

THE LINKAGES BETWEEN INDIVIDUAL USE AND
PUBLIC MANAGEMENT OF FLOOD PLAINS

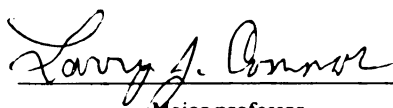
Dissertation for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
DAVID FRESHWATER

1977



This is to certify that the
thesis entitled
The Linkages Between Individual Use and
Public Management of Flood Plains
presented by
David Freshwater

has been accepted towards fulfillment
of the requirements for
Ph.D. degree in Ag. Econ.


Major professor

Date 4/11/77

2022

ABSTRACT

THE LINKAGES BETWEEN INDIVIDUAL USE AND PUBLIC MANAGEMENT OF FLOOD PLAINS

By

David Freshwater

Flooding problems within the United States have caused great damage to private and public property. These losses have resulted in extensive attempts to prevent the recurrence of flood damage. The subject of this thesis is a critical analysis of the methods that have been used to achieve this goal with a view to improving flood plain management methods. This involves consideration of the linkages between public management of flood plains and private decision making. The research deals with the development of an understanding of why existing flood plain management strategies have been characterized as ineffective and the proposal of methods that will aid in the development of better management plans.

The approach employed stresses the importance of individual choice as a mechanism for achieving social goals. The public sector influences the individual by; providing information, constraining opportunities and providing incentives. Flood plain use can be studied by using the methods of decision making under uncertainty and location theory. Consequently, the initial portion of this research analyzes

both these topics in order to develop hypotheses with individual flood plain use. Having developed an individual choice model, a theory linking public and private choice in a flood plain management context is required. This involves an analysis of the question of subsidies to flood plain residents by the general population and a description of the conflicts of interest between flood plain residents and the remainder of society.

Any flood plain management strategy involves the selection of a set of management tactics. The differing nature and effects of these tactics are considered in terms of their impacts on individuals. Tactics are described using a four level taxonomy which employs; method of provision, nature of influence on the individual, means of provision, and physical type as a means of relating similarities and differences in management methods. A discussion of the elements of a sound flood plain management strategy is undertaken and three hypothetical examples are considered, showing the applicability of different tactics to diverse situations. These examples focus on undeveloped rural areas, suburban transition areas, and highly developed urban areas.

The principle result of the thesis is an initial formulation of a behavioral model of flood plain use. This model stresses the importance of formulating management strategies and tactics that take into account the behavior of individuals. The failures of previous flood plain management schemes are attributed, in part, to a lack of consideration

of the impacts of different tactics on individual decision makers. The single overwhelming requirement for an effective application of the management methods suggested by the research is improved information. Both public and private decision makers are incapable of making effective and rational choices in the absence of accurate, relevant information. Information improvement is not, however, an ultimate solution to the flooding problem. A range of management tools are available and each is suitable to particular situations. The design of a functional management strategy requires the selection of an appropriate bundle of tools. The research undertaken is designed to facilitate this selection process and thereby reduce the costs of flooding.

THE LINKAGES BETWEEN INDIVIDUAL USE AND
PUBLIC MANAGEMENT OF FLOOD PLAINS

By

David Freshwater

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1977

To my father for teaching me the pleasure
to be found in work, and my mother
for encouragement when it wasn't.

ACKNOWLEDGMENTS

Like most acts of creation, the production of a thesis requires the efforts of more than one person. Although the ultimate responsibility for the contents of this volume must rest with the author, I would like to thank my guidance committee for their effort to create order from chaos. Byron Brown of the Economics Department, Thomas Edens of Agricultural Economics and Entomology, and particularly Lawrence W. Libby and my major professor Larry J. Connor have given me far more than my money's worth during my studies at Michigan State. Dr. Connor and Dr. Libby both suffered the dubious pleasure of reading and correcting the first draft. From the beginning to end their advice and comments led to a far better final product and also convinced me that I was not, as I often suspected, wasting their time.

Finally, I would like to thank the faculty, staff and students of the Department of Agricultural Economics for making my time in the department a memorable, and for the most part enjoyable, experience.

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CHAPTER I

INTRODUCTION

The subject of this dissertation is flood plain management. This introductory chapter specifies the nature of the problem, the methodology employed and sets out the development of the remainder of the study.

Identification of the Problem

Flooding and the possibility of flooding are important elements in the lives of a vast number of individuals. Within the United States it is estimated that more than half of the communities and seven per cent of the land area suffer significant flood damage (White and Haas, p. 255). Flood hazard is prevalent in every state, and threatens both urban and rural residents alike. Whenever the use of a flood plain is proposed, the question of flood hazard becomes an important factor in determining the net benefits of such use.

Ever since man settled in flood plains there have been attempts to minimize the costs of flooding. These attempts have met with varying degrees of success, depending upon the methods used, the nature of the flooding problem and the activities carried out. In the United States major flood control programs began in 1917 (United States, Water Resources Council, p. V-1). The major effort commenced with the Flood

Control Act of 1936 which placed the responsibility for flood control in federal hands and began a series of structural control measures to reduce flood damage (James and Lee, p. 230). Although these measures have significantly altered the nature of the flood problem, the annual damage caused by flooding has continued to increase over time. Floods are no longer the major disasters they once were. Losses of human life have been reduced greatly and major catastrophes are rare. What remains is a growing problem of property damage resulting from moderate floods, particularly in areas lacking flood control devices.

This continual rise in flood caused damage, despite the expenditure of over ten billion dollars in the 1936-1966 period, has led to serious doubts about current use and management practices of flood plains (James and Lee, p. 230). These doubts are primarily phrased in terms of questions about the desirability of introducing development in flood plains and of the applicability of structural control measures. Opponents of development argue that a full accounting of the costs and benefits of flood plain use would find that the costs exceed the benefits. They further argue that the provision of structural control devices leads to increased development of flood plains, further increasing the potential for flood damage and resulting in major distributional shifts in wealth. These distributional shifts arise since flood control devices are financed from general revenues yet provide benefits to only a segment of the population.

Analytical Framework

As the title of the study suggests, the methodology employed will be an individualistic approach. The focal point of the analysis is the individual decision maker who must decide whether to locate in a flood plain, or some other area, and the nature of the activities to be undertaken at the particular location. The problem for the individual is to select an optimal location, an optimal activity, and to remain at the location and carry out the activity an optimal length of time. This problem although conceptually simple when expressed in an expected utility, general equilibrium framework becomes rather intractable when confronted under a less rigorous set of assumptions. Indeed, in operational terms there is almost no likelihood that the individual can hope to satisfy this three-fold optimization problem. This does not imply that the conceptual approach of traditional theoretical economic studies is without value. Such a methodology provides a starting point. The aim of this piece of research is to make a marginal adjustment to the existing body of knowledge by introducing institutional and environmental variables to the analysis. This has the initial effect of making the problem sufficiently obscure so that no absolute solution exists, while still imposing a level of abstraction that makes the analysis unrealistic, in the sense that it relates to no particular situation. Despite these shortcomings there are some advantages to the approach. First, the

complexity of the choice problem for the individual becomes clearer. In addition, the importance of extra-market forces can be brought out. Within the context of an individual choice framework, the impact of group actions, both constraining and encouraging, can be shown, as can the importance of historical developments.

The framework employed is that of an individual utility maximizer operating in an uncertain world. The individual acquires additional information over time and has the potential to adjust some of the probabilities and potential states of nature through appropriate actions. The role of the group is to apply pressure on the individual by altering the feasible states of nature the individual confronts. Groups are composed of individuals each of whom seeks to maximize individual welfare, but recognizing that higher level goals may only be achieved by joint actions which require foregoing other goals and acting collectively.

According to White and Haas (p. 1) this individualistic approach is a relatively uncommon methodology. In a society where the default methodology of social organization is still to let individuals determine the choices and market forces distribute the impacts, a methodologically individualistic approach would seem to be of significant value, since it is compatible with the existing social mores. As long as individuals retain the rights to develop flood plains any effective management scheme must take into account those forces which affect individual choices and act upon them in a manner

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that is consistent with the management goals. An effective management strategy can impact on individuals in the following ways. These are; through the imposition of constraints which limit choices, through the provision of incentives to make particular choices more or less desirable, and through the provision of information to make the choice process more effective. The manner in which different flood plain management methods impact on individuals is a crucial portion of the research since the actual mix of methods selected determines the directions that individuals will be channeled and depends on the goals sought.

Scope of the Study

The study proceeds from an analysis of individual choice under uncertainty wherein the logical foundations of probability are considered. The point of this exercise is the development of a logical foundation of two views of the nature of the probability which can be applied to flood hazard. A case is made that this fundamental distinction in the conceptual foundations of probability theory can explain, in part, how individual decision makers and those responsible for managing flood plains arrive at different evaluations of the optimal use.

Following this, a development of location theory is undertaken, again from an individual viewpoint. Traditional location theory with its emphasis on cost minimization is criticized as providing an inadequate explanation of

individual behavior. In its place an extended theory is suggested which incorporates institutional and historical forces as central elements in location choice. The location choice of the individual is limited by these forces and within this limited set certain points are emphasized or de-emphasized according to social values. The individual makes the final selection but the alternatives available are socially determined.

Given the set of management tools available as policy variables, it is important to determine the effect of each of these tools on individual choice. Certain techniques can be classified as reducing the available options to the individual, others influence costs and benefits while others alter the information available. These tools can also be characterized according to the means by which they are provided. Some are provided privately while others are the result of collective action. Thus a management method can be selected on the basis of its impact in terms of the direct effect on the individual and on the relative mix of the public and private sectors.

Previous mention has been made of the conflict between private and social values in the context of an individual in opposition to a bureaucracy. This conflict can be extended to a group conflict between flood plain residents and non-residents by considering the relative values of individuals within each group and noting how costs and benefits of different actions are distributed. This latter conflict is

between private groups and is manifest in different ways. Controversies over development activities in flood plains can be usefully analyzed in terms of these two categories of conflict.

Research Objectives

The point of this analysis is to gain additional insight into the nature of the development process in flood plains. The use of an individualistic framework allows the analysis to focus on micro-decision processes rather than on the macro processes which have been the common method of analysis.¹ By considering the forces that shape individual behavior it is hoped that it may be possible to design management practices that encourage individuals to work in the "social interest" rather than trying to force them into it by thwarting private goals, with the expectation that the costs of providing incentives are lower, for the most part, than the costs of regulation.

Further, it is hoped that by providing an analysis which tries to introduce all relevant benefits and costs of flood plain development a better perspective on how to use flood plains will result. Only if management plans are designed to take into account the full range of forces operating on the individual can it be expected that the desired results

¹Examples of the macro or social approach to flood plain management are the works of Leopold and Maddock, Murphy, and the United States Water Resources Council.

will occur. Full consideration of all the relevant costs and benefits may also result in a different management strategy than if only a partial set were to be considered. Finally, it is hoped that the study will provide a means of linking uncertainty theory and location theory from the perspective of individual and social values. The optimal use of the flood plain differs only in degree from the optimal use of any resource. In every case there must be a way of working out conflicts between individual and collective requirements that take place in an uncertain world where spatial distributions have important effects.

The preceding paragraphs provide a general statement of the goals of the study. In terms of specific objectives that will be employed, five distinct points can be distinguished. First, a review of the literature on decision making under uncertainty and location theory will be undertaken. This review will focus on the relevance of individual choice particularly as it affects flood plain use. Second, alternative uses of flood plains by individuals will be appraised in the context of different flood hazards and different historical developments. Third, a relationship between individual and social choice will be developed. Fourth, individual choice models of flood plain use will be defined to show the linkages between private and social objectives and plans. Last, an analysis of different flood plain management methods will be undertaken using the concepts developed as a basis for comparison and evaluation.

CHAPTER II

THE FOUNDATIONS OF DECISION MAKING UNDER UNCERTAINTY

Location decisions in flood plains obviously have much to do with uncertainty. In addition to the normal levels of uncertainty that pervade all phases of life there is an additional element associated with the individual's location choice. Clearly, a flood plain by its nature bears some chance of being inundated, thereby destroying or damaging economically valuable activities and structures in the area.

The analysis of this chapter seeks to provide a plausible explanation of how the individual decision maker evaluates this risk; and also to determine the relationship between social and private risk, in the context of location decisions in flood plains. In order to undertake these tasks some preliminary discussion of the nature and concepts of probability is required. This work will comprise the first section of the chapter. Following this a brief survey of the expected utility approach for individual choice is presented. Then an extension, developed by Fellner, to expected utility theory is considered. This will complete the survey of background information required for the analysis. The next stage involves a consideration of how flooding problems are related to the preceding discussion. This will then permit a conceptual model of individual choice to be developed.

Having established the individual's decision making framework, an attempt to relate individual and social choice under uncertainty can be made. Finally a brief summary of the results conclude the chapter.

The Concept of Probability

The theory underlying decision making under uncertainty has a long and somewhat complex past. It is rooted in the nature of probability theory, which will be the starting point of the discussion. Several schools of thought on the nature of probability and its applicability can be distinguished. These various concepts are sufficiently contradictory that the conclusions flowing from particular schools imply different attitudes in decision making under uncertainty.

The Classical School

The first approach to be considered is commonly referred to as the classical school. It represents the first comprehensive formulation of probability theory. The basic tenet is that probability represents the ratio of the number of favorable outcomes to the number of possible outcomes. Laplace employs such a definition of probability in the Philosophical Essay on Probability. An essential characteristic of the classical framework is that it does not depend on observation. The probability ratio is determined a priori without recourse to experimentation or observation.¹

¹Fellner (p. 39) points out that Laplace, Bernoulli and Bayes did not require either experimental verification or an

Despite the lack of empirical verification in the classical approach many significant observations on the nature of probability were formally postulated. Laplace sought to relate probability to human action in a manner that was consistent with a basically uncertain world. If almost all knowledge is problematic then probability deals with the uncertainty of knowledge. In this respect the classical formulation is very like that of the subjectivist point of view, which will be discussed below. Laplace also postulated the "Principle of Sufficient Reason" as a means to link the past to the present and future. This principle presupposes a causal relationship between events. Thus, by studying the past, it is possible to make inferences about the present. Knowledge is the understanding of those relationships and probability results from the fact that only a partial understanding is possible. Laplace (p. 15) notes that such generalizations from the past to the present are possible only when the underlying relationships have not changed. The process of observing the past to gain information about the future is very like the frequency school of probability, to be considered below, but with the essential difference in that probabilities are established a priori not by observation.

Laplace notes that as the probability of an event becomes arbitrarily close to one there may still be an essential

inductive determination of probability ratios.

difference between the two states of certainty and uncertainty. This difference arises from the ability of the individual to perceive even a small error as being significant (Laplace, p. 8). Laplace thus may be thought of as anticipating the expected utility framework for analyzing uncertain events that is commonly employed at present.

The Subjective and Frequency Schools

As has been indicated above two other schools of thought, the subjective and the frequency, have their origins in the classical conception of probability. They may be thought of as extreme cases. There are two fundamental attitudes underlying probability which determine the applicability and the nature of the concept. These two opposing attitudes are manifest in the frequency or objective view of probability on the one hand and degree of belief or subjective view on the other.

Gillies in the Objective Theory of Probability presents a detailed comparison of the two approaches by concentrating on the analysis of one of the leading proponents of each school. The two authors considered are; John Maynard Keynes as an example of the subjective school and Richard von Mises as an example of the objective school of thought. The following discussion of the two theories borrows heavily from this work by Gillies although the usual caveat regarding misinterpretation must apply. The distinction between the two schools is one of a philosophical basis. On matters of computation and analytical techniques there is no difference between the

two. However, philosophical distinctions are often crucial, and are so in this case. The foundations of a conceptual system say a great deal about the applicability and scope of the system.

As will be shown below, it is possible to think of the frequency approach to probability as an example of inductive reasoning; which involves the process of reasoning from particular premises to general conclusions. By observing repetitive events it is possible to observe a convergence of the ratios of outcomes to some limiting proportion, thereby establishing the probability of any given outcome for an event. There is a subtlety to inductive proofs that applies to their relation to experience. Bertrand Russell shows that probability is always relative to the data available. The presence of additional data may refute expectations based on a smaller data set but this by no means alters the validity of previous conclusion (Russell, p. 153). As Russell notes, "The fact, therefore, that things often fail to fulfill our expectations is no evidence that our expectations will not probably be fulfilled in a given case or a given class of cases" (p. 153). Similarly, experience neither disproves nor proves the inductive principle. Experience may confirm the principle but the validity of any inferences drawn is based on the principle alone, not on the events that are observed. The point of this argument is that fundamentally any hypothesis regarding future events must rely on an "act of faith." The inductive principle acts as a guide to decision making,

revealing relationships that have held in the past, but it is a matter of faith to hold that these relationships will continue into the future.

Given this argument, what may be said regarding the frequency point of view? It would appear that a belief in a concept of probability based on repetitive events that leads to predictions of future events is no different at its roots than a subjective view of probability that starts from the initial assumption that probability is a relative concept measuring degrees of belief. The important distinction arises over the admissible scope of probability. Adopting a frequency theory restricts the applicability of the concept of probability to a restricted range of events, while providing a very definite meaning to the form.

Von Mises claims that the purpose of "...probability theory is to determine from the given probabilities in a number of initial collectives the probabilities in a new collective derived from the initial ones" (Gillies, p. 7). A collective is defined as an infinite sequence of elements of elements which are members of some arbitrary attribute space (Gillies, p. 3). Probability thus becomes an empirical theory based on the law of the stability of statistical frequencies which states that as the number of events increases the probabilities converge to a limit. Probability is therefore only useful when it is possible to undertake repetitive experiments so that the limits of the frequency distribution can be established. Problems that do not meet this criterion are

incapable of being analyzed in a probabilistic framework. The great advantage of adopting such a belief is that probability becomes an unambiguous concept that is agreeable to all reasonable individuals. The objective nature of probability allows a consensus in decisions where expected values are the deciding criterion.

What then is the subjective interpretation of probability? The subjective view of probability is that it is a branch of logic indicating a relationship between two propositions. Probability is a conditional relation which is determined by the available evidence, i.e. a measure of the degree of rational belief. Given two propositions, a and h and if knowledge of h gives a belief of α in a then there is a probability relation (Gillies, p.8). The way a probability relation is formed is by direct acquaintance or logical intuition. Thus the subjective view of probability can be seen as a direct application of Russell's Principle of Induction.² There are no restrictions as to the applicability of the

²The Principle of Induction as stated by Russell in "On Induction" consists of the following: (a) When a thing of a certain sort A has been found to be associated with a thing of a certain other sort B , and has never been found dissociated from a thing of the sort B , the greater the number of cases in which A and B have been associated, the greater is the probability that they will be associated in a fresh case in which one of them is known to be present; (b) Under the same circumstances, a sufficient number of cases of association will make the probability of a fresh association nearly a certainty, and will make it approach certainty without limit.

of probability using a degree of belief approach. Given two propositions it is possible to assign a probability relating the two. The magnitude of the number assigned is a direct relation of the subjective degree of belief in the postulated relationship. Keynes notes that not all probabilities have numerical values. Only when it is possible to apply Laplace's Principle of Insufficient Reason to a set of finite and indivisible outcomes can numerical values be obtained (Gillies, p. 11).

The Laplace Principle of Insufficient Reason is a decision rule to be applied when faced with a choice where no information is known about the likelihood of any possible outcome. It states that, given a state of complete ignorance about the probabilities of different outcomes the decision maker should assign equal probabilities to each outcome.

The concepts of probability considered so far have been polar cases. It is possible to caricature them as; the frequency belief, which restricts probability to a class of uninteresting games of chance where all knowledge but the particular outcome is available, and a subjective point of view where probability is a measure of how any particular individual chooses to relate two events. Clearly neither is a sufficient theory, by itself. The first is unable to address interesting questions, while the second provides uninteresting answers. What is needed is a theory that provides a measure of the interpersonal transmissability of probability values associated with the frequency approach

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yet is able to address a wide range of problems as does the subjective approach. As Gillies (p. 14) notes, there are no computational incompatibilities between the subjective and objective methods. The difficulty arises over the scope and nature of probability. At this point in time it is wise to recall Laplace's reminder that no matter how close an uncertain event becomes to a certain one there is still a perception of the possibility of the other outcome occurring, disrupting the individual's plans. This provides a clue as to the psychological elements underlying human decision making.

Fellner's Semi-Probabilistic Approach

William Fellner in Probability and Profit provides an approach that meets the desired criteria. Fellner characterizes the approach as being semi-probabilistic and an extension of Bayesian decision making.

The approach incorporates the possibility of a set of probabilities, attached to various outcomes, which exhibit the desirable property of being reasonable to a large group of individuals. However, Fellner argues that these probabilities are not directly employed by the individual in the decision process. The probabilities are adjusted by the decision makers conception of how stable they will be over time. Thus there can be a great deal of difference in behavior in situations where the attached probability is, say, 0.3 with great confidence and one where the probability is 0.3 with very little faith in the stability of this value. Fellner

employs the term "slanting" to incorporate the individual's subjective evaluation of the stability of the probabilities. As a further example; consider a case where Laplace's Principle of Insufficient Reason is applied. In this case the individual has no reason to assign anything but equiprobable weights to the possible outcomes. However, it would be very likely for that individual to have very little faith in the stability of those weights. Consequently the slanting factor in this case is quite large.

Expected Utility in a Semi-Probabilistic Context

It has become a matter of course in economic research into uncertain events to adopt an expected utility framework. A question that needs to be addressed at this point is how the semiprobabilistic approach fits into the expected utility framework, and more to the point whether anything is to be gained by employing it.

The Expected Utility Approach

The basic argument of the expected utility framework rests on three axioms and a theorem. From these it is possible to develop a utility ranking that is in a sense measurable, in that utility values are defined to within some arbitrary constant. This assumes that a person behaves rationally which in this case requires that preferences satisfy certain consistency assumptions.

In order to present the theoretical basis of the theory it is necessary to introduce certain notation. Let $f_i(x)$

represent a probability distribution f over outcomes $x = (x_1, x_2, \dots, x_n)$. Thus each $f_i(s)$ represents some prospect and its associated outcomes. Given m possible outcomes then clearly;

$$\sum_{j=1}^m f_j(s) = 1 \text{ in the discrete case,}$$

or

$$\int_0^{\infty} f_i(x) dx = 1 \text{ in the continuous case}$$

Axiom 1: For any prospect $f(x)$ in the set there corresponds a certainty equivalent $\bar{x}$. This axiom ensures that for **any** gamble there can always be found a given certain **amount** for which the individual is indifferent.

Axiom 2: Given a binary choice where there are two possible outcomes; M with probability p , and O with probability $1-p$. As the probability, p , increases from zero to one the certainty equivalent correspondingly approaches M from O . It is possible to find some probability p such that the individual is indifferent between any particular outcome with certainty and a binary prospect with outcomes O or M and associated probabilities $1-p$ and p .

Axiom 3: Given some prospect $f(x)$ it is possible to define a new prospect $f^r(x)$, say, where $f^r(x)$ is identical to $f(x)$ except for the fact that outcome x_r has been replaced with an equivalent binary prospect. Then the individual shall be indifferent between prospect $f(x)$ and $f^r(x)$. By successive application of axiom 3 it is possible to reduce any complex

prospect to an equivalent binary prospect.

These axioms enable any complex prospect to be reduced first to a simple binary choice and then to a corresponding certainty equivalent. Thus any number of arbitrary prospects can be reduced to certainty equivalents and then ranked on the basis of these certainty equivalents, through the use of some preference ranking commonly termed a utility function and denoted, $u(x)$. It can be shown that the utility function is defined up to a monotonic transformation. That is $u(x)$ cannot be distinguished from $v(x) = a + bu(x)$ where a and b are arbitrary constants and b is greater than zero. These results can be stated as a theorem.

Theorem: A preference function satisfying the three axioms can be represented by a utility function unique up to a linear transformation.

The proof of the theorem follows directly from the axioms and is reproduced as an appendix in the Theory of Games and Economic Behavior. These three axioms and the associated theorem are the basis of the expected utility framework, which may be represented as

$$U(f) = \sum_x u(x) f(x)$$

The actual properties of this utility function, $u(x)$ are of interest. Borch (p. 41) shows that, as a general class, mean-variance decision rules fail to satisfy the three axioms and are hence inadmissible. Another property following from Axiom 2 is the requirement that the first derivative of U be positive so that as x increases $u(x)$ also increases.

Finally, interpersonal utility comparisons do not follow from expected utility computations since the individual's preference function determines rankings.

The value of the expected utility approach is that it provides a logically consistent method of ranking uncertain choices while employing only a small number of assumptions that are intuitively appealing. As Luce and Raiffa (p. 38) point out: "One alternative possesses a larger utility than another because it is more preferred, not the other way around." Thus expected utility analysis may be thought of as a convenient summary of individual preferences. Thus in order to specify a utility function it is necessary to obtain some measure of individual preference.

The Significance of Fellner's Approach

By introducing Fellner's slanting factor as a measure of confidence in estimation the expected utility formation incorporates an additional term. Given the discrete form of the expected utility formulation

$$U(x) = \sum_x u(x) f(x)$$

the incorporation of the slanting factor gives a form

$$G(x) = \sum_x u(x) f(x) s(x)$$

where: $u(x)$ is the individual's utility function, $f(x)$ is the estimation of the prospect, and $s(x)$ is the measure of the individuals confidence in the stability of the prospect.

What must be shown is, that it is preferable to isolate the slanting factor as a separate variable rather than to

incorporate its effect either in the individual's utility function or in the specification of the prospect. In the first case, the slanting factor does not reflect the individual's attitude toward the outcomes but is a measure of confidence in the estimated probabilities. Since the utility function reflects preferences it would seem undesirable to place the slanting factor there. In the second instance, the probabilities estimated by the individual reflect the available information at that time. As Russell (p. 153) points out in his discussion of induction, probability is relative to data. Thus the individual has made the best estimate possible but recognizes that these estimates may be subject to change. In effect, what the individual is doing is performing a complex decision with compound probabilities, i.e., a probabilistic confidence value is attached to the original probability estimates. By the axioms of the expected utility hypothesis it is clearly possible to reduce a complex prospect to a simple one-but is it desirable. Fellner's argument is that it is advantageous to separate the two since they reflect different things. The probabilities associated with the prospect reflect an estimation of the likelihood of the various outcomes. The probability associated with the slanting factor reflects the degree of confidence in the predictions which can be a function of an entirely different set of variables.

Since the nature of the slanting function differs from that of the prospect, combining the two will give a hybrid

which will give the same final result but with a loss of information. The value of maintaining this distinction will become clearer in latter portion of the analysis where the difference between social and private risk is considered.

The Importance of Uncertainty in Economics

Given the desirability of using the expected utility hypothesis as a technique for analyzing uncertain situations it is now important to show why the concept of uncertainty is relevant to economics in general and to this work in particular. The general applicability of uncertainty theory has been justified many times and should be apparent to the reader. Some of the lucid rationalizations are to be found in the work of Knight, Mack and Borch.

Uncertainty and Flooding

In the particular case of flood plain use it can be seen that not only do the standard levels of uncertainty associated with life apply, but also there is additional uncertainty arising from the possibility of flooding. Floods may be thought of as one member of a class of natural disasters that are site specific. Other members of the class are; earthquakes, forest fires, and volcanoes. In each case there is some level of information regarding the likelihood of the disasters' occurrence at any given location. These natural disasters add an increased element of uncertainty to the individual choosing to locate in an area where they occur. Thus, location in a flood plain carries, in addition to the

normal uncertainty associated with any activity, an increase in uncertainty attributable to the possibility of a flood. Indeed, the levels of potential flood hazard are used to distinguish flood plains. Consequently, any analysis of flood plain use must take into account the role of uncertainty and methods of dealing with it.

The Differing Natures of Probability Related to Flooding

The preceding analysis has shown that there are two schools of thought to be found in the philosophical basis of probability theory, namely the objective and the subjective. It is hypothesized that this difference may be used to explain a large portion of the conflict between what are commonly termed private and social welfare in flood plain use. In capsule form, the hypothesis is that individuals approach uncertainty from a subjective perspective while society through its planning and management appendages, such as government agencies, and legislative bodies, employs an objective framework. In each case the same computational framework, expected utility analysis, is employed. Since the initial premises differ, the conclusions reached also differ, even though the logic is common.

Society by virtue of a longer time horizon and greater diversity of interests is able to view an individual location choice as an element of a set of replicable events. Consequently floods and the location patterns following from them are developed using a frequency type of analysis. The

individual, by way of contrast, views a location decision as a unique event that is not subject to replication. For the individual the location decision is an infrequent occurrence and one that has ramifications far into the future. The conditions confronting any particular individual are unique when viewed from the individual's perspective. Even when there is information available about historical flood experiences the individual must interpret it. The consequences of a flood are disastrous for the individual and must be carefully considered, particularly where information dealing with flood likelihoods is limited. Thus, a subjective view of probability is appropriate.

It is at this point that Fellner's concept of a slanting factor becomes useful. Both individuals and society may employ the same probabilities of floods, since individuals can obtain data from branches of the government. The essential difference in this case arises from the individual's application of a slanting factor to these raw probabilities to obtain a subjective evaluation of the likelihood of flooding. This slanting factor adjusts the individual's final ranking giving a divergence from that determined by society. A further complication arises in that social and private utility functions are not likely to employ the same arguments and that individuals may determine probabilities of flooding that are different from those of society. These differences in values are important but the intent of the hypothesis is to show that even in a case where it would

appear that individuals and society have compatible inputs to the decision process and compatible values, the fact that they employ different notions of probability can lead to conflicting results.

Summary

To this point a survey of the two philosophies of probability has been presented, followed by a discussion of expected utility methodology. A brief discussion of the relevance of uncertainty to the problem at hand was then introduced. Finally a hypothesis regarding differences in the type of philosophy of probability as cause of incompatibility between private and public choice was proposed.

CHAPTER III

LOCATION CHOICE

Within this chapter a survey of the basic elements of location theory is developed. This includes an historical development of location models and a critical survey of the existing theory. Following this, a formulation of a decision model for location selection is presented that employs the notion of a utility maximizing individual as a basis. Finally, a summary of the results conclude the chapter.

Location Theory as a Branch of Economic Theory

Location theory has its fundamental origins in the works of the classical economists. Of the classical economists Ricardo, through the notion of rent, had the strongest influence on location theory. The concept of the optimal use of land based on intensive and extensive margins as an allocation device is common to much of the analysis of land use. Since the marginal cost of production is primarily determined by the quality of land the output of any particular form is determined by its resource endowment. Similarly the extensive margin of production is determined by land quality. The last unit of land to be employed is that one for which the marginal cost of producing the first unit of output just equals the marginal revenue obtained. In the context of

standard optimizing economic theory the product of any particular unit of land will be determined by equating marginal costs and marginal revenues. When marginal revenues for a particular product are constant, while costs vary with location, a surplus is generated at the low cost sites. The distribution of this surplus underlies the theory of rent.

In the Ricardian framework the price of corn was the determining factor for the marginal revenue, and land prices or rents were derived from fundamental differences in the quality of land. With very little effort the same analysis can be employed, using other location determining variables; such as transportation costs, site amenities, or market availability. In each case intensive and extensive margins are determined showing the output or value, as the case may be, for each particular site and for the entire area.

As Isard has noted "...both time and space must be vital considerations in any theory of economy" (p. 24). Yet, for the most part economists have abstracted from spatial questions, and to a lesser extent, from time. Any realistic theory of actual decision making must take these effects into account. The analysis of flood plain use necessarily requires the development of a theory of location if any structural explanation of the development process is to be developed.

Several different methods of approaching location problems can be distinguished. The first type involves consideration of location decisions where the activity in question uses large amounts of land. This class of problem was the first

to be considered and basic location theory models are formed from this type of analysis. These areal considerations result in land allocation models. A second type of model is formed in terms of location decisions at a point. In this instance the land requirements of the activity are ignored and attention is focused on the attraction and repulsion forces associated with different industries. A third type of model deals with hierarchies of functions, relating size of community to the levels of services provided in order to develop a theory of functional dependence of different size communities. Each of these location models will be considered in greater detail below. Different types of information about the location problem result from these models since each approaches the problem from a different perspective.

Areal Location Theories

The Von Thunen Model

One of the earliest and more important advances in location theory was the work of Von Thunen in the early part of the nineteenth century. Von Thunen's model of an isolated state is an example of the allocation of land among uses where land area is an important element of the activity. The essential basis of the model is a differential in values of final product brought about by transportation costs. A central market in a homogeneous plain is employed to show that distance from the market is the crucial element in determining location. In his analysis Von Thunen shows that different

activities will be dispersed in concentric rings about the market with the size and relative position of the ring being a function of the value of the activity and the cost of transportation for that activity.

Although a homogeneous plain with a single market is postulated, this is clearly only a simplifying assumption and the results follow, although with considerable distortion, if multiple markets or a heterogeneous environment is introduced. For example, in the case of multiple markets, those activities with the lowest net value after transport costs have been deducted from gross value will not be found in the region between the two markets. Similarly, variations in land quality will lead to irregularities in the distribution of activities and may even result in isolated pockets of an activity, if the value of the activity and its associated transport cost combine to dictate that particular use as being optimal, in a particular location, despite an alternative use taking place in the surrounding area.

Problems with the Model

From Von Thunen's analysis it is possible to predict location areas for different activities. However, within an area it is not as easy to predict the actual site occupied by a particular unit. One solution to this problem is to assume that land rents within a region are such that the individual unit becomes indifferent among sites within the area. In this case rents would rise with proximity to the inner

boundary of the ring, with the magnitude of the increase being proportioned to the transport costs associated with that given activity. However, this solution is to some extent unsatisfactory since it fails to explain why land rents take on such a distribution. In order to achieve this distribution a competitive mechanism for allocating land must also be postulated as must a behavior scheme for land-holders which requires the capability and incentive to extract all the available surplus that can be attributed to a particular site. The major problem with such an assumption is that in order for it to be other than a very rough approximation a greater degree of simultaneity in location choices has to be present than is commonly observed. Although it is conceivable that over time an adjustment in land use could take place, which would result in the postulated allocation, the likelihood of such an occurrence would seem small.

Alternatively, a successive application of Von Thunen's concept could be used to determine land use for individual entities. Once the available area has been divided among competing uses, each group of users is disaggregated into individual elements and the process is repeated, using individual preferences as a measure of value that determines location.

The Relationship with General Equilibrium Analysis

The essential features of Von Thunen's theory are similar to general equilibrium analysis. Individual uses compete

for sites on the basis of ability to pay; which is the same as Walrasian general equilibrium, which is also based on ability to pay or effective demand. The process as it is described is similar to the tâtonnement procedure established by Walras. Ability to pay for the land is an essential element in this type of analysis and the land is allocated through the standard mechanism of the economist-the competitive market.

Since the time of Von Thunen, this type of analysis has been applied primarily to land intensive activities, such as agriculture. Webber notes that there are two major types of agricultural land use models. One deals with the effect of location on production for a central market while the second deals with inter-regional equilibrium (Webber, p. 50). This latter form encompasses the possibility of different markets and different production costs. These differences are introduced by the processes and costs of transporting outputs between regions.

The model developed by Von Thunen has only undergone minor modifications since it was first introduced. It retains its applicability for location problems involving the allocation of land among competing uses, particularly when transport costs are important. It was, however, found wanting in a number of areas and consequently a different class of models was developed to approach the location problem from a different perspective.

Point Location Theory

The second class of models to be considered deals with point location questions. In this class of models competition for a particular site is not considered; rather, the issue is choice among locations with disparate characteristics. The primary source for point models is the work of Alfred Weber in the late nineteenth and early twentieth centuries. Isard (p. 28) characterizes Weber's analysis as essentially evolutionary, stressing the phases of development of the social and economic system. The primary feature of Weber's analysis is cost minimization. Different sites have different costs of production, not only because of transportation differentials, but also because of the differing nature of the production process at these different locations. Weber sought to explain location in terms of transport costs, labor costs and agglomeration effects (Webber, p.11). The analysis of transport costs rests on the differing nature of production processes. Those processes that result in a loss of weight during production locate near the source of inputs while those that gain weight locate near the market. Variations in labor availability and cost cause disruptions in the location choice of the firm. However, such variations can be incorporated as part of the production process. The basic advance associated with Weber's theory is the notion of agglomeration effects. Weber showed that there are positive and negative forces that relate the proximity of firms.

Clustering effects are primarily explained in terms of a desire to locate either at a source of raw materials, which is site specific, or at a market, as a result of external economies. These economies result from a variety of causes. Hoover (p. 76-79) distinguishes output variety and economies of the plant, the firm and the cluster as causes of agglomeration.

Output variety indicates that consumers may demand a wide variety of products and the greater the variety at a particular location the greater the demand. This applies primarily to well differentiated products that require inspection prior to purchase. Economies associated with a plant refer to the optimal scale of a particular plant. Similarly economies of a firm refer to economies associated with a multiple plant operation while economies of a cluster refer to multi-firm economies. In each case there are scale advantages which exceed the associated costs.

Central Place Theory

One further central development in location analysis is central place theory. Central place theory is an attempt to explain urban growth in terms of a hierarchical service system. The focus of the work is an attempt to explain differential levels of services provided in market areas and hence to explain why certain settlements are larger than others. Once again transport costs and scale economies contribute to the definition of market areas for various goods.

Christaller and Losch, the two pioneering individuals in the development of central place theory, began with a uniformly settled homogeneous plain and a given set of production and transportation functions. It immediately follows that in order for a cost minimizing solution to result, a regular hierarchy of settlements is necessary.

General Characteristics of Location Theories

The work of Weber and Von Thunen provides the starting point for the existing theories of location decisions, with the notable exception of central place theory. The basic ideas of these two individuals have been extended significantly but the underlying structure of their work has not been greatly changed. There are two virtually distinct streams of development in location theory each having different starting point. Transportation costs are the fundamental tool in making each system work but the orientation is different. Areal theory, in the tradition of Von Thunen, is an example of a general equilibrium system based on micro decision units. Point location theory, although it has micro applications, has its roots in aggregate behavior. The evolutionary development of settlements and the extra-market forces that lead to agglomeration are essential to point location theory. From this aggregate or macro viewpoint it is then possible to develop a corresponding micro location theory. In essence, the two theories analyze the same body but from opposite starting points.

In summary, the principle feature of most works on location is a concentration on transport costs in a static framework with cost minimization as the objective function. Almost all the theoretical analysis of location choice has been in the context of a firm or industry, operating in a perfectly competitive market framework. This has led to significant bias in the development of the theory.

Inherent Limitations

Clearly all the standard criticisms of a perfectly competitive framework apply to location theory but there are also additional problems. Location theory has in many cases focused on transportation costs to the exclusion of all other factors of determination of location decisions. Even when such factors as economies of scale and differentials in resource endowments are introduced into the analysis it is in a supplementary manner. As Alcala (p. 43) notes the introduction of economies of scale of itself carries the implication that a perfectly competitive framework is not appropriate for analysis of the problem.

At a more fundamental level location theorists are very critical of standard economic theory as being irrelevant since it abstracts from location costs (Isard, p. vii). Yet location theory is guilty of as great a simplification by abstracting from time. This criticism introduces the essentially static nature of location theory. The traditional approaches assume an equilibrating framework with instantaneous adjustment. This is an heroic assumption that neglects

one of the key issues of land use--the relatively long life span of the choice. By abstracting from time, a general equilibrium framework can be employed to indicate the adjustment of the system to transportation costs. The result is a series of smooth rent curves indicating the locational premiums of central sites. Suppose now that time is introduced.

In a world of perfect foresight, or even one where uncertain outcomes occur with known distributions, the effects of time on location patterns are insignificant. In these instances the effect of time is incorporated through some appropriate discount rate. In the case where risky events are to be considered a certainty equivalent is also required. It can be easily shown that any complex prospect can be reduced to a simple certainty equivalent once probabilities have been assigned to the respective outcomes (Green, p. 219). It is this assignment problem though, which is at the heart of the matter.

It is apparent that when the assumptions of perfect knowledge and objective probability systems are relaxed, there will be significant impacts on the results of the model. Indeed the applicability of an equilibrium framework of any type is questionable. Some of the more difficult problems of location theory in a more realistic framework include; dealing with fixed assets, the problem of estimating future requirements for services and outputs, adapting to changes in transport systems and costs, the variations in levels of

knowledge about current land availability and prices, the relevance of institutional forces that stimulate or oppose certain land uses, the relationship between location choice and the remainder of the economy, and cultural factors affecting tastes and preferences. This is only a partial listing of relevant factors which can have a great bearing on development patterns. Although the use of the "ceteris paribus" assumption has a long and often valid history of application in economic research there are times when simplification can result in a failure to address the appropriate questions.

The literature of location theory has concentrated on the problem of a cost-minimizing firm where transportation costs are the crucial variable affecting the location decision. The result of this analysis is a theory based on the optimization of a single valued objective function.

This analysis assumes that revenues are constant, irrespective of location choice. For some products this may be a valid assumption. However in cases where the firm has the ability to influence price such an assumption is invalid. In this latter case the relevant objective is profit maximization which implies an adjustment of both revenues and costs. Location choice is likely to influence both the revenue and the cost side of the firm's activities. Consequently, it is improper to formulate the location problem as one of cost minimization. Although extensions to location theory

now incorporate multi-variable objective functions, it is still primarily in a static, partial or general equilibrium framework (Papageorgiou, p. 23-51). These sophisticated models, although providing a more elegant analysis, are still unable to address many of the aforementioned issues; primarily because they are only approachable through some sort of disequilibrium analysis.

A Reformation of Location Theory

Having presented a summary of location theory and some criticisms, it now remains to suggest a reformulation. The scope of the reformulation is considerably wider, taking in decisions by individuals and social requirements as well as the decisions of firms. Consequently, there is a loss in direct applicability since any increase in generality is purchased through a decline in ability to deal with particular details.

The Individual's Actions

The analysis starts with a utility maximizing individual operating in a world where social institutions constrain individual choice but are themselves subject to change. In order to understand changes in social institutions it will be necessary to postulate a model of social interaction. The model begins with the assumption that only individuals undertake actions but that society has some influence on the individual, either by restricting the range of admissible choices or by providing an incentive to select particular choices. The

individual is assumed to be rational in that any choice made is the one that gives the greatest expected utility. An expected utility framework is employed since the individual operates in a world of less than perfect knowledge about both current and future conditions and events.

Location decisions are, in general, discretionary decisions that are made infrequently and involve the commitment of a significant portion of the individual's current and future income and wealth. However, the degree of discretion in location choice can vary widely from individual to individual depending on the level of income and wealth and other constraints involved. The decision criteria may even be lexicographic, at least over some variables. For instance a family with five children is restricted to a home that has sufficient room for the members. There are also cultural or social constraints. They can be overcome at a price, as can physical limits. Similarly, income restrictions require that an individual purchase a home within a specified value range. Transportation costs can also restrict location choices to a particular set of alternatives. The process of determining the feasible set of choices by setting constraints, may be thought of as a lexicographic ranking process since all feasible choices must first satisfy the constraint set.

Institutional Constraints

At any particular point in time there is a set of constraints in effect that are determined by the current

institutional framework. These constraints such as; zoning restrictions, services provided, and terms of contract, direct and constrain the individual's actions. However, in many instances social institutions are sufficiently pliable, over time, that the individual can in the proper circumstances change the institutions. This form of directed institutional change may be accomplished by a single individual, given sufficient will and resources, but is in general accomplished through the combined action of a number of individuals with a common interest. Some common examples are; the extension of city services to urban fringe areas, the rezoning of land to meet some interest group's needs and the construction of new transport facilities as a condition for the location of a new firm. In each case the institutional environment undergoes change as the result of a conscious effort by a group to improve its position.

The Role of Information

The cost and existence of information is of crucial importance in the decision making process. By virtue of the long time horizon of location decisions any decision to change location is weighed carefully by the individual or individuals concerned. Individuals may be said to behave rationally if they act in a manner that maximizes their expected utility. This statement is however, little more than a tautology since it suggests that whatever an individual does is rational. When actions are observed that to an

external observer seem irrational, a difference in available information may be the explanation. Location decisions are an area where information asymmetries are particularly common.

The costs of search for the individual are particularly high since the area to be covered is generally large and quality differentials of different locations are often not obvious. As a result of these high information costs the specialized service of real estate brokers has developed. The real estate broker is a specialist in matching available locations and potential buyers. By specializing, the broker is able to take advantage of the high costs of search and extract a fee for matching buyer and seller. However, even with the presence of real estate agents there is no guarantee that location choices are optimal. In the first place, the real estate broker, although a specialist, has only an imperfect set of information of available buyers and sellers. In the second place, it may not be in the brokers' interest to bring about an optimal matching of buyers and sellers even if the necessary information is available. Brokerage charge differentials may result in the broker arranging a sub-optimal location decision if it results in higher commissions.

Manipulation of information is an important consideration in making the analysis of location decisions. It is clearly in the seller's interest to present a parcel of land in a manner that reflects any desirable attributes while masking any undesirable ones. In this vein, river front lots

are sold on the basis of their scenic view and no mention is made of the possibility of flooding. Throughout flood plains, especially in areas where flooding is infrequent, it is in the seller's interest to minimize or disguise the possibility of a flood.

Dis-Equilibrium Forces

The great body of location analysis has been shown to be in the same tradition of general equilibrium analysis. Kornai has recently questioned the validity of the general equilibrium approach to economics. Although the individual assumptions of the theory can be made plausible, when considered in isolation, in an aggregate form the correspondence between general equilibrium and economic reality is so slight as to be negligible when policy issues are to be addressed. Not only are the assumptions of general equilibrium theory inconsistent with reality, they also fail to provide results that are consistent. Thus, general equilibrium fails to satisfy either the criterion that assumptions reflect reality or the "as if" criterion that stresses prediction not explanation. The principle cause of the inadequacy of general equilibrium theory is its failure to take into account influences that do not have market determined prices and other extra-market phenomena. Any theory that is based on a general equilibrium approach is also subject to such criticism.

Extra-Market Forces

In location decisions extra-market forces are of great importance. Although it is possible that some influences such as perceived quality of a neighborhood may be capitalized into site prices, there are a host of such influences that are not. Ethnic groupings are an example of such a phenomenon. For an individual not of the particular ethnic group concentrated in a given area, a site within this area is likely to be less desirable than one elsewhere, yet the opposite effect will be true for an individual of that particular ethnic persuasion. Since the market price is set by the aggregate demand for housing there is likely to be a form of subsidy or consumer surplus available to individuals who choose to locate in ethnically distinct neighborhoods. This analogy can be extended to neighborhoods in flood plains. Radner in a study of reconstruction in flood stricken areas found the residents of the area wanted to rebuild rather than relocate because of a desire to retain their current neighborhood and from a fear of the consequences of relocation in an unknown environment (White, 1961, p. 77). This desire to accept current conditions rather than experiment with a different environment which may provide either better or worse conditions is characteristic of human behavior. Katona stresses the habitual nature of individual behavior. Only when the individual is faced with a new decision or the costs of making the wrong choice are significant does the individual consciously weigh alternatives. Even in these instances

the costs of acquiring information and the unknown reliability of the information when coupled with a risk averse attitude suggest that the individual will not, unless forced to, make a major change.¹ When flooding is a relatively infrequent phenomenon the costs of change as perceived by the individual outweigh the costs of remaining in the same location.

The Role of Transport Costs

Clearly, transport costs are an important element in locational analysis but only when all other elements are held constant do they become "the factor" in determining location choice. In general, the location decision is such a multi-faceted choice that attributing a dominant influence to a single factor is an heroic assumption. At a macro level, transport cost is likely to be an important influence determining the regional location of various activities. For example transport costs prohibit the construction of a single cement block plant to service the entire nation despite the existence of economies of scale in production. In all cases transport costs are equated with other costs and benefits at the margin.

At the beginning of this chapter the notion of rent was stressed as being a crucial element of location theory.

¹An interesting experiment suggests itself at this point. If individuals in a flood stricken neighborhood were given the option of relocating in another area but at the same time maintaining their neighborhood would they be less resistant to change. In essence the old neighborhood is transferred intact to a new location.

Given the assumptions of the traditional analysis, the resulting equilibrium results in the total cost at any site being equivalent. This total cost is composed of different proportions of site rent and transport cost depending on the distance from the central desination. Figure III-1 depicts such a hypothetical situation. If a perfectly competitive model is postulated, the total costs equal total returns so all surplus is appropriated by the land holder. In a less than perfectly competitive model there is the possibility that rents will not exhaust the entire surplus. However, the inescapable conclusion of this type of analysis is that the individual becomes indifferent between sites and the location problem, at least at the individual level disappears.

One means of escaping from this dilemma is to recognize that all costs are not equivalent for all individuals. Although the aggregate cost may be the same at each point in space the actual mixture of site and travel cost may be crucial to the individual in selecting a location. Under this hypothesis the question of location once again becomes interesting.

Decision Making

Kornai (p. 143) notes that uncertainty may be thought of as the absence of information. In an uncertain situation the appropriate action for a clever individual is to hesitate, gather additional information, weigh alternatives and choose an option. Kornai believes that at the time of decision the individual essentially makes a random choice from a set of

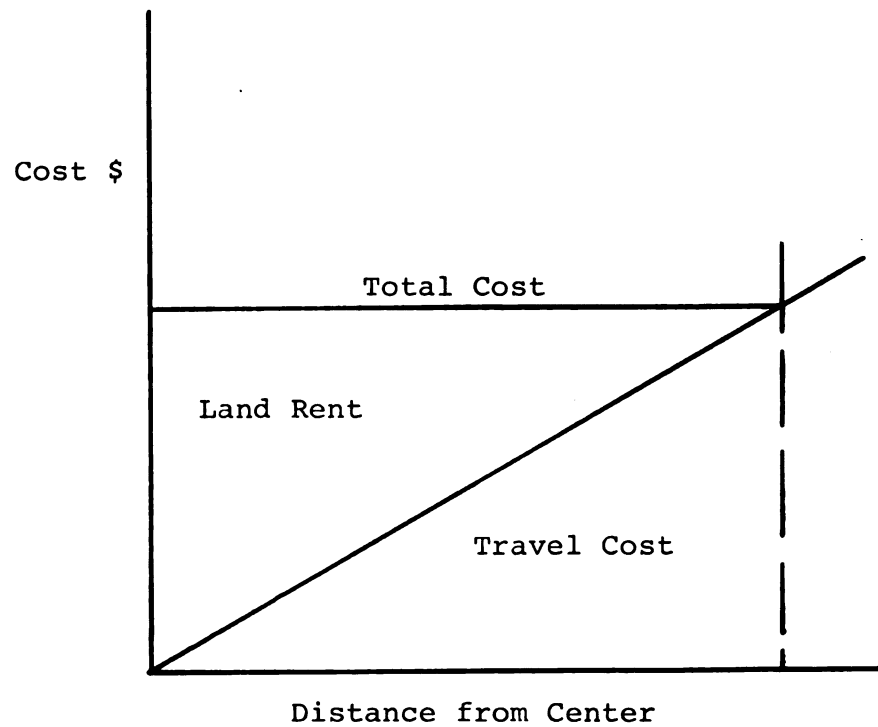


Figure III-1

Proportions of Land Rent and Travel Cost Under a
Perfectly Competitive Land Allocation Scheme

alternatives that are indifferent in some sense. In selecting a location an individual is, in general, in a position where the element of uncertainty is very large since the location decision itself is made so infrequently the individual lacks a large store of information regarding past procedures, choices and their outcomes. Further, the consequences of the decision will carry far into the future and are in part conditioned by the future states of the world. The individual can only guess about future events and changes even though they will significantly effect the outcome of the choice. Current information is also expensive to acquire and of far from uniform quality which also contributes to the element of uncertainty. For these reasons it would seem fair to characterize the locational choice problem not as a careful mechanical price determined general equilibrium process but instead a procedure that is at best satisficing and subject to large, socially determined random forces.

The location decision of the individual must be developed in an institutional setting where cultural values, legal and social constraints and the level of technology both set limits on individual behavior and provide a guide as to what is to be considered valuable and desirable. In addition the high cost of acquiring information and the difficulty in evaluating its value and accuracy ensure that the decision is made in an uncertain environment with a considerable element of random fluctuation. Despite these modifications an individual choice model does seem to be the

appropriate focus for analysis of location decisions. The flexibility of an expected utility approach in incorporating different preferences and constraints makes it a useful technique in developing a land use model.

Summary

In the issues presented above there is a basis for a reformulation of location theory. This reformulation starts with the existing body of knowledge and begins to develop a series of criticisms of the traditional cost minimizing framework. The thrust of the criticisms is that location decisions are complex phenomena that cannot be approached using comparative static techniques for cost minimization if more than a limited abstract level of knowledge is required. It is divergences from the competitive model and the market allocation process that are the basic features of the land market. Only by focusing on these behavioral and institutional factors is it possible to develop a theory of location that can be employed to develop a realistic model of location decisions. Whether this model can be quantified is another question that deals with issues beyond the scope of this research.

The components of a reformulated location theory that would seem to be essential are considered below. The first is a flexible objective function that integrates location choice into the other objectives of the individual decision maker. In the absence of a particular reason for believing

that utility functions are separable, location choice must be considered as part of the individuals aggregate preference mapping, not an isolated component. Secondly, the relationship between individual preferences and the values and rules of society must be considered. The location choice of the individual is conditioned both in terms of the values that the individual derives from society and by the limits that society sets on individual actions. This relationship varies over time as a result of the constant shifts in relative power of individuals and groups and the gradual adjustment of social and private goals. Information availability and improved knowledge are both crucial elements in this adjustment process. If location theory is to proceed in its general equilibrium tradition of building aggregate patterns from individual choices, then greater attention must be paid to elements underlying those choices than has previously taken place.

Summary

The goal of this chapter was to present an analysis of location theory showing its roots in economic analysis and the main trends in its developments. The general characteristics of existing theories were developed as were the inherent limitations of these theories. Following these sections a reformulation of location theory was suggested which relies on individual choice but within a social context. The importance of other factors than transport costs was

stressed and the inherent uncertainty of any location decision that is made in a dynamic world subject to an uncertain future was brought out.

CHAPTER IV

THE USE OF THE FLOOD PLAIN BY INDIVIDUALS

This chapter introduces the use of flood plains by individuals. To this point, location theory and decision making have been treated in an abstract manner. They are now reconsidered in the light of use of flood plains. The first part of the chapter deals with the nature of floods and flood plains, presenting necessary background information. Following this, reasons for the use of flood plains are considered, as is the nature of flood plain use. In considering these aspects the aim of the analysis is to demonstrate the forces operating on an individual in making a location decision in a flood plain.

The Nature of the Flood Problem

A definition of the flood problem is central to any consideration of flood plain use and management. The work of Gilbert White at the University of Chicago provides the seminal literature in this area. White (1949, p. 36) defines four aspects of the problem. "These are: (1) the flood hazard, (2) the environmental features of the flood plain, (3) the human occupance of the flood plain, and (4) the adjustment of human occupance to flood hazard." White provided a new approach to flood analysis emphasizing the

interaction between man and nature, particularly the response of individuals and groups to flood hazards. His initial research provided the basis for numerous papers on flood control and flood plain development by researchers at the University of Chicago and elsewhere. White (1949, p. 36-48) provides an extensive set of definitions employed by hydrologists, engineers and others dealing with flood problems. These definitions are reproduced as Appendix A and may be a useful reference for those unfamiliar with the particular terminology of flooding.

A flood may be thought of as a stream flow which exceeds the average flow to such an extent that damage occurs. This does not necessarily require that overtopping of the stream banks takes place, since damage can result from the erosive and kinetic forces of the water within the normal stream channel. In the context of this research, damage will be considered from a human perspective. Thus for damage to occur, some individual or group must perceive a loss that can be attributed to the increase in stream flow. Damage may consist of elements that do not have market prices in addition to those that do. This allows the consideration of such elements as the aesthetic impact of flooding, as well as physical destruction of human artifacts.

Flood Phases

Two phases of floods are commonly distinguished. The first is the land phase which takes place prior to the

precipitation actually entering the streams and rivers. In this first phase, precipitation accumulates on the surface of the land because the soil cannot absorb the moisture as quickly as it falls. As the soil becomes saturated, the excess moisture flows off, leading to soil erosion. The second, or channel phase, takes place when the water enters the streams and rivers of the watershed. This is the phase most commonly associated with floods, as it is the most apparent. As the surface runoff increases, the volume and flow rate of the stream increase. This leads to an accumulation of water in the normal river channel and if the accumulation is large enough to exhaust the channel capacity the river overtops the banks and spills into the flood plain. It is at this stage that the river has its greatest impact on human settlement since it is now occupying land that is normally dry.

Damage prior to the point where the river overtops its banks is confined to the channel. Such damage consists of erosion of stream banks, disruption of navigation, impairment of water quality and damage to structures occupying the channel. This type of damage may be thought of as an increase in the normal effects of the river, not as something peculiar to flooding. By contrast when the river overflows its banks it creates damages that are of a different nature since water is now found where it is normally not expected to be.

Flood Probabilities

Floods are generally characterized according to their expected frequency in terms of historical observations. A hundred year flood is a flood of a magnitude that can be expected on the average, every hundred years. Thus, a hundred year flood can be expected to occur with probability .01 in any given year, if an objective probability framework is employed. Similarly, a ten year flood, which is of smaller magnitude, can be expected to occur with .10 probability in any particular year if the same analysis is employed.

Problems with Flood Classification Schemes

There are some severe problems with this form of classification scheme. The most notable being that there is the implicit use of an objective probability framework without the essential conditions of that framework being satisfied. In Chapter 2, the necessary assumptions of the objective school of probability were presented. They included the requirement of replicability. Floods, especially those of great magnitude, fail to meet this requirement. Any flood is the result of a particular set of events that distinguish it, often in a non-trivial way, from other floods. Particularly, meteorological conditions in association with a given stage of development of the river basin and seasonal variations result in each flood having some unique attributes. The greater the elapsed time between floods of equal magnitude the more these circumstances are peculiar to a particular

flood. Since, as will be discussed below, it is the infrequent floods of large magnitude that are most interesting for the purpose of this thesis, this is an important distinction.

Further, the impact of the flood in terms of its effects on individuals, singularly and collectively, is to an important extent dependent on both the time of the flood and the historical events that preceded the flood. Thus, two hundred year floods, even with the same physical attributes, would have very different impacts on man depending on the point in time when they occurred. An area that has already been devastated and not rebuilt and is again flooded differs significantly from an area where sufficient time has passed for reconstruction to take place.

Floods may also be defined in terms of the physical extent of the flooding; that is the high water mark. Such a characteristic ignores two essential elements that are crucial to an understanding of the flood problem. They are; differences in the causes of the flood, and differences in the effects. By focusing on the physical extent of the water a false concept of the flood problem has been established. This reliance on single variable measure of floods has resulted in the attribution of a degree of replicability to flood hazards that has resulted in a failure to comprehend the true nature of the problem of optimal social development of the flood plain.

Concentration on the area inundated as a measure of flooding disguises the essential differences of floods both in terms of their causes and their effects. It results in the creation of static solutions to what is essentially a dynamic problem. The failure is not one of ignoring history and the lessons to be learned from it but one of attributing too much faith in history repeating itself. The lesson to be learned is that, although on a superficial level regularities can be detected, the essential features of each event are different enough that an adaptive response is needed if human adjustment to floods is to be channelled in a better direction.

Adaptive Behavior by Individuals

If the objective probability framework is an inadequate tool for the analysis of flood problems and is employed only as a result of attributing a greater degree of replicability to floods than is appropriate, then some other means of analysis must be developed. In order to facilitate the development of such an analysis, a further distinction in the nature of floods will be employed. Several researchers have noted that the floods that cause the greatest disruption of human activity are relatively infrequent (White, 1961, p. 46-58 and p. 91, and Kates, 1962, p. 136). When floods of a particular magnitude are common events, human response adapts itself to minimize the adverse impacts of the flood. This adaptation may involve changing the nature of use of the flood plain or

modifying the flood but in either case the effects of the flood are taken into consideration in the planning process. For more infrequent floods the adaptive process is not as affective.

Individual Perception of Flood Hazard

There are several reasonable explanations for the variations in individual behavior which will provide a basis for further investigation of the use of flood plains. A first explanation is the absence of information about the possibility of flooding. This lack of information can be attributed to complete ignorance on the part of the residents, or to insufficient information to make a judgment. A second cause is the difficulty of dealing with a flood of great magnitude, both in terms of adjusting uses or in controlling the flood. A third reason is the inherent nature of individuals to discount future events, especially those with a low expectation. Even when the individual possesses information about the relative frequencies of floods of different magnitudes the larger magnitude floods may be discounted to a very small net present value. One further factor that may influence individual choice is the provision of disaster aid. The frequency of an event partially determines charitable responses to victims. For infrequent floods the victims are eligible for disaster assistance from other members of society since they are victims of what appears to be a random act of God. For more frequent events this aid is

not forthcoming as the individuals subject to the event are assumed to have made a conscious choice on the basis of adequate information to come up with a well defined solution.

Individual and Social Response to Flood Hazard

The effect of these explanations is to create divergences between individuals and social administrators over the optimal response to flood hazards for relatively infrequent floods. For the more common floods which have a greater frequency and smaller magnitude there is a greater degree of compatibility between the two as to the appropriate response to the problem.

Individuals and Subjective Probability

The thrust of the argument to this point has been the inappropriate application of objective measures of probability. Some concept of probability is necessary as a replacement. The natural replacement would seem to be a subjective concept which allows the individual to adapt to changing levels of information and to form decisions in a world where events are not replicable. The next stage of the analysis is to introduce the subjective probability framework developed earlier into the location decision of an individual in a flood plain. In order to do this a concept of individual decision making will be introduced at this point.

Individual Choice Model

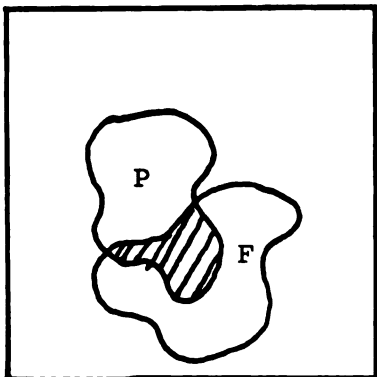
There are two relevant aspects to any problem of individual choice. They will be referred to as the set of

feasible choices, which are those choices actually available to the individual; and the set of perceived choices, which are those choices the individual believes are available. In a set theoretic framework, these two spaces can be thought of as intersecting and the intersection is the relevant decision space. Each set arises from different circumstances. The set of feasible choices is the result of the rules of the environment and hence is exogenous to the decision process, limiting the available options. This environment encompasses both social and natural constraints. As examples at a point in time zoning laws provide a social constraint on individual actions. Similarly the topography of the flood plain is an example of a physical phenomenon that influences the set of feasible choices.

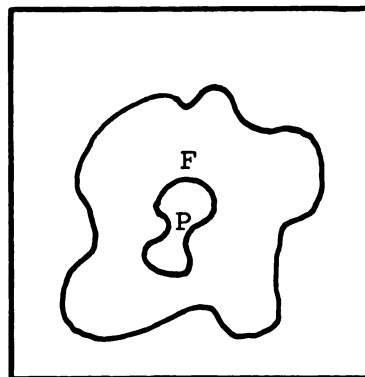
Although the set of feasible choices is fixed at any point in time, it is not in general the relevant set for individual decision making. Because information is costly and at times inaccurate, the individual develops a set of what will be termed perceived choices. These choices are formed from available information and are updated as new information becomes available. The set of perceived choices may be a wholly contained subset of the set of feasible choices but it may also contain elements that are not feasible. The possibility of the inclusion of infeasible choices in the perceived choice set is the reason for considering the relevant decision space to be the intersection of the two sets.

As an example, the individual locating in a flood plain must form some perception of the likelihood of a flood of a particular magnitude. The set of feasible choices in this case is determined by the nature of the river and its watershed, climatological factors, the stage of development of the basin and other environmental factors. In this case a great portion of the set of feasible choices is likely to be unknown to the individual. The individual does not possess objective knowledge of the true distribution of floods for the particular area since it is impossible to acquire all the relevant information. Instead the individual has a set of perceived choices of probabilities of flooding based on the information that is available and an evaluation of that information. These perceived choices will have a greater or smaller intersection set, with the set of feasible choices, depending on the extent and accuracy of the information available to the individual and that person's ability to assimilate the information and draw the appropriate conclusion. Figure 4-1 provides a graphic illustration of possible cases.

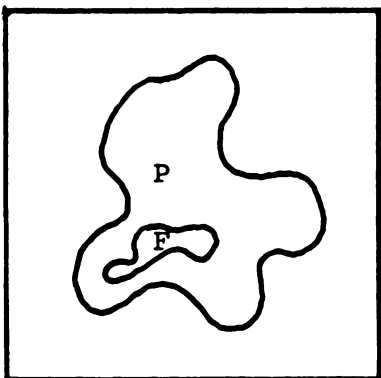
The analogy of a filter can also be employed to describe the phenomenon. The individual may be thought of as viewing the possible states of nature through a filter of perceptions which may provide a distorted image or block out certain alternatives. The filter may be thought of as being determined by the individual's tastes and preferences. Such factors as, attitude to risk or a belief in the necessity of particular outcomes can result in a filtering out of a large



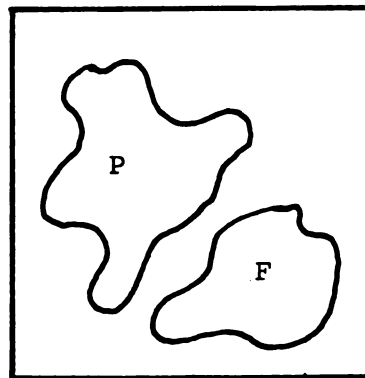
Intersection of the set of Feasible and Perceived Choices - only points in the intersection set are admissible solutions.



Perceived Choices as a Wholly Contained Subset of Feasible Choices - all perceived choices are admissible solutions.



Feasible Choices as a Wholly Contained Subset of Perceived Choices - only the perceived choices which the feasible set are admissible intersect.



Non-Intersecting Perceived and Feasible Choices - there are no admissible solutions.

Figure IV-1

Venn Diagrams Illustrating Feasible
Choice Set Intersections

subset of alternatives. The final result of the process is a set of outcomes which the individual employs in making the decision. If the individual attempts to implement an infeasible option, the result is failure. If a state of nature occurs that is not in the intersection of the feasible and perceived sets, the individual's choice process is irrelevant. Only if the individual selects an element from the intersection set has the decision exercise been meaningful.

When the individual's set of perceived choices is small relative to the set of feasible choices, there is great potential for the individual to make a decision that will result in an unfulfilled end. Thus in order for the individual to make choices that are likely to be fulfilled, two conditions are necessary. There must be no elements in the perceived set of choices that are not in the feasible set and the intersection of the feasible and perceived sets must contain a large amount of the feasible set.

The Role of the Slanting Factor

The slanting factor introduced by Fellner is a measure of the degree to which these conditions are satisfied. If the slanting factor is small, the individual believes that the perceived set and the feasible set are equivalent. When the slanting factor is large, the degree of intersection or covering is small.

In the flooding problem short run information is both more available and more reliable than for the longer time

periods and so short term decisions are more likely to result in fulfilled expectations. Individual evaluation of frequent floods is likely to result in the vast majority of individuals reaching the same conclusion as to the appropriate action. For less frequent floods as information and perceptions begin to differ radically for different individuals so does the nature of their actions. This results in a lack of consensus on the appropriate level and type of development for the flood plain.

The Impact of Flood Plain Use on
Non-Flood Plain Residents

In addition to the individuals actually considering a flood plain as a location site, it is necessary to also incorporate two other groups into the analysis. Others not residing in flood plains also are affected by the level and type of use of the flood plain. In some instances the impacts are direct while at other times they are indirect. The magnitude of the interaction also varies from slight to significant. The primary group that is affected will be termed society and is composed of both flood plain residents and all other individuals. The individual interests of those residing within the flood plain and those outside it must be aggregated in a manner that resolves each group's particular interests to bring about a "socially acceptable consensus." Although a particular use of the flood plain may impose costs on either the residents or nonresidents, there are limits to these costs. One group or the other

will refuse to participate if the perceived costs are too high. Consequently any use of the flood plain must be one that both residents and nonresidents can tolerate.

The nature of this process is described below in detail. For now it will be sufficient to note that the primary focus of attention and forum for discussion is the interface between government and individual residents. It is at this level that conflicts of interest become most apparent and that the major struggles over flood plain use occur. Government regulations and directions ostensibly designed to protect society's interests are challenged both by users of the flood plain as being preemptive of individual rights and by residents of areas outside the flood plain as being a means of providing subsidies for flood plain development. The interests of the two groups are often perceived as being directly opposed. In this case, any attempt at resolution will lead to the dissatisfaction of at least one group. In other words there are no Pareto-better movements possible.

Individual Location Decisions in Flood Plains

Prior to an analysis of the validity of the preceding statement, an understanding of the reasons why flood plains are developed must be acquired. A standard assumption of economics is that individuals act in a manner consistent with their perceived self interest. This is often expressed in a simple manner by stating that individuals behave rationally. When the time comes, however, to deal with actual

behavior the assumption of rationality can easily degenerate into the tautology that all individual behavior is rational because that is what the individual did. If there is to be any hope of developing a predictive analysis of individual choice, some means of determining how the individual goes about the selection process among different alternatives must be found. The classical assumptions of economics in this case are that an individual maximizes utility while a firm maximizes profit. The case of the individual is more interesting and more difficult than the firm since in the former case the objective function has multiple arguments while in the latter there is a single common denominator that permits optimization over a single variable. Location analysis that employs a cost minimizing framework lacks the richness of the utility maximizing model although it does have the advantage of a greater potential for empirical analysis.

If self interest is to be employed as a motive in dealing with flood plain use, then there must be advantages to a location in a flood plain that offset the use of an alternative site that is not subject to flood hazard. Clearly an individual given a choice between two sites, identical in all respects except that one is subject to flooding, will choose the one without the flood danger under any non-pathological decision rule.

Historical Patterns

In terms of the historical development of various civilizations, a common facet is the tendency of populations to cluster on the banks of rivers. Numerous reasons for this phenomenon may be distinguished. Among them are the presence of the river which acts as a source of water for human use, a means of disposing of wastes, a transportation system and an input in the industrial process. The river also acts as an impediment to land travel often necessitating that a bridge or ferry be constructed to allow land transportation to take place. In such cases urban concentrations are likely to develop to service the travellers and maintain the bridge or ferry. Once an urban area has been established it has a tendency to grow. This growth pressure can lead to development of the flood plain when other more desirable sites are fully developed. However this pattern is not necessarily followed. White, (1964, p. 19) in a study of the adjustment patterns of several cities in the United States, observed that in some cases initial settlement took place in the flood plain. This initial development was in some instances followed by relocation at a less flood prone site but in other cases the threat of floods provided a stimulus to provide some type of protection. This indicates that urban development in a flood plain does not follow a single specific pattern but must be considered in terms of a number of factors. To conclude that development moves into a flood plain at a latter stage may reflect the general pattern

but there are sufficient counter examples to require a more detailed explanation employing other influences in addition to flood hazard, if the true nature of flood plain development is to be understood.

Urban development within flood plains is a phenomenon common to all civilizations throughout history. In 1958 a survey of urban flooding problems in the United States found that there were more than 1,020 places, with a population exceeding 1000 people, having significant flooding problems (White, 1958, p. 33). This provides an indication of the magnitude of the problem. Given the historical growth of flooding damage and the increase in size of urban areas, it is reasonable to assume that flooding problems are at least as pervasive today despite the vast expenditures on flood protection of the last twenty years.

Urban Flood Plains

Two broad classes of urban land use may be distinguished. They are commercial use which encompasses manufacturing and service industries, and residential use. To a great extent these uses are jointly determined, for residential development tends to follow job availability, while much commercial activity springs up to service residents of the area. One theory of urban development is as a form of growth machine. The development of the area is considered to be self sustaining once a critical level has been reached. This is often referred to as "growth pole" theory.

The factors influencing commercial development of a flood plain can be assessed in terms of the traditional analysis of economic geography. The river provides a source of transport services and a source of process water used in manufacturing directly or indirectly. It also provides a means of waste disposal. In addition, construction costs may be lower; in part because of the flatter terrain, and in part due to a lower site price which results from the presence of the flood hazard. Traditional location theory with its emphasis on transport cost minimization also provides another rationale for flood plain development. Given the fact that urban places develop on the river those industries where the final product gains weight will tend to locate as close as possible to the market. In summary, the forces attracting an industry to flood plains may be classified as transportation related, process related and site cost related.

Locational Costs of Floods

In making a location choice an industry balances expected costs and benefits of various sites to determine which site has the highest net benefit. In a flood plain one of the costs that must be considered is the expected damage from flooding. The expected damage from flooding is a function of a number of variables. These include; the distance of the site from the river, the frequency of flooding, the timing of the flood, the nature of the activity, the availability of flood protection, and the distribution of the burden of

costs of flooding. In determining expected damages from flooding the simplifying assumption will be made that the individual is choosing among sites on a homogeneous flood plain where the land market operates in a manner that discounts land closer to the river in that it has a higher flood hazard. For the moment, transportation costs and location advantages are ignored in order to establish the nature of the discounting procedure for flood hazards.

Given the nature of floods, land further from the river is less susceptible to flooding in general and experiences lower water levels during a flood. Damage is a function of both the frequency and magnitude of flooding and of its timing. Following the accepted procedures of economic analysis, the rational individual will attempt to determine that location which maximizes expected net benefits. Since costs depend on the state of nature that prevails and benefits are being held constant, the problem reduces to one of cost minimization.

For each site the individual may be thought of as preparing an evaluation of the probability of floods of different magnitude. The nature of this computation has been discussed above. At this point it is sufficient to note the subjective nature of the process. Floods of different magnitudes can be thought of as causing different levels of damage given a particular site. Thus for some given site a ten-year flood may be expected to cause x dollars in damage while a fifty year

flood causes y dollars, where x is less than or equal to y .¹ Floods of a magnitude insufficient to cause total destruction will be more common the further the site is from the river. In other words, the closer the site is to the river the more likely a flood of a particular magnitude is to cause a greater degree of damage.

As noted above, the timing of the flood hazard is important in determining damage, as is the nature of the activity. Given a project with a finite life time, the later the flood occurs within that lifetime the lower the level of damage that will be associated with the flood. This results from the fact that benefits may be expected to accrue over the life of the activity while a major portion of the costs are likely to be experienced at the beginning of the life span. Thus a flood occurring early in the life span will destroy the investment prior to the recovery of a significant portion of the stream of income. Conversely, a flooding occurring late in the life of an investment will not result in as great a loss since the great proportion of the "sunk costs" have been recovered. Thus, one would expect that projects with long useful lives and high initial costs will be found further from the river than other activities,

¹A strict inequality is inappropriate since at some stage total destruction occurs. When a flood of sufficient magnitude to completely destroy the site is experienced, damage reaches a maximum value for the individual and any flood of greater magnitude will only produce equivalent damage at the given site.

given the simplifying assumptions of the model.

For any particular activity at any given site the individual can construct an expected loss function. This function is composed by weighting the damage associated with a flood of a given magnitude by the probability associated with that flood. In order to incorporate the effect of time, the damage function must discount the investment as time progresses. This requires that the loss function be of a dynamic nature reflecting the changing conditions that accompany the passing of time. When this process has been completed, the individual is in possession of a vector of expected costs for a particular activity at various points in space. From this point, it is a simple matter of applying the basic land allocational model of von Thunen to determine the exact dispersion of the various activities, according to their costs and revenues.²

This simplified model isolates the costs associated with flooding and provides a methodology for incorporating their effects in a rational decision making framework. Clearly, however, the analysis must be applicable to more complex situations which are closer approximations to reality if it is to be useful. As has been noted previously, in addition to the increased probability of flooding associated with closer proximity to the river there are positive forces leading to incentives to occupy river front sites. The effect

²For an example of a dynamic programming solution to this problem, see the work of J. P. Brown.

of these attractive forces is to offset the costs of flood damage. By incorporating the positive features of flood plain location into the analysis, a conceptually richer analysis can be developed providing a more realistic picture of actual events.

Attraction Forces

In addition to the behavioral processes of the individual, such as attitude to risk, and the physical nature of the environment, there are also social or institutional elements which condition location choices. The provision of services such as sewers, roads, rail lines and other social infrastructure determines feasible location choices. Also the legal framework such as building codes and zoning ordinances establishes the direction and nature of flood plain development. Indeed it is through these instruments that society influences the use of the flood plain; either consciously or inadvertently. The nature of these influences will be developed more fully in another chapter.

To this point the analysis has not considered residential development, but has relied primarily on commercial use of flood plains. When dealing with commercial use of flood plains, it is possible to couch the analysis in terms of monetary values alone with a reasonable expectation that the analysis will adequately reflect the behavior of firms. Such a framework is less applicable to the decisions of an individual consumer acquiring a residence. Although monetary costs

associated with flooding are clearly a significant element in the individual's decision, there is also an important class of nonpecuniary influences.

Traditional economic analysis of residential location theory has focused on travel costs as the primary explanation of housing choice. Much of this research is descriptive, employing geometrical models based on variations of the concentric circle development pattern first applied to urban areas by Burgess in 1925.³ For the most part, the literature abstracts from irregularities, which disrupt the development pattern, in order to obtain generalization about location choices. The purpose of this piece of research demands that location decisions be analyzed in a context where irregularities dominate the regular locational determining factors.

What then is the effect of the flood plain on residential development patterns? To a great extent, this will depend on the development pattern of the remainder of the city; whether the flood plain was an integral part of the initial settlement or whether it was an area developed at a later date. Hoyt, in a survey of seventy cities, developed a number of principles of residential development. One of these was that high rent housing develops away from flood prone areas but toward lakes, bays and rivers if industry is not found there (Loewenstein, p. 103). Upon closer analysis this finding appears paradoxical; for it is the land bordering the

³See Louis K. Loewenstein, p. 99-100, for a survey of the basic research on urban residential location patterns.

lakes, bays and rivers that are the areas most susceptible to flooding, yet these lands are also the most desirable for residential development. The resolution of the paradox is quite simple if probabilities of flooding are introduced. Although land bordering rivers may be thought of as being susceptible to flooding, there are major variations in the level of susceptibility, resulting from variations in the stage of development or age of the river and other natural features of the river basin.

The city that initially developed on the flood plain will have either adapted to its environment or modified that environment. The nature of these changes is the subject of a later chapter. For now the only adaptations to be considered are those related to residential uses. Residential use of flood plains involves housing of varying qualities. It is not possible to exclusively associate either high quality or low quality housing with flood plains. The nature of the housing that is found in a particular flood plain is more closely related to the age of the housing and the proximity to the urban core. Housing in flood plains is similar to housing in other areas. Older urban homes are generally low quality housing as a result of the suburban movement of the post war period.

Flood hazard doubtless contributes to this decay process. The presence of flood hazard reduces incentives to maintain housing particularly where it is not owner occupied. The form of tenure within the flood plain is a variable that

may be of considerable interest in explaining adjustment patterns. An investigation of the relationship between housing quality and tenure form in flood plains could provide information describing the extent to which rental housing is found in flood plains. A priori one would expect low quality housing in flood plains to be primarily rental. In the absence of major urban renewal projects, which would require flood control projects, the use of urban flood plains for low quality housing is likely to remain. If the area is converted to open space, additional housing must be created elsewhere. A major advantage of an urban area is its proximity to service employment and public transportation. Both these factors are crucial for the urban poor who lack both private transportation and the skills required by the manufacturing sector of the economy.

Residential development that is just starting to spread into the flood plain from an urban area that is flood free can be expected to exhibit different characteristics. A common theme of urban development literature is that higher income areas are found on the fringe of the city. If the city is pushing into the flood plain, then it is possible that high quality housing may be found in areas susceptible to flooding, particularly when the area has a high aesthetic value and the flood hazard is not high. Where a flood hazard is recognized, the response in this case may be pressure for flood control or design of homes to minimize flood damage.

The thesis developed in the preceding section is that residential use of a flood plain follows two patterns, depending on the initial development site of the urban area. If the city initially developed on the flood plain social and economic forces operating in the housing sector will convert the flood plain zone into low income housing. This is the trickling down effect of housing that deteriorates as it ages, On the other hand, if the flood plain is occupied at a later stage in the development of the city, the housing will be found to be of high quality. Of course these are only general principles not rigorous rules, and counter examples are readily found.

If the thesis is true, then interesting issues involving interests and power arise. The poorer area may well be abandoned by the remainder of society and forced to fend for itself with minimal aid; primarily in the form of disaster relief, while the richer area receives assistance in the form of flood control structures. This pattern would be expected for several reasons. In the first place wealthy individuals have both the time, money and knowledge to ensure that their particular interests are served. Secondly, in terms of social investment, there is likely to be a greater concentration of wealth, held both privately and collectively, in richer areas leading society to take greater efforts to protect it.

For the individual, at a point in time, the choice of a residence is conditioned by a multitude of factors

including income, available choices, personal tastes, and in the case of a residence in a flood plain, attitude to risk. If the assumption is made that the individual is aware that the residence is subject to potential flood damage, then he must evaluate the expected net benefits of that site. If the individual then locates at a site in the flood plain, it is because this site is perceived as the best alternative available.

A major problem results from defining a flood in terms of a level of water at which damage begins when the development of a flood plain is being considered. As development takes place, a particular depth of water may cause flood damage although in previous times no damage would have occurred. This makes the characterization of the uses of a flood plain a difficult procedure as the actual uses will be determined by topography, the level of urbanization and the flood hazard.

In terms of flood frequency, areas that are subject to frequent flooding will exhibit development patterns that result in minimal flood damage, either as a result of making limited use of the flood plain or of using it for activities with a high tolerance for flooding.

In a homogeneous flood plain a development pattern would be expected which results in low value, short lifetime uses close to the river and in high value, long lived uses further back from the river. The presence of site specific attributes or the necessity of an activity taking place close to the river may disrupt this pattern.

Rural Flood Plains

To this point, only urban uses of the flood plain have been considered. Agricultural use of flood plains has an important impact both in terms of the effects on the individual farmer and on the watershed as a whole. As noted previously, there are two phases to a flood; the land phase and the channel phase. The land phase, prior to the water entering a stream is of great concern to farmers. Proper cultivation practices can not only reduce the flooding hazard by allowing greater infiltration, but also reduce the costs of erosion and crop damage to the farmer. Land in flood plains is often of greater fertility than surrounding acreage as a result of the periodic deposition of new soil by the flood waters. It may also be easier to cultivate, being flatter than the surrounding land. This supposes no major differences in soil types. In areas where flooding is a seasonal problem and drought is also common, a site near the river has the advantage of yearly floods to replace soil moisture and also lower irrigation costs since it is close to a ready source of water. For these reasons land in flood plains has some distinct advantages for agricultural purposes. Clearly these advantages are offset by the possibility of crop damage and a weighing of costs and benefits of different locations must be carried out by the rural land holder just as in the urban case.

Although urban flood damage is more spectacular and extensive than rural damage when a single flood is considered,

the frequency of flood hazard is greater in most rural areas. In general, rural areas lack all but the most rudimentary flood control devices. Agricultural land is particularly susceptible to flood damage since a flat river basin, although well suited to cultivation, has greater flood problems.

Summary

This chapter presented background information relating to the problem of flood hazard to individual location choice. Following a brief development of the physical concepts associated with floods, a methodology based on adaptive behavior of individuals was presented. The essence of this methodology is the fact that the individual is forced to make choices in an uncertain world. To a great extent this uncertainty is a result of information deficiencies with respect to past, present and future events. Although it is possible to provide information about the past and present, there still remains the uncertainty associated with the future. One way the individual takes into account this information problem is through the use of a slanting factor which measures the perceived stability of assigned probabilities.

The distinction between individual and social evaluation of uncertain events is brought out in the context of a criticism of the method of assigning flood probabilities. It is argued that flood probabilities as they are currently

formulated are of limited value in evaluating individual behavior.

The use of the flood plain has impacts on more than those residing on it. There are indirect impacts on the rest of society. The problem is introduced but detailed analysis of it takes place in the following chapter. An analysis of flood plain development is carried out which points out that development of flood plains can take place at various stages in the urban development process depending on the nature of the urban place and the flood plain. Since flooding imposes significant costs on individuals and society, an analysis of these costs is required. Given the existence of costs associated with flood plain locations there must be offsetting benefits for the individual if flood plains are to be developed and rebuilt in the event of flooding. The principal weakness of the literature dealing with flood plain use has been a failure to adequately analyze the benefits associated with such use. The failure to develop such an analysis is a major reason why past flood plain management programs have performed inadequately. To this point the analysis has been in terms of urban and suburban flood hazard. In a final section rural flood plains are considered. Appendix A consists of a glossary of terms commonly employed in works on flooding problems. Appendix B consists of a conceptual framework of the individual location decision presented in an abstract notation that emphasizes the crucial relationships in the process.

CHAPTER V

THE RELATIONSHIP BETWEEN SOCIAL AND PRIVATE CHOICE IN THE FLOOD PLAIN

This chapter deals with the conflict between the individual and society in the context of the degree and type of development that should take place in the flood plain. It is this issue that is often the focal point in considerations of past experiences and in flood plains. A common sentiment in much of the literature is that residents of flood plains are subsidized by the remainder of society; consequently excessive development of flood plains takes place. The range of opinion on this issue varies from demands for prohibition of building on flood plains (Wilson, p. 31) to a point of view which is critical of the means employed to accomplish social goals (United States Water Resources Council, p. II-6). In each case emphasis is placed on the transfer of benefits to flood plain residents from non-residents. The principal vehicles for this transfer are structural flood control devices such as dams, levees and other constructs. The reasons why individuals may choose to settle in flood plains are not deeply investigated. It often appears that the provision of flood control benefits at less than their cost is a sufficient reason to attract flood plain development.

The Partitioning of Society

In dealing with the conflict between private and social interests it is useful to separate the participants into three groups. The first is society as a whole consisting of all members of the particular political unit in question. This aggregate can then be divided into two interest groups - those who live in a flood plain and those who don't. This latter distinction is made on the grounds that those who inhabit a flood plain have a direct interest in what happens in that flood plain while others have but a secondary or indirect interest. Further the values held by the two groups with respect to the optimal development pattern are also different. Consequently, both the incentives and desired outcomes are different for the two classes.

As an aid in understanding the conflict resolution process an individualistic approach is employed where the role of the group is to prohibit or encourage particular acts by the individual. The individual exists in a world of constraints and incentives some of which are the result of actions taken by the administrative, legislative or judicial branches of various governments. It is this particular class of impacts that is the subject of this chapter. While this thesis is not intended to be an exercise in the analysis of public choice, it is impossible to ignore the implications of that particular approach to economic problems. The approach employed in this analysis follows the traditions of

economics, in that the individual is the focus of attention. This methodological individualistic approach has been the basis of most economic analysis. Where the notion of public choice is employed it is as a reinforcing influence on the individual, not as an independent approach. Clearly an analysis focusing on group conflicts per se, could also be undertaken, but to incorporate such an analysis in this work would be inconsistent with the basic philosophy adopted, which is to start at the bottom with the individual rather than at the top with the government.

In some manner a set of desirable outcomes or objectives are assumed to be determined by public agencies charged with administering and developing social welfare. Along with these objectives the agencies also have a set of tools; such as a regulatory power, power to spend, and power to certify, to name a few, which are employed in working toward these objectives. It is the effect or impact that these regulations have on the individual, in particular in the case of flood plain management that is to be analyzed.

Goals of the U. S. Water Resources Council

The goals of the United States Water Resources Council as set forth in A Unified National Program for Flood Plain Management (p. III-2) for a sound management scheme are:

- a. The goals of wise use, conservation, development, and utilization of interrelated land and water resources to serve objectives of economic efficiency environmental quality, and social well-being as consonant with responsibilities assigned to respective levels of

government by law.

- b. Future needs and the role of the flood plain in the context of both the physical and socio-economic systems of which it is a part. An image of the expected and desired future is prerequisite to appropriate selection of implementing means and tools.
- c. All alternative strategies for alleviating floor losses evaluated individually and in combination for modifying (1) the characteristics of flooding, (2) the susceptibility of people and their property to flood damage, and (3) consequences of flooding for the individual, the community, and the Nation.
- d. Accounting for (1) public and private, economic, social, and environmental benefits and costs, and (2) interrelated impacts that are likely to result from actions taken both within and outside the jurisdiction of local governmental units--for example, hydrologic land-water environment, technological, economic, legal, and social impacts.
- e. Motivation of decisionmaking individuals, through use of positive and negative incentives, using such management tools as insurance and tax rates, grants withheld, cost sharing ratios, and standards for manmade or altered improvements to prevent increasing a flood hazard.
- f. Coordination of (1) agency programs at and among all levels of government, (2) agencies charged with regulation (monitoring the actions of public and private decisionmakers for conformance with prescribed standards) and those charged with planning (evaluation and selection among alternative courses of action within the context of goals and priorities), (3) agencies charged with different functional areas of flood plain management such as water quality and water supply, (4) agencies charged with predisaster and post-disaster responsibilities, and (5) agency program elements for citizen participation.
- g. Evaluation of the flood plain management effort through a continuous program of monitoring and periodic reporting to the public.

This represents a comprehensive overview of the requirements for a truly effective management scheme which achieves a given task with the most efficient methods. In other words, the preceding statements represent a set of general goals or principles which can be termed a strategy.

The Structural Solution

In the past, flood plain management methods have concentrated on structural solutions to flood problems; attempting to confine the flood to a specific area or to contain flood waters behind dams. Such a strategy has generally required large expensive projects that are financed out of general tax revenues. Conflicts over the desirability of such a strategy have raged for decades. Some notable examples of the early literature are the works of Leopold and Maddock, Leuchtenburg, and Hoyt and Langbein all of whom criticize excessive concentration on structural measures as a solution to the flood problem. A principle argument of the critics of structural measures and indeed of all those opposing flood plain development, is that society is providing subsidies for flood plain residents in the form of flood control devices and also in terms of aid in the case of flood recovery assistance. Such expenditure on protection and aid is held to be a misallocation of resources that induces a suboptimal location pattern.

The essence of the argument is that the provision of flood control devices results in individuals forming expectations that the protected area is free from flood hazard, which

leads to increased development since the costs of location are reduced by the removal of the flood hazard discounting factor. A problem arises in that the level of protection provided is sufficient to control only floods of less than some given magnitude. Should a greater than project flood occur the area will be inundated, destroying all the development. In many instances, the level of protection provided is determined by the value of the area at the time of the construction of the project. Thus, a flood plain having development of value x million dollars, say, would justify an expenditure of some amount which would contain some flood of given magnitude. If the creation of the control structure induces additional development as a result of individuals forming expectations that the area is free from flood hazard, so that the value of the area becomes $3x$ million dollars, a more comprehensive control structure would be justifiable. This argument can clearly degenerate into an infinite regression with each expenditure on flood protection inducing additional investment which in turn justifies further expenditure on protection. The limiting factor is the cost of relocating all flood plain activity outside the flood plain. However, such a relocation scheme although superficially appealing, has significant problems. Not only may there be no relatively close substitutes for the land in the flood plain, which means that the direct relocation costs will be great, but in addition there are secondary displacement costs that must also be considered. Should flood plains be abandoned

their former residents must displace residents of other sites who in turn displace other residents in a ripple effect. The costs of these secondary disruptions and relocations may, in the case of non-marginal adjustments, be of sufficient magnitude that the total cost of abandoning development of the flood plain is prohibitive. Thus it is important that these indirect displacement effects be taken into consideration.

Decisions that are taken to alter the use or development of the flood plain impact on those outside the flood plain. It is for this reason that the interests of both residents and non-residents must be considered separately.

A Defense of Structural Methods

The argument that individuals occupying flood plains having structural protection are reaping an undeserved subsidy is not particularly valid and can be criticized on several grounds. In the first place such an argument ignores all but a narrowly defined set of economic variables. Only priced variables are allowed and a narrow interpretation of human motivation is adopted. Only in the case of a narrow calculating economic man for whom relative prices are the only decision criterion would such a criticism be valid. Suppose, however, such a caricature of humanity is a reasonable approximation to reality. Even then it is not clear that such subsidies can be criticized. In an imperfectly competitive world the "second best theorem" shows that increasing the competitive nature of one sector may lead to a

decline in social welfare. Thus once again it is not possible to conclude that the subsidy is bad. Further if a competitive structure is assumed, the presence of transfer payments is not inconsistent. In a world where time and uncertainty are relevant variables the provision of dams and other structural protection can be thought of as a form of social insurance. As a clarifying example consider land that may be flooded one year out of ten. If no protection is provided the land may not be used and society will forego the net benefits from employing that particular site. Provision of protection ensures that society obtains the benefits for all years. Thus the cost of the protection may be offset by the gain in welfare from development. Thus it is again not clear that subsidized flood control measures are inappropriate.

Although the example chosen for the preceding analysis was structural protective devices, the same arguments hold for disaster relief and warning systems. When the question of multiple use is introduced, the analysis becomes even more complex since costs and benefits have to be allocated fairly to every individual use. Such a partitioning scheme is at best rudimentary since in many instances the quantity and quality of the services provided cannot be adequately defined.

The Conflict of Interests Between the Residents and Non-Residents

To this point, the analysis of the chapter has dealt with the problem of subsidies in flood plain management

schemes. It has been shown that the existence of subsidies is not an undesirable phenomenon per se, but the result of a complex set of arrangements by the participants. The question that springs from the above analysis is that if the existence of subsidies can be shown to be a desirable phenomenon, at least in some instances, how can the persistence of the argument for the elimination of subsidies be explained?

As an initial reason the presence of self interest provides a ready explanation. Individuals outside the flood plain, although seemingly expressing an aversion to subsidizing flood plain residents may in fact be expressing a desire for flood plain residents to carry more than a fair share of the costs.

By this action residents of areas outside the flood plain are able to reap unearned benefits from flood plain occupants while at the same time making the argument for a redistribution of costs appear to be an argument for an inefficient allocation of resources. This may explain the conflict between residents and non-residents but there is still the conflict between the individual and society as a whole to be considered.

A significant portion of this latter conflict can be attributed to the differing nature of the treatment of uncertainty discussed in a preceding chapter. Members of public agencies charged with administering the public interest have a different perspective on the process of evaluating uncertain events than do the individuals directly concerned. When

this is coupled with differing time horizons and differing discount rates the existence of a conflict over perceived optimal use is easily understood.

Members of public agencies commonly adopt an objective or frequency view of probability. This point of view is a result of the larger focus of attention and the repetitive nature of the decision process. Public organizations such as federal agencies deal with problems from a national perspective. This means that they deal with all river basins not just an individual reach. Further such an agency has a different time perspective than the individual. For the agency, floods are repetitive events and no single flood takes on the importance that an individual attaches to a particular flood. Given a different methodological approach to the problem of evaluating an uncertain event and a different objective function it is hardly surprising that government agencies arrive at different conclusions about the optimal degree of development of flood plains than do individuals.

Having demonstrated that this is a real conflict where each position can be seen to reflect a consistent and rational behavior pattern for the particular individual or group, what else can be said? Ideally some means of reconciling the two points of view would exist. This ideal seems to be unachievable even in principle. When the possibility of collective action is introduced the potential for compatibility is increased but not significantly. Individuals may be willing to bargain away lower level goals to attain the power and

influence of group action. The problem arises in that development patterns in the flood plain are not a low level goal for the individuals in that area. The costs and benefits associated with different uses differ significantly making it difficult for a resolution of the conflicts over use to occur.

There is often a fundamental incompatibility between the goals of the individual and the public interest that stems from the fact that society is more than a simple sum of its constituents. This aggregation problem requires that over time different approaches be employed in resolving conflicts. The appropriate approach at a particular point in time will be conditioned by the distribution of power and responsibility between individuals and groups. Different approaches to the flood plain problem that have been employed are considered in the next chapter.

Strategies and Tactics in Flood Plain Management

Given that flood plains will be managed, and that individuals do undertake some planning in their location choices, a discussion of strategies and tactics available to both managers and individuals is important.

The Distinction between Strategy and Tactics

Strategy and tactics both denote a planning situation or a conscious attempt to approach a problem using analytical tools in an attempt to resolve some difficulty. Some assumed goal is required, as is an environment about which some information is available.

Strategy is a long range process that provides a general direction for approaching the desired goal. A strategy covers the basic issues in question and provides a general plan for allocating resources over time. By its nature a strategy is designed for a particular context of goals and means but in broad terms not specifics. Thus a viable strategy must be flexible to take into consideration a wide range of possible actual outcomes.

Tactics by contrast are short term approaches to a specific problem. They consist of particular solutions to particular problems. A tactic concentrates on an isolated event and represents an attempt at resolving that situation.

Boettinger (p. 23) considers strategies as dealing with the longest time period worth considering while tactics deal with the shortest period. Although tactical solutions are designed to deal with a particular problem they may have ramifications in other areas. Thus the decision to protect a particular town by building a dam means that upstream residents will acquire a reservoir which they may or may not desire. Thus the choice of tactical responses has an impact on the success or failure of the overall strategy. One of the functions of a well designed strategy is to select a set of admissible tactics. Tactics which resolve one problem at the expense of creating new and bigger problems elsewhere should seldom be included in this set.

Management Strategies and Tactics

For flood plain managers the strategy selected is chosen with a view to optimizing the use of the flood plain from the perspective of society. Most of the literature on flood plains approaches the subject with this goal in mind. The actual strategy recommended, however, depends on the context that the problem is formulated in. Thus, the perceived benefits and goals to society of various courses of action, and the actual environment will determine the strategy employed. As noted above, strategies deal with broad generalizations such as prohibiting development in flood plains, eliminating flood hazard by using structural devices, or making individuals absorb the full costs of their actions. In each of these examples a general principle is suggested, but the actual applications of this principle are left unspecified.

The tactical portion of a management plan deals with the specific applications. Depending on the strategy selected there are varying numbers of admissible tactics. In the case where a structural strategy is specified, the tactical options are limited to various sizes and types of dams, levees and channelization projects. Similarly other strategies specify other tactics. In a tactical situation the prime consideration must be the resolution of a particular problem, but this should not require major disruptions of the overall strategy.

Individual Strategies and Tactics

For the individual, strategies are formulated at the time of selecting a particular location and activity. When the individual chooses from the set of locations and choices available, it is with a view to maximizing expected utility. Once this choice has been made, a general strategy or plan has been chosen. What remains is the day to day management of this plan and the selection of particular means to deal with problems. The repetitive nature of the choice of a particular option for recurring problems is a characteristic of tactical decisions. Tactical problems tend to reoccur over the life of the strategy. Thus for the individual the recurring threat of flooding once a location has been chosen becomes a tactical problem. The response of this problem is chosen from the set of options which might include flood proofing, flood insurance or varying the level of activity.

Individual and Management Relations

The relationship between strategy and tactics for individuals and management is complex. At one end of the spectrum is management strategy which for the most part is a given for everyone concerned. The major confusion arises over the relationship between management tactics and individual strategies. Since the time horizon of management is far longer than that of individuals, changes in management tactics will affect individual strategies. Thus the decision to build a dam will have a significant impact on those individuals

contemplating locations and activities within the area to be protected. Tactical decisions by the management body will have important impacts on the nature of individual location patterns. In addition, tactical decisions adopted by individuals are also influenced by the particular tactics chosen by managers. The individuals tactical response considers management tactics as an environmental variable in most cases, because of the differences in time horizons.

This is not to suggest that there is no influence on management by individuals. The success or failure of both management strategies and tactics depends on how individuals respond to these policies. If individuals respond in a manner unforeseen by managers, or one contrary to management objectives, the viability of both the general management strategy and the particular tactic is brought into question. This points out the necessity of determining how individuals will react to management schemes both at a strategic and tactical level if flood plain management programs are to be successful.

Summary

An introduction to the conflicts over the use and management of flood plains was the purpose of this chapter. In it a partitioning of society into occupants and non-occupants of the flood plain was employed to bring out the central conflict. This conflict has in the past been phrased in terms of a criticism of structural measures as providing undue subsidies to flood plain occupants. Consequently the nature of

this argument is presented as is a refutation of it. The conclusion of this section is that the conflicts between occupants and non-occupants, both collectively and individually, are of such a fundamental nature that their resolution may be impossible. The final portion of this chapter presents a discussion of strategies and tactics for flood plain managers and individuals. The nature of the relationship between individuals and managers in terms of strategies and tactics is outlined.

CHAPTER VI

FLOOD PLAIN MANAGEMENT METHODS

In this chapter a multi-level classification scheme for dealing with various methods of flood plain management is presented. The methodology employed classifies techniques from an individual decision maker's perspective, as this is the primary focus of this research. The impacts of various management techniques are considered with a view to influencing the behavior of the individual in a manner that is consistent with the interests of society.

The Individuals' Perspective

It is assumed that the goals of society are, in fact, appropriate so that the channeling of individual actions is in a socially desirable direction. For the individual, flood plain management strategies are environmental features not subject to private influence. The individual formulates decisions within some environment for the most part, but at times has the potential to change parts of it.

Since flood plain management schemes in the final analysis are subject to political ratification and supervision there exists an avenue for an individual with sufficient power and ability to influence the social environment in which he operates. Such ability is very rare, however, and for most residents of flood plains any change in the environment can be

thought of as being beyond individual influence. Collective action is one way that individuals go about achieving their goals and the importance of such action will be considered below. Changes in management schemes and methods like any other unpredictable change introduce an additional element of uncertainty into the individuals decision calculus, making the selection of the proper response even more complex.

Classification Schemes

Broadly speaking flood plain management methods can be divided into two major types. These are structural alternatives which deal with the flooding problem by controlling the flood itself and non-structural methods which deal with the use of the flood plain. Such a classification scheme is the one commonly employed in analysis of flood control methods.¹ For the purpose of this paper it is not a sufficiently precise taxonomy since the influence of a particular management method on the individual is not stressed.

In addition to the standard classification scheme management methods will be classified as to their impact on the individual. Thus, any measure can be seen as affecting incentives, constraints and information. Methods can also be classified according to a market or non-market orientation which provides a further measure of information about the individual's likely response. One further refinement of the

¹See White, (1949) James and Lee, and Brown as examples.

classification scheme is suggested by the work of Buchanan and Tullock in The Calculus of Consent. They employ a distinction between private goods, goods that are provided collectively through private agreement and goods that are provided by the state (Buchanan and Tullock, p. 49). The point of this distinction is that in some cases the optimal method for the provision of a public good may be through private agreement. Figure 6-1 provides an aid in visualizing this taxonomy.

Structural Measures

The historical experience of flood control measures in the United States has been documented in a number of sources. The authors are consistent in their evaluation that structural measures have been the principal techniques employed in dealing with flooding problems in the country. Consequently, the first group of techniques to be analyzed are those that are elements of structural control. As noted previously, structural controls deal with flooding problems by regulating the magnitude, and to a lesser extent, the timing of the flood. Physical constructs such as levees, dams and reservoirs, as well as channel modification are employed to contain flood waters and slow the flow rate so that the river banks are able to contain the flood discharge.

Method of Provision

The initial major experiment with flood control devices in the United States took place on the lower Mississippi

			Incentive	Constraint	Information
STRUCTURAL	State	Market			
		Non-Market			
	Private	Market			
		Non-Market			
	Collective	Market			
		Non-Market			
NON-STRUCTURAL	State	Market			
		Non-Market			
	Private	Market			
		Non-Market			
	Collective	Market			
		Non-Market			

Figure VI-1
A Classification Scheme for Flood Plain
Management Techniques

River early in the eighteenth century (James and Lee, p. 230). Plantation owners banded together in a cooperative attempt to construct a levee system to protect the land. Thus the first instance of flood control was an example of a cooperative attempt to provide flood protection, not state provision. The absence of such activities today can be explained by a number of features of the problem. In the first instance the provision of flood protection is a non-exclusive good. Once the services are provided it is impossible to exclude residents of the protected area from protection. This results in significant free rider problems. Any individual has an incentive to avoid contributing to the flood protection plan if the contribution is not essential to the provision of the protection. Thus in any case where less than unanimous contributions are required it is in the self interest of the individual to avoid paying. As a second point, the number of individuals involved in collective provision of flood services can make agreement impossible even where the free rider problem can be eliminated. The transaction costs in reaching agreement with a group large enough to provide efficient protective devices are high.²

Consequently the provision of structural devices is now a state function financed out of the general tax fund, not a private agreement among individuals. What then are

²For an extensive discussion of the problem of collective choice, see Buchanan and Tullock, The Calculus of Consent and Mancur Olson, Logic of Collective Action.

the impacts of such structural methods on individuals residing in flood plains?

Influence on Individuals

The purpose of a structural device is to protect the flood plain from inundation. The installation of a dam or levee results in a change in the use of the area by changing the way individuals view the likelihood of flood damage. As discussed in a previous chapter, the effect of installing a structural device is to stimulate development. From the individual land holder's point of view a higher level of development becomes the optimal strategy; ceteris paribus.

Although initial holders of flood plain land rarely are charged for the increased benefits provided to their land there is every reason to expect that the benefits provided by the structural device will be quickly capitalized into land prices. Thus initial landholders reap a windfall gain. Subsequent land purchasers by contrast pay a price that reflects the increased value derived from the reduced possibility of damage.

For the individual the provision of structural protection results in a non-marginal environmental change. Constraints are changed and the opportunity set expands. Benefits and costs of activities undergo relative shifts and new activities may become possible if the environment changes sufficiently. A different mix of activities in the area might be expected but this should not be attributed to a

change in preferences. Individual utility functions may be thought of as containing sufficient arguments to evaluate any possible activity so that the changes brought about by structural improvement take place in the set of feasible alternatives.³ The effect of structural measures is to alter costs and benefits of particular activities and to alter the probabilities of floods of given magnitudes. The effect may be thought of as analogous to a shift in relative prices or a simple shift in income in the standard indifference curve model of consumer theory. In this case, though, the effects occur over the individual location-activity combinations, and in addition there is a shift in relative probabilities of floods as the structural measures can be expected to contain floods of less than the design capacity.

Structural Methods and Flood Losses

The primary criticisms of structural methods stem from their apparent failure to limit the costs of flooding which have shown a definite increase over time. This observation is commonly used to substantiate the claim that providing structural devices encourages excessive use of flood plains, thereby leading to increasing costs for society both in terms of provision of the structures, providing aid to flood

³For example, should a dam be built that results in a large reservoir that can be used for recreational purposes the set of states of nature would be expected to change. For the time the analysis will ignore the multiple use aspects of the problem and focus on the single issue of flood control.

victims and the damage attributable to the flood.

The existence of this correlation between the provision of structural protection and flood damage can, however, be interpreted in another manner. In general, property values have risen over time so that part of the increased damage reflects changes in nominal values. Second, changes in damage reporting methods ensure that more extensive and comprehensive information is made available. A third possibility is that changes in the frequency and magnitude of floods may be taking place, making flooding a more common phenomenon. Fourth, the higher flood damage figures may be a reflection of a structural shift in land use patterns that is completely unrelated to flood protection measures. The shift of population from rural to urban areas and the growth of suburbs may explain higher damages. Thus it is possible to argue, using any combination of the above points, that the correlation between flood control structures and flood damages is spurious, in that causality cannot be substantiated. In some cases it is possible to show that provision of flood control devices has resulted in increased development, but to conclude that a reduction of structural measures will result in less flood damages is not an appealing hypothesis.

Indirect Structural Methods

In addition to structural methods that are designed with a view to managing the flooding problem there are a number of constructs that have significant impacts on flooding

problems both in controlling and exacerbating the problem. Road construction, particularly when it involves elevated road beds, can have a major impact on flooding. The road acts as either a levee or a dam depending on its relative orientation to the river basin. If it is recognized prior to construction that the road has this impact, then the design can take into account the flooding impacts and it will be possible to minimize the harmful effects and perhaps even to incorporate features that provide flood protection. Similarly bridges over watercourses also may have major impacts on floods, particularly in winter when ice can jam against pilings creating dams that flood surrounding areas. If the pressure destroys the bridge this sends a wave of high energy water downstream, causing increased disruption and flood damage.

Public Provision

Structural devices are provided publicly for a number of reasons. The high initial cost and long life span of such projects preclude private provision. The public good nature of the device and the free rider problem tend to thwart private agreements. Thus, if structural controls are to be provided it must be through public effort. A further aspect that has been largely ignored is the multiple use aspect of structural alternatives. Dams, channelization and other methods provide more than just flood control services. Ideally, those that reap the additional services such as

recreation, navigation benefits and irrigation, to name a few, should pay a fair share of the costs. In practice, it becomes impossible to allocate such costs in an equitable, or consistent, manner. Consequently, a second best alternative of public provision through general tax revenues is commonly employed.

Non-Structural Measures: Market Effects

Despite, or perhaps in reaction to, the historical emphasis on structural control measures, the last decade has seen stress placed on non-structural measures as a means of approaching the flooding problem. In part this can be seen as a reaction to the perceived failure of structural measures to alleviate the problem of flood damage. It also represents an implicit recognition that there are several ways to approach the problem and that structural measures rely on only one.

Influence on Individuals

As noted above, structural controls are based primarily on public provision of non-market goods. An advantage of non-structural methods is an ability to impact at other control points in the system. In terms of the classification system introduced previously, the first group of non-structural controls considered are those market forces that impact on the individual. The single over-riding factor influencing private decisions is the individual's attitude to risk. This willingness to absorb risk is embedded in the individual's utility

function and is determined as part of the basic preference set. A change in attitude to risk would reflect a change in preferences. Attitudes to risk are reflected in willingness to pay for a particular site in the form of risk premiums. Conventional assumptions of risk averse individuals would suggest that sites with a higher flood hazard should be discounted relative to less hazardous sites.

Floodproofing

Floodproofing when undertaken on a voluntary basis is an example of a private market phenomenon. The individual evaluates the perceived benefits of flood proofing relative to the market cost of the materials and changes required. The use of elevated sills, elevated sites and sealable lower floors are all elements of floodproofing practices that have market prices and impact directly in the individual's objective function. J. R. Sheaffer has devoted an entire book to methods and effectiveness of flood proofing. His results show that individuals and firms make the decision to undertake floodproofing measures when they perceive the costs of such actions as being less than the benefits. Since the majority of these costs and benefits have market values and are absorbed by the individual concerned, it is reasonable to classify voluntary floodproofing decisions as a market phenomenon.

Flood Insurance

One other market type adjustment process that could be supplied privately is flood plain insurance. Although flood

insurance theoretically has the potential of being a privately supplied market good, there are a series of intractable aspects that have prevented the implementation of such a scheme. Conceptually the existence of an insurance scheme allows the individual to transfer utility between states of nature through the purchase of contingency claims. Thus, the existence of a perfect insurance scheme would allow the individual to convert a risky situation to a certain one. The theoretical literature underlying insurance schemes in a general equilibrium context is extensive but largely irrelevant in the context of flood prevention schemes, since the major assumptions are violated. The analysis relies on; the existence of markets for risk transfer that are actuarially fair, well defined preference functions, and low transactions cost. All of these assumptions fail in the real world. Although the theory of insurance schemes provides some clues as to the nature of insurance plans, the problem of implementation has yet to be solved.

The works of Vaut and Shabman provide insightful analysis of the problems of instituting flood insurance measures. Their analysis concentrates on the public provision of a flood insurance program as a viable activity. It does not seem likely that such an insurance scheme can be provided either privately or collectively. The justification for this last statement is quite evident. Any privately provided insurance scheme must be actuarially sound. That is, the payments must not exceed the receipts. For a private flood

insurance scheme this is likely to be an unachievable goal. The first problem encountered in such plans is that floods are site specific. Thus only those individuals living in a flood plain will purchase flood insurance. In addition, floods are a mass phenomenon concentrated in a particular area. Thus, flood insurance payments will be concentrated in time and space and rather large. This effectively precludes a single company or a private group underwriting a flood insurance scheme. In addition, floods in a particular river basin are sufficiently unpredictable to prevent the insurer from establishing well defined probability tables. The consequence of these effects is that if flood insurance is to be a viable alternative it must be as a compulsory national plan that is able to draw on federal funds as a reserve for claims. Even with a compulsory national plan, an actuarially sound premium rate may result in a sub-optimal allocation of resources for reasons discussed previously in the section on subsidies to flood plain residents.

The aim of a compulsory insurance plan is to require the resident who chooses to occupy the flood plain to accept all the costs associated with such location decision. If the individual does bear the total cost, such a scheme can be shown to be justifiable. However, in a world of interdependence and cross-subsidization it is not evident that such results are indeed desirable. Flood insurance may indeed be a desirable flood plain management scheme but its desirability may arise because it is a convenient tool to allocate flood

costs fairly. Subsidies from the public purse to flood plain residents in the form of reduced insurance premiums, may in fact be an equitable way to compensate such residents for accepting the hazard of occupying a flood plain for society's benefit.

Taxation

One further market related measure is the property tax. By varying property taxes in relation to flood hazard it is possible to have some impact on uses of the flood plain. This measure is more likely to have an impact on commercial uses of the flood plain than residential. Since property taxes are primarily a function of site and building value, the effect of a marginal adjustment for flood plain occupancy is not likely to be great. If the area is desirable in the eyes of individual property holders, the increased tax burden will not offset the positive attributes of the location, unless the magnitude of the tax is large. In the case where slum housing occupies flood plains, higher taxes would result in a regressive penalty that further punishes the poor for no reason other than they cannot afford to live elsewhere. In the case of commercial flood plain occupancy where strict pecuniary relationships are more likely to govern location choices a tax adjustment scheme may have some impact. However, even in this case the costs of the tax differential will have to offset other factors; so that in order for the tax to be effective the individual must already be almost indifferent

as to either a flood plain site or one off the flood plain, or the tax differential must be large.

Tax adjustment schemes can provide an incentive for the individual to modify behavior. In cases where non-marginal changes in land use are not desired, the imposition of large proportional taxes such as development taxes, may prevent land conversion from a socially desirable to a socially undesirable state. In this instance, the tax forces the individual to consider the goals of society while at the same time allowing the individual to ignore those goals providing compensation is paid. Thus the individual is still the ultimate decision maker but the costs have changed. The use of tax adjustments, in isolation, is not a particularly effective means to influence flood plain use, especially in a heavily developed area. The advantages of tax schemes are enhanced when taxation is used in combination with other measures.

Impact of Market Forces

The distinguishing feature of a market related phenomenon is that its impact is felt within the existing set of opportunity states. Thus, market influences impact on the vector of inputs, outputs and prices associated with any particular state of nature. Extra-market forces, by way of contrast, have the effect of altering the possible states of nature or opportunities by either introducing or deleting states from the set of feasible outcomes.

Non-Structural Measures: Extra-Market Effects

Moving from the consideration of market type methods of non-structural control the next set of options consist of a series of state regulations which operate on the set of feasible states of nature confronting the individual. These policy tools include various types of building and housing codes, the provision of services, and zoning ordinances.

Building and Housing Codes

Building and housing codes can be used for several purposes. By limiting the design and construction methods through these ordinances, it is possible to make buildings less susceptible to flood damage and to ensure that in the event of a flood repairs are made in a manner that ensures the safety of the occupants. Building codes can specify such factors as material types, sill levels, elevations, anchoring requirements and other construction parameters to ensure that in the event of a flood the damage to a particular site is minimized.

Zoning

Zoning, in the past decade, has been put forward as an ultimate solution to the flood problem. Proponents of zoning ordinances seek to eliminate flood damage by eliminating use of the flood plain for any purpose that requires concentrated economic activity. If the flood plain can be regulated so that only those uses which have a positive net value; after the expected damage from the flooding is taken into

consideration, then society will have moved to a higher level of welfare. The normal design criteria for zoning schemes incorporate open space bordering the river which is dedicated to parks and recreational uses. Alternatively this area may be used for pasture in a rural setting. The next zone from the river would be composed of manufacturing which is less susceptible to flood damages. Finally only those areas safe from almost any flood hazard are to be used for residential purposes. A hypothetical design scheme of this nature is put forward in Murphy's work Regulating Flood Plain Development.

The proponents of zoning as a management practice argue that since society must come to the assistance of flood victims and that a flood leads to a diminution of national welfare, then there is a valid case for society having the right to regulate use of the flood plain. From an abstract point of view it is difficult to fault this argument since there are undeniable links between the individual residents of the flood plain and the rest of the society. However these linkages are not uni-directional. The transfer of aid and benefits is in both directions. The goal that zoning tries to achieve is to optimally allocate resources to different areas in order to maximize social welfare. The argument for zoning is that the individual will not act in a manner commensurate with the public interest and therefore society must take the necessary steps to ensure that the individual does not harm society while pursuing his private interest. Implicit in this analysis is the assumption that those administering the

public interest understand the nature of the public interest and possess the information necessary to evaluate what are socially desirable courses of action. In the case of zoning, this is a particularly important point since zoning decisions are relatively long lived and result in rather nonmarginal changes in use patterns. Implementation of zoning restrictions preempts a subset of choices from the individual. The effect of this preemption on social and individual welfare depends on how well those designing the zoning ordinances are able to evaluate the true needs of individuals and society, both in the present and in the future. This is in a sense a problem of information. In the absence of an adequate data base, to establish social welfare and values, zoning cannot be expected to result in a "better" use of the flood plain since the zoning regulations in this case merely reflect private perspectives of what is desirable. That the perspective comes from a group of administrators, rather than a group of developers, is largely irrelevant from a social welfare perspective.

In practice, zoning has been associated with attempts to limit development of flood plains, rather than to ensure the optimal level of development. This distinction is crucial. The former practice results in zoning becoming a barrier to efficient use of the flood plain while in the latter it acts to channel private interests in an appropriate direction. The effectiveness of a zoning plan will depend on the care with which it is formulated. Plans that are able to

analyze the dominant forces operating in an area and can discriminate between desirable and "undesirable" forces and block the latter without harming the former are the desired means. A zoning plan that is hastily instituted can result in consequences that in the final analysis are less desirable than the problems zoning was to cure.

Provision of Services

The provision of services, or social infrastructure, has an important role in the development of flood plains. Unless there are compelling forces that dictate otherwise, urban development expands linearly from the urban core. A prerequisite for the development of a particular area is the provision of transportation links, sanitary services, water and power. Thus, one method to thwart development in a particular area is to limit the services that are provided. Flood plain areas have in the past been prime candidates for development. Even where the initial urban development took place above the flood plain, with urban growth the flood plain became attractive. It is easier to extend power, water and sewage connections from existing trunk lines than to develop new systems. Similarly, flood plains are often selected as road and rail locations. Given these advantages in the provision of services, it is not difficult to understand why development takes place. Even the provision of public buildings, such as schools and libraries, can have an important influence on development directions. These indirect influences

are capable of significant control of the flood plains in areas where development is starting to take place. In areas that have already been developed, the level of social services has already reached such a high level that any further effects are not likely to be important.

Expropriation

Expropriation of property is a logical extension of the zoning process in the sense that it involves a further pre-emption of property rights. The distinction between the two methods is one of degree not of kind. In a zoning plan the individual retains title to the property but is restricted in the uses that can be made of it. In acquisition the state obtains title to the land itself thereby ensuring that only those uses which are sanctioned by society's administrators take place.

The distinctions between zoning and expropriation are significant from a distributional point of view. In the case of zoning the individual land holder bears the full cost since no compensation for lost rights is paid. In the case of expropriation with compensation there is the potential for an equitable distribution of costs and benefits from the action. Zoning results in the loss of some rights by the individual while expropriation results in a loss of all rights. The difference in effects of each action must be analyzed on a case by case basis. If the individual loses relatively worthless rights then the cost of zoning may be low. In the case where

a single set of rights determines the value of the land, the removal of these rights through zoning may be thought of as being equivalent to expropriation. Thus the merits of zoning and expropriation as confiscatory powers vary on a case by case basis.

Even when expropriation takes place with compensation it is essentially an extra-market phenomenon since the ultimate effect is a reduction in the options available to the individual, not a change in the costs of options. Prices will change reflecting the increased scarcity of land for private use and the injection of cash into the private sector. These indirect effects may be just as important as the direct effect of acquiring land. The magnitude of the impact in each case will depend on the amount of land expropriated, relative to the total land available on the supply side, and on the demand side, such factors as compensation payments, income and wealth distribution, and population density will be important factors.

Non-Structiral Measures: Information

The last class of management practices to be discussed are best classified under the general heading of information services. Flood information like all information has certain public good characteristics in that once the information has been assembled the marginal cost of dissemination to an additional user is small. In addition, information has the awkward properties from a market distribution perspective of

lacking exclusiveness and having a value that is difficult to determine until it is acquired. These factors make the establishment of a private information market in any area very difficult. In the case of flood plains where there is such a great overlap of individual and public interest, the provision of flood information is a public task.

Types of Information

Three types of information may be distinguished. The first is flood warning systems which alert residents when the danger of flooding is imminent. The second type is flood plain evaluation which provides information about the land area susceptible to flood hazard. The last type is general information about the nature and mechanics of the flood process and the methods of flood control. This will be referred to as flood hazard information. The three forms of information provide different services to different aspects of the flooding problem.

Flood Warning Systems

Flood warning systems are primarily a meteorological activity. Although in most instances the season of the year most likely to experience flooding is well known, a flood can result from a large number of combinations of factors. This wide range of environmental forces which can result in a flood means that a continual monitoring of stream flow rates is necessary for the safety of flood plain residents. Although in most instances floods are not an instantaneous

phenomenon, there are a sufficient number of flash floods that require a high speed warning system if the danger message is to be distributed in time. Given any minimal warning the loss of human life from floods is negligible. The advantage of a longer warning time is reduced damage as residents can take steps to floodproof their property or evacuate their belongings to a safer place.

Flood Plain Information.

Flood plain information indicates those areas that are susceptible to flood hazard. This information may be conveyed in a number of ways. Buildings may be marked with high water plaques. Signs can be posted in flood plains or deeds to property or rental contracts may be stamped with information indicating the site is susceptible to flooding. Radner found that in areas where floods were a relatively infrequent event it was possible for individuals to move into the flood plain without recognizing that they were doing so (White, 1958, p. 67). Clearly, this is an undesirable state. There is a major distinction from an allocation perspective between an individual who consciously weighs the costs and benefits of locating in a flood plain and decides to do so, and one who moves into the flood plain thinking that flood hazard is an irrelevant consideration, when it is not. The purpose of flood plain marking is to prevent such inefficiencies.

Flood Hazard Information

The last type of information is general information about the problem of floods. The value of this information lies in that both potential and actual flood plain residents become more aware of the nature of the flooding problem and means to reduce costs and probabilities of floods. Even when an individual is provided with the first two types of information they are of limited value, unless they can be interpreted properly. The nature of such phenomena as flood probabilities is not clearly understood in many cases. For example, a hundred year flood refers to the magnitude of a flood more than to its probability. In a river basin that is undergoing extensive modification by man, the use of historical data is a dangerous practice. Floods are the result of an intricate combination of variables, not simply heavy precipitation. The individual who understands the nature of floods and what can be done to minimize their impact is better able to look after his private interests and to pressure society to act in a desirable manner. The best method of providing this information is not certain. Education within the school system, public seminars in flood prone areas for both residents and public servants, and pamphlets all provide means of providing this information.

Role of Information

The role of information is to facilitate the making of choices by providing the decision maker with a clearer view

both of the choices available and of the benefits and costs associated with those choices. If the individuals' expectations are not to be fulfilled it should be as a result of exogenous forces not because the consequences of an action were unforeseen. It is information uncertainty that motivates Fellner's introduction of the slanting factor.⁴ Even when faced with a less than adequate information base, the individual must still make choices but these choices are weighted by the confidence the individual has in the stability of the assigned probabilities. The value of the three types of flood information systems is that they allow the slanting factor to be reduced, reflecting increased confidence in the stability of the evaluation of expected outcomes.

Summary

This chapter has provided a brief analysis of various flood management techniques which can be used as policy variables in an overall flood plain management strategy. The perspective has been the impact of each method on an individual either occupying or choosing to occupy the flood plain. The aim of this chapter was not an exhaustive analysis of the merits and faults of each particular tactic since not only is such an analysis beyond the scope of this work but it has also been the subject of much of the literature on flooding.

⁴See the discussion of Fellner's methodology in Chapter 2 or for greater detail see William Fellner, Probability and Profit.

CHAPTER VII

FLOOD PLAIN MANAGEMENT STRATEGIES

To this point a number of seemingly unrelated topics have been considered with the only unifying theme being the suggestion that at some point their relevance to flood problems may become apparent to the reader. The purpose of this chapter is to bring that suggestion to reality. The means employed is a methodology for developing a flood management strategy. By developing the concepts underlying such strategies the importance of each of the preceding chapters will become clear, as will the nature of the linkages.

The Magnitude of the Problem

A flood plain management strategy assumes a concern with an entire river basin since for most flood problems the impacts, of both floods and flood control methods, occur throughout the basin. It also implies, by virtue of being a strategy, a concern with total effects and a mechanism for selecting various tactics or tools to obtain an aggregate goal. Since the river basin is the relevant physical dimension of the problem, the question of multiple-use must also be considered if the flood management strategy is to blend into the overall river basin management plan.

The Importance of the Individual to the Strategy

This work employs the individual decision maker as the focal point for the analysis. The preceding chapters have considered individual decision making under uncertainty, individual location choices, and the impact of different flood management tactics on individuals. Consequently, the strategy to be employed will operate through the individual. By this, it is meant the policies that are part of the strategy will be selected on the basis of how they will impact on the individual decision maker. It is by adjusting the responses of the individual that the flood plain is managed. In a sense the management strategy may be thought of as indirect control. Once individuals have been provided with an appropriate set of information, incentives, and constraints; private or market forces are allowed to bring about the actual adjustment. Thus, there is little day to day, or month to month, manipulation in the strategy. The underlying philosophy is to allow individual interests and arrangements the flexibility to adapt to fluctuations in conditions, while maintaining the use of flood plains in the collective interest.

The Importance of an Effective Strategy

In a very important sense, flood plain management is development strategy. In an undeveloped river basin there is little need for a management strategy since the impacts on man of flooding are minor and indirect. It is when man

moves into the river basin and attempts to bring the land and water into his service that the need for management becomes apparent. Because both the river, and man's use of the river and the surrounding land change with time, any management plan that is to be more than momentarily successful must take the dynamics of the process into account. It is for this reason that the focus of the study is on the individual. By providing the individual with a social environment that is flexible enough to allow individuals to adapt to change yet firm enough to cushion the individual from disruptive shocks, a mechanism for bringing about the continued development of the community can be ensured. Part of the underlying philosophy of any individualistic framework is that flexibility and adaptability can best be achieved by giving individual decision makers sufficient freedom of choice to allow diversity in behavior. If diversity is combined with an institutional system that rewards success while providing a guarantee that failure will not be disastrous, there is an incentive for the individual to experiment, in the hope of finding better solutions to the problems at hand. Under such a system the individual appropriates a sufficiently large portion of the benefits from innovation to make the effort worthwhile. Clearly, part of the costs of this experimentation are failures by the individual to improve conditions, but to eliminate these failures one would also have to eliminate the successes. If an individualistic framework is to be employed, then improvement

in social welfare depends on the efforts of individuals to improve their lives. Given the proper set of institutions, benefits for society can be made to flow from the individual's acts. What needs to be done is to maximize the net benefits from individual actions, not minimize the costs of such actions.

Optimal Design

In the case of a flood plain management scheme, the conceptual goal is to maximize the stream of expected net benefits from the use of the flood plain. This has been treated as an example of a dynamic programming problem by Brown in The Economic Effects of Floods. He simplifies the choice problem to one that is computationally feasible, but in so doing such a level of abstraction is reached that the conclusions become uninteresting from a policy perspective. A conclusion that can be drawn from Brown's effort is that even with the computational assistance of digital computers a formal model of individual investment choice in flood plains is still beyond current technology. In order to make such models reasonable approximations of reality, a vast array of data dealing with; specific formulations of individual welfare, the options available at the present time and alternative futures must be available in a mathematically tractable form. The lack of this information precludes the use of dynamic programming algorithms as anything other than a guide to general trends. Since mathematical

modeling is unable to provide a solution with sufficient complexity, other types of conceptual models must be employed. The goal is still to work toward the best use of the flood plain but since the best use is unclear the problem becomes somewhat more challenging. One approach that does suggest itself is to try to avoid rigidities where possible. Since both perceived goals and knowledge change over time a plan that seemed right may become wrong. If the costs of adjustment are high it may not be possible to change direction for a considerable period of time.

Flexibility must, however, be balanced against the advantages that are associated with specialization. When faced with a choice of having a number of options and given a finite resource constraint, there are times when committing all available resources to a single activity will provide the greatest net return. Economies of scale of various types which lead to decreasing average costs over the relevant range of investment may exist. Thus the advantages of specialization can exceed those of diversity. These advantages may also manifest themselves as reduced dislocation and adjustment costs. Adaptation is often a costly undertaking, particularly for the individual.

The River Basin as the Planning Unit

In the context of flood plain planning, the basic unit for planning purposes is the river basin. This is for both physical and social reasons. In physical terms a flood is

not a phenomenon that occurs in some particular reach of the river but one that has its causes and effects distributed over a large area. The economic impact of floods and flood control measures are even more widely felt, but a useful distinction can be made between direct and secondary effects with the boundary drawn along the watershed. From a planning perspective the river basin is large enough to allow the full range of policy variables to be employed yet small enough to be manageable.

The link between the use of the river basin as a planning unit and an individualistic methodology occurs as follows. Given the need for a set of institutional incentives, constraints and information systems, some administrative unit, such as a river basin planning commission, is required to oversee the management strategy and supply those services that are provided publicly. By selecting the river basin a unit of sufficient size to incorporate all relevant economies of scale is chosen. At the same time these economies of scale are small enough, relative to the size of the planning unit, so that there is sufficient scope for flexibility through diversity of use and diversity of management tools.

Linkages

The strategy chosen has to take into consideration a number of different relationships. In the first place, there are the direct relationships between the planning authority and the individuals affected by the strategy. There are also

the relations between individuals that are also affected by the tactics chosen. Finally, there are the relations between the planning authority and what may be termed the external environment which consists of agencies and individuals outside the watershed. The nature of the relationship in each case depends on the particular interests of the concerned parties and the mix of tactics chosen.

Since any strategy chosen is designed to operate on the individual, the nature of the impact must be made clear. There are three separate ways that individuals can be influenced. They are; through the provision of information, through the adjustment of incentives, and through the imposition of constraints. The effects of different tactics in terms of this taxonomy was the subject of the preceding chapter. In terms of desired effects of a management strategy as discussed in the preceding paragraphs of this chapter, it is clear that the first two means of influence are preferable to the latter. Imposing constraints means a restriction of individual choice and in the absence of a compelling reason for accepting an increase in rigidity this method will be considered undesirable.

Briefly, the difference between an incentive altering method and a constraint producing one is the latter reduces the opportunity set of the individual by precluding certain options while an incentive altering method alters the prices or inputs and outputs of a particular state, leaving the range of choices the same. As examples of the two methods--

zoning is a constraint method since it precludes certain choices, while flood insurance, which adjusts the costs of particular actions, is an incentive adjustment.

Distribution Aspects

One of the attributes most commonly associated with incentive altering methods is the shifting of costs and benefits of particular actions onto those who are responsible. The argument ignores the distribution altering impacts of such changes. As noted previously, these impacts can be quite large. There is, however, something appealing in an argument that suggests an individual should bear the costs and benefits of his actions. The effect is to bring about a more careful consideration of the possible choices (if the necessary information is available).

In a case where flood plain residents provide few benefits to society then it seems only fair they should not be entitled to disproportionate benefits from society simply by virtue of their being flood plain residents. However, where they do provide a socially useful service by residing in the flood plain it must also be fair that they be compensated for the service. In order to determine the desirability of a particular use some form of cost-benefit analysis would be necessary. By comparing the level of welfare with and without the activity its desirability could be determined. This, however, ignores the question of the distribution of the benefits. There are a large number of ways to distribute the costs and benefits associated with a particular activity.

Choosing the best one is a task far beyond the scope of this research.

Information Aspects

In providing information, the problem becomes how to determine the value of an additional increment relative to the cost when it is impossible to determine the value until the cost has been accepted and the information acquired. Information is more than data, it is also the ability to assimilate the data and put it to use. Thus a flood information system must educate flood plain residents as to the options that will confront them and the nature of the options.

Private and Collective Responsibility

What then can be said about a generalized flood management strategy? First, the principles of importance are to maintain flexibility, to stimulate information acquisition and dissemination and to provide the incentive to act in a socially desirable manner. The question though of what a socially desirable manner is has been debated since individuals first formed groups. It is a question of the individual's responsibility to the group. The exact nature of the responsibility changes with time and the particular state of nature. It becomes the payment for the insurance that the group provides the individual in the form of aid and public works. It can be partially explained through the notion of the social contract and the notion of the individual's responsibility to society. The incentives and constraints that

society provides are reminders of this social responsibility, ensuring that the responsibilities are accepted and fulfilled.

Macro Issues

At a macro level flood plain management strategies are a part of a larger economic and social system. Consequently national priorities will play an important role in determining the resources to be allocated to flood plain management. For any given resource allotment it is possible to select a best strategy but it need not be true that a particular strategy dominates all other strategies. Thus it is important that an estimate of resource availability be taken into account in designing the strategy.

The links between the river basin and the rest of the economy are important in determining the type of management policy. River basins that have features crucial to the nation, such as those which contain major metropolitan areas or important manufacturing facilities, can be expected to be under a far more extensive management strategy than primarily agricultural areas. The question of how a particular flood plain fits into the national economy is an empirical matter which is of great importance in selecting management strategies.

Examples of Flood Plains

In order to demonstrate the potential application of the management strategies discussed in the chapter some hypothetical cases are considered. For each case a

combination of tactics appropriate to the particular conditions that exist will be developed. The principles that are followed in selecting this set of tactics are; compatibility with the specified aim of preserving individual freedom of choice, effectiveness of the technique in producing the desired management results, and preventing the creation of additional problems while solving the given one. By the appropriate choice of a subset from the set of available tactics, it is possible to satisfy these principles. Three cases are considered as being representative of the dominant types of the flood plain management problem. Since these are abstractions, they do not reflect the complex nature of actual flood plains where goals conflict and individual rights are defended against any challenge. The point of this exercise is to indicate that it is possible to select management tactics in a manner that will provide a better chance of success in management than exclusive reliance on a particular tactic or a random choice of management tactics.

The three flood plain situations considered are; a developed urban area, an undeveloped rural area, and an undeveloped suburban area or transition zone. In this context, the term "developed" refers to the concentration of human activity on the flood plain and is roughly represented by land value per acre. Each particular case represents a different flood management problem although the last case, the transition zone, is probably the most interesting. In the first two cases the level of development is relatively static so

that the potential for changes in use is rather small. It is in the transition zone where development is beginning to take place that a flood plain management strategy has the potential for altering and directing changes in land use.

Differences in land use within the zones are the primary reason for differing management tactics. The rural undeveloped zone is used primarily for activities which require large quantities of land and produce a relatively low return per unit of land. Activities such as agriculture, forestry and recreation do not require large investments per acre relative to urban activities such as manufacturing and retailing. Only at scattered locations where buildings are erected is there a high investment per unit of land. Land use changes within the rural area reflect changes in the degree of activity not in the type. The changes that take place are not new activities but modifications or variations on existing ones. Consequently there is, in general, little scope for flood plain management tactics that require large expenditures to protect a relatively small area. This precludes most structural measures. Transitions in land use in rural areas are slow relative to suburban areas. This is a result of little demand for land in those areas for uses other than agriculture, forestry and recreation. Rural land lacks sufficient population density and other location advantages to attract more land intensive uses. As a result there is little effective demand for increased services.

Urban land, like rural land, experiences few changes in the intensity of land use. In the urban case the reason occurs on the supply side rather than the demand side as in rural areas. In urban zones land is a highly valued commodity as a result of the agglomeration forces associated with the manufacturing and service sectors of the economy. These activities tend to require relatively little land and produce high value outputs. As a result, land prices in urban areas are high, reflecting both the locational advantages of such land and the ability to pay of the land users. Changes in land use within the urban area reflect the increasing value of urban land. Ability to bid land away from competing uses requires that the successful bidder be engaged in higher value per unit of land activity than the unsuccessful bidders. The appropriate management tactics in urban areas must take into account the high value of the land and the intensity use that is made of it. With a fixed supply of land attempts to reduce the supply will be met with great opposition. Transitions in use in the area will also be small because of the large, long-lived investments associated with urban land use.

In the suburban fringe there is a transition from the land use pattern of rural areas to the one associated with urban areas. This is reflected in land values. In the transition zone land is taken away from low value per unit of land activities, such as agriculture, and dedicated to high value activities, such as housing and manufacturing. This transition requires the provision of additional services.

New roads, water mains, and schools must be provided in the transition zone. The increasing intensity of land use reflects the growing importance of site values relative to the productive capability of land in determining relative values. In the transition zone both supply and demand forces are relatively unconstrained. Land is made available as it is required while demand grows with the trend expansion of the population and economy.

The transition zone may be thought of as an intermediate stage between rural and urban use. As such it reflects the dynamics of the adjustment process. In a sense, the spatial pattern observed at a point in time is a reflection of the historical development of a particular location. Clearly this analogy only holds in the neighborhood of urban areas. It is, however, a useful way of approaching the management problem since there is some indication of future development patterns within the present structure.

The actual nature of the different tactics adopted must, of course, depend on the goals to be achieved which are determined by the strategy and on the environment that they must operate in. In order to facilitate a comparison of the three cases chosen, Figure 7-1 indicates the range of management tools available and those which are appropriate to each particular case. Each particular tactic is considered below in terms of its applicability to the different cases.

Structural measures are only recommended for flood control purposes in highly developed urban areas where the high

Management Tactics	Undeveloped Rural Area	Undeveloped Suburban Transition Zone	Developed Urban Area.
Structural Measures (dams, levees, etc.)			X
Provision of Services (roads, sewers, etc.)		X	
Flood Insurance			X
Taxes	X		
Zoning	X	X	
Building Codes		X	
Floodproofing	X	X	X
Expropriation			X
Information - Warning System	X	X	X
Flood Plain	X	X	X
Flood Hazard	X	X	X

Figure VII-1.
Management Tactics Applicable to Different
Types of Flood Plains

level of public and private investment justifies the expense of providing dams, levees, or channels. Where structural devices exist primarily for purposes other than flood control, it may be possible to employ them for rural and suburban flood protection also. Such instances as projects built to provide power, improve navigation or for irrigation are examples of this potential.

The provision of services is used as a management tool only in the case of the transition zone. In the urban areas social capital or infrastructure already exists, and in rural areas the potential for changes in the level of services provided is small. It is the suburban fringe where new services are demanded and supplied. By controlling the provision of roads, sewers, and power it is possible to regulate the speed and direction of development. Failure to recognize the potential of the provision of services as a management tool results in the loss of an effective tool.

Flood insurance is recommended only for developed urban areas. This particular technique is envisioned as a means of redistributing the costs and benefits of flood plain occupance. In undeveloped areas the type of land use is better served by other methods. Crop insurance for agricultural land is a possible alternative to flood insurance. In developing areas there is such a great fluctuation in values in a short period of time that an insurance scheme becomes intractable. Flood insurance may be thought of as a last resort to be applied where other techniques for redistribution fail. By varying

premium structure, it is possible to divide the cost of insurance between the public and the insured parties in any manner desired.

In the comments on the use of taxes it was noted that they are likely to have their greatest influence where the marginal net benefits of sites on and off the flood plain are almost equal. Since in the urban and rural areas there is far less change in development levels than in the transition zone, taxes are not employed in the former cases. Where there is little change in use it seems reasonable to assume that there exist few close substitutes for flood plain sites. Consequently, taxes are suggested in transition zones. These taxes may be of two forms. Penalty taxes can be used to discourage use of the flood plain, while transfer taxes can be used to discourage changes in the use of flood plains.

Zoning is not recommended in urban areas since there is such a large level of existing investment in the area that transitions in use are likely to be very slow, limiting the value of zoning as a means to stop particular forms of use. In rural areas the selective use of zoning to appropriate particular bundles of rights can preclude undesirable changes in land use without imposing excessive costs on the individuals. In the transition zone the potential of zoning is more problematic since the rights that are to be appropriated through the zoning process are likely to be those valued both by existing and future land holders. This will result in major conflicts both in implementing zoning ordinances and

keeping them in existence. Zoning involves the confiscation of rights without compensation. If those rights are not considered valuable by the individuals losing them, then resistance to the loss will be small. When the rights are considered valuable, great resistance must be expected.

Building codes, although in principle applicable in all areas, are likely to be effective only in the transition zone. In the other areas, which are more stable, percentage change in the stock of buildings is likely to be small in the short run. Thus building codes will have their major effect in the transition zone where there is a large change in the stock of buildings in the short run.

Floodproofing may be thought of as similar to building codes in its effects since both deal with the structural integrity of the building. The essential difference is that floodproofing is a private, voluntary action. Hence, it can take place in all types of flood plains and is dependent only on the individuals perception of the value and costs involved.

Expropriation has been considered previously as the logical extension of zoning. It is recommended for use in urban areas where the only practical way to effect changes in land use is to acquire the land through expropriation with compensation. In non-urban areas the benefits of expropriation are not likely to match the costs. In these areas zoning is a lower cost option. In urban areas, the high value of the land and the static nature of its use preclude most alternative management tactics.

Information, as has been stressed before, is applicable in all situations. The provision of information allows individuals to make rational choices and is essential to the success of most of the previous management techniques. Perverse behavior by individuals may result from a failure to understand the options open to them. In the absence of the proper information, individuals may respond to management tactics in a manner other than they would if given the information.

The actual choice of a combination of tactics depends on the magnitude of the problem involved and the goals to be developed. The actual effects of the different tactics when used in combination may be quantitatively different than may be expected. Unfortunately, the only way to determine the appropriate magnitude of the management inputs is through experimentation, preferably with a model.

Summary

This chapter presents the conceptual problems underlying flood plain management strategies. By looking at the physical and social relations that specify flood plain strategies some knowledge of factors that must be considered in formulating a particular strategy is obtained. Relevant factors that must be considered are; the area to be managed, the nature of this area and its importance, distributional effects, possible linkages and types of tactics to be employed. The issue is approached from an individualistic point

of view, thus the recommendations made are suitable to this particular approach. A management strategy that is based on something other than a reliance on the individual as the driving force in the system would come to other recommendations.

CHAPTER VIII

CONCLUSIONS

This final chapter commences with a summary of the conclusions of each of the preceding chapters. The implications of the preceding work are then combined to form a general conclusion. From this general conclusion recommendations for flood plain management policies can be drawn, as can suggestions for further research.

Summary

The fundamental distinction between subjective and objective conceptions of probability resulted from the analysis of decision making under uncertainty. This distinction was interpreted as a partial explanation for the different evaluations of flood hazard by individual flood plain residents and flood plain managers. In addition to variations in personal willingness to bear risk individuals formulate subjective probabilities of flood hazard. Flood plain managers by contrast formulate expectations over a longer time horizon and from a detached perspective using relative frequencies as a measure of probability. These differences in the evaluation of the probability of flood hazard are an important factor in the conflict over the optimal development strategy for flood plains. The importance of the slanting factor as a measure

of individual confidence in the stability of the probability evaluations was introduced. The slanting factor may be thought of as a measure of the information the individual has available and of the confidence that can be attached to this information. Since all choice must be made in an uncertain environment where the nature of the future cannot be foreseen, a fundamental understanding of the ways in which it is possible to evaluate uncertainty is important.

The analysis of location theory which comprises the third chapter serves as a critical review of existing location theories. The current body of theory is found to lack sufficient flexibility to account for individual location choice. As an extension a richer set of variables affecting decisions are introduced. Imperfections in the housing market are likely to be significant. They can be attributed to limited information availability, high transaction costs, and for the individual the long life of the investment. An individual investor is confronted with a decision that will have consequences stretching far into the future. Yet the information available to the individual for use in making the decision is generally of low quality. This can partially explain the problems associated with achieving efficient use of land in general and for the purpose of this work, flood plains.

The uncertain nature of the future makes the location decision of the individual and the land use pattern of the flood plain a dynamic adjustment problem. Even though the

individual may be committed to a particular location, and use of that location for a considerable period of time, there is still adjustment potential. These adjustments take place through the rate or intensity of use, the level of depreciation of the resources and the potential to impose changes on the environment over time.

The conclusions of the chapter on the individual's use of the flood plain stresses the potential for rational occupancy of the flood plain. It is possible for the individual to evaluate the costs and benefits of flood plain use and to conclude that the benefits exceed the costs. Use of the flood plain is also seen to result from more than an individual's evaluation of personal benefits. Historical patterns of development and the stimuli provided by society also play important roles in determining flood plain use.

In the consideration of the relationship between social and private choice a distinction is drawn between the aims of residents of the flood plain and other members of society. It is noted that this conflict of interests has motivated much of the literature on floods and flood management. By considering the management goals of the United States Water Resources Council some concept of management strategies for flood plains can be developed. It is concluded that structural measures are not a priori inferior to non-structural methods of flood plain management. The chapter concludes by introducing the concepts of strategies and tactics as they relate to flood plain managers and individuals. The different

goals and time horizons of the two groups result in a feedback process between flood plain management tactics and individual strategies and tactics that ultimately determine the effectiveness of the management strategy.

Chapter 6 analyzes flood plain management tactics from the perspective of their impact on individuals occupying the flood plain. By classifying management methods according to a multi-level hierarchy it is possible to show in what manner these measures influence the individual. The methods are considered according to whether they affect incentives, constraints or provide information. The decomposition provides a key to choosing particular management tactics in a given situation according to what is perceived to be the proper means of influencing the individual.

The final chapter looks at the components that will determine how a management strategy develops. The complexity of the problem is emphasized in terms of the magnitude of flood hazard, the linkages with river basin planning and the distributional problems. It is concluded that management strategies should seek to provide development guidelines that allow individuals sufficient flexibility to adapt to changing situations without changes being necessary in the management strategy. The role of the individual is seen as an agent of society acting to bring about social goals by working in a manner that focuses on the satisfaction of private goals. It is through the careful selection of a management strategy that the interests of society and individuals are brought into

a context where they can be satisfied simultaneously.

Implications

Having summarized the content of each of the preceding chapters some general conclusions or implications must be drawn. The aim of this work was to view floods and flood plain management from an economist's perspective and in particular with expectation that by approaching the problem from the individual's point of view insight could be gained into why flood damage continues to mount and why management schemes are perceived as failing. If these issues can be resolved, it will allow the formulation of some guide posts for formulating management strategies that are effective in terms of bringing about social ends without crushing individual freedom.

Philosophical Issues

From the analysis of the preceding chapters a number of conclusions may be drawn. As usual these conclusions are, to a considerable extent, a reflection of the assumptions that underlie the analysis and in particular the individualistic approach that is employed. The first important effect of this assumption is a stress on methods that provide the individual with as much freedom of choice as is possible. Individual freedom of choice is presented as a solution to the micro decision processes in flood plain use. Flood plain management strategies and tactics may set guidelines for uses of general areas of the river basin, but the actual use of

particular sites is an individual choice. This stress on individual choice arises from the philosophical position, that in general the individual is more responsive to change than an organization. Hierarchical decision making processes take time, particularly when an entrenched bureaucracy is involved. This results in slower adaptation to changing conditions.

It must be noted that there is no suggestion intended that individual self interest left to its own devices will result in the optimum level of social welfare. What is intended is a social system where market forces are shaped; by the provision of incentives, constraints and information, to bring about desired ends. The problem may be thought of as one of institutional design. How does society through its administrators go about selecting a set of policies and programs that will result in the achievement of social goals at the lowest possible cost? The approach recommended in this work is to rely on market forces and individual action wherever possible. This recommendation follows from the assumptions that; (a) choice is valuable to the individual and that to forego the possibility of free choice imposes costs, (b) the cost of compelling individual behavior through a command system will in most cases exceed the costs associated with providing incentives in a market system and (c) the traditions of western social systems are more amenable to market solutions and thus the likelihood of a market based management strategy being implemented is greater than that of a command strategy.

Policy Issues

From the analysis carried out a number of recommendations can be made for those responsible for flood plain management. If a single issue had to be considered the most important it would be information availability. Under any management strategy, but particularly one relying on individuals and markets, information is vital to the success of the strategy. The three types of information considered in the sixth chapter provide a convenient way to formulate the problem.

Information about the imminent arrival of floods is clearly of value to both individual residents and managers. Given even minimal warning, the damage associated with a flood can be greatly reduced. Loss of human life is the single greatest element of damage reduction associated with warning systems, but the reduction in physical damage brought about by the removal of property from the flood zone is significant. Flood warning systems need not be elaborate or expensive. The crucial issue is that they be implemented so that information can be made available. In an area subject to seasonal flooding such systems need only monitor increases in the stage of the river, since there are significant lags between the first indication of flood hazard and the actual overflowing of the stream banks. In areas where floods rapidly follow precipitation and have no seasonal pattern, warning systems must be more elaborate and operate quickly if they are to be effective.

Where flooding is an infrequent phenomenon, information about the limits of the flood plain and the frequency of flooding is important. This information setting out the extent of the flood plain, when combined with general information about the nature of the flood hazard and how to interpret flood plain information will provide a means for individuals to evaluate flood hazard. From the individual's perspective, an increase in information allows a more rational choice process to be made and will result in a greater likelihood of perceived choices matching available choices.

The provision of data is not the same as the provision of information. In order for data to provide useful information it must be in a form that can be assimilated by the user and also be correct. Faulty or non-applicable data results in confusion for the decision maker and a breakdown of the rational choice process, which is the basis of an individualistic management strategy. The provision of flood related information of the three types discussed above is a relatively inexpensive management tool. Information makes the market system work more effectively, leading to improved performance of the management strategy.

No matter what types of management method are involved in a tactical situation, it is important that an accounting of all the impacts associated with each method be undertaken prior to the selection of a particular method. The dynamic relationship between individual strategies and tactics and management tactics consists of a multi-level feedback system.

Individuals respond to the particular management methods that are implemented, but the nature of their response may not be that predicted or desired. If this happens, it is an indication that policy makers do not fully understand the responses that the particular policy triggers in individuals.

For this reason it becomes essential that indirect effects or externalities be taken into account. The external effects to be considered are of the technological rather than the pecuniary type. Within this technological class it is possible to distinguish what will be termed physical externalities from social externalities. Physical externalities may be thought of as those effects which result from an environmental change. In a sense, a physical externality changes the opportunity set available to the individual, generally by removing some choices. As an example, construction of a dam can result in changes in the water table. In the neighborhood of the dam this may result in soil moisture build up that can either harm or help crop production. Downstream it may result in a reduction of soil moisture and soil fertility since flooding is curtailed.

By way of contrast, social externalities may be thought of as resulting in behavioral changes in individuals. The costs and benefits of particular alternatives are changed as a result of some management action. An example of this is the provision of social capital such as highways and sewer lines. These facilities built to service a particular area tend to attract development in surrounding areas. Similarly,

development of a flood plain may result in agglomeration forces that continue to draw investment into the area.

Understanding the impacts of particular management methods is essential if these methods are to be used to induce behavior by the individual that is compatible both with the management strategy and with the overall development goals of society. A major portion of the problems associated with flood plain management can be attributed to this failure to determine ahead of time what the effects of a method, such as dam construction, would be on individual behavior. Given a relatively unsophisticated understanding of flood hazard by the general public it is not surprising that development moves into an area that receives structural protection. This process is compounded by the advertising associated with the construction of public works. In order to justify expenditures on public works, claims of benefits are often inflated, leading to the provision of faulty information to individuals.

Prior policy formation recommendations within the paper have stressed the value of providing individuals with as much freedom of choice as possible. The limits to this freedom of choice cannot be defined explicitly, but it is possible to formulate instances where constraints may be applicable. One such case involves large scale development in an area. Development companies provide a useful function of assembling land and planning its use but to some extent this private planning may usurp some of the powers of public planners. Where the planning process is designed to integrate land

development into the general development of the area, deviations in land use brought about by private developers may have to be prohibited. In the absence of such a comprehensive public development plan, justification for controls on private development simply to allow inadequate public planning, is hard to find.

Other reasons for the use of prohibitions may involve irreplaceable resources such as scenic values of areas, or if development of the flood plain has the potential of providing major conflicts with other uses of the river such as navigation. Once the development process starts it becomes irreversible, over almost all time spans. Attempts to resettle communities have proved to be unsuccessful unless all residents are forced to relocate. This irreversibility of the development process brings about a fundamental distinction in policy between developed and undeveloped portions of the flood plain.

In an undeveloped portion of the flood plain prohibition of particular uses may be a viable management tool. In a developed area the range of policy tools will be limited to those that are compatible with existing uses. The high levels of investment by individuals and society ensure that any attempts to "undevelop" the area will fail. In a democratic market economy the political choice process will make it difficult for any planning agency to force abandonment unless there is a clear and compelling reason for such abandonment. The perception that an area is overdeveloped is not such a

reason, particularly when others hold different opinions about optimal uses.

A further feature that needs to be considered is the shift in the distribution of population from rural to urban areas. Urban areas located in flood plains are just as likely to experience population growth as other urban areas. This suggests that demand for land for both residential and commercial purposes in these flood susceptible areas will continue to increase. Given this pressure for growth, expansion into and development of the flood plain becomes a necessity. The pressures for development will become irresistible so that the relevant considerations for flood plain managers are not whether development will take place but how it will take place. Any management strategy must take into account the environment in which it operates. Strategic ends are not likely to be achieved if they are not compatible with broader environmental needs.

As is normal in any policy oriented research, the ultimate conclusion is that the appropriate response is one that maintains balance or dynamic stability. The proper technique for a particular situation depends on the context and nature of that situation. All that can be said is that certain techniques will result in a particular set of impulses. The choice of technique depends on the goal sought and the medium on which the impulse acts. The same stimulus can draw forth different responses depending on where it is applied. The underlying lesson that follows is that in order for a

management strategy to be effective the managers must understand the world in which they operate.

Unfortunately the absence of information prevents such knowledge so in an uncertain situation the appropriate response may differ from that in a certain situation. Flexibility and adaptability become important characteristics. In part, the purpose of this paper is to show how these characteristics can be fostered.

Suggestions for Further Research

The analysis of this study is primarily conceptual. It is an attempt to integrate elements of location theory and decision theory in the context of flood hazard problems. As such, it is primarily subject matter research. The single most pressing issue needing further research is a means of testing the validity of the individualistic theory developed. This will require empirical analysis either of a particular flood plain or of a model of a flood plain. By considering actual flood plains and using survey techniques estimates can be made of; individual perception of flood hazard, those variables affecting location choice, and the development processes at work in the flood plain. These surveys will provide descriptive information of the current uses of flood plains and a basis for determining parameters that can be used in the construction of models. The value of a model, given that the components are accurately specified, is in the ability to test the sensitivity of the outputs to

variations in inputs and parameters. This will allow flood plain managers to test alternative tactics prior to implementation.

It was noted that the provision of information is a key element in making an individualistic management strategy effective. Consequently an area of research that would be worth considerable effort is information theory. Current availability and needs are the first areas that should be considered. Subsequently, systems to provide different forms of information could be developed. This research should develop the body of knowledge dealing with the causes and nature of floods and determine an effective way to transmit it to flood plain occupants and managers.

In a more abstract vein there is need for further research into the basis of probability theory and location theory. The process of subjective probability assignment is not well understood. The effect of this lack of understanding is increased difficulty in evaluating how individuals will respond to flood hazard. Economic theory has not probed the differences between the subjective and frequency schools of probability but has focused on the mechanics of the expected utility process which assumes a set of probabilities.

Similarly, location theory has relied on transport costs as the key explanatory variable in location decisions. This has resulted in an essentially univariate approach to a complex problem where there are a large number of significant variables influencing location choice. There is also a need

for a unified location theory which is able to incorporate the information conveyed by areal theory, point theory and central place theory into a single generalized theory.

In general, the nature of flood research could profitably follow the direction of the monographs published by the Geography Department of the University of Chicago. These studies focus on particular aspects of the flood problem and provide both a theoretical analysis and some empirical estimates of the magnitude of the problem and effectiveness of solutions. This focus on a particular aspect of flood hazard allows sufficient concentration to give a detailed analysis of the significant aspects while the standardized format of the research provides a measure of continuity.

Contributions of this Research

The analysis of this paper is primarily designed to analyze the linkages between social goals and methods and individual goals and methods in flood plain use. It is motivated by the apparent dissatisfaction with current management efforts. By approaching the problem from the perspective of the individual, insight into ways to employ individual self-interest for social purposes can be developed.

In a society that is still primarily oriented toward market methods and the self interest of individuals it makes sense to employ these methods where possible. Previous management practices have rarely been designed with a view to using individual behavior as part of the management scheme.

Indeed the impacts on individual behavior of most management methods have been ignored. It is the stress on the requirements that individual interests and response patterns be taken into account if management methods are to be successful, that is the dominant theme of the work. The conclusion of the analysis is that by taking account of individual preferences and behavior a flood plain management strategy can be designed that will succeed in reaching its desired effects.

Auxiliary conclusions that are important to the planner are also developed. Flood plains are like all other resources in that their efficient use depends on the opportunity costs involved. It is difficult to prescribe policies that require abandonment of flood plains if economic efficiency is employed as a value criterion. When the expected benefits of flood plain use exceed the expected costs, then the use of flood plains is desirable. Of course, the magnitude of benefits and costs depends to a great extent on the particular goals of society and in particular existing strategies and tactics employed by the managers. This emphasizes the need for comprehensive planning of flood plain use since the effects of current decisions still have significant impacts far into the future.

Flood plain management is a complex problem and simplistic solutions that ignore important components are not likely to result in their expected outcome. It is only through a careful selection of the relevant variables that an effective management policy can be determined. If this

thesis provides additional insight into what variables must be considered relevant, it will have served a useful purpose.

APPENDICES

APPENDIX A

GLOSSARY OF TERMS

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GLOSSARY OF TERMS

A flood event is a series of flows constituting a distinct progressive rise, culminating in a peak, crest, or summit, together with the recession that follows the crest arbitrarily selected for consideration as a unit of flood occurrence.

Flood stage is that elevation of the water surface--selected by local usage or by an investigator--above which the stream is considered to be in flood. Commonly, it is the stage at which damage begins.

Flood crest is the highest elevation reached by flood waters in a flood event. It is commonly measured in feet above an accepted datum, such as flood stage.

Momentary flood peak is the maximum rate of flow attained during a flood event; usually this is the flow at the time flood crest is reached. (It commonly is measured in cubic feet per second).

Daily flood peak is the maximum daily flow during the flood event.

Annual flood is the maximum daily flow during the flood event.

Annual flood is the maximum daily flow during 12 consecutive months, that is, the highest daily flood peak for

a year of record.

Average annual flood is the mean of the annual floods during the period of record.

Probable maximum flood is the maximum flow expected to occur on a given stream during the designated period or during an infinite period.

Flood plain is that land outside a stream channel described by the perimeter of the probable flood. It is land which is not covered by the stream at flow or average flow, but which has been flooded in the past or may be flooded in the future. It has no other essential feature; it may be broad or narrow, frequently flooded or rarely flooded. In this sense, every stream which has floods also has a flood plain.

Flood zones is all the land in a flood plain which is subject to floods of approximately the same frequency, the zones of most frequent flooding lying at the lowest elevation, and nearest to the channel, except where there are natural levees or other obstacles to overflow.

Adjustment to floods means an ordering of occupancy to floods and to the flood hazard. The ordering may be systematic or unsystematic, rational or irrational, conscious or unconscious, but it comprises an observable arrangement of occupancy in relation to floods.

Land elevation. The elevation (up-building) of the surface of a flood plain so as to render it less susceptible to flooding.

Flood abatement. The application of land-management measures upstream from a flood plain to prevent the accumulation of all or part of a flood flow in a stream channel.

Flood protection. The use of levees, channel improvements, cut-offs, floodways, reservoirs, and other engineering devices to reduce flood crests in a stream channel or to prevent floods from overflowing flood plains.

Emergency measures. The temporary removal or protection of property and persons, and the temporary re-scheduling of human activities.

Land use. The arrangement of the pattern of land use of flood plain.

Relief. The granting or loaning of private or public assistance to flood sufferers.

Insurance. The accumulation of premium payments from property owners in order to compensate them for losses resulting from floods.

APPENDIX B

A CONCEPTUAL REPRESENTATION OF THE PROBLEM

APPENDIX B

A CONCEPTUAL REPRESENTATION OF THE PROBLEM

The individual may be thought of as selecting both a location and an activity. The goal of the individual is considered to be maximization of expected utility. For any particular activity, denoted x there is some associated vector of inputs and outputs and a transformation function such that we may write

$$x = (i_0, \dots, i_m, o_0, \dots, o_n, T)$$

where: $i_0, \dots, i_m$ are inputs,

$o_0, \dots, o_n$ are outputs,

and T is a transformation function determined by the existing technology.

Note that the exact representation of any x varies for each site and each activity. Thus for any particular site and activity the particular set of associated inputs and outputs is unique.

Suppose now that the individual confronts a single period situation where there are k possible activities and h possible locations. Define a matrix A which will be the matrix of activities and locations. Since not all activities may be possible at every location there may be zero elements in the activity matrix.

matrix of slanting weights S where

$$S \equiv (s_{ij}; i = 1, \dots, a, j = 1, \dots, a)$$

where $i, j = 1 \dots a$ denotes flood stages of differing magnitude.

S_{ij} is a weight based on the individual's subjective evaluation of floods of different magnitude; $S_{ij}=0$ for $i \neq j$.

By premultiplying the previous result by S an expected value matrix of various activities is generated which relates a subjective evaluation of flooding potential at each location to the possible range of actions.

Finally if these elements of the final expected value matrix are converted to utility space by applying a utility function a matrix of expected utilities results. From this it is possible to select that element having the highest expected utility.

Clearly the assumption of timelessness greatly simplifies the analysis, the introduction of dynamic considerations requires several modifications and extensions. The first change is that the vector of associated inputs and outputs for each element of the activity matrix. A must have its arguments discounted to present values. Once this has been done it is possible to perform the calculation for the initial decision to locate in the flood plain.

In order to consider the appropriate response once the initial location decision has been made and a flood has taken place the matrix of activities must be supplemented with additional activities $k+1, \dots, p$ which reflect the cost of

rebuilding a particular activity at the same site. This allows the introduction of less than total damage and reflects the existence of depreciation of the investment. Clearly the decision to rebuild or relocate will be a function of the time of flooding, magnitude of flood, and magnitude of destruction in addition to other investment opportunities.

BIBLIOGRAPHY

BIBLIOGRAPHY

Floods and Flood Plains

- Boisvert, Richard N. Impact of Floods and Flood Management Policy on Area Economic Development and Recovery. AE. Res. 75-31, Department of Agricultural Economics, Cornell University, Ithaca, N. Y., 1975.
- Bromley, Daniel W., A. Allan Schmid, and William B. Lord. Public Water Resource Project Planning and Evaluation. Center for Resource Policy Studies and Programs, University of Wisconsin, 1971.
- Brown, J. P. The Economic Effects of Floods. Lecture Notes in Economics and Mathematical Systems #70, Springer-Verlag, New York, 1972.
- Cheatham, Leo R. A Case Study of Some Economic Aspects of the National Flood Insurance Program. Water Resources Research Institute, Mississippi State University, Mississippi State, Mississippi, 1975.
- Cook, Neil R. Effects of Upstream Flood Protection on Land Use in the Upper Washita River Basin, Oklahoma. Unpublished thesis. Oklahoma State University, Stillwater, Oklahoma, 1964.
- Cram, J. S. Water - Canadian Needs and Resources. Harvest House, Montreal, 1973.
- Herfindahl, Orris C. and Allen V. Kneese. Economic Theory of Natural Resources. Charles E. Merrill, Columbus, Ohio. 1974.
- Hoyt, William G. and Walter A. Langbein. Floods. Princeton University Press, Princeton, New Jersey, 1955.
- James, L. Douglas and Robert R. Lee. Economics of Water Resources Planning. McGraw Hill, New York, 1971.
- Kates, Robert W. Industrial Flood Losses. University of Chicago, Department of Geography Research Paper #98, Chicago, 1965.
- Kates, Robert W. Hazard and Choice Perception in Flood Plain Management. University of Chicago, Department of Geography Research Paper #78. Chicago, 1962.

- Kaul, Jawahar L. and Cleve E. Willis. "An Application of a Floodplain Land Use Decision Framework with Zero-One Controls" in The Journal of the Northeastern Agricultural Economics Council, Vol. IV, No. 1, p. 37-47, 1975.
- Kneese, Allen V. and Stephen Smith ed. Water Research. Johns Hopkins Press, Baltimore, 1967.
- Krutilla, John V. and Otto Eckstein. Multiple Purpose River Development. Johns Hopkins Press, Baltimore, 1969.
- Lacewell, Ronald D. and Vernon E. Eidman. "A General Model for Evaluating Agricultural Flood Plains" in The American Journal of Agricultural Economics, Vol. 54, No. 1, p. 92-101, 1972.
- Leopold, Luna B. and Thomas Maddock, Jr. The Flood Control Controversy. The Ronald Press Co., New York, 1954.
- Leuchtenburg, William Edward. Flood Control Politics. Harvard University Press, Cambridge, Mass., 1953.
- Lind, Robert C. "Flood Control Alternatives and the Economics of Flood Protection" in Water Resources Research, Vol. 3, No. 2, p. 345-347, 1967.
- Lowenthal, D. Environmental Perception and Behavior. University of Chicago, Department of Geography Research Paper #109. Chicago, 1967.
- Mitchell, J. K. Community Response to Coastal Erosion. University of Chicago, Department of Geography Research Paper #156. Chicago, 1974.
- Murphy, F. C. Regulating Flood Plain Development. University of Chicago, Department of Geography Research Paper #62. Chicago, 1958.
- National Water Commission. Water Policies for the Future. U. S. Government Printing Office, Washington, D. C., 1973.
- Oglesby, Ray T., Clarence A. Carlson and James A. McCann. River Ecology and Man. Academic Press, New York, 1972.
- Pilgrim, D. H. and I. Cordery. Design Flood Estimation - An Appraisal of Philosophies and Needs. Water Research Laboratory, University of New South Wales, Munly Vale, N.S.W., Australia, 1974.

- Raitt, Daryll D. "The Willamette River, Flood Control or Flood Management" in Natural Resources Journal, Vol. 9, No. 1, p. 35-52, 1969.
- Sargent, Frederick O. "A Critique of Floodplain Planning in the Connecticut River Basin" in The Journal of the Northeastern Agricultural Economics Council, Vol. IV, No. 1, p. 76-86, 1975.
- Shabman, Leonard A. An Economic Perspective on the Federal Flood Insurance Program. Staff Paper SP 75-5, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1975.
- Sheaffer, J. R. Floodproofing. University of Chicago Department of Geography Research Paper #65. Chicago, 1960.
- Smith, Stephen and Emory Castle. Economics and Public Policy in Water Resource Development. Iowa State University Press, Ames, 1964.
- TRW Systems Group. A Methodology for Flood Plain Development and Management. Report submitted to U. S. Army Engineer Institute for Water Resources, Redondo Beach, California, 1969.
- United States. A Unified National Program for Managing Flood Losses August 1966. House Document 465, 89th Congress, Second Session, 1966.
- United States Water Resources Council. A Unified National Program for Flood Plain Management. United States Water Resources Council, Washington, 1976.
- Vaut, Gregory A. The Economics of Flood Insurance. Water Resources Research Center, University of Massachusetts at Amherst, Amherst, 1974.
- White, Gilbert F., and J. Eugene Haas, Assessment of Research on Natural Hazards. M.I.T. Press, Cambridge, Mass., 1975.
- White, Gilbert F., et al. Changes in Urban Occupance of Flood Plains. University of Chicago, Department of Geography Research Paper #57, Chicago, 1958.
- White, Gilbert F. Choice of Adjustment to Floods. University of Chicago, Department of Geography Research Paper #93, Chicago, 1964.

- White, Gilbert F. Human Adjustment to Floods. University of Chicago, Department of Geography Research Paper #29, Chicago, 1949.
- White, Gilbert F., et al. Papers on Flood Problems. University of Chicago, Department of Geography Research Paper #70, Chicago, 1961.
- White, Gilbert F. Strategies of American Water Management. Ann Arbor Paperbacks, Ann Arbor, 1971.
- Wilson, Wallace. "Danger: Flood Plain" in Michigan Natural Resources, Vol. 45, No. 3, p. 28-31, 1976.

Location Theory

- Alcaly, Roger E. "Transportation and Urban Land Values" in Land Economics, Vol. 52, No. 1, p. 42-53, 1976.
- Beckman, Martin. Location Theory. Random House, New York, 1968.
- Bish, Robert L. and Hugh O. Nourse. Urban Economics and Policy Analysis. McGraw Hill, New York, 1975.
- Clawson, Marion. Suburban Land Conversion in the United States. Johns Hopkins Press, Baltimore, 1971.
- David, Philip. Urban Land Development. Irwin, Homewood, Illinois, 1970.
- Evans, Alan W. The Economics of Residential Location. Macmillan, New York, 1973.
- Fredland, Daniel R. Residential Mobility and Home Purchase. Lexington Books, Lexington, Mass., 1974.
- Haggett, Peter. Locational Analysis in Human Geography. St. Martin's Press, N. Y., 1966.
- Hoover, Edgar M. An Introduction to Regional Economics. Alfred A. Knopf, New York, 1971.
- Isard, Walter. Location and Space Economy. Wiley and Sons, New York, 1956.
- Johnston, R. J. Urban Residential Patterns. G. Bell and Sons Ltd., London, 1971.
- Keiper, Jos. S. et al. Theory and Measurement of Rent. Chilton Co., Philadelphia, 1961.

- Krutilla, John V. and Anthony C. Fisher. The Economics of Natural Environments. Johns Hopkins, Baltimore, 1975.
- Loewenstein, Louis K. The Location of Residences and Work Places in Urban Areas. Scarecrow Press, New York, 1965.
- Papageorgiou, George J. Mathematical Land Use Theory. Lexington Books, Lexington, Mass., 1976.
- Perloff, Harvey S. The Quality of the Urban Environment. Johns Hopkins Press, Baltimore, 1969.
- Romanos, Michael C. Residential Spatial Structure. Lexington Books, Lexington, Mass., 1976.
- Smith, Barton A. "The Supply of Urban Housing" in The Quarterly Journal of Economics, Vol. XC, No. 3, p. 389, 1976.
- Toyne, Peter. Organization, Location and Behaviour. Wiley and Sons, New York, 1974.
- Webber, Michael J. Impact of Uncertainty on Location. M.I.T. Press, Cambridge, Mass., 1972.

Management and Decision Making

- Boettinger, Henry M. "To Manage Tomorrow" in Bell Telephone Magazine, Vol. 49, No. 6, p. 20-25, 1970.
- Brown, G. Spencer, Laws of Form. Bantam Book, New York, 1973.
- Buchanan, James M. and Gordon Tullock. The Calculus of Consent. Ann Arbor Paperbacks, Ann Arbor, 1965.
- Chavooshian, B. Budd and Thomas Norman. Transfer of Development Rights: A New Concept in Land Use Management. Leaflet 492, Cooperative Extension Service, Rutgers University, New Brunswick, N. J., undated.
- Green, H. A. John. Consumer Theory. Penguin Books, Harmondsworth, 1971.
- Johnson, Glenn L. et al., eds., Managerial Processes of Mid-western Farmers. Iowa State University Press, Ames, Iowa, 1961.
- Johnson, Glenn L. and Lewis Zerby. What Economists do About Values. Center for Rural Manpower and Public Affairs, Michigan State University, East Lansing, Michigan, 1973.

- Katona, George. Psychological Economics. American Elsevier, New York, 1975.
- Kaufman, Herbert. The Limits of Organizational Change. University of Alabama Press, University, Alabama, 1971.
- Kornai, János. Anti-Equilibrium. Elsevier, New York, 1971.
- Olson, Mancur. The Logic of Collective Action. Harvard University Press, Cambridge, Mass., 1965.
- Schmid, A. Allan. Property Power and Public Choice. Unpublished material.
- Tummala, V. M., Rao and Richard C. Henshaw, eds., Concepts and Applications of Modern Decision Models. Michigan State University, East Lansing, Michigan, 1976.
- Weisskopf, Walter A. Alienation and Economics. Dell Publishing Co., New York, 1971.

Probability and Uncertainty

- Arrow, K. J. and Robert Lind. "Uncertainty and the Evaluation of Public Investment Decisions" in The American Economic Review, Vol. 60, No. 2, p. 364-378, 1970.
- Borch, Karl. The Economics of Uncertainty. Princeton University Press, Princeton, N. J., 1972.
- Brown, G. Spencer. Probability and Scientific Inference. Longmans Green and Co., London, 1957.
- Dillon, John L. "Decision Theory in Agriculture" in The Review of Marketing and Agricultural Economics, Vol. 39, No. 1, p. 3-80, 1971.
- Egner, Robert E. and Lester Denonn eds., The Basic Writings of Bertrand Russell, p. 145-259, 311-345, 485-521. Simon and Schuster, New York, 1961.
- Fellner, William. Probability and Profit. Richard D. Irwin, Homewood, Ill., 1965.
- Gillies, D. A. An Objective Theory of Probability. Methuen and Co., London, 1973.
- Henderson, J. M. and R. E. Quandt. Microeconomic Theory. McGraw Hill, New York, 1971.

- Henry, Claude. "Investment Decisions Under Uncertainty: The Irreversability Effect" in The American Economic Review, Vol. 64, No. 6, p. 1006-1012, 1974.
- Knight, Frank. Risk, Uncertainty and Profit. University of Chicago Press, Chicago, 1971.
- Laplace, Pierre Simon Marquis de. A Philosophical Essay on Probabilities, translated by F. W. Truscott and F. L. Emory. John Wiley and Sons, New York, 1902.
- Lucas, J. R. The Concept of Probability. Clarendon Press, Oxford, 1970.
- Luce, Duncan and Howard Raiffa. Games and Decisions. John Wiley and Sons, New York, 1957.
- Mack, Ruth P. Planning on Uncertainty. Wiley Inter-Science, New York, 1971.
- Mishan, E. J. "Uncertainty and the Evaluation of Public Investment Decisions: A Comment" in The American Economic Review, Vol. 62, No. 1, p. 161-167, 1972.
- von Neuman, J. and Oscar Morganstern. The Theory of Games and Economic Behavior, 2nd edition. Princeton University Press, Princeton, New Jersey, 1947.

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