = the benefit index for population, \( p \), from project \( n \), for recreation and is equal to the value of the acceptance function for recreation. The reason for the name "Benefit Index" will become clearer as the discussion proceeds. The benefit index is the algebraic product of \( Q_{nf} \) and \( K_{fp} \) (\( f \) represents the particular factor under consideration). The benefit index for recreation would be figured according to the following formula:

\[ R_{np} = Q_{nr} \cdot K_{rp} \ldots \ldots \ldots (1) \]

If both \( Q_{nf} \) and \( K_{fp} \) are positive, the benefit index will be also. If \( K_{fp} \) is positive; i.e., the value rating of the population, \( p \), is favorable toward a particular factor, \( f \); and \( Q_{nf} \) is negative; i.e., the project destroys some of the particular factor; the benefit index will be negative. In the case of recreation, it can be assumed that the value rating would be positive generally; if this is true and a project destroys recreation, the benefit index for recreation would be negative, which is realistic. The equation is also logical in the unlikely cases where \( K_{fp} \) and \( Q_{nf} \), are both negative; i.e., when a project eliminates what people do not want; producing a positive effect; and where \( K_{fp} \) is negative and \( Q_{nf} \), is positive; i.e., the effect is negative if the project provides a factor the people have a negative feeling about. It may be better to limit the value rating to the positive ranges as they would be generally realistic (for instance, how many people have strong feelings against recreation, aesthetics, or ecology?) in which case the last two possibilities are eliminated.

The benefit index may be graphed for use in the development of further indices. For example, if availability is the ability of the population to use a particular factor provided by a proposed project and \( r_{pn} \) is the availability of recreation provided by the project, \( n \), to population, \( p \), then the benefit to the population from the project can be defined as the product of the benefit index for the factor under consideration and the availability of that factor provided by the project to the population. For recreation, this is:

\[ B_{rnp} = R_{np} \cdot r_{pn} \ldots \ldots \ldots \ldots (2) \]

\[ \text{where} \]

\[ B_{rnp} \] = the benefit of recreation provided by project \( n \) to population \( p \)

\[ r_{pn} \] = the availability of recreation provided by project \( n \) to population \( p \)

\[ R_{np} \] = is defined as above.

The above concept could be useful particularly in evaluating alternative projects affecting the same population. If one wished to consider the number

\[ 1 \text{These suggestions are further discussed in Masteller (1977: Appendix E).} \]
of people affected (i.e., number in population \( p \)) then one side of equation (2) can be multiplied by the size of the population to form a new value for this purpose:

\[
V_{rnP} = \text{Value to population } P \text{ of recreation } r \text{ provided by project } n.
\]

\[
P_p = \text{size (number of population } p). \]

\[
V_{rnP} = R_{np} \cdot r_{pn} \cdot P_p \quad \quad (3)
\]

or substituting (1) in (3)

\[
V_{rnP} = Q_{nr} \cdot K_{rp} \cdot r_{pn} \cdot P_p \quad \quad (4)
\]

The concept of value would be useful in comparing flood projects in different areas (different \( P_p \)) to determine which would provide the greatest benefit considering the number of people benefited. When one does not desire or does not need to consider population numerical differences, then the Benefit is a useful concept. \( V_{fnP} \) and \( B_{fnP} \) can both be graphed to provide profiles for alternative proposals. This could be done with \( V_{fnP} \) in considering which proposal to fund in different areas with limited funds for maximum value for the factor under consideration, or with \( B_{fnP} \) when considering alternative flood control measures affecting the same population.