AN EXPOST STUDY OF THE ECONOMIC PERFORMANCE OF FEDERAL INVESTMENTS IN FLOOD CONTROL PROJECTS IN THE BOISE VALLEY, IDAHO

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YOSEPH GUTEMA

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ABSTRACT

The primary purpose of this study is to estimate the benefits and costs of federal flood control projects on the Bosie River, southwestern Idaho. The estimation of benefits and costs of federal flood control projects is essential because there is doubt regarding the economic efficiency of these projects. Expost estimation of benefits and costs will also reveal how accurate the ex-ante estimates of benefits and costs were.

In this study flood control is viewed as a production process which utilized limited federal funds as inputs to produce flood control services as outputs. The outputs of flood control cannot be directly valued in the market as flood control services are collective goods. To overcome this handicap, it was assumed that consumers are willing to pay an amount equivalent to the damages prevented. Thus, for a flood control project to be economically feasible the damages prevented (benefits) should exceed the cost of preventing the damages (costs of the flood control measures). To estimate the prevented damages one needs to know the damages with and without flood control projects.

This study uses data from an actual flood plain survey and develops six models to estimate annual flood damage with and without the flood control projects in the Boise Valley to

estimate flood control beneftis for the period 1950 to 1974. Each of the six models hypothesize that flood damage is dependent upon the level of economic development in the flood plain and the magnitude of floods.

In estimating the annual cost of the flood control projects on the Boise River, this study considers the annual cost of borrowing the federal funds from the government, the annual cost of operating and maintaining the flood control projects, and the annual depreciation of the flood control projects as the projects have a definite life time.

Due to theoretical and methodological limitations this study will not even attempt to estimate intangible costs and benefits. It should be borne in mind, however, at least from a theoretical standpoint an optimum economic use of limited resources cannot be determined until all effects including intangible effects are fully evaluated. But, one cannot sit and wait until intangibles become quantifiable to evaluate public projects because decisions have to be made.

In assessing the economic performance of the federal flood control projects in the Boise Valley for the period 1950 to 1974, this study found the results given below:

Annual rate of economic growth	Benefits (damages prevented) (1943 dollars)	Costs (1943 dollars)	Benefits / costs
0 percent	13,043,500	18,972,053	0.69
2.2 percent	19,167,269	18,972,053	1.01
4.2 percent	29,187,413	18,972,053	1.54

CHAPTER 1

INTRODUCTION AND DEFINITIONS

Introduction

The Flood Control Act of June 22, 1936 recognized that destructive floods on the nation's rivers and their tributaries are a "menace to national welfare" and established as a national policy the control of floods on navigable rivers and their tributaries as a proper federal activity "if the benefits to whomsoever they may accrue are in excess of estimated costs" (14). Clearly, the Act established the economic criterion that benefits must exceed costs for any federal flood control projects before they can be financed by the federal government.

However, the Act did not clearly define benefits and costs. The Act also did not prescribe that consistent procedures be developed and used in assessing the economic feasibility of flood control projects. In addition, the Act gave the impression that all benefits and costs possess monetary value. Thus, the federal agencies responsible for water resources development were left with the task of defining and evaluating the benefits and costs of water resources projects. The organization of water resources development by function also contributed to the development of different project evaluation standards. The Flood Control Act of 1936 also did not require that expost evaluation of flood control projects be done. Once the projects were approved for construction little has been done to assess their economic performance. As a result, it is not known whether the projects are economically feasible (benefits exceed costs) or not since the gain-loss calculus that directs decision making in the private sector is virtually nonexistent in the public sector.

Expost economic feasibility studies of flood control projects are essential for three major reasons. First, they provide the opportunity to compare the expected and the actual economic consequences of the flood control projects. Second, they expose past mistakes and thus help avoid future mistakes in present planning. Third, they give the public the opportunity to assess the merits of past flood control projects and as a result produce a well-informed public. On the need to inform the public about the economic consequences of public water projects Eckstein (12, p. 16) says:

> The public should also be informed about the merit of projects. For only an informed public opinion can assure that the challenge of water resources development will be met in a way that promotes the welfare of the country as a whole.

This study examines the economic performance of the federal flood control projects on the Boise River by estimating and comparing the benefits and the costs of the flood control projects since they started operation. A major problem faced in estimating flood control benefits was lack of annual flood damage data. To overcome the problem, this study develops a methodology to generate annual flood damages from a 1943 Boise River flood plain damage survey by the Corps of Engineers (51).

Statement of the Problem

The federal flood control projects in the Boise Valley have been in operation for over 20 years. These federal flood control projects are just a few of the several federal flood control projects in the whole country. Except for a few cases no expost economic studies were made to evaluate the ex-ante planning that took place. As the result, there is lack of information regarding the economic performance of federal flood control projects. Therefore, it is desirable to select representative federal flood control projects like the ones in the Boise Valley that have over 20 years of performance record for investigation to evaluate their real economic performance.

The central problem in this study then is to estimate the expost benefits and costs to be able to determine the economic performance of federal investments in flood control in the Boise Valley.

Why This Study

This study is undertaken for three reasons. First, this study looks at a neglected phase of project planning. According to Haveman (15, p. 3) the law and most analysts put much emphasis on the initial stages of project evaluation (ex-ante evaluation). However, project evaluation is not complete until an appraisal of the actual and estimated (predicted) values is done. Thus, an expost appraisal of the economic performance of federal investments in flood control will enable one to see how good the ex-ante estimates were and evaluate the planning that took place.

Second, the primary concern of economics is the proper allocation of resources. Thus, it is the task of economists to see that projects that compete for federal funds are evaluated on standardized procedures so that the use of questionable techniques will not favor projects that would not have qualified for federal funds under more scrutinizing procedures. The science of project evaluation is far from being perfect and suffers from lack of analytical tools. This study develops a procedure that can be used to estimate flood damages.

Third, according to the Task Force on Federal Flood Control Policy (43, pp. 3-5) flood damages have been increasing despite massive federal investment. But, hydrologists such as Hoyt and Langbein (18, p. 91) say "floods have not increased either in magnitude or in frequency during this century and a half." Later in this study, we will look into some of the factors that contribute to increased flood damage.

Objectives of the Study

This study has the following objectives.

(1) To develop a methodology for estimating flood damages in the Boise Valley with and without the federal flood control projects.

(2) To identify some of the problems involved in the estimation of benefits and costs of flood control.

(3) To make an expost appraisal of the benefits and costs of federal flood control projects in the Boise Valley and to compare the benefits and costs of flood control since the projects started operation.

The first objective will be accomplished by developing six flood damage models that use a combination of two flood control levels (no flood control and with flood control) and three economic growth rates (no growth, restricted growth, and actual growth). The objective relates to the problem in that it provides the methodology to estimate the damages with and without flood control that are in turn needed for the estimation of flood control benefits.

The second objective will be accomplished by making a study of the procedures used to estimate benefits and costs. This objective enables us to recognize some of the problems faced in project evaluation. Moreover, it cautions us in the interpretation of results. This objective relates to the problem in that some economic effects cannot easily be evaluated and make appraisal of economic performance difficult.

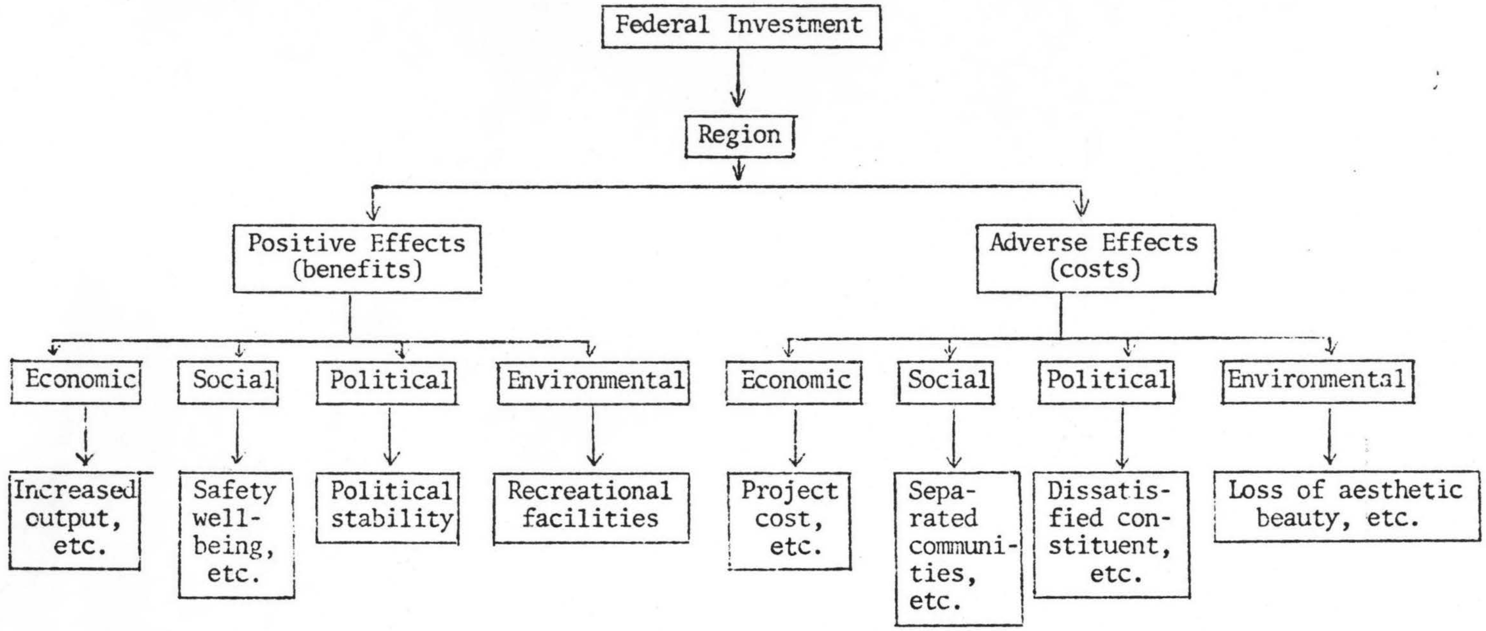
The third objective will be accomplished by estimating and comparing the benefits and costs of the federal flood control projects in the Boise Valley since the structural flood control measures went into operation.

Hypotheses

An approach to the analysis of the problem at hand can be diagrammatically visualized as shown in Figure 1. In accordance with Principles and Standards (59, p.6) federal investments in flood control are viewed as producing desirable (benefits) and adverse (costs) effects. The desirable effects include reduced property damage, incresed output, safety from flood disaster, recreation, and orderly business transaction. The adverse effects of flood control include the cost of the project and all other adverse effects produced by the project.

The problem as described earlier is to assess the economic performance of the federal flood control projects in the Boise Valley since they started operation. It is clear from Figure 1 that all the positive and negative effects of federal investment cannot be evaluated. This study estimates the economic positive (benefits) and adverse (costs) effects. To help us direct our investigation the following hypotheses will be tested.

Hypothesis 1: For the federal flood control projects



Note: The list in each category is not all inclusive as the intention is to show complexity of the problem. We are interested in the expost estimation of benefits and costs in the economic area.

Figure 1: Diagrammatic exposition of the problem.

in the Boise Valley the estimated expost total and annual benefits exceeded estimated expost total and annual costs for the period 1950 to 1974. This hypothesis will be tested by comparing estimated expost total benefits to estimated expost total costs. Also the estimated expost annual benefits will be compared to expost estimated annual costs. Both the expost estimated benefits and costs will be estimated by this study. If the estimated expost benefits exceed the estimated expost costs the hypothesis will be accepted and the federal investments in flood control will be considered an economic success.

Hypothesis 2: For the federal flood control projects in the Boise Valley actual project costs exceeded estimated ex-ante project costs. This hypothesis will be tested by comparing the actual total project costs adjusted for price changes to estimated ex-ante project costs adjusted for price changes. The actual total project costs will be obtained from the various federal agency publications. The ex-ante total project costs will be obtained from the original authorizing documents. The hypothesis will be accepted if acutal total construction costs exceed the estimated ex-ante total construction costs.

Study Methodology

This study views flood control as a production process which utilizes limited federal funds as inputs to produce flood control services to reduce flood damage as outputs. To assess the economic performance of the production process one needs to evaluate the inputs and the outputs in common units (dollars) and compare them. The dollar value of inputs will constitute the costs while the value of outputs will constitute the benefits. The major economic variables in this study will be benefits and costs. The economic performance of the federal flood control projects over the 25-year period this study coveres (1950 to 1974) will be determined by estimating and comparing the benefits and costs. Both benefits and costs will be estimated in 1943 constant dollars.

Flood Damage Models

The estimation of flood control benefits in the Boise Valley (Ada and Canyon Counties) will be carried out by developing six flood damage models that utilize two levels of flood control (no flood control and with flood control) and three growth rates (no growth, growth without flood control, and growth with flood control). All six models are built on the assumption that a flood of a given discharge, Q has a given damage, D associated with it. Or in mathematical symbols:

$$D = f(Q)$$

All six models will utilize the same base year's (1943) discharge-damage relationship. The 1944 discharge-damage relationship for the Boise River is used because the Corps of Engineers (51, Appendix A, Tables 5, 15-20) surveyed the Boise River flood plain and determined the flood damages that were associated with selected floods at 1943 level of economic development.

Model 1: Model 1 estimates the annual flood damage without economic growth and without flood control at 1943 level of economic development. Model 1 is:

$$D_1(NG, NFC) = f(Q_i)$$

where: $D_1(NG, NFC)$ = annual flood damage with no growth and no flood control.

Q_i = annual springtime maximum mean daily natural flow of the Boise River (this is the flow for which during the flood season the daily mean natural flow was a maximum) in the ith year.

From now on the annual springtime maximum mean daily natural flow, Q_i, will be referred to as the natural flow. To estimate the annual flood damages without economic growth and without flood control (Model 1) one needs the 1943 discharge-damage curve and the value of Q_i. Note that in Model 1, two floods of the same magnitude regardless of the length of time between them cause the same damage as there is no economic growth.

Model 2: Model 2 estimates the annual flood damages without economic growth and with flood control. Model 2 is:

$$D_2(NG,FC) = f(Q_i')$$

where: $D_2(NG,FC)$ = annual flood damage without growth and with flood control.

Q_i' = annual springtime maximum mean daily regulated flow of the Boise River (this is the flow for which during the flood season the daily mean regulated flow was a maximum) at Boise in the ith year.

From now on the annual springtime mean daily regulated flow of the Boise River, Q_i' will be referred to as the regulated flow. To estimate D_2(NG,FC) one needs the 1943 discharge-damage curve and the annual regulated value of Q_i'.

Model 3: Model 3 estimates the annual flood damages with restricted economic growth and without flood control. Model 3 is:

$$D_3(RG,NFC) = (1+p)^n f(Q_i)$$

where: D_3(RG,NFC) = estimated annual flood damage with restricted growth and no flood control.

p = estimated annual rate of growth without flood control.

n = number of years after base year (1943).

To estimate D_3(RG,NFC) one needs the 1943 discharge-damage curve, the values of Q_i, and p. The discharge-damage curve (1943) and the values of Q_i are readily available. But, the value of p should be estimated. To estimate the value of p in this study, data on the annual value of property in Ada and Canyon counties (southwestern Idaho) was used. Note the link between Models 1 and 3, that is, recall that Model 1 was: $D_1(NG,NFC) = f(Q_i)$. Thus by substituting D_1(NG,NFC) for $f(Q_i)$ in Model 3 one gets:

$$D_3(RG,NFC) = (1+p)^n D_1(NG,NFC)$$

Thus, the estimated annual damages with restricted growth and no flood control (Model 3) can be obtained by multiplying Model 1 by $(1+p)^n$.

Model 4: Model 4 estimates the annual flood damage with restricted growth and with flood control. Model 4 is:

$$D_4(RG,FC) = (1+p)^n f(Q_i')$$

where: $D_4(RG,FC)$ = estimated annual flood damage with restricted growth and flood control.

To estimate $D_4(RG,FC)$ one needs the discharge-damage curve, the annual regulated flows (Q_i') and the average growth rate without flood control (p). The discharge-damage curve (1943) and the Q_i' are readily available. The value of p has already been estimated in Model 3. Note the link between Model 2 and Model 4, that is, $D_2(NG,FC) = f(Q_i')$. Thus, substituting $D_2(NG,FC)$ for $f(Q_i')$ in Model 4 one gets:

$$D_4(RG,FC) = (1+p)^n D_2(NG,FC)$$

Thus Model 4 can be obtained by multiplying the estimated annual damage in Model 2 by $(1+p)^n$.

Model 5: Model 5 estimates the annual flood damage with actual economic growth and no flood control. Model 5 is:

$$D_5(AG,NFC) = (1+r)^n f(Q_i)$$

where: $D_5(AG,NFC)$ = estimated annual flood damage with actual growth and no flood control.

r = annual rate of economic growth with flood control.

To estimate D_5(AG,NFC) one needs to estimate r as the 1943 discharge-damage curve and data on the natural discharge (Q_i) is already available. In this study r will be estimated by using assessed valuation of property in the flood plain by the Corps of Engineers. Note that Model 5 can also be written as:

$$D_5(AG,NFC) = (1+r)^n D_1(NG,NFC)$$

Model 6: Model 6 estimates the annual flood damage with actual economic growth and flood control. Model 6 is:

$$D_6(AG,FC) = (1+r)^n f(Q_i')$$

where: D_6(AG,FC) = estimated annual flood damage with actual growth and flood control.

Note that D_6(AG,FC) can be written as:

$$D_6(AG,FC) = (1+r)^n D_2(NG,FC)$$

To estimate D_6(AG,FC) one needs the results of Model 2 and the value of r.

Use of the Six Models to Estimate Prevented Damages

The six flood damage models were developed to estimate prevented damages (flood control benefits). The prevented flood damages are the difference between damage without flood control and damage with flood control. Table 1 has been

Table 1: Use of the six flood damage models to estimate flood control benefits (prevented damages).

Rates of growth	Levels of flood control: No flood control	Levels of flood control: With flood control	Flood control benefits
No growth	Model 1	Model 2	Model 1 — Model 2
Restricted growth	Model 3	Model 4	Model 3 — Model 4
Actual growth	Model 5	Model 6	Model 5 — Model 6

prepared to enable the reader to remember the six flood damage models and also to show how the six models are used to estimate prevented damages. It can be seen from Table 1 that prevented flood damages are computed for three rates of economic growth (no growth, restricted rate of growth, and actual rate of growth).

Procedure

The following steps are essential to estimate annual prevented flood damages (flood control benefits):

Step 1: Select a base year for which sufficient discharge-damage data are available.

Step 2: Plot discharge against damage to obtain the base year's discharge damage curve.

Step 3: Obtain annual natural flow data (Q_i) of the river since the project started operation.

Step 4: To obtain damage estimates for Model 1, read damages from the base year's discharge-damage curve for the annual natural flows (Q_i).

Step 5: Obtain annual regulated flows (Q_i') of the river (with flood control) since the project started providing its intended services.

Step 6: Damage estimates for Model 2 are obtained by reading damages that correspond to the regulated flows (Q_i') from the base year's discharge-damage curve.

Step 7: The annual rate of economic growth without flood control, p, is estimated by selecting either the area surrounding the flood plain or a region that is similar to the study area, but does not have flood control projects.

Step 8: Model 3 is obtained by multiplying the damages obtained in Step 4 (Model 1) by $(1+p)^n$ where p is as defined earlier and n is the number of years after the base year.[1/] Model 4 is obtained by multiplying Model 2 by $(1+p)^n$.

Step 9: Estimate the actual average annual rate of economic growth in the study, r, for the period since the project started operation to a current year.

Step 10: Model 5 is obtained by multiplying the damages obtained in Model 1 (Step 4) by $(1+r)^n$. Model 6 is obtained by multiplying the damages in Step 6 (Model 2) by $(1+r)^n$.

Step 11: Subtract Model 2 from Model 1, Model 4 from Model 3, and Model 6 from Model 5 to get prevented flood damages with no growth, with restricted growth, and with actual growth respectively.

Figure 2 summarizes the steps outlined above. Figure

[1/] Where $(1+p)^n$ is a compounding factor from the compound interest formula [i.e., $V_n = V_o(1+p)^n$]. Given the values of V_n, V_o and n it can be shown that $p = \sqrt[n]{\frac{V_n}{V_o}} - 1$

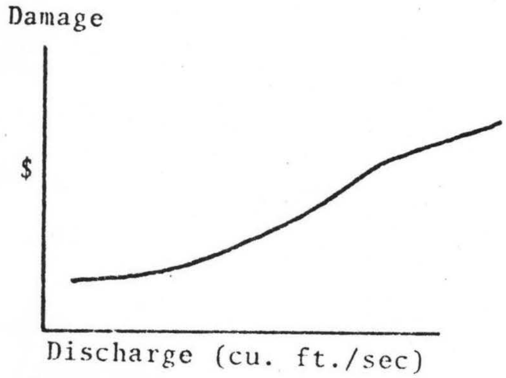


Fig. 2(a) A hypothetical base year's discharge damage curve.

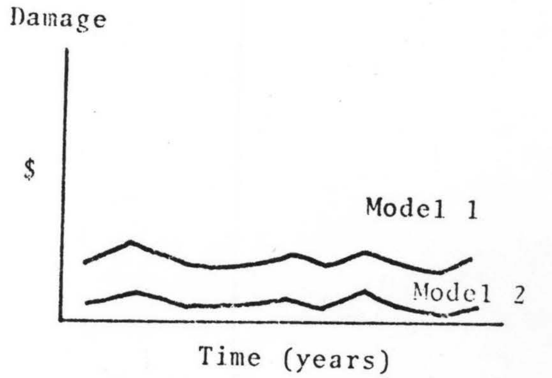


Fig. 2(b) Annual flood damages without economic growth.

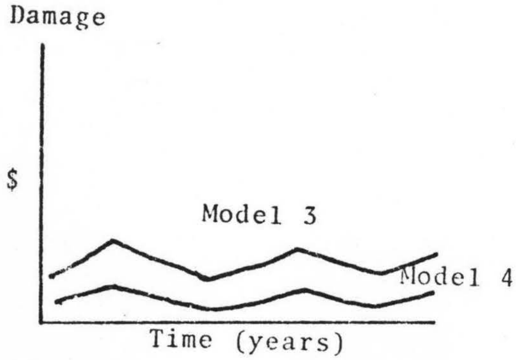


Fig. 2(c) Annual flood damages with restricted economic growth.

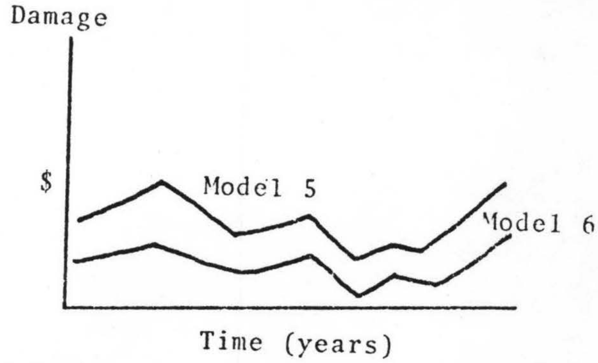


Fig. 2(d) annual flood damages with actual economic growth.

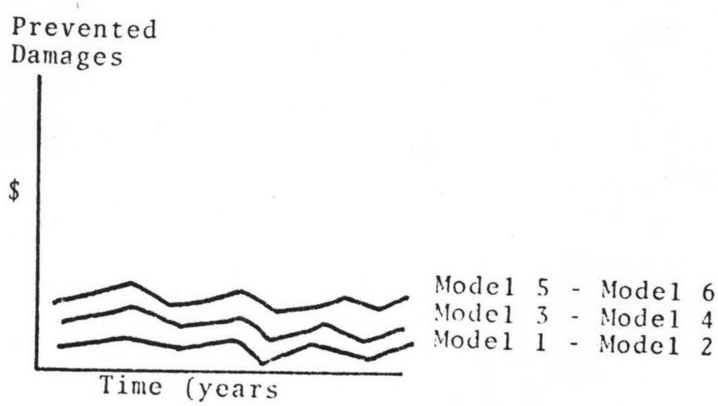


Fig. 2(e) Prevented annual flood damages

Figure 2. Diagrammatic exposition of how the six flood damages can be used to estimate flood control benefits.

2(a) shows a hypothetical base year's discharge-damage curve (general model). Figure 2(b) presents the annual flood damage with no growth, no flood control (Model 1), and with flood control (Model 2). Figure 2(c) shows the annual flood damage with restricted growth, no flood control (Model 3), and with flood control (Model 4). Figure 2(d) presents the annual flood damages with actual growth, no flood control (Model 5), and with flood control (Model 6). Note that the prevented damages (flood control benefits) in Figures 2(b), 2(c), and 2(d) are the difference between Model 1 and Model 2, Model 3 and Model 4, and Model 5 and Model 6 respectively.

Before proceeding any further it is essential at this point to emphasize that the hydrologic, technologic, and economic information contained in the 1946 Crops of Engineers study (52) is assumed to be correct.

Definition of Terms

Flood: The term flood is used to mean any stream flow which exceeds the safe channel capacity of a stream. This definition is adopted for this study because the safe channel capacity for the Boise River has been specified. However, the term has been defined variously to mean "any flow equal to or greater than a designated basic flow," (25, pp. 463-464) or "an unusually high flow of a stream," (33, p. 117) or "any stream flow which greatly exceeds the average stream flow" (60, p. 36).

Magnitude of a Flood: The magnitude of a flood is measured by its maximum rate of discharge of water either during the peak period or the peak instant and it is measured in cubic feed per second (12, p. 117).

Flood Stage: Flood stage is the number of feet by which a river exceeds the safe channel capacity.

Annual Maximum Mean Daily Natural Flow: This is the natural flow which has the highest value during the entire flood season in one year. The flows are maximum mean daily natural flows because more than one reading is taken. In this study the annual maximum mean daily natural flow will be referred to as a natural flow.

Annual Maximum Mean Daily Regulated Flow: This is the regulated flow which has the highest value during the entire flood season in one year. The daily flows are maximum mean daily regulated flows because more than one reading is taken. The annual maximum mean daily regulated flows will be referred to in this study as regulated flow.

Flood Probability: This is the measure of the average percentage chance of occurrence of any flood in any given year. A 100-year flood is a flood that on the average has a one percent chance of occurrence in any one given year, or one that on the average occurs once in 100 years. It should be kept in mind that the flood may or may not occur. The reliability of flood probability estimates are influenced by the number of observations and the accuracy of the hydrologic data in any given area. For a stream that has a long stream flow record, the probability of any flood in the record according to James and Lee (24, p.231) is:

$$f = \frac{m}{n+1}$$

where: f = probability of any given flood

m = rank of the given flood in descending order

n = number of year of record.

The formula above cannot be used to assign probabilities to larger floods that have not been recorded before. The Water Resources Council recommends a different procedure for such cases.[2/]

Flood Plain: This term will be used to mean "land outside of a stream channel described by the perimeter of the probable limiting flood" (60, p. 37). Leopold and Maddock (29, p. 10) define a flood plain as "a smooth or relatively flat area bordering a stream..."

Flood Damage: This term is used to mean the reduction in the value of goods and services as the result of direct and indirect actions of flood waters.

Flood Control Benefits: This term will be used to mean prevented flood damages. More specifically, it is the

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[2/]The procedure recommended by Water Resources Council in determining flood probabilities is the log-Pearson type III distribution found in: Water Resources Council, Hydrology Committee, "A Uniform Technique for Determining Flood Flow Frequencies," Bulletin 15 (1967).

difference between flood damages without flood control and flood damages with flood control.

Flood Control Costs: In this study flood control costs will be used to mean the sum of the alternative investment opportunity of federal funds invested in flood control, the operating and maintenance costs, and depreciation.

CHAPTER 2

THEORETICAL BACKGROUND

This chapter provides theoretical background discussion in the economics of flood control. In the process of providing theoretical background the outputs of flood control will be identified and some of the problems faced in valuing some of the outputs of flood control will be discussed. A look at benefit-cost analysis will be taken and some arguments will be advanced why it should be used in appraising the merits of public projects.

Framework of Analysis

A simplistic approach to the expost evaluation of flood control is to visualize flood control as a production process which utilizes inputs (labor, land, capital, and management) to produce outputs (prevented loss of goods and services, increased productivity of goods and services because of intensive use of property, prevented loss of life, health, and prevented emergency expenditures). Assuming that the inputs and outputs have market value, the job of the analyst is a simple one. To measure the value of inputs and outputs, one needs the per unit value and the quantity involved. Then by comparing the cost of the production process to the revenue it generates, the analyst can determine if the production process is feasible (total revenues exceed total costs) or inefficient (costs exceed revenue). However, by considering various alternatives the analyst can determine if the production process is economically efficient.[3/]

The above approach is simplistic because flood control services are not marketable goods. The inputs that produce flood control services are marketable but the outputs are not. Therefore no market values exist for flood control benefits, so the valuation of flood control outputs (benefits) pose major problems to the analyst.

Collective Goods

Flood control services belong to the general class of goods called collective goods. Collective goods are defined by Samuelson (38, p. 387), Breton (5, p. 457) and Strotz (42, p. 329) as goods that are equally available to all members of a community and no one can be excluded from enjoying them once they are made available. Flood control services are equally available to all people that inhabit the flood plain. No one can be excluded from enjoying flood protection as it is very difficult to exclude anyone from not enjoying it. A

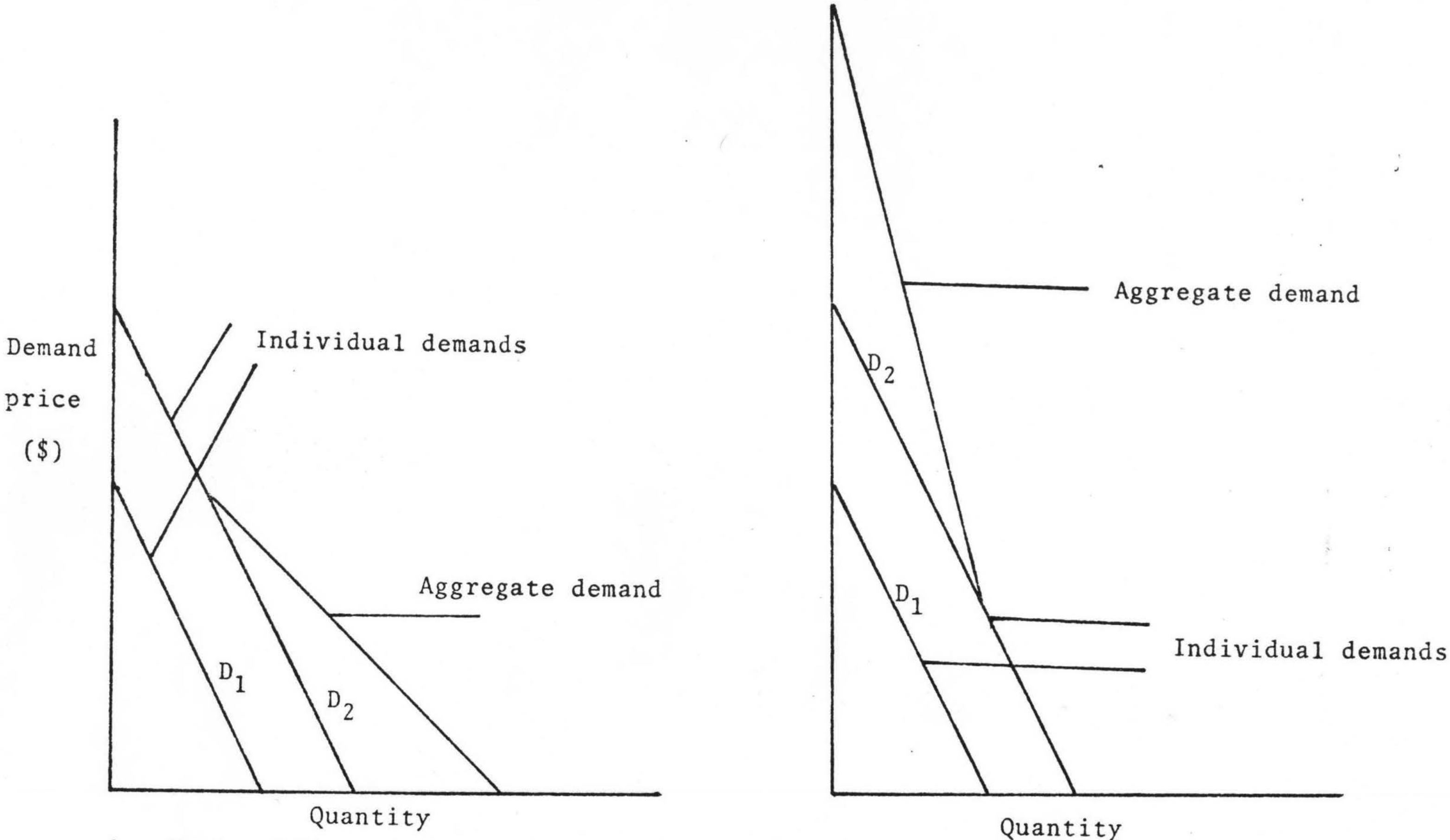
[3/] In Welfare Economics, the technical term for economic efficiency is Pareto-optimality. Pareto-optimality is a situation in which productive resources are so allocated that it is impossible to make anyone better off without making any other member worse off. For a detailed description of economic efficiency, see John V. Krutilla and Otto Eckstein, Multiple Purpose River Development, (Baltimore, Johns Hopkins, 1958), p. 15-51.

diagrammatic exposition of the difference between the demand functions for marketable goods (e.g. irrigation water) and collective goods (e.g. flood control) is given by Prest and Turvey (36, pp. 695-696) using Bowen's (3) explanation in Figure 3. The aggregate demand for irrigation water is a horizontal summation of the individual demands in Figure 3.

Individual valuation of flood control services may vary, however, since they are equally available to all the landowners of a given community, the quantity of flood control services consumed by each member is the same. Therefore, the aggregate demand for flood control is a vertical summation of the individual demands instead of the customary horizontal summation for marketable goods (36, pp. 695-696).

The demand curve for flood control may not essentially have the same shape as that in Figure 3. Haveman (15, p. 5) feels that it has the peculiar shape shown in Figure 4 because the willingness to pay is less for protection against smaller floods, but the willingness to pay increases as the protection against larger floods is provided. However, the willingness to pay startes to decrease after a level of protection the consumers believe is adequate is reached.

The rationale for government provision of flood control services rests on the nonexclusion principle, i.e., private enterprises do not posess the police power of the government to force people to pay for flood control services as nobody can be excluded from receiving the services once they become available.

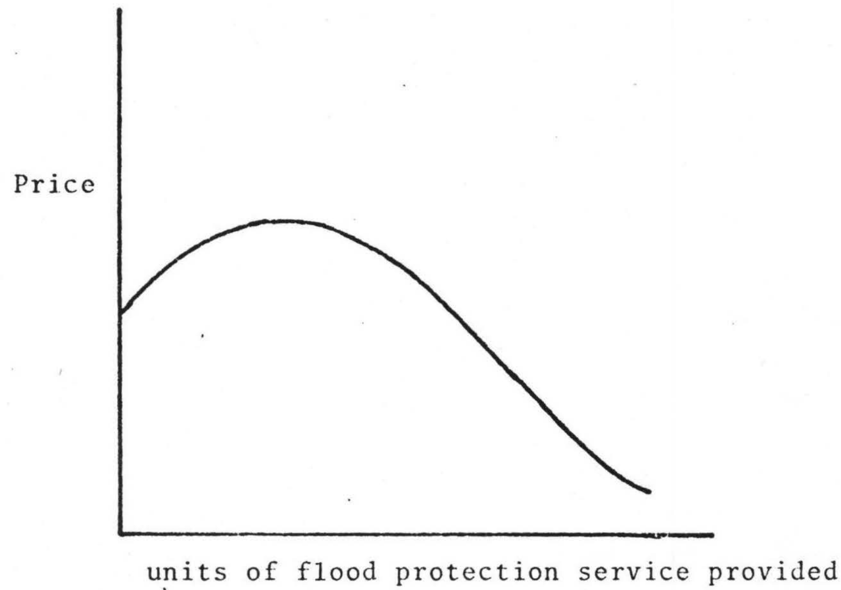


A. Marketable goods (irrigation water).

B. Collective goods (flood control).

Source: A.R. Prest and R. Turvey, "Cost-Benefit Analysis: A Survey," Economic Journal, 75 (December 1964), 965-696.

Figure 3: Aggregate demand functions for marketable and collective goods.



Source: Robert H. Haveman. The Economic Performance of Public Investments (Baltimore: Johns Hopkins Press, 1972).

Figure 4: Aggregate demand function for flood control services.

Market Value

The use of the market system in which market values are determined by supply and demand has limits and presents problems in determining the worth of public projects. Since in the economic analysis of federal projects a comprehensive public viewpoint (local, regional, and national) should be taken into consideration, the price of a product or service in the private market may inadequately reflect its value from the public viewpoint (13, p. 7); but market prices do not exist for flood control benefits. An indirect procedure is used to value the benefits from flood control projects as the willingness to pay does not exist. The divergence of social value and private value and the existence of externalities weakens the use of the market value in public projects.

Despite the limits of the market system in reflecting values from the public viewpoint, the lack of an acceptable and a well-developed theory of social value forces one to fall back on the market value. The concept of market value has undergone much theoretical development since the Classical Economists while social value has received little attention by economists.

Value was determined by different factors to the different schools of economic thought. For example, to the classical economists such as Smith (41, p. 14) and Ricardo (37, p. 14) value depended on the quantity of labor that the good or service embodied. To the Austrian School, for example such as Jevons (26, pp. 1-2), the value of a good or service depended entirely on utility. To the Neo-classical school led by Marshal (32, pp. 348-350) value depended on the costs of production (on the supply side) in the long run and on the marginal utility (on the demand side) in the short run.

The Economics of Expost Evaluation

Expost evaluation is concerned with the economic consequences of investments that have performance records. Expost evaluation can be employed by both the public and the private sectors. The primary goal of expost evaluation is to appraise past performance to enhance future planning. Private enterprises review their past performance periodically and the profit-loss calculus forces them to do that. However, such an endeavor is rare in the public sector. According to Haveman (15, p. 1) "Neither the criteria for expost evaluation nor approaches for measuring economic results are at all well developed."

Charles Schultze (15, p. 64) points out another reason why expost evaluation is necessary: "Feedback of operating results to program planning is essential."

In the ex-ante evaluation, flood control projects (actually all comprehensive water resouce development projects) should satisfy the following criteria according to the President's Water Resources Council (35, p. 7):

(1) "Tangible benefits exceed economic costs."

(2) "Each separable unit or purpose provides benefits at least equal to its costs."

(3) "The scope of development is such as to provide the maximum net benefits."

In the absence of criteria and approach for expost evaluation as pointed out by Haveman earlier, an analyst should perhaps take the original data used by the responsible agency in the ex-ante evaluation and also other data since the project started operation and then appraise the performance of the project by using a generalized procedure as to how:

(1) ex-ante and expost benefits compare;

(2) ex-ante and expost costs compare;

(3) ex-post benefits and expost costs compare.

Benefit-Cost Analysis

Benefit-cost analysis has been defined as "a way of looking at problems of choice in monetary terms" (10, p. 14), or an analytical tool mainly used to set out factors which need to be taken into consideration in making certain economic choices. Krutilla (28, p. 23) says that benefit-cost analysis in the public sector is the counterpart of the private sectors cost-gain calculus.

In benefit-cost analysis, one needs to know the following according to Prest and Turvey (12, p. 686):

(1) identification of future benefits and costs that should be included in the study;

(2) measurement of future benefits and costs;

(3) discount rate;

(4) specification of constraints.

Perhaps the hardest part in benefit-cost analysis is the identification and valuation of benefits. On the difficulty of the measurement of benefits and costs, Eckstein (12, p. 48) says:

> Measuring all benefits and costs...is not only beyond the present ability of economic science, but presents conceptual difficulties which by their very nature can never be overcome except by making specific assumptions...

Prest and Turvey (36, p. 729) feel that problems in the evaluation of benefits arise because essentially the measurement of benefits is the measurement of surpluses and this brings us to the problem of the measurability of utility, and the comparability of utilities between persons. Furthermore, the addition of benefits that accrue to different people necessitates making the assumptions that equal weight be attached to benefits that accrue to different people (12, p. 48). Simplifying assumptions, however, are not perculiar to benefit-cost analysis. Most analytic tools have simplifying assumptions built into them. For example, linear programming assumes linear relationships which may not be valid under every circumstance.

Ciriacy-Wantrup (8, pp. 16-21) gives the following reasons for using benefit-cost analysis:

(1) It restrains the abuse of economic arguments in the political process.

(2) Benefit-cost analysis necessitates quantification both in physical and economic terms. This stimulates scientific understanding of the physical and social problems involved in public resource development.

Prest and Turvey (36, p. 730) see other advantages to benefit-cost analysis:

(1) It forces those responsible to quantify and serves as a check against biases.

(2) It may not provide the right answers but it can play the negative role of screening projects.

(3) It can stimulate more questions.

(4) Emphasis and recognition of its weaknesses strengthens the case for its use.

Krutilla (28, p. 31) feels benefit-cost analysis provides systematic thinking about problems in making decisions.

Flood Control Benefits

The measurement of flood control benefits presents the problems of identification of benefits and valuation of these benefits. Before the beneftis can be valued one has to clearly identify the benefits. After the benefits are identified they have to be classified and a per unit value must be determined for each type of benefit.

Flood control measures provide benefits in the following ways:

(1) by avoiding loss of goods and services which would otherwise occur as a result of flood;

(2) by making possible increased production of goods and services through intensive use of property which would otherwise be under utilized because of flood hazard;

(3) by avoiding loss of life, health, etc. which would otherwise occur as a result of flood;

(4) by obviating temporary emergency costs which would otherwise be needed as a result of flood.

Because flood control is not a marketable good, the value that people place on the protection it provides cannot be determined directly. Usually, the general principle according to Prest and Turvey (36, pp. 708-709) is to determine the mathematical expectation of annual flood damage based on the frequency of floods of different magnitudes and think of this sum as the maximum annual amount people are willing to pay for flood control.

The theoretical background discussion revealed that:

(1) Flood control is a collective good and market prices do not exist for flood control services.

(2) The use of market value in determining the

economic worth of projects has some weaknesses unless it is complemented by a system of social value.

(3) The outputs of flood control are:

(a) averted flood damages;

(b) avoidance of death;

(c) avoidance of temporaty costs of flood fighting;

(d) better utilization of land and property in the flood plain.

(4) Benefit-cost analysis may be subject to abuse and weakness, however, it should be used to appraise the merit of public projects.

CHAPTER 3

GENERAL CHARACTERISTICS OF THE BOISE RIVER FLOOD PLAIN

The purpose of this chapter is to familarize the reader with the Boise River flood plain and the federal flood control projects on the Boise River. A closer look at the economy of the Boise Valley and the nature of the flood problms in the Boise River flood plain will be taken.

Location of the Flood Plain

The Boise River, a major tributary of the Snake River and a part of the Columbia River drainage system, originates in the Sawtooth Mountains of southwestern Idaho and flows southwesterly through rugged mountain terrain onto the fertile alluvial Boise Valley. After it enters the Boise Valley, it flows southwesterly through portions of the cities of Boise, Eagle, Star, Middleton, Caldwell, Notus, and Parma and finally enters the Snake River. Figure 5 shows the location of the Boise River and its tributaries in the state of Idaho. Figure 5 also shows the storage reservoirs on the Boise River.

The Boise River has a drainage area of 4,134 square miles and its major tributaries include South Fork, Middle Fork, North Fork, and Mores Creek with drainage areas of

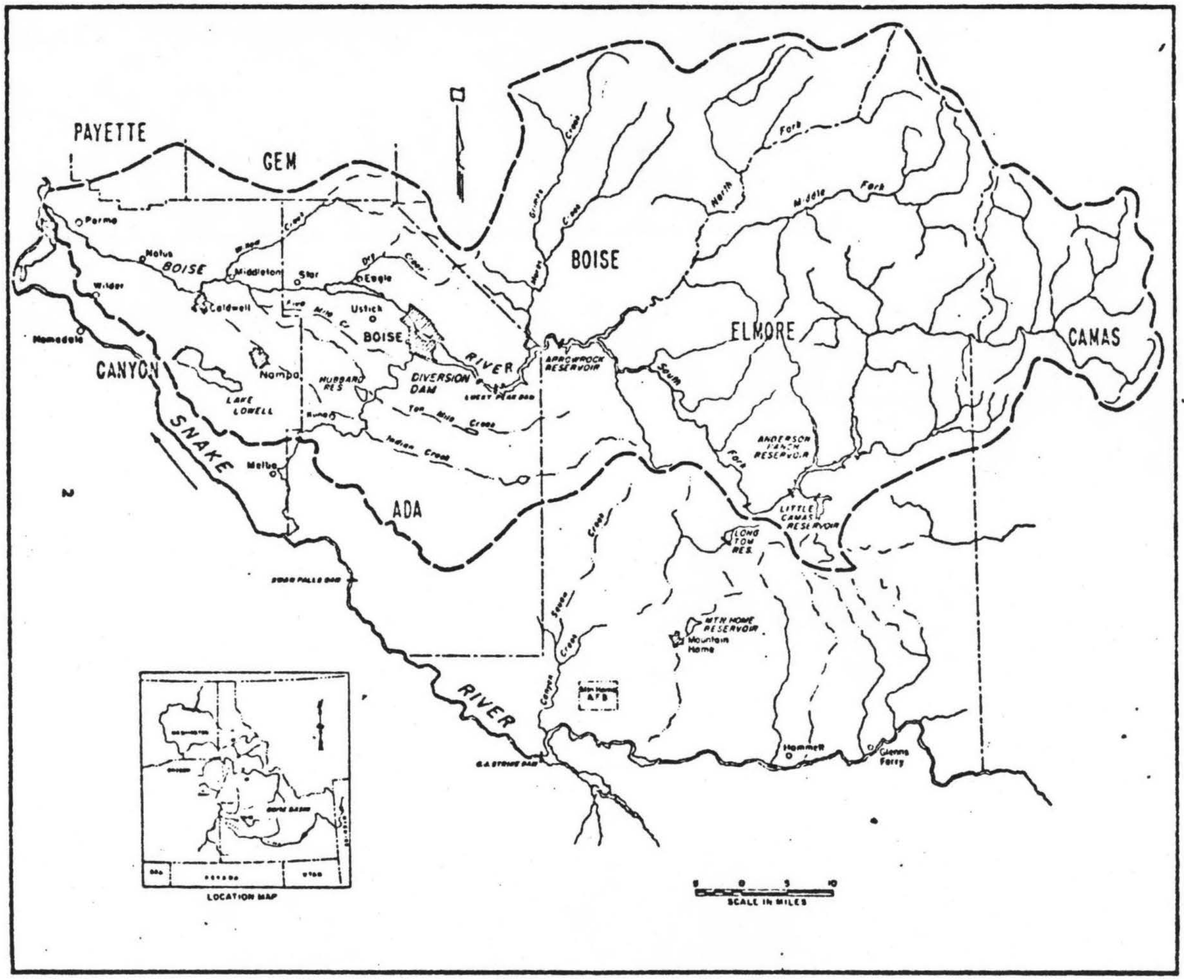


Figure 5: The Boise River basin.

1,314, 380, 382, and 426 square miles respectively.

The flood plain in which we are interested to estimate the benefits of federal investment in flood control extends from Barber Dam, 7 miles upstream from the city of Boise, to the confluence of the Boise and Snake Rivers, near Parma, Idaho (see Figure 5). The flood plain has a length of about 60 miles and varies in width from 1 to 3 miles. A map of the flood plain of the Boise River was made by the Army Corps of Engineers in 1939 (46). This map indicates the different zones that will be inundated by a 2, 5, 10, 50, and 1000-year floods. A 2-year flood is a flood that has a 50 percent chance of occurring in any given year or a flood that may be expected to occur once in every two years on the average. The other years' floods can be defined similarly. The 2-year flood has its own flood plain. The 5-year flood which has a 20 percent chance of occurring in any given year covers the 2-year flood plain plus some additional area. The 1000-year flood covers the 2-year, 5-year, 10-year, 50-year, and 1000-year flood plains.

According to the 1939-1940 flood damage appraisal by the U.S. Bureau of Agricultural Economics, U.S. Forest Service, U.S. Soil Conservation Service, and the U.S. Corps of Engineers the total area of the 1000-year flood plain was 57,300 acres. Total wasteland in the 1000-year flood plain was 6,590 acres and the rest was productive agricultural land (46, Table AP-F-1).

According to the Corps of Engineers Report, Definite Project Report on Lucky Peak Dam and Reservoir in 1949, "... the potential flood plain...includes some 56,000 acres of highly productive agricultural lands and 1,780 acres of urban and suburban areas. The latter includes portions of the cities of Boise, Caldwell, Parma, Eagle, and Star" (49, pp. 8-9).

The flood plain is narrower in Boise and broader towards the southwest. It is narrow in Boise as the river channel is constrained by natural barriers, man-made embankments, and levees. The flood plain is broader as the river moves southwesterly because the river channel forks and forms Eagle Island and then rejoins some 3.5 miles southwest of the city of Eagle. The river has a gradient of 11.5 feet per one horizontal mile as it flows through the flood plain (7, p. 83).

Federal Flood Control Facilities on the Boise River

There are three major federal reservoirs that provide storage for irrigation and flood control in the Boise Valley. These reservoirs are Arrowrock, Anderson Ranch, and Lucky Peak.

A coordinated plan to operate the three reservoirs jointly for flood control, irrigation, power and recreation purposes was worked out by the Corps of Engineers, Walla Walla District, and the Bureau of Reclamation, Region I, Boise, Idaho, at the field level and was signed into an agreement by the respective secreatries of the Department of the Army and the Department of Interior on Nobember 20, 1953. The official name of the agreement is Memorandum of Agreement between the Department of the Army and the Department of Interior for Flood Control Operation of the Boise River Reservoirs, Idaho. The main features of the agreement are as follows:

(1) Storage space of up to the total active space of the three reservoirs, 983,000 acre-feet, will be used primarily for flood control and irrigation subject to forecast of runoff.

(2) Forecast of runoff volume will be made from January 1 throughout the flood season and reservoir refill and release will be made based on forecast so that the downstream bankful capacity is not exceeded.

(3) Diversion of water to New York Canal, the canal that carries water to Lake Lowell Reservoir (an off stream storage reservoir for irrigation), will be considered to average 1,365 CFS in March and 2,820 CFS from April 1st through July 31st.

(4) Reservoirs will be evacuated by proceeding upstream and filled in the reverse order for the purpose of flood control. At least 60 percent of the flood control space will be maintained in

Lucky Peak and Arrowrock Reservoirs.

(5) Lucky Peak will be kept filled from the end of flood season until September 15 for recreation purposes.

(6) This plan of operation may be altered by the two departments if justified (50, Appendix A).

Table 2 shows the federal facilities on the Boise River in addition to the ones mentioned above and gives the year the facilities were completed, what county in Idaho they are located, the federal agency that operates it, the physical capacity, and the primary purposes for which the facility was built.

Economy of the Boise Valley

Presently, agriculture and allied industries are the major economic base of the Boise Valley (Ada and Canyon counties). However, this was not the case in the early 19th Century. Fur trading was the primary economic activity that brought thousands of people and millions of dollars to the then Idaho Territory of which the Boise Valley was a part. Gradually, fur trade gave way to mining in which in turn brought thousands of people and changed the economic base of the Idaho Territory. Depletion of the richest and most accessible mineral deposits made mining unattractive and thus ranching became a dominant activity (23, p. 41).

The existence of vast ranges encouraged raising cattle

Table 2: Federal facilities on the Boise River.

Facility	County	Year completed	Owner	Capacity (ac. ft.)	Purpose
Arrowrock Dam	Boise	1915[1/]	Bureau	286,000	I & FC
Anderson Ranch Dam	Elmore	1950	Bureau	493,000	I & FC
Boise Diversion Dam	Ada	1908	Bureau	negligible	I & P
Lake Lowell	Canyon	1908	Bureau	190,000	I
Lucky Peak Dam	Ada	1954	Corps	306,000	I & FC

Source: Water Resources Research Institute, University of Idaho, Idaho Water Resources Inventory, Moscow, Idaho, 1968, p. 340-345.

[1/] Raised 5 feet and received some repair work because of deterioration between 1935-1937.

I = Irrigation
FC = Flood control
P = Power

Contrary to what Bollinger's study showed for the state of Idaho, according to Nybroten (34) population never declined in the Boise Valley (Table 3).

In the Boise Valley, in addition to agriculture, services and trade are extremely important. The city of Boise provides most of the service requirements of southwestern Idaho. Manufacturing also displayed exceptional growth in the 1950's. There are meat and poultry packing plants, dairy processing plants, and canneries in the Boise Valley. There are also lumber and wood processing mills, trailer fabricating plants and food processing plants (53, pp. 22-23).

The development of federal irrigation projects in the Boise Valley enhanced the growth of agriculture. Availability of water for irrigation in the arid Boise Valley encouraged people to come to the valley. Increased population created the market for many products which encouraged nonagricultural producers of services and goods to come to the area. Thus, urban centers developed in the Boise Valley.

Initially, the land close to the river was preferred by irrigators. Because water is essential for some industrial use, some industries were also located close to the river. The federal investment in irrigation and the conducive environment encouraged large investments in the Boise Valley. But, some of the property in the Boise Valley faced the danger of being flooded if located in the flood plain. For the

Table 3: Population in the Boise Valley 1890-1970.

Year	Ada	Canyon	Boise Valley
1890	8,368	--	8,368
1900	11,559	7,497	19,056
1910	29,088	25,323	54,411
1920	35,213	26,932	62,145
1930	37,924	30,930	68,854
1940	50,401	40,987	91,388
1950	70,649	53,597	124,246
1960	93,460	57,662	151,122
1970	112,230	61,288	173,518

Source: Norman Nybroten, Idaho Statistical Abstract 1971, Idaho Bureau of Business and Economic Research Report No. 14, University of Idaho Moscow, Idaho, 1971, p. 37.

protection of this porperty, the federal government invested in Lucky Peak Dam to help control floods. To some degree federal investment encouraged the use of property in the flood plain through irrigated agriculture, which in turn necessitated federal investment in flood control.

Flood Problems in the Boise Valley

The Boise River originates in the Sawtooth Mountains where a considerable amount of snow falls during the winter months. As spring temperatures increase, snow starts to melt and the runoff feeds into the Boise River through its tributaries.

The pattern of natural flows of the Boise River is characterized by low flows from late July through February, increasing flows in March and high flows in April, May, and June. This pattern is occasionally disturbed by high flows of short duration during the winter months caused by rainstorms.

A study of the natural stream flows of the Boise River from 1865 to 1973 by Brockway and Warnick (6, p. 42) shows the time of occurrence of floods (Table 4). From Table 4, one can see that most floods in the Boise Valley take place between April 1st and June 30th.

Most flood water in the Boise Valley is generated above Lucky Peak Dam as there are no perennial streams below Lucky Peak Dam. However, some streams which have low,

Table 4: Summary of time of occurrence of floods on the Boise River 1865-1973.

Month	Number of floods	Percent of the total number of floods
April	20	18.3
May	68	62.4
June	18	16.5
April 15 - June 2	90	82.7
April - June 30	106	97.3

Source: C.C. Warnick and Brockway, Hydrology Support Study, Boise Project, Water Resources Research Institute, University of Idaho, Moscow, Idaho, June 1974, Table 8.

infrequent flows are known to generate substantial flow occasionally from summer thunderstorms. These flows have short duration. The flood plains of these streams (Cottonwood Creek, Hulls Gulch, Crane Gulch, and Stuart Gulch) cover a large portion of the residential development in north Boise (50, p. 4). For the purpose of this study, the flood damage of these streams will not be considered since they are off-stream from the Boise River flood plain. They are not perennial streams and the duration of their flooding is too short. Most floods in the Boise Valley are generated above Lucky Peak Dam.

According to Corps of Engineers Report (52, p. 41), the capacity of the Boise River channel from Diversion Dam through the Boise Valley changes from 3,700 cubic feet per second (CFS) to 10,000 CFS and the safe channel capacity at critical sections is 6,500 CFS. If the discharge is 6,500 CFS below Diversion Dam, the report maintains that none of the irrigated lands will be inundated. In this study, it will be assumed that floods below 5,000 CFS would not cause any damage in the Boise Valley.

The safe channel capacity of the Boise River according to the 1940 U.S. Department of Agriculture Report was 10,000 CFS (8,000 CFS in channel and 2,000 CFS in diversions). However, the 1946 Corps of Engineers Report (52, p. 20) says that a discharge of 10,000 CFS would flood 13,000 acres of productive agricultural land.

Records of the discharge of the Boise River at Diversion Dam have been kept since 1895. Table 5 shows the annual natural discharge of the Boise River.

An examination of Table 5 shows that over the 80 years for which records have been kept, the flow of the Boise River exceeded 10,000 CFS in 46 of the 80 years, i.e., there was a flow of over 10,000 CFS once in 1.4 years. In the same fashion, the flow of the river was more than 6,500 CFS in 75 of the 80 years, i.e., there was a flow of over 6,500 CFS once in every 1.1 years.

Effectiveness of Flood Control Projects

The construction of Arrowrock, Anderson Ranch, and Lucky Peak dams reduced the flow of the river below Diversion Dam considerably. This can be seen from Table 6 which shows the natural flow at Diversion Dam, the regulated flow at Diversion Dam, and the regulated flow at Boise. The regulated flow at Boise is much less because of irrigation diversions between Diversion Dam to the New York Cannel. Table 6 shows the differences in flows for the years 1955-1974. In the 20 years since Lucky Peak Dam came into operation, the regulated flow at Boise has always been below 10,000 CFS, and in only 6 out of the 20 years have the flows of the river exceeded 6,500 CFS. During the same period, the highest discharge was 7,350 CFS, only 850 CFS above the safe channel capacity of 6,500 CFS.

The flood problems of the Boise Valley are enhanced

Table 5: Flood discharge data of annual natural flow of the Boise River for period 1895-1974.

Year	Date	Natural flow-cfs	Year	Date	Natural flow-cfs
1895	May 6	7,900	1935	May 25	9,500
1896	Jun 14	35,500	1936	Apr 24	19,790
1897	Apr 19	29,500	1937	May 6	7,700
1898	Apr 27	7,960	1938	May 2	19,290
1899	May 10	19,000	1939	May 1	8,410
1900	May 11	12,000	1940	May 13	9,870
1901	May 16	13,900	1941	May 27	8,860
1902	May 29	8,190	1942	May 27	10,690
1903	Jun 2	16,800	1943	Apr 18	25,040
1904	Apr 15	19,700	1944	May 16	7,630
1905	Jun 2	6,260	1945	May 5	11,640
1906	May 12	8,710	1946	Apr 19	18,840
1907	Apr 15	17,000	1947	May 9	13,840
1908	Apr 22	10,600	1948	May 29	15,260
1909	Jun 6	16,000	1949	May 16	12,830
1910	Mar 22	16,600	1950	May 17	13,670
1911	Jun 13	15,100	1951	May 29	14,030
1912	Jun 9	15,600	1952	Apr 28	23,430
1913	May 28	13,300	1953	Apr 29	12,780
1914	Apr 16	11,300	1954	May 21	14,460
1915	Apr 20	6,230	1955	May 10	10,480
1916	Jun 19	16,500	1956	May 25	22,950
1917	May 15	17,850	1957	May 21	16,930
1918	Jun 14	12,600	1958	May 22	21,750
1919	May 30	11,580	1959	May 16	9,040
1920	May 18	9,620	1960	May 13	11,840
1921	May 17	18,740	1961	May 27	7,830
1922	May 26	18,170	1962	Apr 21	11,340
1923	May 26	11,950	1963	May 24	11,480
1924	May 18	5,190	1964	Dec 25	27,290
1925	May 20	14,350	1965	May 1	20,500
1926	May 6	7,090	1966	May 10	8,220
1927	May 18	20,060	1967	May 25	15,600
1928	May 10	20,710	1968	Jun 4	7,050
1929	May 25	9,370	1969	Apr 24	15,930
1930	May 30	7,560	1970	May 28	14,850
1931	May 15	5,270	1971	May 14	20,250
1932	May 14	13,580	1972	Jun 2	19,600
1933	Jun 4	12,510	1973	May 20	9,550
1934	Mar 30	6,110	1974	May 9	18,470

1895-1916 Flows are recorded maximums, Boise River near Boise

1917-1954 Boise River at Dowling Ranch + Mores Creek near Arrowrock + storage changes

1955-1974 Boise River near Boise + storage changes

Source: C.C. Warnick and C.E. Brockway, Hydrology Support Study, Boise Project University of Idaho, Idaho Water Resources Research Institute, Moscow, Idaho, June, 1974, Table 5.

Table 6: Annual discharge of Boise River.

Year	Unregulated at diversion dam (cfs)	Regulated at diversion dam (cfs)	Regualted at Boise (cfs)
1955	10,480	5,110	1,740
1956	22,950	9,470	6,840
1957	16,930	10,600	6,870
1958	21,750	10,000	6,320
1959	9,040	5,390	1,800
1960	11,840	8,200	5,710
1961	7,830	5,360	1,560
1962	11,340	5,320	1,540
1963	11,480	9,820	5,870
1964	10,940	7,230	4,630
1965	20,850	11,600	7,170
1966	8,220	4,960	1,760
1967	15,600	5,270	1,640
1968	7,050	5,130	1,800
1969	15,930	8,660	5,280
1970	14,850	8,500	5,030
1971	20,250	10,800	6,850
1972	19,600	10,200	6,710
1973	9,550	4,760	1,460
1974	18,500	10,815	7,350

Source: Idaho Department of Water Resources, Review of Boise River Flood Control Management (November 1974), Boise, Idaho, Table 3.

by distrubance of plant cover on the headwater areas because of livestock grazing, fire, timber cutting, and mining. The 1940 U.S.D.A. study (46, pp. 225-227) says that deposition of silt reduced the channel capacity of the Boise River from 11,000 CFS in 1920 to 8,000 CFS in 1939. The pond back of Barber Dam, owned by a private group, is filled with silt. Due to the instability of the structure a major flood might release silt which will deposit sand in the canals and river and thus reduce channel capacity.

The maximum controllable flood by the Boise system of reservoirs according to the 1946 Corps of Engineers study (51, pp. 17-20), is 55,000 CFS, and the same study says that for flows greater than 35,000 CFS the main diversion canal will be overtoppped and become inoperative.

Finally, the following conclusions come out of this chapter. First, most floods in the Boise Valley occur during the spring months. Second, the safe channel capacity of the Boise River is 6,500 CFS, i.e., any flow greater than 6,500 CFS causes some damage. Third, the three federal reservoirs (Arrowrock, Anderson Ranch, and Lucky Peak) have succeeded in reducing the flow of the river to the safe channel capacity (see Table 6 for details) since they began operation.

CHAPTER 4

ESTIMATING ANNUAL FLOOD DAMAGES IN THE BOISE VALLEY

The primary purpose of this chapter is to estimate annual flood damages in the Boise Valley using the six flood damage models developed in Chapter 1. To a lesser extent this chapter will also be concerned with the estimation of expected annual flood damage in the Boise Valley with and without flood control. In addition, previous flood damage studies in the Boise Valley will also be reviewed.

The Nature of Flood Damage

Rivers can bring both wealth and disaster to a region. They are sources of wealth when they flow within their banks and provide water for human needs. In the Boise Valley as in many other parts of the world, river water has turned arid deserts into productive agricultural lands. Problems arise when rivers overflow their banks. That portion of the river water which has overflown the river banks needs space. However, often this space is already taken up by people for other uses. It is this conflict in space requirements between human activities and natural phenomena (floods) that result in flood damage (4, p. 1).

Classification of Flood Damages

Flood water can cause damage to property and life by direct contact. It can also cause damage by an indirect means. Thus, because of this diversity in damages caused by floods, it is appropriate to classify flood damages for proper evaluation. Three classes of damages will be discussed. However, it should be noted that there is no uniform set of categories for flood damages and they are plagued by inconsistencies (24, pp. 164-165).

Direct damages (primary damages) are those damages that result from physical contact of flood water with property. Direct damages are of local and regional scope and are limited to the flooded region. According to Eckstein (12, p. 127) one can evaluate direct damages by "the cost of restoration of the damaged property to its preflood condition."

Haveman (15, p. 16), however, feels that direct damages should be estimated by the cost necessary to restore the property to its preflood value not preflood physical condition. Breaden (2, p. 3) says that direct damages may be taken as the least of any one of the following:

(1) "The cost of restoring the property to a state adequately performing its preflood function."

(2) "The present worth of the expected future productivity if the flood had not occurred."

(3) "If some other property can be used to fulfill the same function at less cost, the damage may

be taken as the cost of the substitute measure."

Indirect damages (secondary damages) are losses that result from flood water, but not by physical contact of flood water with property. Indirect damages can be of local, regional, and national scope depending on the exports and imports of the flooded area. For an economy that is self-sufficient and does not trade with other areas, indirect damage will be of local scope. But, for a region that trades with only surrounding areas, indirect damage will be of regional scope. On the other hand, for a region that buys from and sells to many regions of the nation, indirect damages will be of national scope.

Examples of indirect flood loss are: cost of precautionary flood fighting; costs of evacuation and reoccupation; cost of alleviating hardship; cost of protecting health and victims; increased transportation cost due to rerouting of highways, railroad; loss of business and wages; increased cost of business operation; and delay in deliverey of goods.

Because indirect flood damages are so numerous, it is impractical to measure indirect flood losses precisely. To combat the problem, the Corps of Engineers take indirect damages as a fixed percentage of direct damages. Kates (27, p. 13) reports that the Corps of Engineers, after a detailed study of a 1955 flood, adopted the percentage figures shown in Table 7. Holmes (16, p. 38) feels that there is danger in assuming secondary losses (indirect damages) bear a fixed

Table 7: Relation of direct damages to indirect damages.

Category of damage	Indirect damage / direct damage
Residential	0.15
Commercial	0.35
Industrial	0.45
Utilities	0.10
Public facilities	0.34
Agriculture	0.10
Highways	0.25
Railroad	0.23

Source: Robert W. Kates, Industrial Flood Losses: Damage Estimation in Lehigh Valley, Department of Geography Research Paper No. 98, University of Chicago (Chicago: University of Chicago Press, 1965), p. 13.

relation to direct damages since indirect damages are related to frequency, length of warning time, duration of flooding, and other hydrologic factors which vary from river basin to river basin. The use of a fixed percentage in estimating indirect damages, however, simplifies the estimation procedure. But, it does not mean that it is a better way. In fact, a better way to estimate damages is to survey the flooded region for direct damages and indirect damages and then use input-output models to determine indirect regional and national damages. However, flood victims might exaggerate their losses if the survey is done right after the flood. Thus, care must be taken in compiling flood damages.

Data for flood losses can be obtained from either the Corps of Engineers or the Weather Bureau. The Corps of Engineers survey the region after each flood to obtain the flood damages. The Weather Bureau distributes questionnaires to county agricultural agents, mayors, county and city engineers, postmasters, and river observors (18, p. 80).

Intangible damages are those damages caused by flood water for which no monetary evaluation can be made. Examples of this category include loss of life, grief, and hardship. etc. Attempts have been made to place value on human life, but because of various assumptions each investigator came up with different values.

Dublin and Lotka (11, pp. 549-557) attempted to place value on human life in the late 1920's. Dublin assumed an annual income of $2,100 and a discount rate of 3 1/2 percent, and estimated the economic value of each male at $19,000 and each female at $9,500, assuming females are worth half as much as men. Thus, the average annual value of an individual's life, according to Dublin, was $14,250.

Clark (9, pp. 216-219) felt that the $2,100 annual income assumed by Dublin was too high for males and said $1,500 was the appropriate amount. This enabled Clark to value the life of an individual (male and female) at about $10,000.

The approach used by Dublin and Lotka is referred to as the "human capital approach," by which a person's life is equated with the person's expected future earnings. Essentially, this is the formula used in life insurance. However, this approach is unacceptable in public policy in that the lives of richer persons are worth more than the lives of poorer person. In addition, the lives of men are worth more than that of women.

Another procedure used in valuing human life is to relate the pay increase a person is willing to accept to the percent increase in the risk of death. Using such a methodology, Robert Smith of Cornell University determined human life to be equal to $15 million, while another study evaluated human life at $200,000 (56, p. A_1-A_2).

<u>Uncertainty damages</u>: This class of flood damages is taken to be the amount in excess of the expected value of flood damage that individuals are willing to pay to avoid

flood damage (4, p. 7). This category of flood damage is special in that it is neither direct nor indirect flood damage. It is the difference between the annual insurance premium that individuals pay and expected annual flood loss.

Dimensions of Flood Damage

It should be borne in mind that the amount of flood damage depends on a variety of factors. These include the depth of the flood, velocity of flood water, the duration of the flood, the nature of sediments deposited, warning time, the lapse of time between subsequent floods, and the season of the year. The amount of property damage due to a flood is also dependent on land use planning in a given area.

The damage caused by a given flood depends upon the depth to which property is inundated. The shallower the depth, the lesser the damage. This is specially true for crops. The flood has to reach an appreciable depth to cause substantial damage. The speed with which flood water moves is also important. The greater the velocity of the flood water, the greater the damage. In addition the nature of sediment carried by flood water is important. If it deposits fertile top soil in will enhance the productivity of the land. However, if it is debris, removing it involves cost. The length of time for which a given property remains under water also affects the damage caused. The damage is larger when the property stays inundated for a longer period. Longer warning time gives residents time to move their more valued properties to higher elevation or out of the flood plain. Shorter intervals between subsequent floods means lesser damage unless the build up in the flood plain after each flood is high. The season of the year during which a flood takes place is also important.

Homan and Waybur (17, p. 5-6), after a study of the factors causing flood damage, found that flood depth was the most important variable in flood damage estimation.

Previous Flood Damage Studies in the Boise Valley

Flood problems in the Boise Valley did not get much attention before the 1940's.

In 1940, the Department of Agriculture did a three volume study on the Boise River (46). The first volume contained factual information on climate, percipitation, and economy of the region. The second volume provided information on hydrology. Some of the pertinent information given in the second volume includes stream flow, channel capacity, flood flow, probability of floods, and groundwater. The third volume is an appendix in which among other things a procedure of flood damage estimation is inculded. This three volume study will be referred to as the 1940 U.S.D.A. study.

Table 8 gives the value of property in the various flood zones and the damages the various flood flows could have caused had they occurred in 1940. Frequency of occurrence

Table 8: Discharge-damage and probability data, the Boise River, 1940.

Discharge (cfs)	Average probability of occurrence in any one year	Flood damages (dollars)	Value of property in the flood plain (dollars)
13,000	0.50	100,000	930,000
21,000	0.20	261,000	1,359,800
27,000	0.10	441,000	1,843,000
43,000	0.02	1,384,000	4,059,000

Source: U.S. Department of Agriculture, Field Flood Coordinating Committee No. 17B, <u>Survey Report, The Boise River</u>, Part III, Appendix, Part F, Tables AP-F-1 and AP-F-2, 1940, mimeographed.

of the different magnitude of floods in any given year is displayed in Table 8. From this information one can plot discharge against damage to obtain the discharge-damage curve. Similarly, discharge can be plotted against probability to get the discharge-probability curve. The damage-probability curve can be obtained by plotting damage agianst the probability of occurrence of the particular flood that produced the damage.

The 1940 U.S.D.A. study concentrated on the intermediate flows.

House Documents 916 (44) and 957 (45) also recognized flood problems in the Boise Valley. However, both documents were preliminary survey reports on Anderson Ranch Dam and power plant. The information contained in these two documents are benefits to be derived by building Anderson Ranch Dam and the costs that will ensue as the result. The documents provide minimal information as they are summary reports.

The Corps of Engineers appraised the value of property in the flood plain and estimated the likely flood damage (direct and indirect damages only) to the then existing property in 1943. This report will be referred to as the 1946 Corps of Engineers Report (51).

Table 9 shows the value of property located in each flood's flood plain, damages (includes direct and indirect damages only) that each flood would have caused had it occurred, and the probability of occurrence of each flood.

Table 9: Value of property in the flood plain, discharge, damage and probability of flood occurrence, Boise River, 1943.

Discharge (cfs)	Average probability of occurrence in any one year	Estimated damages (1943 dollars)	Value of property in the flood plain (1943 dollars)
2,500	0.99	0	NA
6,500	0.925	57,060	NA
7,500	0.875	79,820	2,815,000
10,300	0.70	133,200	3,135,000
16,100	0.38	455,990	6,097,000
20,000	0.24	997,350	6,445,000
35,500	0.04	4,846,800	12,018,500
42,000	0.02	6,358,900	NA
55,000	0.0065	9,939,900	21,590,000

Source: Corps of Engineers, Portland Branch (now Walla Walla District), Survey of Review Report with a View to Control of Floods, Portland, (January 2, 1946), p. 31 and Appendix A Chart 6.

NA = Not available

In the 1946 Corps of Engineers study, property was classified as agricultural, irrigation developments, flood control works, urban, municipal, industrial, highways, railroads, and utilities.

The 1946 Corps of Engineers study divided the flood plain into six zones in the valuation of property and appraisal of damages. Valuation of property and likely damage to property by a flood of a given magnitude were carried out for each flood zone and then finally the value of property and damage for a given flood were summed.

A Corps of Engineers study of 1949 also looked at flood damages in the Boise River Valley (49). This study was brief and was more of a follow up report on costs and benefits of the 1946 study. In this report the Corps of Engineers re-estimated the federal investment needed for completion of Lucky Peak Dam. The 1949 Corps of Engineers study did not add much new material to the 1946 study except to use the 1949 price level.

The latest Corps of Engineers study in the Boise Valley is that of 1974.[4/] In the 1974 study the Corps of Engineers appraised the value of property in the Boise River flood plain and estimated damages that could have occurred. This information is given in Table 10. The value of property in

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[4/] At present the study has not been published. However, the Corps of Engineers, Walla Walla District provided the information.

Table 10: Discharge-damage information at 1974 level of economic development (Boise Valley).

Discharge (cfs)	Damage (1974 dollars)	Value of property in the flood plain (1974 dollars)
6,500	40,000	NA
10,000	557,000	22,667,000
15,000	8,644,000	78,276,000
57,000	224,271,000	547,163,000

Source of data: Crops of Engineers, Walla Walla District.

the flood plain and the likely damage associated with a given flood increased substantially compared to both the 1940 U.S.D.A. study and the 1946 Corps of Engineers study.

In the 1974 Corps of Engineers study, the flood plain was divided into nine zones. The appraisal of the flood plain, however, covered only five different flows--namely 6,500 CFS, 10,000 CFS, 15,000 CFS, 27,000 CFS, and 57,000 CFS. The appraisal did not completely cover the 27,000 CFS flood plain. For this reason, the damage and value of property in the 27,000 CFS flood plain were not given in Table 10.

Another study that looked at the flood problems of the Boise Valley was conducted by the Idaho Department of Water Resources in 1974 (20). This study was more of a survey of the adequacy of the flood control operations on the Boise River. This study found that the stream flow forecasts were relatively inaccurate and recommended that stream flow forecasts be done more frequently.

Two general conclusions that can be drawn from the previous flood damage studies in the Boise Valley are:

(1) The previous studies gave detailed physical and hydrological data.

(2) The previous studies provided insufficient economic and financial data.

Estimation of Expected Annual Flood Damages in the Boise Valley

The purpose of this section is to estimate the expected annual flood damage at 1943 level of economic development when:

(1) there are no flood control projects;

(2) all the flood control projects are in place.

The expected annual flood damage is the summation of the product of the probability of occurrence of each flood and the damage the particular flood causes had it occurred. A more precise way of saying this is as follows:

$$EFD = \sum_{i=1}^{n} P_i d_i$$

where: EFD = expected annual flood damage

P_i = probability of the ith flood

d_i = damage caused by the ith flood

i = various flood levels

The expected annual flood damage is a theoretical estimation of the annual flood damages. The expected annaul flood damages considers the probability of all possible floods whereas the annual flood damage procedure (discussed in the next section) uses actual flood discharge data in a given year to estimate annual flood damages. To estimate expected annual flood damage one needs to know:

(1) magnitude of flood discharge (CFS) or stage (feet)

(2) the probability of occurrence of a flood with

a given discharge or stage;

(3) the damage that a flood with a given discharge or stage causes.

From the above information one can obtain the discharge-damage curve by plotting discharge against damage. Similarly, by plotting discharge against probability one can obtain the discharge-probability curve. The damage-probability curve can either be obtained from the discharge-damage curve and the discharge-probability curve or by setting up a table that provides discharge, probability, and damage. The expected annual flood damage can be estimated by finding the area under the damage-probability curve. Assuming that the flood flows are continuous and given the damage for flow Q is D(Q) and the probability of Q is P(Q) then,

$$EFD = \int_{Q=0}^{Q} D(Q)P(Q)dQ$$

Figure 6 shows the discharge-damage curve for the Boise Valley. This curve is obtained by plotting discharge against damage from Table 9. The discharge-probability curve for the Boise Valley is given in Figure 7 and it was obtained from the 1946 Corps of Engineers study (52).

<u>Procedures for estimating expected annual flood damage:</u>

The steps that are involved to estimate the expected annual flood damages at 1943 level of economic development in the Boise Valley when: (a) there are no flood control projects

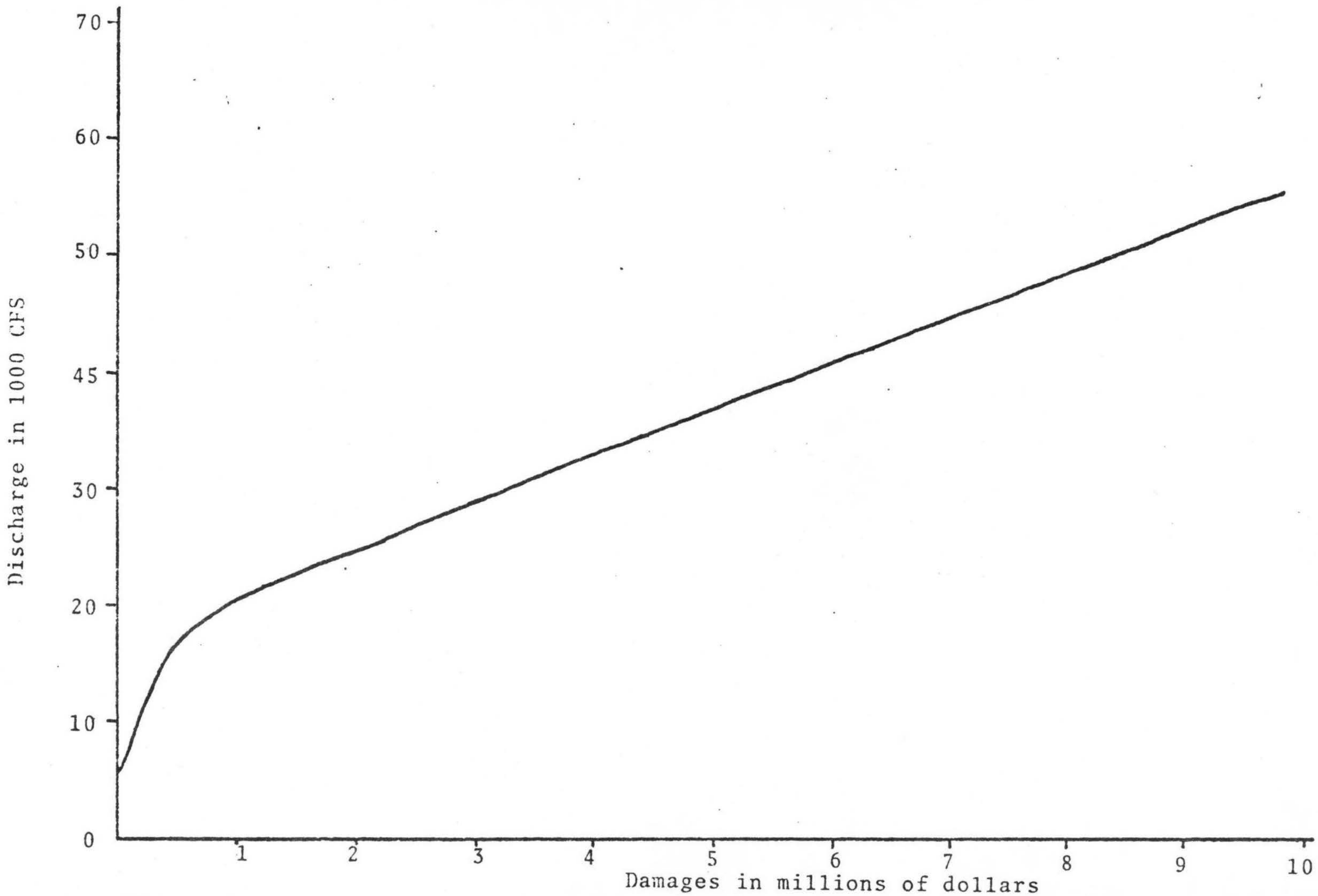
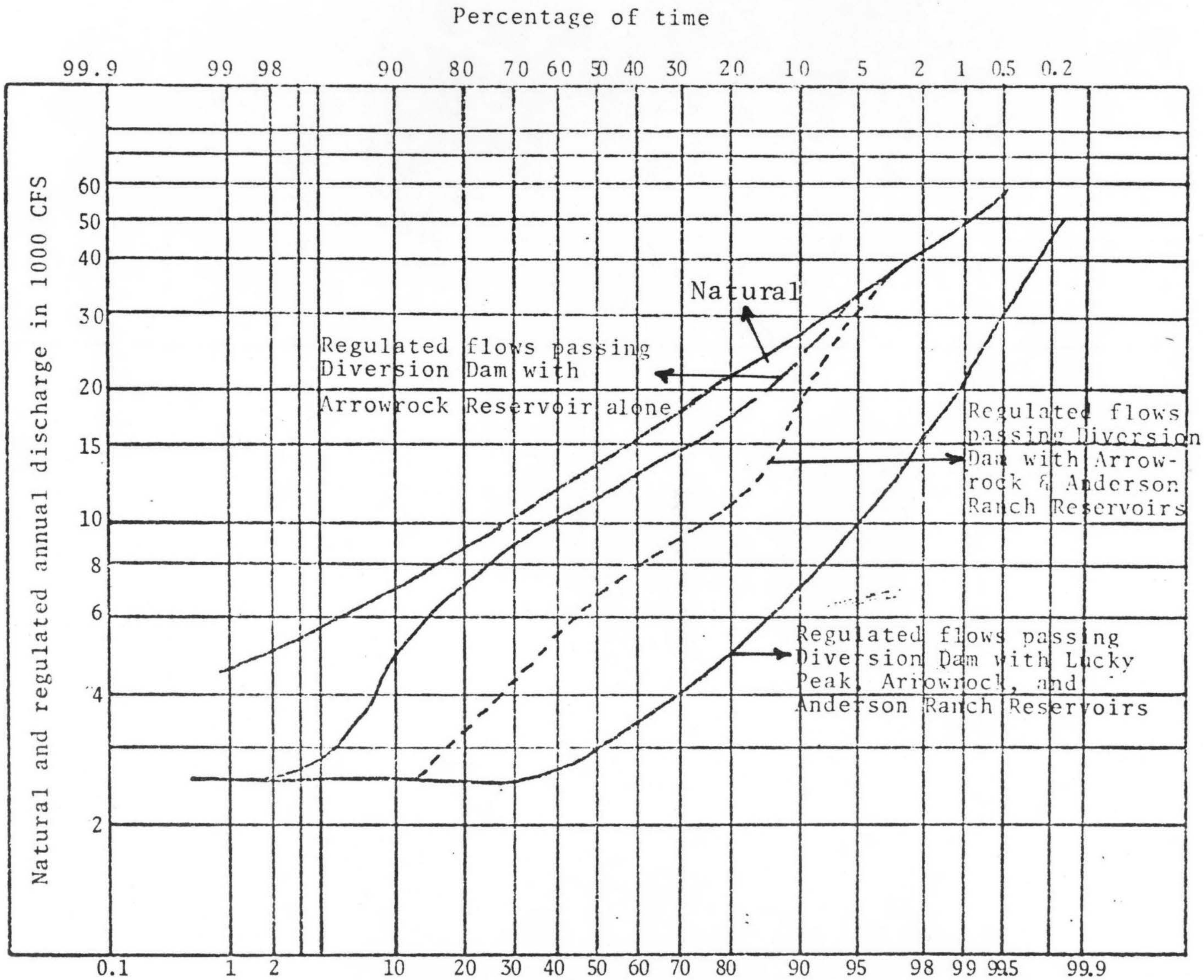


Figure 6: Discharge-damage curve for the Boise River at 1943 level of economic development.



Source: U.S. Dept. of Army, Corps of Engineers, Portland Office, Review of Survey Report, Boise River, (Jan. 2, 1946), Appendix A, Chart 6.

Figure 7: Discharge-probability curve for the Boise River.

given in Table 11, (b) all the flood control projects are in place given in Table 12 are as follows:

(1) Beginning with the lowest damaging flow, list discharges in reasonable increments in column 1 of Tables 11 and 12.

(2) Read the probability of the selected discharge from Figure 7. Put probability in column 2.

(3) Read the damage of the selected discharge from Figure 6. Put damage in column 3.

(4) Column 4, average damage of interval, is the average of the low and high flows next to each other.

(5) Column 5, probability of interval, is the difference between the probability of the high and the low flows. The probability of interval is the expected probability of floods with discharges between the high and low flows.

(6) Annual expected damage, column 6, is obtained by multiplying column 4 and column 5.

(7) Column 7, expected accumulated damage, is the sum of the subsequent expected annual damages.

(8) Expected annual damage is the last number in column 7 or the sum of column 6.

The expected annual flood damage at 1943 level of economic growth without flood control projects is given in Table 11. Without flood control projects in the Boise Valley

Table 11: Computation of estimated accumulated annual flood damage (expected annual flood damage) without flood control at 1943 level of economic development in the Boise Valley.

Potential discharge of river	Probability of occurrence in any one year	1943 damages	Average damages of interval	Probability of intervals	Expected annual damage	Accumulated damages[1/]
cfs		1943 dollars	1943 dollars		1943 dollars	1943 dollars
5,000	0.980	0	0		0	0
6,500	0.925	57,060	68,530	0.055	3,770	3,770
8,000	0.84	80,000	40,000	0.085	3,400	7,170
10,000	0.72	160,000	120,000	0.12	14,400	21,570
12,000	0.58	250,000	205,000	0.14	28,700	50,270
13,000	0.52	300,000	275,000	0.06	16,500	66,770
15,000	0.42	400,000	350,000	0.10	35,000	101,770
16,000	0.38	455,000	427,500	0.04	17,100	118,870
20,000	0.24	997,350	726,175	0.14	101,665	220,535
22,000	0.18	1,500,000	1,248,675	0.06	74,920	295,455
28,000	0.095	3,000,000	2,250,000	0.085	191,250	486,705
31,000	0.07	3,750,000	3,375,000	0.025	84,375	571,080
36,000	0.04	5,000,000	4,375,000	0.03	131,250	702,330
40,000	0.026	6,000,000	5,500,000	0.014	77,000	779,330
43,000	0.02	6,750,000	6,375,000	0.006	38,250	817,580
50,000	0.01	8,500,000	7,625,000	0.01	76,250	893,830
55,000	0.004	9,939,000	9,219,950	0.006	55,320	949,150

[1/] Rounded to the nearest 5 dollars.

Table 12: Computation of estimated accumulated annual flood damage (expected flood damage) with flood control at 1943 level of economic development in the Boise Valley.

Discharge	Probability of occurrence in any one given year	Damage	Average damage of interval	Probability of intervals	Annual damage	Accumulated damage
cfs		1944 dollars	1944 dollars		1944 dollars	1944 dollars
5,000	0.20	0				0
6,500	0.12	57,060	68,530	0.08	5,480	5,480
8,000	0.08	80,000	40,000	0.04	1,600	7,080
10,000	0.05	160,000	120,000	0.03	3,600	10,680
12,000	0.036	250,000	205,000	0.014	2,870	13,550
13,000	0.03	300,000	275,000	0.006	1,650	15,200
15,000	0.024	400,000	350,000	0.006	2,100	17,300
16,000	0.020	455,000	427,500	0.004	1,710	19,010
20,000	0.0125	997,350	726,175	0.0075	5,446	24,456
22,000	0.010	1,500,000	1,248,675	0.0025	3,122	27,578
28,000	0.0056	3,000,000	2,250,000	0.0044	9,900	37,478
31,000	0.0045	3,750,000	3,375,000	0.0011	3,712	41,190
36,000	0.0032	5,000,000	4,375,000	0.0013	5,688	46,878
40,000	0.0028	6,000,000	5,500,000	0.0004	2,200	49,178
43,000	0.0024	6,750,000	6,375,000	0.0004	2,550	51,628
50,000	0.00152	8,500,000	7,625,000	0.00088	6,710	58,338
55,000	0.015	9,939,900	9,219,950	0.00002	184	58,522

at 1943 level of economic development, the expected annual flood damage would have been \$949,150. The expected annual flood damage with all the flood control projects (Arrowrock, Anderson Ranch, and Lucky Peak Reservoirs) in 1943 would have been \$58,522 (Table 12). Thus, at 1943 level of economic development the federal flood control projects would have reduced the expected annual flood damage by \$890,628 had they all been in place.

Estimation of Annual Flood Damage Using the Flood Damage Models

In the previous section the expected annual flood damages in the Boise Valley were estimated by taking due account of the probability of occurrence of each flood. In this section the annual flood damages will be estimated by using actual (recorded) flow data and the flood damage models developed in Chapter 1.

Model 1: Estimation of annual flood damage without economic growth and without flood control at 1943 level of economic growth.

Recall that Model 1 was:

$$D_1(NG,NFC)_i = f(Q_i)$$

It was pointed out that one needs the 1943 damage-discharge curve and Q_i to estimate $D_1(NG,NFC)_i$. The 1943 damage-discharge curve in the Boise Valley can be seen from

Figure 6. The annual flood damages are estimated by reading the damage that corresponds to a given flow from Figure 6. Table 13 shows the natural flows and the corresponding damages on annual basis for the period 1950 to 1974. Without flood control and economic growth, the annual flood damage at 1943 level of economic development in the Boise Valley varied from $60,000 to $1,760,000 between 1950 and 1974 (Table 13). Total flood damage without flood control and economic growth between 1950 and 1974 was $13,845,000 at 1943 level of economic development (Table 13). This corresponds to an annual flood damage of $553,000 (Table 13).

Model 2: Estimation of annual flood damage without economic growth and with flood control at 1943 level of economic development.

Recall that Model 2 was:

$$D_2(NG,FC) = f(Q_i^!)$$

It was pointed out that one needs the discharge-damage curve for the Boise Valley (Figure 6) and the annual regulated flow of the Boise River (Table 14) to estimate the annual flood damage without growth and with flood control. Table 14 gives the annual flood damage estimated by using Figure 6 and the regulated flows ($Q_i^!$). Table 14 shows that without economic growth and with flood control total flood damage between 1950 and 1974 was $801,500 at 1943 level of economic development. Average annaul flood damage for the

Table 13: Estimated annual flood damages in the Boise Valley without economic growth and without flood control in constant 1943 dollars, 1950 to 1974 (Model 1).

Year	Natural discharge (cfs)	Damages (1943 dollars)
1950	13,670	330,000
1951	14,030	360,000
1952	23,430	1,825,000
1953	12,780	295,000
1954	14,460	380,000
1955	10,480	190,000
1956	22,950	1,760,000
1957	16,930	575,000
1958	21,750	1,450,000
1959	9,040	140,000
1960	11,840	250,000
1961	7,830	90,000
1962	11,340	225,000
1963	11,480	230,000
1964	10,940	200,000
1965	20,500	1,150,000
1966	8,220	100,000
1967	15,600	440,000
1968	7,050	60,000
1969	15,930	450,000
1970	14,850	400,000
1971	20,250	1,075,000
1972	19,600	950,000
1973	9,550	160,000
1974	18,470	760,000
Total		$13,845,000
Average		553,800

Table 14: Estimated annual flood damages in the Boise Valley with no economic growth and with flood control in constant 1943 dollars, 1950 to 1974 (Model 2).

Year	Natural discharge (cfs)	Damages (1943 dollars)
1950	6,720	50,000
1951	7,510	75,000
1952	7,790	80,000
1953	8,110	95,000
1954	6,030	25,000
1955	1,740	0
1956	6,840	59,000
1957	6,870	59,500
1958	6,320	40,000
1959	1,800	0
1960	5,710	20,000
1961	1,560	0
1962	1,540	0
1963	5,870	25,000
1964	4,630	0
1965	7,170	70,000
1966	1,760	0
1967	1,640	0
1968	1,800	0
1969	5,280	10,000
1970	5,030	10,000
1971	6,850	59,000
1972	6,710	49,000
1973	1,460	0
1974	7,350	75,000
Total		801,500
Average		32,060

period 1950 to 1974 was \$32,600 (Table 14). Thus, the flood control projects reduced the total flood damage between 1950 and 1974 by \$13,043,500 (total damage in Table 13 minus total damage in Table 14 for the period 1950 to 1974). Thus, the average annual damage reduction at 1943 level of economic development without economic growth attributable to the flood control projects was \$521,740.

Model 3: Estimation of annual flood damage with restricted economic growth and no flood control.

Recall that Model 3 was:

$$D_3(RG,NFC) = (1+p)^n D_1(NG,NFC)$$

Also recall that $D_1(NG,NFC)$ is the annual flood damage with no growth and no flood control (Table 13) while p is the annual rate of economic growth without flood control. To estimate $D_3(RG,NFC)$ one needs to estimate p. How can one go about estimating p? The rate at which the economy of the Boise Valley could have grown without federal investments in flood control (p) can be estimated in any one of the following ways.

First, an ideal way to determine the rate at which the economy of the Boise Valley grew without federal flood control projects is to find a region that is identical with the Boise Valley except for flood control. While this is theoretically feasible, in practice it is hard to come by with. Perhaps, a realistic approach is to "trace the pattern and rate of economic structure to the project region, with the exception of project construction," as suggested by Haveman (15, p. 20).

An alternate approach suggested by Haveman (15, pp. 20-21) is to assume that the project had substantial impact on the flood plain not on the region that encompasses the flood plain and use the rate of growth of the surrounding areas as the appropriate annual rate of growth for the study area without flood control. This approach is more practical than the first one. Perhaps, it is possible to find a region that is identical to the Boise Valley. But, comparing a region that is entirely in a different environment to another one does not bear much significance. Thus, in this study the rate at which the areas surrounding the Boise River flood plain grew between 1950 and 1974 will be taken to be equivalent to p. Since the flood plain is located in Ada and Canyon counties, the annual rate of growth of Ada and Canyon counties will be used to estimate the annual rate of growth of the flood plain without federal flood control projects (p). Had there not been federal flood control projects in the Boise River flood plain the most likely way for the flood plain is to grow at the same rate with the surrounding areas.

According to the annual report of the Idaho Tax Commission (22), the value of property in Ada and Canyon counties increased from $65,684,413 in 1946 to $366,218,740 in 1976. After adjustments for price changes using the consumer price index[4/] with 1943 at a base (1943 = 100) the real annual rate of economic growth becomes 2.2 percent. It should be noted that the assessed valuation of property for tax purposes is different from the market value of property. The assessed valuation of property for tax purposes under-estimates the market value of property by as much as 80 percent. However, as far as the assessed value of property for tax purposes consistently underestimates the market value it will not have effect on the annual rate of growth.

Since D_1(NG,NFC) has already been estimated (Table 13) all one needs now to estimate D_3(RG,NFC) is p. The value of p has been estimated to be 2.2 percent annually. Table 15 gives the estimated annual values of Model 3. Table 15 shows that without federal flood control projects, at 2.2 percent annual growth the total flood damage in the Boise Valley would have been $20,898,270 between 1950 and 1974. Annual flood damages at the same rate of growth as the areas surrounding the Boise

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[4/]The consumer price index is a composite index which measures price changes of goods and services purchased by city wage earners and clerical workers. According to the Historical Statistics of the U.S. (53) the consumer price index with 1967 as a base was 58.5 in 1946 and 169.2 in 1976. Shifting the base of the index to 1943 (1943 = 100) the value of the index was 112.9 in 1946 and 326.6 in 1976. Adjusting the value of property in the Boise Valley in 1946 ($65,684,413) for price changes one gets $48,179,285 in constant 1943 dollars. Similarly, the value of property in 1976 ($366,218,740) when adjusted for price changes becomes $112,130,661 in 1943 constant dollars. Using the compound interest formula $V_n=V_o(1+p)^n$ where V_n=$112,130,661, V_o=$58,179,285, n=31 the value of p becomes 2.2 percent.

Table 15: Estimated annual flood damage in the Boise Valley with restricted economic growth and without federal flood control in constant 1943 dollars, 1950 to 1974 (Model 3).

Year	1943 damages D_1 (NG, NFC)	Growth factor $(1+p)^n$	Estimated annual flood damage D_3 (RG, NFC)
1950	$ 330,000	1.164	$ 384,120
1951	360,000	1.190	428,400
1952	1,825,000	1.216	2,219,200
1953	295,000	1.243	366,685
1954	380,000	1.270	482,600
1955	190,000	1.298	246,620
1956	1,760,000	1.327	2,335,520
1957	575,000	1.356	779,700
1958	1,450,000	1.386	2,009,700
1959	140,000	1.416	198,240
1960	250,000	1.448	362,000
1961	90,000	1.480	133,200
1962	225,000	1.512	340,200
1963	230,000	1.545	355,350
1964	200,000	1.579	315,800
1965	1,150,000	1.614	1,856,100
1966	100,000	1.650	165,000
1967	440,000	1.686	741,840
1968	60,000	1.723	103,380
1969	450,000	1.761	792,450
1970	400,000	1.800	720,000
1971	1,075,000	1,839	1,976,925
1972	950,000	1.880	1,786,000
1973	160,000	1.921	307,360
1974	760,000	1.963	1,491,880
Total	$13,845,000		$20,898,270
Average	553,800		835,931

River flood plain (2.2 percent) would have varied from $103,380 to as high as $2,335,520 (Table 15).

Model 4: Estimation of annual flood damage with restricted economic growth and with flood control.

Recall Model 4 was:

$$D_4(RG,FC) = (1+p)^n D_2(NG,FC)$$

Aslo recall that D_2(NG,FC) was the annual flood damage with no growth and with flood control (Model 2). Model 2 was given in Table 14. Also recall that p was estimated to be 2.2 percent in the previous section. To estimate D_4(RG,FC) one needs to multiply Model 2 (Table 14) by the factor $(1+p)^n$. Estimated annual flood damages with restricted economic growth and with the federal flood control projects are given in Table 16. Total flood damages between 1950 and 1974 with the federal flood control projects at 2.2 percent annual rate of growth was $1,173,001 (Table 16). The annual flood damage varied between zero and $147,225 during the 25-year period of analysis (Table 16). The prevented total flood damages at 2.2 percent annual growth was $19,725,269 over the 25-year period (Tables 15 and 16).

Model 5: Estimation of annual flood damage with actual economic growth and no flood control.

Recall that Model 5 was:

$$D_5(AG,NFC) = (1+r)^n D_1(NG,NFC)$$

Table 16: Estimated annual flood damages in the Boise Valley with restricted economic growth and with the federal flood control projects in constant 1943 dollars (Model 4)

Year	1943 damages D_2(NG, FC)	Growth factor $(1+p)^n$	Estimated annual flood damage D_4(RG, FC)
1950	$ 50,000	1.164	$ 58,200
1951	75,000	1.190	89,250
1952	80,000	1.216	97,280
1953	95,000	1.243	118,085
1954	25,000	1.270	31,750
1955	0	1.298	0
1956	59,000	1.327	78,293
1957	59,500	1.356	80,682
1958	40,000	1.386	55,440
1959	0	1.416	0
1960	20,000	1.448	28,960
1961	0	1.480	0
1962	0	1.512	0
1963	25,000	1.545	38,625
1964	0	1.579	0
1965	70,000	1.614	112,980
1966	0	1.650	0
1967	0	1.686	0
1968	0	1.723	0
1969	10,000	1.761	17,610
1970	10,000	1.800	18,000
1971	59,000	1.839	108,501
1972	49,000	1.880	92,120
1973	0	1.921	0
1974	75,000	1.963	147,225
Total	$801,500		$1,173,001
Average	32,060		46,920

Also recall that D_1(NG,NFC) is Model 1 and r is the annual rate of economic growth in the flood plain. The annual values of D_1(NG,NFC) were given in Table 13. To estimate D_5(AG,NFC) one needs to estimate r first.

The value of property in the Boise River flood plain (55,000 CFS) was $21,590,000 according to the Corps of Engineers (52). The value of property in the Boise River flood plain was given in Table 10. In their 1974 appraisal of property in the Boise River flood plain the Corps of Engineers did not specifically assess the value of property in the 55,000 CFS flood plain. The value of property in the 55,000 CFS flood plain was estimated by plotting discharge against the value of property using the data in Table 10 (Figure 8). From Figure 8 the value of property in the 55,000 CFS flood plain was $533,000,000 in 1974. Most of the property in the Boise River flood plain was structures, thus, an appropriate index to deflate the value of property in the flood plain is a general construction index. In this study the Engineering News-Record[5/] general construction index will be used to deflate the 1974 value of property in the flood plain. After adjustment for price changes the annual rate of economic growth in the flood plain between 1950 and

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[5/] The Engineering News-Record construction cost index is comprised of steel, cement, lumber and labor rate. The index measures the change in prices in the components of the index. For a detailed description of the index see U.S. Office of Business Economics, <u>Business Statistics</u>, Government Printing Office, 1971, p. 53.

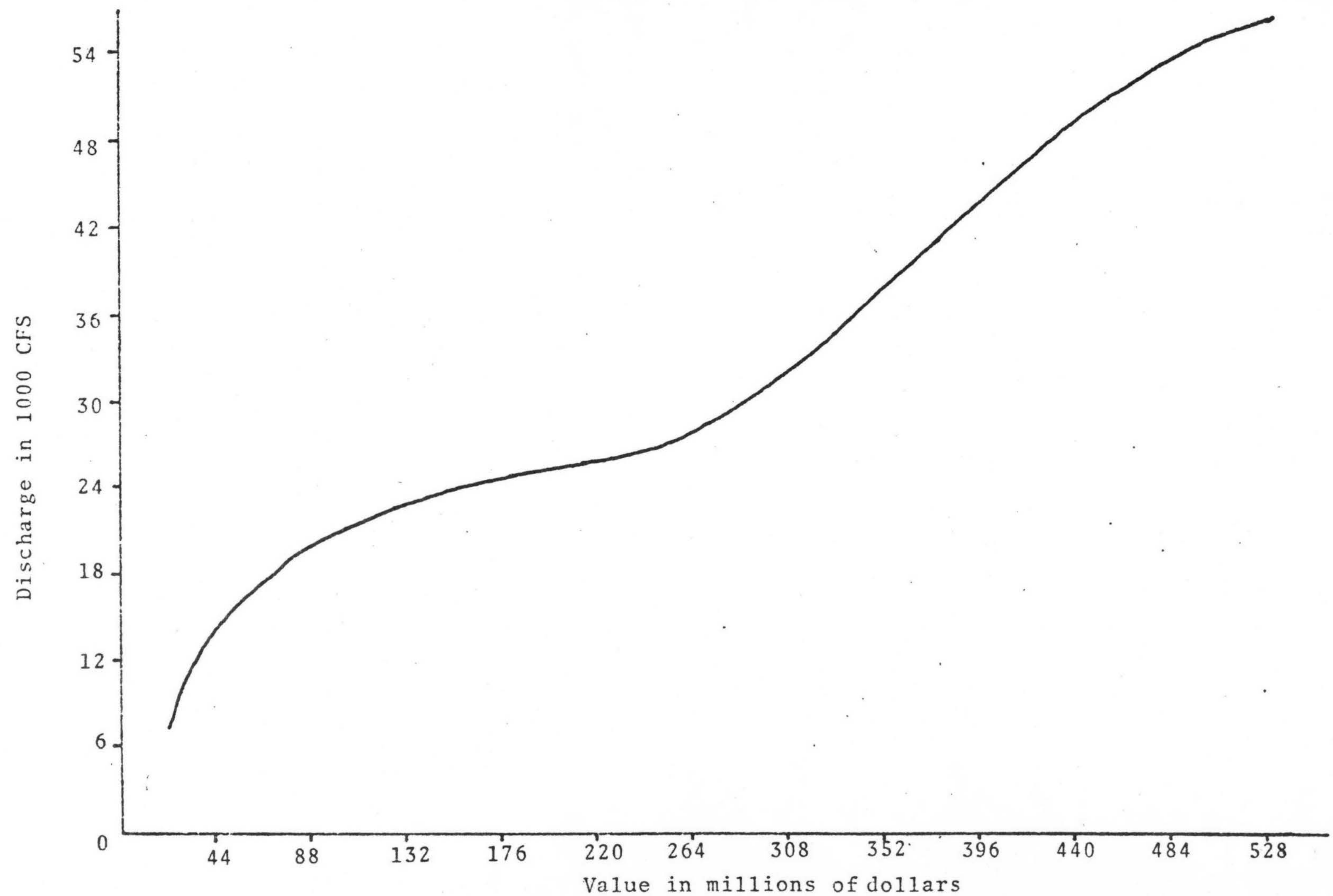

Figure 8: Discharge-value curve for the Boise River at 1974 level of economic development.

1974 was 4.2 percent.[6/] Having estimated r (4.2 percent) and D_1(NG,NFC) in Table 13, Model 5 can be estimated by multiplying the annual flood damages in Table 14 by $(1+r)^n$. Table 17 gives the annual flood damage with actual economic growth in the flood plain, but without flood control. Total flood damages with actual growth and without flood control between 1950 and 1974 would have been $30,884,045 (Table 17). Without the federal flood control projects the annual flood damages in the Boise Valley would have varied between $167,820 and $3,004,320 (Table 17).

Model 6: Estimation of annual flood damage with actual economic growth and with flood control.

Recall that Model 6 was:

$$D_6(AG,FC) = (1+r)^n D_2(NG,FC)$$

Also recall that D_2(NG,FC) is the estimated annual flood damage with no growth and with flood control (Model 2). The estimated values of Model 2 were given in Table 14. The value of r was estimated in the preceeding section to be 4.2 percent annually. To estimate D_6(AG,FC) one has to multiply Model 2 by $(1+r)^n$. The estimated values of

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[6/] According to the Historical Statistics of the U.S. (54) the Engineering News-Record construction indes with 1967 as a base (1967 = 100) was 188.2 in 1974. Shifting the base of the index to 1943 (1943 = 100) the index in 1974 was 694.5. Deflating $533,000,000 by $\frac{100}{694.5}$ gives $76,745,860. Thus, the growth rate r can be determined from $V = V_o(1+r)^n$ where V = $76,745,860, V_o = $21,590,000, n = 31, Solving for r one gets 4.2 percent.

Table 17: Estimated annual flood damages in the Boise Valley with actual economic growth and without the federal flood control projects in constant 1943 dollars (Model 5).

Year	1943 damages D_1(NG, NFC)	Growth factor $(1+r)^n$	Estimated annual flood damages D_5 (AG, NFC)
1950	$ 330,000	1.334	$ 440,220
1951	360,000	1.390	500,400
1952	1,825,000	1.448	2,642,600
1953	295,000	1.509	445,155
1954	380,000	1.572	597,360
1955	190,000	1.638	311,220
1956	1,760,000	1.707	3,004,320
1957	575,000	1.779	1,022,925
1958	1,450,000	1.854	2,688,300
1959	140,000	1.931	270,340
1960	250,000	2.013	503,250
1961	90,000	2.097	188,730
1962	225,000	2.185	491,625
1963	230,000	2.277	523,710
1964	200,000	2.373	474,600
1965	1,150,000	2.472	2,842,800
1966	100,000	2.576	257,600
1967	440,000	2.684	1,180,960
1968	60,000	2.797	167,820
1969	450,000	2.914	1,311,300
1970	400,000	3.037	1,214,800
1971	1,075,000	3.164	3,401,300
1972	950,000	3.297	3,132,150
1973	160,000	3.436	549,760
1974	760,000	3.580	2,720,800
Total	$13,845,000		$30,884,045
Average	553,800		1,235,362

D_6(AG,FC) are given in Table 18. The total flood damage between 1950 and 1974 with actual economic growth and with flood control was $1,696,632 (Table 18). Thus, at 4.2 percent annual rate of growth the federal flood control projects reduced flood damage by $29,187,413 (Tables 17 and 18).

Summary of the Six Flood Damage Models: The six flood damage models estimated the annual flood damages by using a combination of two flood control levels (no flood control and with flood control) and three levels of economic growth (no growth, 2.2 percent annual growth rate, and 4.2 percent annual growth rate). Table 19 summarizes the total flood damages estimated by each of the six flood damage models. It can be seen from Table 19 that had there not been federal flood control projects the total flood damages would have varied from $13,845,000 (Model 1) to $30,884,045 (Model 5). However, with the flood control projects the total flood damage would have varied from $801,500 (Model 2) to $1,696,632 (Model 6).

Finally, four conclusions can be drawn from the discussion in this chapter. First, the discussion on categories of flood damages revealed that there are no uniform set of categories of flood damage, i.e., experts in the field do not use a consistent terminology. Second, a review of the previous flood damage studies in the Boise Valley showed that the studies concentrated on physiography and hydrology.

Table 18: Estimated annual flood damages in the Boise Valley with actual economic growth and with the federal flood control projects in constant 1943 dollars (Model 6).

Year	1943 damages D_2 (NG, FC)	Growth factor $(1+r)^n$	Estimated annual flood damages D_6 (AG, FC)
1950	$ 50,000	1.334	$ 66,700
1951	75,000	1.390	104,250
1952	80,000	1.448	115,840
1953	95,000	1.509	143,355
1954	25,000	1.572	39,300
1955	0	1.638	0
1956	59,000	1.707	100,713
1957	59,500	1.779	105,850
1958	40,000	1.854	74,160
1959	0	1.931	0
1960	20,000	2.013	40,260
1961	0	2.097	0
1962	0	2.185	0
1963	25,000	2.277	56,925
1964	0	2.373	0
1965	70,000	2.472	173,040
1966	0	2.576	0
1967	0	2.684	0
1968	0	2.797	0
1969	10,000	2.914	29,140
1970	10,000	3.037	30,370
1971	59,000	3.164	186,676
1972	49,000	3.297	161,553
1973	0	3.436	0
1974	75,000	3.580	268,500
Total	$801,500		$1,696,632
Average	32,060		67,865

Table 19: Total flood damages in the Boise Valley as estimated by each of the six flood damage models for the period 1950 to 1974 in 1943 constant dollars.

Growth rates (annual)	Levels of flood control	
	No flood control	With flood control
No growth	$13,845,000	$ 801,500
2.2 percent	20,898,270	1,173,001
4.2 percent	30,884,045	1,696,632

As the result, the previous flood damage studies provided inadequate economic and financial data. Third, the expected average annual flood damages (computed using probabilities of the various floods) without flood control (Table 11) and with flood control (Table 12) are a good approximation of the estimated annual flood damages (computed using actual flood discharge data) without flood control (Table 17) and with flood control (Table 18). Fourth, estimated annual flood damages in the Boise Valley varied from $13,845,000 (with no economic growth) to $30,484,045 (with actual growth) for the 25 years this study covered (Table 19).

CHAPTER 5

ESTIMATION OF FLOOD CONTROL BENEFITS IN THE BOISE VALLEY

The primary purpose of this capter is to estimate annual flood control benefits of the federal flood control projects on the Boise River for the period 1950 to 1974 in 1943 dollars. A brief description and evaluation of the methods of estimating flood control benefits will also be given.

Categories of Benefits

Flood control benefits may be defined as increases in the value of goods and services because of reduction or elimination of flood damages. Flood control benefits include tangible benefits and intangible benefits.

Tangible benefits are "those benefits that can be expressed in monetary terms," (35, p. 8) while intangible benefits are "those benefits which, although recongized as having real value in satisfying human needs or desires, are not fully measurable in monetary terms..." (35, pp. 8-9). Benefits may also be classified as primary benefits (direct benefits) and secondary benefits (indirect benefits). Primary benefits are "the value of goods and services directly resulting from the project" (35, p. 9). Primary flood control benefits are the reduction in direct flood damages. Secondary benefits are "the value of goods and services which indirectly result from the project" (35, p. 9). Secondary flood control benefits are the reduction in indirect flood damages.

Methods of Estimating Flood Control Benefits

A comparison of two situations may be used in estimating the benefits of a flood control project--with the project and without the project. This is undertaken to see what would happen to the economy of the region both with the project and without the project. Eckstein (12, p;. 51-52) says that use of the with and without principle guards one against making the mistake of attributing all development in a region to a project. However, had the project not been there, one expects some development would have taken place in the region. Thus, it is fallacious to compare before the projcet and after the project conditions in estimating benefits as that may imply the credit for all economic development results from the project.

The estimation of benefits necessitates two steps: 1) identification of benefits, and 2) measurement of benefits. There are disagreements among experts in the field as to what should be considered as benefits. There is also the problem of quantifying certain flood control benefits such as human lives saved because of a flood control project. Thus, the estimation of flood control benefits poses many problems to and sheep and this in turn led to the present major economic activity in the valley--development of land into farms through irrigated agriculture (23, p. 42).

Various factors were probably responsible for changing the economic base from one activity to another. However, in the Boise Valley the change from ranching to irrigated agriculture was encouraged by passage of the Carey Act of 1894 and the Federal Reclamation Act of 1902. Both these acts authorized the development of federal projects to provide water to both private and federal lands.

Since 1870, population growth in the Boise Valley has been steady. The population of the valley tripled between 1900 and 1920. This was the period when most federal irrigation projects were completed. A study by the Idaho State Planning Board says, "The close dependence of the population upon irrigation can be seen from the fact that the most rapid development occurred during the years when irrigation projects were being completed the most rapidly" (21, pp. 31-32).

What was the trend of population and economic growth between 1940 and 1970? A study by Bollinger (2, p. 1) for the Idaho Bureau of State Planning and Community Affairs says that for the state of Idaho, between 1940 and 1970, there was subnormal economic growth and net out-migration of population. The same study tells us that the reverse has taken place during the 1970's in the state of Idaho (2, p. 1). But what has the trend been in the Boise Valley?

the analyst.

Generally, two methods can be used to estimate flood control benefits. These are referred to as the direct measurement procedure and the comparative land value procedure (15, p. 19). A brief description of each procedure will be given.

A. Direct Measurement Procedure: The direct measurement procedure also referred to as the damage method by White (60, p. 139) is based on the assumption that reduced flood damages are the equivalent of benefits (15, p. 19). It requires information on the hydrology, technology, and economy of the region. In particular the following pieces of information are essential to determine reduced flood damages, i.e., benefits:

(1) probability of each annual peak discharge;

(2) stage or discharge of each flood;

(3) damage that a flood with a given discharge or stage and frequency inflicts on the area without flood control;

(4) damages that a flood with a given discharge or stage and frequency inflicts on the area with flood control.

Given the above information, annual flood control benefits can be computed as the difference between the damages without flood control and damages with flood control, other factors held constant.

B. Comparative Land Value Procedure: This procedure is based on the assumption that changes in the land value of locations within the flood plain will capture flood control benefits (60, p. 139). This method was referred to by White (60, p. 139) as the differential method. The comparative land value procedure will capture all the benefits if the following conditions are met according to Haveman (15, p. 22).

(1) The economy is in competitive equilibrium. There is a set of market prices for all types of land including the flood plain.

(2) Rent value of each type of land is equivalent to the marginal value product. The introduction of flood control measure leaves other prices unchanged except for rent and thus increased rent that accrues to the landowners.

(3) Interest rate in all markets is the same and equals the social rate of discount.

(4) Rents that prevailed before the project do not include anticipated returns from project construction.

The expression to estimate benefits, B, using land value procedure is given by Lind (30, p. 351) as follows:

$$B = n[(S_f^x - P_f) - (S_u^x - P_u)]$$

where: n = number of activities in the flood plain

S_f^x = earning of activity x (defined as net receipts exclusive of land costs) located in flood plain

P_f = rent value of land in the flood plain

S_u^x = earning of activity x (defined as net receipts exclusive of land costs) located outside flood plain

P_u = rent value of land outside the flood plain

There are several factors that make the use of comparative land value procedure or more recently the land enhancement method difficult.

First, the estimation of benefits on differential land values makes one believe that flood control benefits accrue to property owners, especially landowners. However, flood control measures have other benefits besides increase in land utilization.

Second, a multiplicity of environmental, social, and economic factors influence the development of an area. Similarly, changes in land value are caused by a complex set of economic forces in addition to the flood control investments and one needs to adjust the change in land value by removing those changes in land value that would have occurred without the project (15, p. 23).

Lind (30, p. 351) brings out the practical difficulties in using the land enhancement procedure for estimating flood control measures:

(1) one needs to know which activities will move into the flood plain;

(2) under flood protection, one needs to know the new set of rents after equilibrium is established;

(3) one needs to know where an activity that moves

into the flood plain comes from;

(4) the market interest rates and social rate of discount diverge.

Some of the information that the comparative land procedure requires is impossible to obtain. It necessitates classification of lands into homogeneous units both within the flood plain and outside the flood plain and knowing the unit value of these homogeneous units, the earning of all activities both inside and outside the flood plain. Thus, the use of this procedure to estimate flood control benefits presents both empirical and application problems. The major weakness of the damage method is that damage data are subject to error and it also disregards intangible and potential (future) benefits (60, pp. 140-141).

C. The Corps of Engineers Method: The Corps of Engineers method is not fundamentally different from any of the other two methods. In fact, it combines both the damage method and the differential method (land enhancement method) discussed above under two different conditions--when there is no project induced growth and when there is project induced growth. Under the no project induced growth, "total benefits are equivalent to damages reduced," (48, p. 17) and also "the land use and its rate of development will not be affected by the introduction of the project" (48, p. 21). However, when there is project induced growth, flood control benefits will be the sum of: (1) flood damage reduction to activities that will locate in the flood plain with and without flood control measures, and (2) flood damage reduction to new activities that locate in the flood plain only with flood control measures (48, pp. 25-28).

The problem with the Corps of Engineers method is that one has to determine whether there is project induced growth or not. In addition, the Corps of Engineers method also has the weaknesses of the damage method and the land enhancement method as it combines the two.

Estimation of Flood Control Benefits in the Boise Valley

In this section flood control benefits in the Boise Valley will be estimated for the period 1950 to 1974 when:

(a) there has been no economic growth;

(b) there has been 2.2 percent annual growth;

(c) there has been 4.2 percent annual growth.

(a) Estimated Annual Flood Control Benefits with no Growth: Recall that flood control benefits were defined as damages prevented or the difference between the damages with flood control and damages without flood control. The estimated annual flood dmaages with no growth and no flood control (Model 1) were given in Table 13. Similarly, the estimated annual flood damage with no growth and flood control (Model 2) were given in Table 14. Thus, the estimated annual flood control benefits (damages prevented) with no growth can be obtained by subtracting Model 2 from Model 1. This is presented in Table 20. It can be seen from Table 20 that the total prevented flood damages (flood control benefits) between 1950 and 1974 were $13,043,500 without economic growth. For the same period prevented flood damages varied from $60,000 to $1,745,000 (Table 20).

<u>(b) Estimated Annual Flood Control Benefits with 2.2 Percent Annual Growth:</u> Recall that estimated annual flood damages with 2.2 percent growth and no flood control (Model 3) were given in Table 15. Also, estimated annual flood damage with 2.2 percent economic growth and with flood control (Model 4) were presented in Table 16. Estimated annual flood control benefits (prevented damages) will be the difference between Models 3 and 4. This result is given in Table 21. Table 21 shows that estimated annual flood control benefits varied from $103,380 to $2,257,227. For the 25-year period, 1950 to 1974, estimated total flood control benefits at 2.2 percent annual growth was $19,167,269 (Table 21).

<u>(c) Estimated Annual Flood Control Benefits at 4.2 Percent Annual Growth</u>: Recall that the estimated annual flood damages with 4.2 percent annual growth and no flood control (Model 5) were given in Table 17. Estimated annual flood damages at 4.2 percent annual growth with flood control (Model 6) were given in Table 18. Estimated annual prevented damages (flood control benefits) will then be the difference between Models 5 and 6 (Table 22). Estimated total flood control beenfits between 1950 and 1974 were $29,187,413

Table 20: Estimated annual flood control benefits in the Boise Valley without economic growth in constant 1943 dollars.

Year	Damages without flood control D_1(NG, NFC)	Damages with flood control D_2(NG, FC)	Flood control benefits D_1(NG, NFC) − D_2(NG,FC)
1950	$ 330,000	50,000	$ 280,000
1951	360,000	75,000	285,000
1952	1,825,000	80,000	1,745,000
1953	295,000	95,000	200,000
1954	380,000	25,000	355,000
1955	190,000	0	190,000
1956	1,760,000	59,000	1,701,000
1957	575,000	59,500	515,500
1958	1,450,000	40,000	1,410,000
1959	140,000	0	140,000
1960	250,000	20,000	230,000
1961	90,000	0	90,000
1962	225,000	0	225,000
1963	230,000	25,000	205,000
1964	200,000	0	200,000
1965	1,150,000	70,000	1,080,000
1966	100,000	0	100,000
1967	440,000	0	440,000
1968	60,000	0	60,000
1969	450,000	10,000	440,000
1970	400,000	10,000	390,000
1971	1,075,000	59,000	1,016,000
1972	950,000	49,000	901,000
1973	160,000	0	160,000
1974	760,000	75,000	685,000
Total	$13,845,000	$801,500	$13,043,500
Average	553,800	32,060	521,740

Table 21: Estimated annual flood control benefits in the Boise Valley with restricted economic growth (2.2 percent) in constant 1943 dollars.

Year	Damages without flood control D_3(RG,NFC)	Damages with flood control D_4(RG,FC)	Estimated annual flood control benefits D_3(RG,NFC) − D_4(RG,FC)
1950	$ 384,120	58,200	$ 325,920
1951	428,400	89,250	339,150
1952	2,219,200	97,280	2,121,920
1953	366,685	118,085	248,600
1954	482,600	31,750	450,850
1955	246,620	0	246,620
1956	2,335,520	78,293	2,257,227
1957	779,700	80,682	699,018
1958	2,009,700	55,440	1,954,260
1959	198,240	0	198,240
1960	362,000	28,960	333,040
1961	133,200	0	133,200
1962	340,200	0	340,200
1963	355,350	38,625	316,725
1964	315,800	0	315,800
1965	1,856,100	112,980	1,743,120
1966	165,000	0	165,000
1967	741,840	0	741,840
1968	103,380	0	103,380
1969	792,450	17,610	774,840
1970	720,000	18,000	702,000
1971	1,976,925	108,501	1,868,424
1972	1,786,000	92,120	1,693,880
1973	307,360	0	307,360
1974	1,491,880	147,225	1,344,655
Total	$20,898,270	$1,731,001	$19,167,269
Average	835,931	46,920	766,691

Table 22: Estimated annual flood control benefits in the Boise Valley with actual economic growth (4.2 percent) in constant 1943 dollars.

Year	Damages without flood control D_5 (AG, NFC)	Damages with flood control D_6(AG, FC)	Estimated annual flood control benefits D_5(AG, NFC) – D_6(AG,FC)
1950	$ 440,220	66,700	$ 373,520
1951	500,000	104,250	395,750
1952	2,642,600	115,840	2,526,760
1953	445,155	143,355	301,800
1954	597,360	39,300	558,060
1955	311,220	0	311,220
1956	3,004,320	100,713	2,903,607
1957	1,022,925	105,850	917,075
1958	2,688,300	74,160	2,614,140
1959	270,340	0	270,340
1960	503,250	40,260	462,990
1961	188,730	0	188,730
1962	491,625	0	491,625
1963	523,710	56,925	466,785
1964	474,600	0	474,600
1965	2,842,800	173,040	2,669,760
1966	257,600	0	257,600
1967	1,180,960	0	1,180,960
1968	167,820	0	167,820
1969	1,311,300	29,140	1,282,160
1970	1,214,800	30,370	1,184,430
1971	3,401,300	186,676	3,214,624
1972	3,132,150	161,553	2,970,597
1973	549,760	0	549,760
1974	2,720,800	268,500	2,452,300
Total	$30,884,045	$1,696,632	$29,187,413
Average	1,235,362	67,865	1,167,497

(Table 22). Estimated annual flood control benefits varied from $167,820 to $3,214,624 (Table 22).

Summary of the Estimated Flood Control Benefits

Table 23 summarizes the estimated flood control benefits at three levels of economic growth. It can be seen from Table 23 that the higher the growth rate the higher are the flood control benefits. Annual flood control benefits with no growth, restricted growth, and actual growth are shown in Figures 9, 10, and 11 respectively.

Finally, the following conclusions can be drawn from this chapter. First, even though it is too early to say that the flood control projects on the Boise River are economically feasible, one can conclude that the prevented flood damages between 1950 and 1974 were equal to $29,187,413 with actual growth and $19,167,269 with restricted growth (Table 23). Second, a critical evaluation of the methods of evaluating flood control benefits revealed that the methods of evaluating flood control benefits (damage method and land enhancement method) suffer from lack of data and application problems.

Table 23: Summary of the estimated flood control benefits at three levels of economic growth, Boise Valley, 1950 to 1974.

Level of growth	Estimated total flood control benefits (1943 dollars)
No growth	$13,043,500
2.2 percent growth	19,167,269
4.2 percent growth	29,187,413

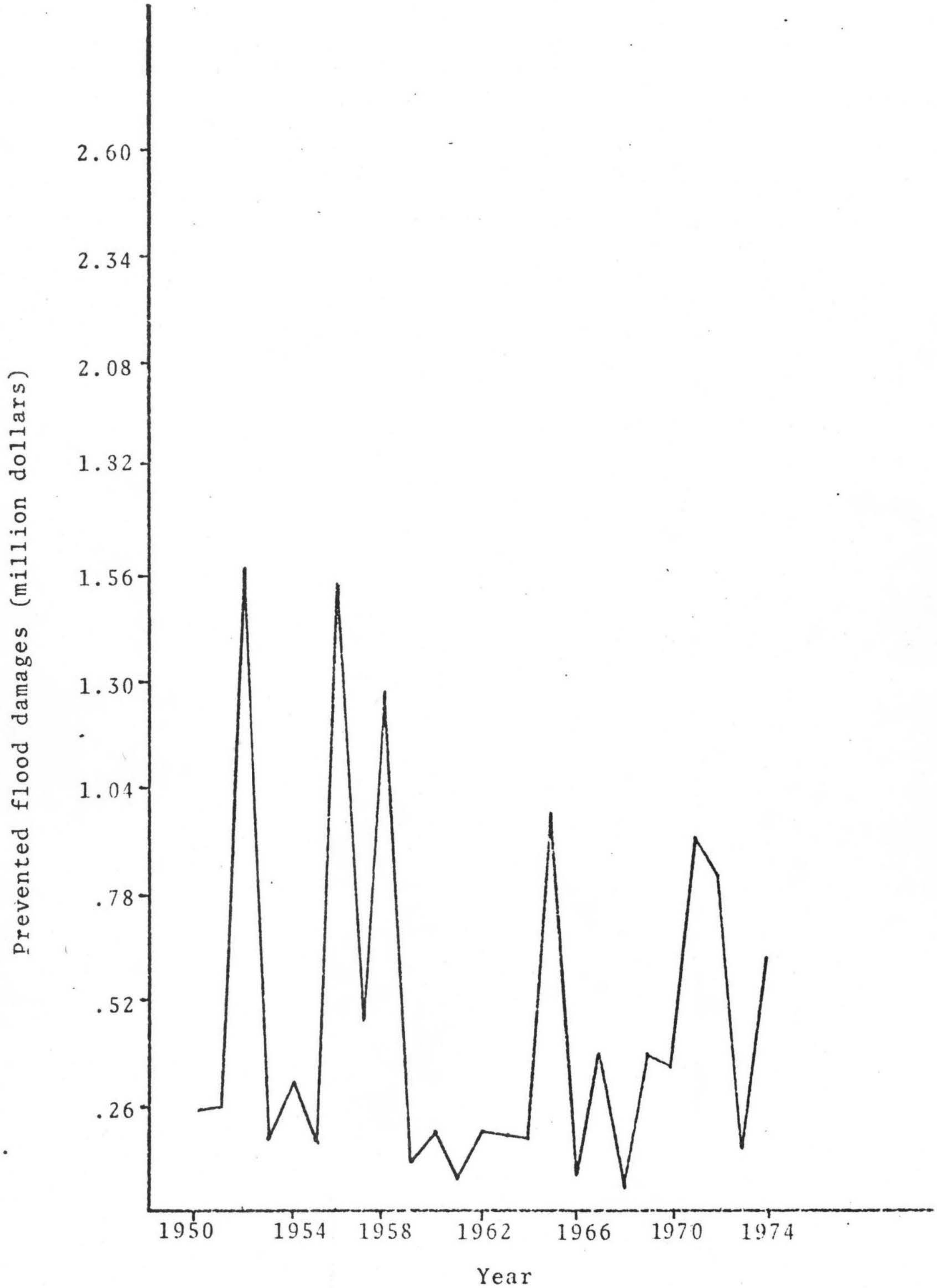

Figure 9: Annual prevented flood damages without economic growth.

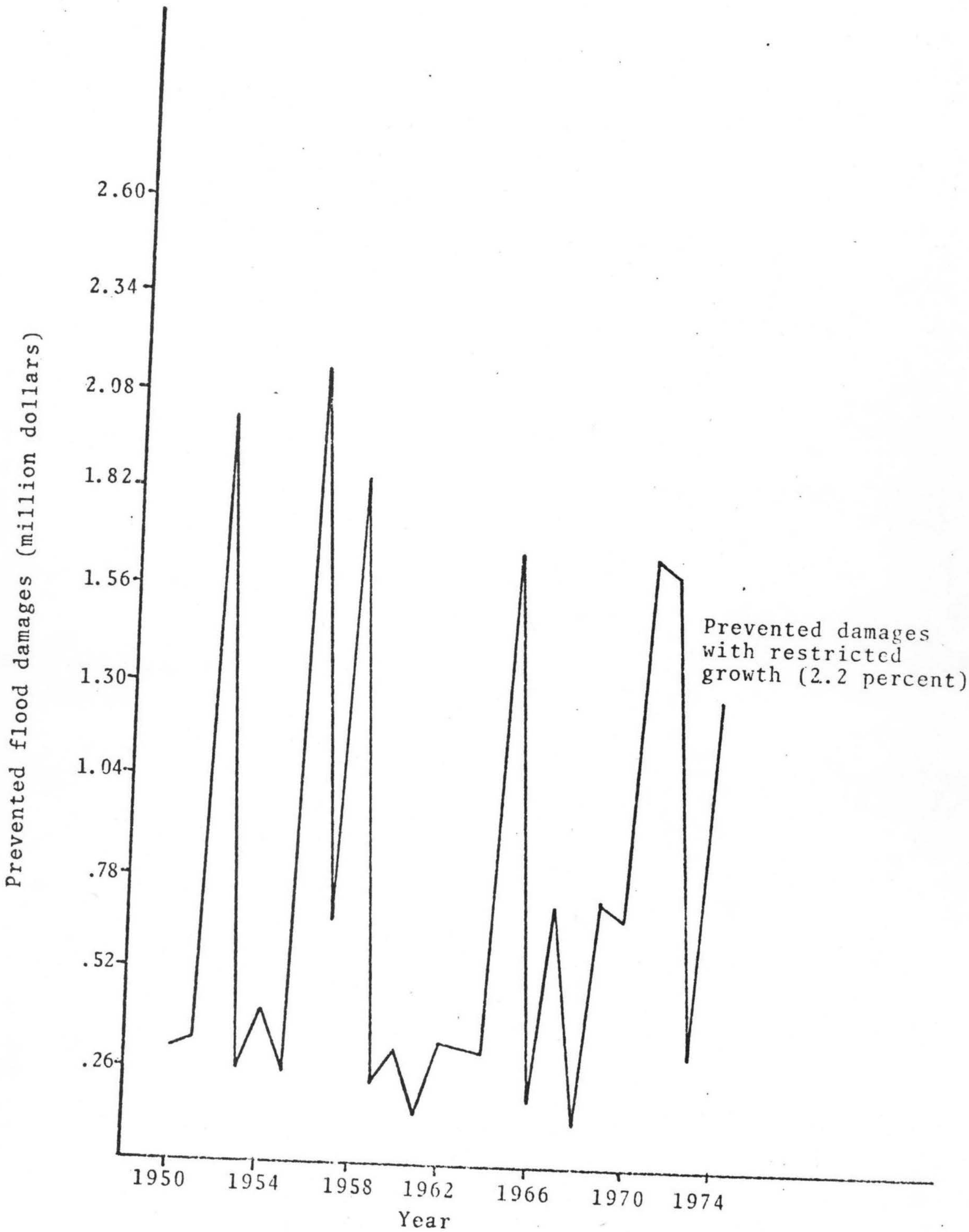

Figure 10: Annual prevented flood damages with restricted economic growth.

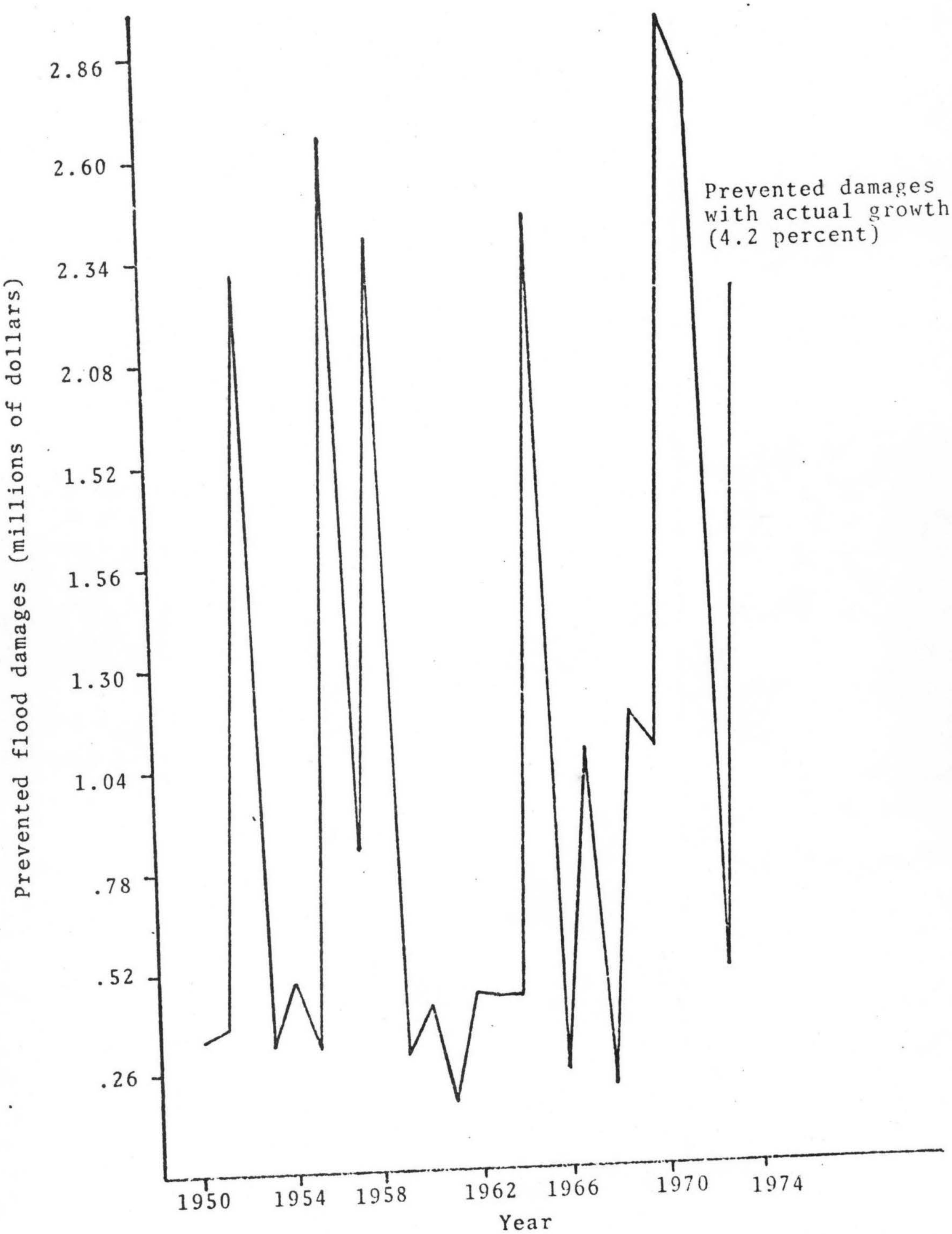

Figure 11: Annual prevented flood damages with actual economic growth.

CHAPTER 6

ESTIMATION OF ANNUAL FLOOD CONTROL COSTS IN THE BOISE VALLEY

The primary purpose of this chapter is to estimate the annual costs of the federal flood control projects in the Boise Valley for the period 1950 to 1974 in constant 1943 dollars. The annual flood control costs will be the sum of annual depreciation, annual alternative investment costs, and annual operating and maintenance costs.

Procedure of Annual Cost Estimation

Recall that the three storage reservoirs (Arrowrock, Anderson Ranch, and Lucky Peak) are multipurpose reservoirs (serve to store water for flood control, irrigation, and other water uses). Therefore, before one attempts to estimate the annual flood control costs, one needs to know what the actual total costs were by the time each structure was completed and how much was allocated to flood control. To facilitate the estimation of annual costs of federal flood control projects in the Boise Valley in constant 1943 dollars, the total flood control costs of each reservoir will be deflated by the appropriate price index to adjust for price level changes.

Actual Total Costs of Flood Control Projects in the Boise Valley

Anderson Ranch Reservoir was completed in 1950 and its actual total cost including the power plant was $31,410,558 according to the Revised Allocation and Repayment Report (56, p. 11). In allocating the total construction cost for Anderson Ranch Reservoir between the three functions (irragation, flood control, and power) the Bureau of Reclamation used the use of space method (56, p. 1). The use of space method is a physical criterion by which costs are assigned to a given water storage purpose in proportion to the space allocated to the purpose. The Bureau of Reclamation assigned 47.5 percent of the total cost of Anderson Ranch Reservoir and power plant to flood control (56, p. 11). Thus 47.5 percent of $31,410,558 (total cost of Anderson Ranch Dam and power plant in 1950) was the investment in flood control. This amounts to $14,920,000 in 1950. Adjusting this value for price level changes using the Engineering News-Record general construction index,[7/] the $14,920,000 allocated to flood control becomes $8,477,272 in 1943.

Lucky Peak Dam was completed in 1955 and its actual

[7/] According to the Historical Statistics of the United States Colonial Times to 1970 (54), the Engineering News-Record Construction index changed from 27.1 in 1943 to 47.6 in 1950 using 1967 as the base year (1967 = 100). Splicing and shifitng the base of the index number from 1967 to 1943 (that is 1943 = 100) the index for 1950 becomes 176. Thus, $\$14,920,000 \times \frac{100}{176} = \$8,477,272$ in 1943.

total cost was $19,081,250 according to the Annual Report of the Chief of Engineers (47, pp. 39-3). All the total costs of Lucky Peak Dam was allocated to flood control. The Corps of Engineers did what they called "theoretical allocation of costs" (52, p. 70). Accroding to the "theoretical allocation" 70.3 percent of the total cost was allocated to flood control while 15.2 percent of the total cost was allocated to irrigation and 14.5 of the total cost was allocated to power and recreation (52, p. 70). The allocation was "theoretical" because all the cost of Lucky Peak went to flood control. After adjustment for price changes using the Engineering News-Record general construction index the $19,081,250 invested in Lucky Peak Dam in 1955 becomes $8,394,742 in 1943.[8/]

The construction of Lucky Peak Dam also necessitated alterations in Arrowrock Dam. The cost involved in changing the outlets of Arrowrock Dam ($232,000) was allocated to flood control (56, p. 12). It will be assumed here that the alteration of the outlets of Arrowrock Dam was completed in 1955. Adjusting the $232,000 spent to alter the outlets of Arrowrock

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[8/] According to the Historical Statistics of the United States Colonial Times to 1970 (54), the Engineering News-Record Construction index changed from 27.1 in 1943 to 61.6 in 1955 using 1967 as a base (1967 = 100). Splicing and shifting the base of the index from 1967 to 1943 (i.e., 1943 = 100) the index for 1955 becomes 227.3. Thus, deflating $19,081,250 by $\frac{100}{227.3}$ gives $8,394,742 in 1943.

Dam for price changes using the Engineering News-Record construction index (which was 227.3 in 1955 using 1943 as a base) makes the investment to alter the outlets of Arrowrock Dam ($232,000 in 1955) $102,068 in 1943 (see footnote 8 for details on the index).

Thus, the total investment in flood control measures is the sum of the investments in each of the three reservoirs. The investment in flood control in the Boise Valley in 1943 dollars then becomes $16,974,082, that is, $8,477,272 (for Anderson Ranch) + $8,394,742 (for Lucky Peak) + $102,068 (for Arrowrock) = $16,974,082. Table 24 gives the investment cost of the federal flood control projects in the Boise Valley in 1943 dollars.

Estimation of Annual Flood Control Costs

In this section, annual depreciation costs, annual alternative investment costs, and annual operating and maintenance costs will be estimated separately. Later, all the three annual cost items will be added together to determine the annual costs of the federal flood control projects in the Boise Valley.

Annual Depreciation

Physical structures like dams and reservoirs have limited life. As time passes, silt accumulates in the back of dams. Accumulated silt takes up storage space and thus

Table 24: Investment cost of flood control projects on the Boise River in 1943 dollars.

Completion date	Structure	Structure cost[3/]	Accumulated cost
1950	Anderson Ranch[1/] Dam & power plant	$8,477,272	$ 8,477,272
1955	Arrowrock Dam[2/]	102,068	8,579,340
1955	Lucky Peak Dam	8,394,742	16,974,082

[1/] Based on the assumption that 47.5 percent of the total cost of Anderson Ranch and power plant was allocated to flood control.

[2/] Arrowrock Dam was primarily built for irrigation, however, when Lucky Peak Dam was built alteration of the outlet works to Arrowrock Dam was made necessary. The cost shown ($102,068) was the cost of changing the outlet works for flood control purposes.

[3/] The structural costs of each of the federal flood control projects are deflated costs, that is, each structure's actual cost adjusted for price level changes using the Engineering News-record general construction index with 1943 as a base.

reduces the possible benefits from a project. Structures might also deteriorate physically because of long exposure to sun, wind, and rain. The sub-committee on Benefits and Costs recommended an upper limit of 100 years on the period of analysis (57). According to Eckstein (12, p. 83) the 100 year upper limit is imposed to force all agencies to use the same limit on the period of analysis in order to produce comparable benefit-cost ratios and to disregard benefits remote in time as the risks are extremely large. In this study all the Bureau of Reclamations and the Corps of Engineers flood control projects will be considered to have a 100-year life. In addition, a straight line depreciation schedule, by which a given investment decreases in value by the same amount annually until the salvage value of the structures is zero will be used. Note that from Table 24 the flood control investments come in 1950 and 1955. Depreciating the flood control investment costs in Anderson Ranch by one one-hundredth of its 1950 deflated value (Table 24) gives an annual depreciation of $84,773 in 1943 dollars (Table 25). Similarly, the annual depreciation for Lucky Peak Dam becomes $83,947 in 1943 dollars (Table 25). Table 25 gives the annual depreciation applied to the accumulated costs of the three dams.

Alternative Investment Costs

In a free market economy where there is less than full

Table 25: Annual depreciation on federal investments in flood control projects in the Boise Valley, 1950 to 1974 in constant 1943 dollars.

Year	Annual depreciation
1950	$ 84,773
1951	84,773
1952	84,773
1953	84,773
1954	84,773
1955	169,741
1956	169,741
1957	169,741
1958	169,741
1959	169,741
1960	169,741
1961	196,741
1962	169,741
1963	169,741
1964	169,741
1965	169.741
1966	169,741
1967	169,741
1968	169,741
1969	169.741
1970	169,741
1971	169,741
1972	169,741
1973	169,741
1974	169,741
Total	$3,818,685
Average	152,747

employment of productive resources the alternative investment opportunity of capital is not zero. A free market economy also allocates resources such that they earn the maximum returns. Had federal funds not been invested in flood control where else could they have gone? It is hard to say where the funds might have been invested had they not gone into flood mitigation. However, with the stiff competition for federal funds among the various federal activities, it would be safe to assume that the funds would not have been idle. Could the investments have come from private firms? Flood control investments are unattractive to private firms because private firms cannot easily exclude the beneficiaries from using their services without paying for them. Flood control projects also require massive capital outlay and they also last many years. It appears that the only source of investment for flood control could only have been from the government. The federal government pays the bond rate of interest when it borrows money from the public. Thus, the minimum the federal government can charge annually on its investments is the bond rate of interest.

The alternative investment costs are the costs of borrowing the funds for flood control investments from the federal government. In other words, alternative investment costs are the costs of using federal funds for flood control investments. There is widespread agreement among economists that there should be alternative investment costs. However, there exists disagreement as to what percent the annual alternative costs should be. Some economists like Baumol (1, p. 801) feel that the interest rate on public projects should be closely equated to the market rate of interest. Others like Sen (40, p.495) and Marglin (31, p.111) feel that the interest rate for public projects should be less than the market rate of interest as there is no one market interest rate and the market rate of interest overlooks the interest of future generations. It is clear from the above discussion that there is no agreed upon rate of interest to be used in determining the alternative investment costs of public projects. In this study the long term government bond rate of interest will be applied to the investment costs that were adjusted for prices. Annual alternative investment costs will be determined by multiplying the net investment (total investment less depreciation) by the annual long term government bond rate of interest.

Table 26 gives the annual alternative investment costs of federal investments in flood control in the Boise Valley. The annual long term government bond rate of interest was obtained from the Historical Statistics of the United States (54) and the United States Statistical Abstract (55). As can be seen from Table 26 the alternative annual investment costs of federal investments in flood control varied from $196,673 in 1950 to $919,435 in 1974. The total alternative investment costs for the 25-year period, 1950 to 1974, was

Table 26: Annual alternative investment costs of federal investments in flood control in the Boise Valley in constant 1943 dollars 1950 to 1974.

Year	Long term government bond rate	Alternative investment cost
1950	2.32	$ 196,673
1951	2.57	215,687
1952	2.68	222,647
1953	2.94	241,755
1954	2.55	207,524
1955	2.84	228,717
1956	3.03	496,328
1957	3.47	562,512
1958	3.43	550,206
1959	4.07	645,960
1960	4.01	629,631
1961	3.90	605,739
1962	3.95	606,800
1963	4.00	607,692
1964	4.15	623,436
1965	4.21	625,303
1966	4.66	684,231
1967	4.35	631,199
1968	5.25	753,038
1969	6.10	864,604
1970	6.59	922,870
1971	5.74	794,092
1972	5.63	769,318
1973	6.30	850,177
1974	6.90	919,435
Total		$14,455,574
Average		578,223

$14,455,574 (Table 26). It should be noted that the alternative investment costs are real in that they represent opportunities foregone. The alternative investment costs represent real costs if the federal government borrowed the money at the long term bond rates from the public to invest in flood control.

Annual Operating and Maintenance Costs

Operating and maintenance costs are costs incurred to make the flood control facilities perform their prescribed functions properly. Table 27 gives the annual operating and maintenance costs for Bureau of Reclamation and Corps of Engineers projects for flood control separately. Note that the annual operating and maintenance costs for Bureau of Reclamation and Corps of Engineers flood control projects given separately in Table 27 are in terms of actual costs incurred each year. The total annual operating and maintenance costs for both Bureau of Reclamation and Corps of Engineers projects given in Table 27 is also in incurred annual costs in each year's dollars. The total annual operating and maintenance costs for both Bureau of Reclamation and the Corps of Engineers given in column 4 of Table 27 are deflated by the Engineering News-Record general construction index to adjust for price changes. Column 6 of Table 27 gives the deflated annual operating and maintenance costs in 1943 dollars. From Table 27, column 6 the annual operating and

Table 27: Total annual operating and maintenance costs of federal flood control projects in the Boise Valley.

Year	Corps of Engineers (dollars)	Bureau of Reclamation (dollars)	Total cost (dollars)	Construction index[1/]	Total in 1943 dollars
1950	$ --	$ 4,107	$ 4,107	176.0	$ 2,333
1951	--	5,489	5,489	187.1	2,934
1952	--	6,431	6,431	196.3	3,267
1953	--	3,626	3,626	206.6	1.755
1954	--	10,091	10,091	216.5	4,659
1955	9,668	10,857	20,525	227.3	9,030
1956	54,858	6,334	61,292	238.7	25,677
1957	64,841	5,776	70,617	249.4	28,315
1958	81,662	14,965	96,627	262.0	36,881
1959	72,726	6,243	78,969	274.9	28,726
1960	73,669	10,353	84,002	283.8	29,606
1961	77,146	9,909	87,055	292.2	29,793
1962	90,456	6,719	96,175	300.7	31,984
1963	74,112	6.669	80,781	310.7	26,000
1964	123,977	15,922	139,899	322.5	43,380
1965	81,881	15,905	97,786	335.0	29,190
1966	115,486	23,723	139,209	351.3	39,627
1967	125,374	33,059	158,433	369,0	42,935
1968	235,884	11,067	246,951	398.1	62,032
1969	109,059	24,892	133,951	438.0	30,582
1970	137,776	30,451	168,227	475.6	35,372
1971	125,057	29,764	154,821	541.7	28,581
1972	181,739	33,384	215,123	601.5	35,764
1973	236,500	30,211	266,711	651.3	40,951
1974	308,414	27,800	336,214	694.5	48,411
Total	2,380,285	383,747	2,764,032		697,494
Average	119,014	15,350	110,561		26,912

Note: Operating costs in columns 2, 3, and 4 are not in 1943 dollars.

[1/] The construction index is the Engineering News-Record general construction index with 1943 as a base.

maintenance costs for flood control projects varied from $1,755 in 1953 to $62,032 in 1968 (in 1943 dollars). The total annual operating and maintenance costs for the flood control projects in the Boise Valley were $679,794 (Table 27) for the 25-year period 1950 to 1974.

Total Annual Costs of Federal Flood Control Projects

Total annual costs of the federal flood control projects are the sum of annual depreciation, annual alternative investment costs, and annual operating and maintenance costs. Table 28 presents the annual costs of the federal flood control projects in constant 1943 dollars for the period 1950 to 1974. The total annual costs were $283,779 in 1950, and rose to $1,137,587 in 1974 (Table 28). The average annual costs for the 25-year period was $758,882 (Table 28). Figure 12 presents the annual costs (Table 28) in graphical form. From Figure 12 it is clear that annual costs have shown an increasing trend over the 25-year period (1950 to 1974).

Table 28: Total annual costs of federal flood control projects in the Boise Valley for the period 1950 to 1974 in constant 1943 dollars.

Year	Total annual costs[1/]
1950	$ 283,779
1951	303,394
1952	310,696
1953	328,283
1954	296,956
1955	407,488
1956	691,746
1957	760,568
1958	756,828
1959	844,427
1960	828,978
1961	805,273
1962	808,525
1963	803,433
1964	836,557
1965	824,234
1966	893,599
1967	843,875
1968	984,811
1969	1,064,927
1970	1,127,983
1971	992,414
1972	974,823
1973	1,060,869
1974	1,137,587
Total	$18,972,053
Average	758,882

[1/] Total annual costs is the sum of Tables 25, 26, and 27.

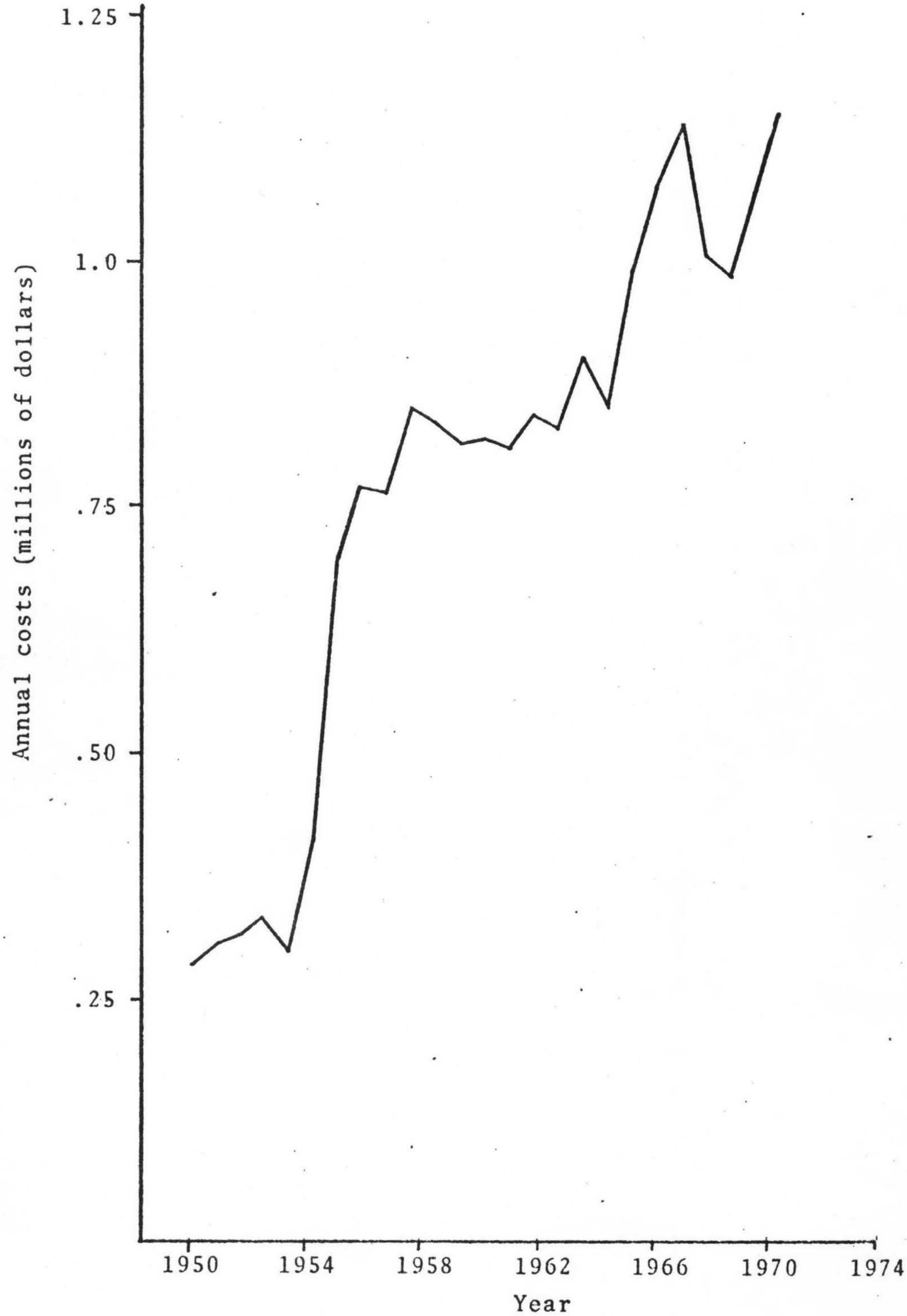

Figure 12: Annual federal flood control costs in the Boise Valley (1943 dollars).

CHAPTER 7

COMPARISON OF FLOOD CONTROL BENEFITS AND COSTS

The primary purpose of this chapter is to assess the economic performance of the federal flood control projects in the Boise Valley for the 25-year period 1950 to 1974. The economic performance of the federal flood control projects will be determined by comparing the benefits and the costs over the 25-year period (1950 to 1974). A minor concern of this chapter is to examine how good the original Bureau of Reclamation and Corps of Engineers estimates and benefits and costs were.

Ex-ante Cost Estimates

Anderson Ranch Dam and power plant was estimated to be completed at a total cost of \$13,100,000 when it was approved in 1940 (44, p. 5). However, it was completed for a total cost of \$30,494,286 in 1950 (56, p. 9). Adjusting the 1940 and the 1950 costs for price changes using the Engineering News-Record general construction index[9/] that uses 1943 as a base (1943 = 100) the \$13,100,000 cost estimate becomes

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[9/] According to the Historical Statistics of the U.S. (54) the Engineering News-Record construction index was 83.4 in 1940 with 1943 = 100. Thus \$13,100,000 in 1943 becomes $\$13,100,000 \times \frac{100}{83.4} = \$15,707,434$. Similarly the index was 176 in 1950. Thus \$30,494,286 in 1943 becomes $\$30,494,286 \times \frac{100}{176} = \$17,326,299$.

$15,707,434 in 1943. Similarly, the $30,494,286 cost estimate becomes $17,326,299 in 1943 using the Engineering News-Record construction index with 1943 as a base. Thus, for Anderson Ranch Dam and power plant there was a cost overrun of $1,618,865 in 1943 constant dollars or a 10 percent cost overrun.

Lucky Peak Dam was estimated to be completed at a total cost of $10,684,000 in 1946 (52, p. 58). However, it was completed in 1955 at a total cost of $19,081,250 (47, pp. 39-3). Adjusting the 1946 cost estimate for price changes using the Engineering News-Record general construction index[10/] one gets $8,963,087 in 1943 constant dollars. Similarly the 1955 value ($19,081,250) when adjusted for price changes with the Engineering News-Record construction index becomes $8,394,743 in 1943 constant dollars. Thus, for Lucky Peak Dam the original cost estimate (1946) exceeded the actual construction cost (1955) by $568,344 or a 6 percent cost underrun. In 1949 the Corps of Engineers reestimated the total cost of Lucky Peak Dam at $22,066,000 (49, p. 26). This estimate ($22,066,000) when adjusted for price changes

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[10/] According to the Historical Statistics of the U.S. (54) the Engineering News-Record general construction index was 61.6 in 1955 with 1967 as a base year (1967 = 100). Shifting the base of the index to 1943 (1943 = 100) the index in 1955 = 227.3 deflating $19,081,250 by $\frac{100}{227.3}$ gives $8,394, 743. The index was 119.2 in 1946 and 164.2 in 1949 with 1943 = 100. The 1946 and the 1949 estimates were deflated by 119.2 and 164.2 respectively.

using the Engineering News-Record general construction index with 1943 as base becomes $13,438,490 in 1943 constant dollars. This estimate ($13,438,490) exceeded the deflated 1955 actual cost ($8,394,743) by $5,043,747 in constant 1943 dollars. Thus, the 1946 estimate was a better estimate when one compares the deflated cost estimate and the actual cost.

Arrowrock Dam was built in 1915 primarily for irrigation and all its costs were allocated to irrigation. The only federal investment in Arrowrock Dam for flood control was $232,000 to improve the outlets of Arrowrock Dam when Lucky Peak Dam was built in 1955 (56, p. 9).

For Anderson Ranch and Lucky Peak dams the total actual construction costs ($25,721,042 from the above paragraphs) exceeded the initial construction cost estimates ($24,670,386 also from the preceding paragraphs).

Ex-ante Annual Benefit and Cost Estimates

The annual cost of the federal flood control portion of Anderson Ranch Project was estimated to be $215,000 in 1940 (44, p. 14). The annual cost estimates consisted of annual operating and maintenance costs plus annual interest and amortization. The $215,000 annual cost estimate in 1940 when adjusted for price change using the Engineering News-Record construction index [11/] becomes $257,794 in constant 1943 dollars. For the Anderson Ranch Project, annual flood control benefits were estimated to be $298,000 in 1940 (44, p.14). Adjusting the annual benefit for price changes in 1943 using the Engineering News-Record construction index makes the annual benefits $357,314 in 1943 (see footnote 11 for details).

Annual costs for Lucky Peak Dam were estimated to be $507,630 in 1946 (52, p. 71). Annual costs were defined to be the sum of annual operating and maintenance costs plus interest and amortization. For Lucky Peak Dam the annual flood control benefits, excluding power benefits, were $543,710 in 1946 (52, p. 69). Adjusting the annual costs ($507,630) and annual benefits ($543,710) for price changes using the Engineering News-Record construction index[12/] with 1943 as a base (that is, 1943 = 100) one gets $425,864 (for annual costs in 1943 dollars) and $456,132 (for annual benefits).

Thus, the annual costs for flood control for Lucky Peak and Anderson Ranch projects according to the ex-ante estimates in constant 1943 dollars were $683,658 (sum of

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11/ According to the Historical Statistics of the U.S. (54) the Engineering News-Record construction index was 22.6 in 1940 using 1967 as base. Shifting the base of the index to 1943 (i.e., 1943 = 100) one gets 83.4 in 1940. Inflating the annual benefits and costs by $\frac{100}{83.4}$ one gets $357,314 and $257,794 respectively in 1943.

12/ The Engineering News-Record construction index with 1967 as base year was 32.3 according to the Historical Statistics of the U.S. (54). Shifting the base of the index to 1943 the index in 1946 becomes 119.2. Deflating the 1946 annual benefits and costs by $\frac{100}{119.2}$ one gets $456,132 (for benefits) and $425,864 (for costs).

deflated annual costs for Anderson Ranch and Lucky Peak). Similarly, the annual flood control benefits from Lucky Peak and Anderson Ranch projects according to the ex-ante estimates were $813,446 in constant 1943 dollars. Thus, the ex-ante annual benefits underestimated the expost annual benefits (Table 22). Note that the ex-ante annual benefits for Arrowrock Dam is not known.

Ex-post Benefit and Cost Estimates

The expost annual and total flood control benefits (prevented flood damages) were estimated for three different real growth rates (0 percent, 2.2 percent, and 4.2 percent) in Chapter 5 and were given in Tables 20, 21, and 22 for the 25-year period from 1950 to 1974. The expost annual costs for the federal flood control projects were estimated for the period 1950 to 1974 (Table 28). Table 29 presents the annual flood control benefits at three different growth rates, namely, no growth, 2.2 percent growth rate, and 4.2 percent annual growth rate. Table 29 reveals that with no growth the annual flood control benefits would have been between $60,000 and $1,745,000. At 2.2 percent growth rate the annual flood control benefit would have been between $103,000 and $2,257,227 (Table 29). At 4.2 percent growth the annual benefits would have varied from $167,000 to $3,214,624 (Table 29). Table 29 also gives the annual costs of the federal flood control projects. Table 29 shows that the annual

Table 29: Estimated annual benefits and costs of the federal flood control projects in the Boise Valley in constant 1943 dollars, 1950 to 1974.

	Annual benefits with annual growth rate of			
Year	0 percent	2.2 percent	4.2 percent	Annual costs
1950	$ 280,000	$ 325,920	$ 373,520	$ 283,779
1951	285,000	339,150	395,750	303,394
1952	1,745,000	2,121,920	2,526,760	310,696
1953	200,000	248,600	301,800	328,283
1954	355,000	450,850	558,060	296.456
1955	190,000	246,620	311,220	407,488
1956	1,701,000	2,257,227	2,903,607	691,746
1957	515,500	699,018	917,075	760,568
1958	1,410,000	1,954,260	2,614,140	756,828
1959	140,000	198,240	270,340	844,427
1960	230,000	333,040	462,990	828,978
1961	90,000	133,200	188,730	805,273
1962	225,000	340,200	491,625	808,525
1963	205,000	316,725	466,785	803,433
1964	200,000	315,800	474,600	836,557
1965	1,080,000	1,743,120	2,669,760	824,234
1966	100,000	165,000	257,600	893,599
1967	440,000	74.,840	1,180,960	843,875
1968	60,000	103,380	167,820	984,811
1969	440,000	774,840	1,282,160	1,064,927
1970	390,000	702,000	1,184,430	1,127,983
1971	1,016,000	1,868,424	3,214,624	992,414
1972	901,000	1,693,880	2,970,597	974,823
1973	160,000	307,360	549,760	1,060,869
1974	685,000	1,344,655	2,452,300	1,137,587
Total	$13,043,500	$19,167,269	$29,187,413	$18,972,053
Average	521,740	766,691	1,167,497	758,882
Total benefit / Total cost	0.69	1.01	1.54	

flood control costs varied from $283,779 in 1950 to $1,137,587 in 1974. The annual costs showed a consistently increasing pattern whereas the same cannot be said of the annual flood control benefits (Table 29). The annual costs show an increasing pattern because the costs are incurred every year and variable costs are increasing. Moreover, the long term government bond rate has also increased since 1950 over the years. However, the occurrence of floods is probabilistic. As the result, annual benefits do not show a pattern like the annual costs. Some years the floods will be large and the prevented damages (flood control benefits) will also be large. Other years the floods will be low and as a result the prevented damages will also be low. Therefore, in assessing the economic performance of flood control projects such as the ones in the Boise Valley one should compare the annual benefits and costs over a long period of time because of the probabilistic nature of the occurrence of floods. One should not necessarily expect each annual benefit to exceed each annual cost because of the randomness of flood occurrence.

A comparison of the annual benefits with no economic growth (Table 29, column 2) and annual costs (Table 29, colunm 5) shows that annual flood control benefits with no growth exceeded annual costs in 4 of the 25 years. Over the 25 year period, 1950 to 1974, total flood control benefits with no growth were $13,043,500 while total costs for the same period were $18,972,053 (Table 29). Thus, without economic growth the federal flood control projects were uneconomical investments as the costs ($18,972,053) exceeded the benefits ($13,043,500). At 2.2 percent annual growth, the federal investments in flood control in the Boise Valley were sound investments because total benefits ($19,167,269) exceeded total costs ($18,972,053) for the 25-year period 1950 to 1974 as can be seen from Table 29. At 4.2 percent annual growth rate, the federal investments were even better investments as the total benefits ($29,187,413) exceeded the total costs ($18,972,053) for the 25 years of analysis by 54 percent (Table 29). Note that 2.2 percent growth rate was the annual rate of growth in the areas surrounding the flood plain. The federal investments were good investments even if the flood plain grew at the 2.2 percent annual growth rate. However, since the rate of growth in the flood plain annually was 4.2 percent from 1950 to 1974 the federal investments were even better investments.

Table 30 presents estimated annual benefits and costs of federal flood control projects in the Boise Valley in actual annual prices. Estimated annual benefits are given for 5.7 percent and 10.8 percent annual growth rates. Note that these two growth rates have not been adjusted for inflation. To obtain the annual benefits in Table 30, the annual benefits with no economic growth (Table 20) were compounded annually at 5.7 and 10.8 percent annually. The 5.7 percent annual growth rate (rate of growth in the areas

Table 30: Estimated total annual flood control benefits and costs of federal flood control projects in the Boise Valley in actual annual prices, 1950 to 1974.

Year	Annual benefits at		Annual depreciation	Operating and maintenance cost	Alternative investment cost	Total annual costs
	5.7 percent	10.8 percent				
1950	$ 411,600	$ 574,000	$ 149,200	$ 4,107	$ 346,144	$ 499,451
1951	441,750	646,950	149,200	5,489	379,610	534,299
1952	2,879,250	4,379,950	149,200	6,431	391,859	547,490
1953	348,000	556,000	149,200	3,626	425,489	578,315
1954	653,200	1,093,400	149,200	10,091	365,242	524,533
1955	368,600	649,800	342,332	20,525	951,038	1,313,895
1956	3,487,050	6,446,790	342,332	61,292	1,004,291	1,407,915
1957	1,118,635	2,165,100	342,332	70,617	1,138,250	1,551,199
1958	3,228,900	6,556,500	342,332	96,627	1,113,387	1,552,346
1959	338,800	721,000	342,332	78,969	1,307,199	1,728,500
1960	591,100	1,313,300	342,332	84,022	1,274,201	1,700,555
1961	243,900	569,700	342,332	87,055	1,225,897	1,655,284
1962	643,500	1,577,250	342,223	96,175	1,228,092	1,666,599
1963	621,150	1,592,850	342,332	80,781	1,229,944	1,653,057
1964	640,000	1,722,000	342,332	139,899	1,261,860	1,744,091
1965	3,654,000	10,303,200	342,332	97,786	1,265,691	1,705,809
1966	357,000	1,057,000	342,332	139,209	1,385,026	1,866,567
1967	1,663,200	5,156,800	342,332	158,433	1,277,998	1,778,763
1968	239,400	778,800	342,332	246,951	1,524,439	2,113,722
1969	1,856,800	6,327,200	342,332	133,951	1,750,371	2,226,654
1970	1,739,400	6,216,600	342,332	168,227	1,868,415	2,378,974
1971	4,795,520	17,942,560	342,332	154,821	1,607,770	2,104,923
1972	4,495,990	17,632,570	342,332	215,123	1,557,686	2,115,141
1973	843,200	3,468,800	342,332	266,711	1,721,492	2,330,535
1974	3,815,450	16,440,000	342,332	336,214	1,861,823	2,540,369
Total	39,475,395	115,888,120	7,592,640	2,764,032	27,462,314	37,818,986
Average	1,579,015	4,635,525	303,706	110,560	1,098,493	1,512,759

surrounding the Boise River flood plain) and the 10.8 percent annual growth rate (average annual growth rate in the Boise River flood plain) were estimated using the actual values of property in the Boise Valley and the Boise River flood plain.[13/] Annual benefits at 5.7 percent annual growth rate varied from $243,900 to $4,795,520 (Table 30). At 10.8 percent annual growth rate, the estimated annual benefits varied from $569,700 to $17,942,560 (Table 30). Table 30 also gives annual depreciation, annual operating and maintenance costs, and alternative investment costs separately. In estimating annual depreciation in Table 30, a 100-year life was assumed for each structure. Also a straight line depreciation was used. Recall that the total construction costs for each reservoir, the percentage of the total cost allocated to flood control and the year each structure was completed were given in Table 24 and the first section of Chapter 7. Operating and maintenance costs of federal flood control projects in the Boise Valley in Table 30 are the combined operating and maintenance costs for the Bureau of Reclamation and the Corps of Engineers projects. Annual alternative investment costs of federal investment in flood control in the Boise Valley in actual

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[13/] Recall from Chapter 4 (footnotes 4 and 6) that the value of property in the Boise Vally changed from $65,684,413 in 1946 to $366,218,410 in 1976. This corresponds to an annual rate of growth of 5.7 percent using the compound interest formula. Similarly, the value of property in the Boise River flood plain (55,000 CFS) changed from $21,590,000 in 1943 to $533,000,000 in 1974 (Figure 8). This corresponds to a growth rate of 10.8 percent using the compound interest formula.

prices were estimated by multiplying the net investment in flood control (total investment less depreciation) by the long term government bond rate of interest (given in Table 26). Estimated annual costs of federal flood control projects in Table 30 are the sum of annual depreciation, annual operating and maintenence costs, and annual alternative investment costs. Estimated annual costs varied from $499,451 in 1950 to $2,540,369 in 1974 (Table 30). It should be noted that the estimated benefits and costs in Table 30 have not been adjusted for price level changes. That is, the benefits and the costs have not been expressed in a common year's dollars. To make a meaningful comparison of the benefits and the costs in Table 30 one needs to take all the benefits and the costs to a common year. The conclusions drawn from Table 29 also hold for Table 30.

Figure 13 presents the annual benefits with no growth and the annual cost over a 25-year period. The annual cost curve is above the annual benefits curve for 20 of the 25 years as can be seen from Figure 13.

Figure 14 shows the annual benefits with 2.2 percent annual growth and the annual costs over a 25-year period. In Figure 14 the annual benefits and costs intersect at many places showing that some year's benefits are greater than costs and other year's costs exceed benefits.

Figure 15 presents the annual benefits with 4.2 percent annual growth and annual costs. In Figure 15 annual

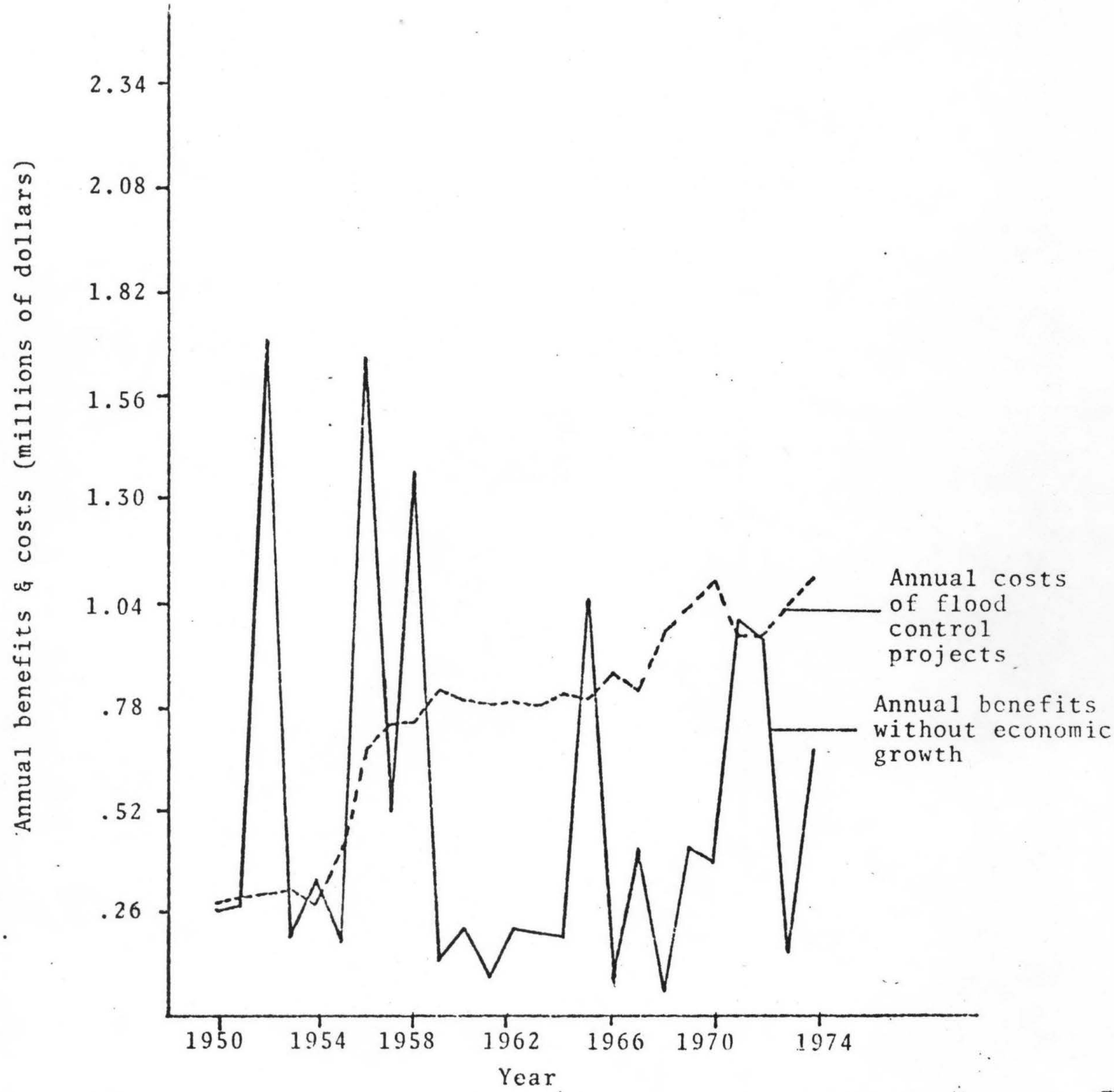

Figure 13: Comparison of annual benefits without economic growth and annual costs.

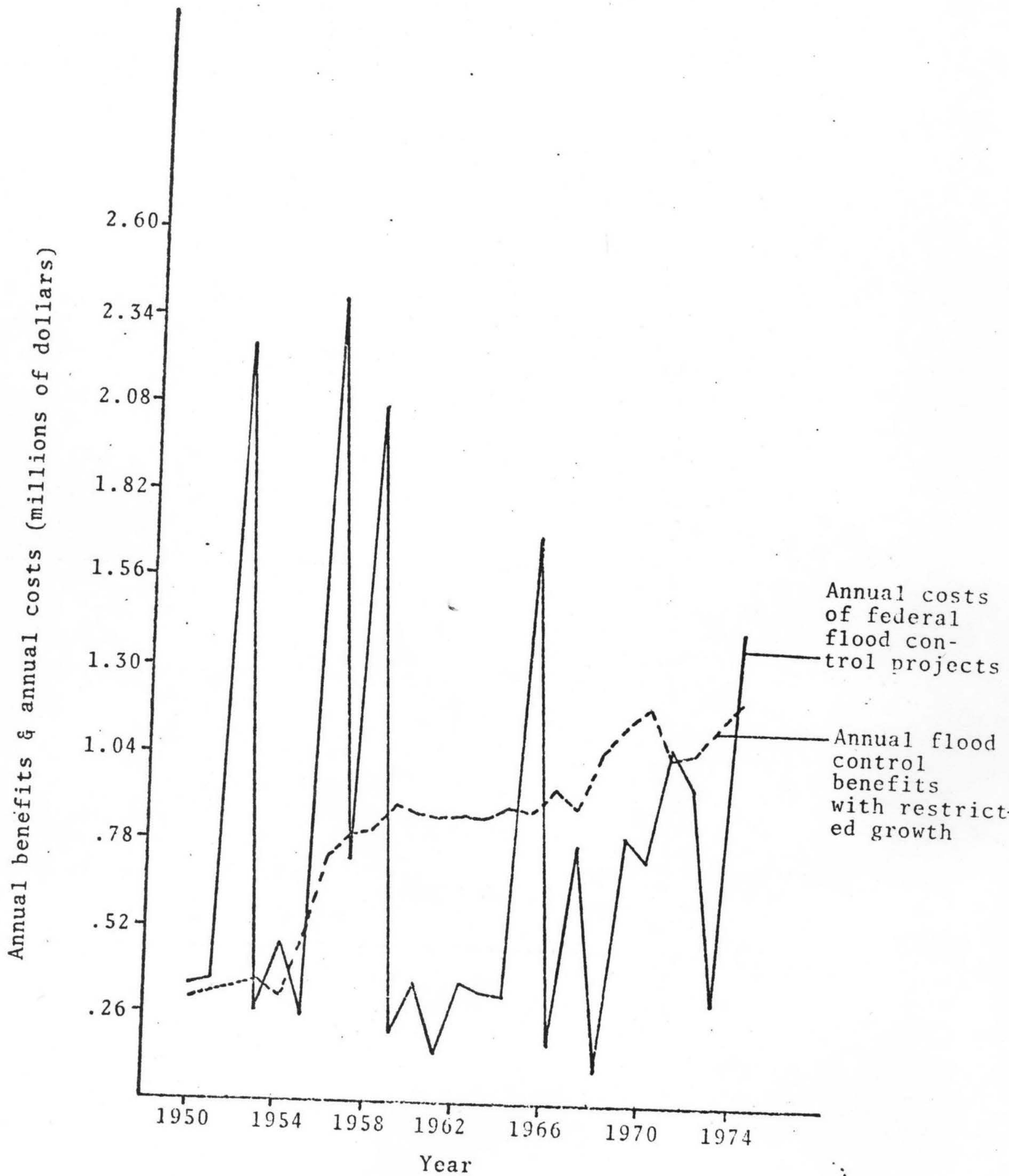

Figure 14: Comparison of annual benefits with restricted economic growth and annual costs.

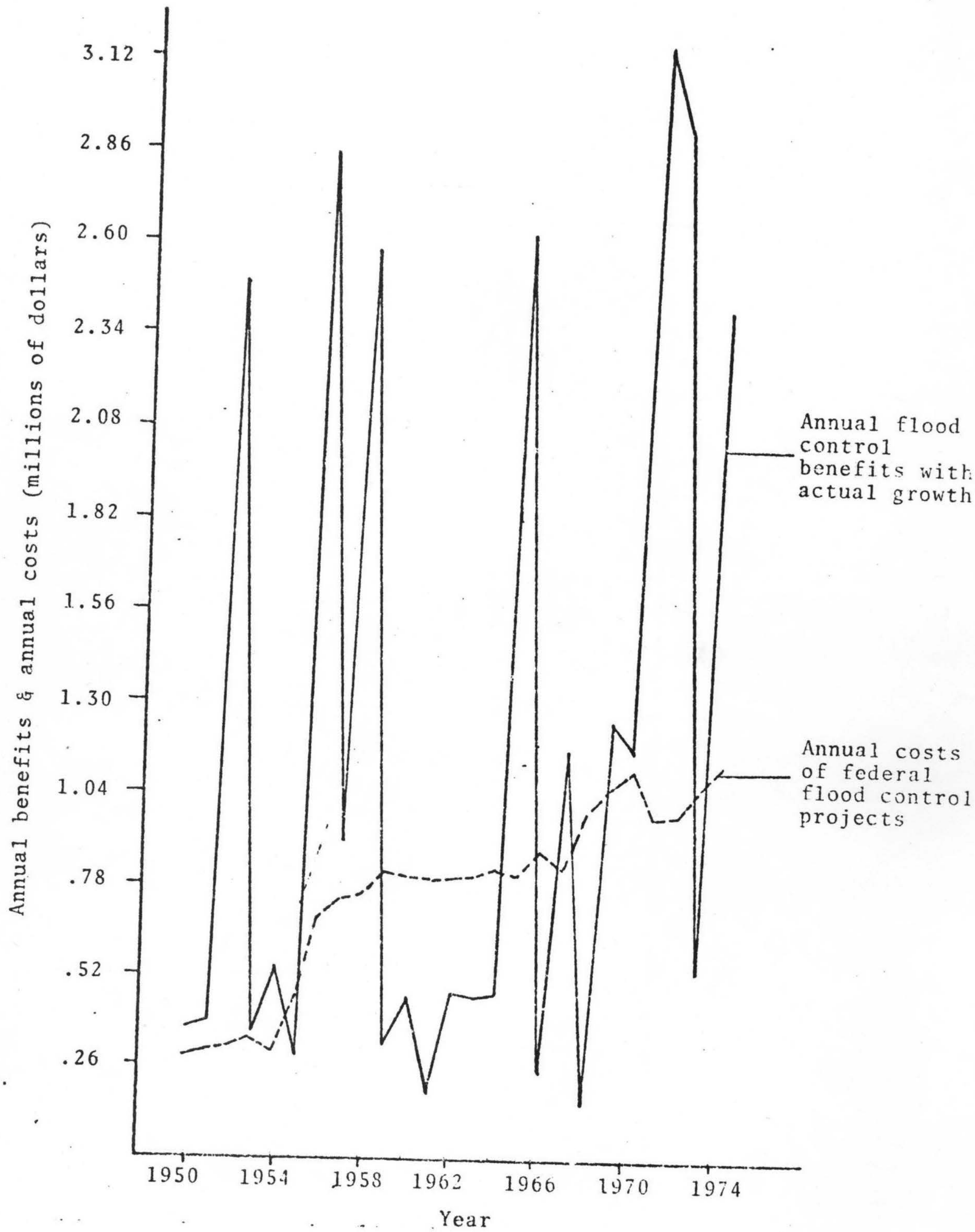

Figure 15: Comparison of annual benefits and annual costs.

benefits exceed annual costs most of the time.

Three conclusions emerge out of this chapter. First, ex-ante total construction estimates for Anderson Ranch and Lucky Peak dams underestimated the actual construction costs for the two structures. In this respect Anderson Ranch and Lucky Peak reservoirs are not unique among federal water projects. In appraising the cost estimation performance of the Corps of Engineers, Tennessee Valley Authority,and the Bureau of Reclamation, Hufschmidt and Gerin (19, p. 279) found that the ex-ante cost estimates in most cases underestimated the actual cost estimates in the late 1940's and early 1950's. Cost estimation in the private sector is based on prevailing prices or on forecasts that cover a short period of time. But, in the public sector cost estimation is based on prevailing prices or on forecasts that cover a long period of time. In the public sector, the period from planning to construction may exceed a decade and also variation in project magnitude may result after projects have been approved (12, p. 149). Thus, cost estimation in the public sector is plagued by both economic and administrative complications. For the flood control projects in the Boise Valley after adjustment for price changes the cost overrun was 7 percent for Anderson Ranch and the cost underrun was 4 percent for Lucky Peak. Thus, compared to the other estimates the ex-ante cost estimates of the flood control projects in the Bosie Valley were not bad.

The second conclusion is that over the 25 years this study covered, the federal flood control projects prevented more damages ($19,167,269 at 2.2 percent annual growth rate and $29,187,413 at 4.2 percent annual growth rate) than the cost incurred to prevent the damages ($18,972,053). Another way of putting the same thing is to say that total benefits (prevented damages) exceeded total costs. Had the federal flood control projects been private enterprises they would have paid for themselves and shown some profit. The economic performance of the federal flood control projects in the Boise Valley over the period covered by this study then has been good (total benefits exceeded total costs at both the restricted and the actual growth rates).

CHAPTER 8

SUMMARY AND CONCLUSIONS

The primary purpose of this study has been to assess the economic performance of the federal flood control projects in the Boise Valley by estimating and comparing the benefits and costs of the federal flood control projects since they started operation. A minor concern of this study has been to critically evaluate the methods used to estimate flood control benefits. In addition, this study also outlined procedures for generating annual flood damages with and without flood control projects from a given year's flood discharge-damage relationship given the annual natural and regulated flows of the river.

Summary

This study accepted the economic criterion that benefits must exceed costs for a given flood control project to pass the economic feasibility test. Since flood control services are nonmarketable goods, i.e., colletive goods (goods that are equally available to all members of a community and no one can be excluded from the use of the goods once the goods are made available), it was felt essentially to view federal investments in flood control as producing desirable and adverse effects and evaluate them in terms of these effects. However, a moments reflection convinced the author that some of the adverse and desirable effects do not have market value and as a result they do not lend themselves to quantitative economic analysis. Because of lack of a well developed theory of social value and methodological limitations, social, political and environmental effects were left out from the analysis and emphasis was placed on the economic effects.

It was pointed out that the estimation of benefits of flood control necessitates the identification and the measurement of the desirable outputs of flood control effects. The desirable flood control effects are reduced crop damages, reduced property damages, increased productivity of bottomlands, reduced indirect production losses, and reduced loss of human lives. It was pointed out that to estimate reduced flood damages (flood control benefits) one needs to estimate the damages with and without flood control. Two problems were confronted in the estimation of flood control projects. First, flood damage data were not available on annual basis. Second, the flood damage data that were available included only damages that had market value.

To combat the problem of lack of flood damage data, six flood damage models were developed. The flood damage models were developed on the assumption that flood damage is a function of flood discharge. Flood discharge is measured in cubic feet per second and can be converted to flood depth (measured in feet) easily. The six flood damage models used a combination of two flood control levels (no flood control and with flood control) and three rates of annual real economic growth (no economic growth, restricted economic growth, and actual economic growth in the flood plain) to estimate annual flood damages in the Boise Valley for the period 1950 to 1974. The first two flood damage models were no growth models and the last four models contained growth factors. The first model estimated annual flood damages without economic growth and without flood control in the Boise Valley. The second model estimated annual flood damage without economic growth and with flood control. The difference between Model 1 and Model 2 was the annual flood control benefit without economic growth. Model 3 estimated the annual flood damages with the annual rate of growth of the areas surrounding the Boise River flood plain and without flood control. Model 4 estimated the annual flood damage with the annual rate of growth of the areas surrounding the Boise River flood plain and with flood control. The difference between Model 3 and Model 4 was the annual flood control benefit with restricted economic growth. Model 5 estimated the annual flood damage with the annual rate of growth of the Boise River flood plain and with no flood control. Model 6 estimated the annual flood control with actual economic growth in the flood plain and with flood control. The difference between Model 5 and Model 6 was the annual flood control benefit with actual economic growth. The damage models included only flood damages that had market value.

In estimating the annual costs of the federal flood control projects three cost items were considered. These were annual depreciation, annual alternative investment costs, and annual operating and maintenance costs. Each of the three cost items were separately determined. To estimate the annual costs the total actual federal investments in flood control were taken and deflated using the Engineering News-Record general construction index to obtain all costs in 1943 dollars.

A review of the methods of estimating flood control benefits showed that the methods fall into two general classes. The first class is called the damage method. The damage method assumes that flood control benefits are the equivalent of prevented flood damages. The second procedure is called the land enhancement method. This method equates flood control benefits with increased land utilization. It was pointed out that the land enhancement method requires lots of data and is hard to apply.

A comparison of the expost flood control benefits and costs showed that had there not been economic growth in the Boise Valley the expost flood control costs would have exceeded the benefits. However, with the rate of growth of the areas surrounding the flood plain (2.2 percent annual growth) the benefits of the federal flood control projects barely exceeded the costs over the 25 years this study covered.

Finally, with the actual rate of growth of the Boise River flood plain (4.2 percent annual growth) the expost benefits substantially exceeded the costs over the 25 years covered by this study. In other words, the project would have barely paid for itself with the restricted growth whereas with the actual growth the project more than paid for itself. With the actual growth the economic performance of the federal flood control projects were good, i.e., expost total benefits exceeded expost total costs.

Limitations of this Study

The major weakness of this study is that it did not evaluate intangible effects in estimating benefits and costs. As was pointed out earlier this was due to lack of a well-developed theory of social value that puts exchange value on intangibles.

Needed Further Reserach

The area of secondary benefits presents problems to the analyst. This is because indirect flood damages cannot be readily evaluated like direct flood damages and indirect flood damages are highly dependent upon the economic link that exists among the sectors of the economy of a region. There is also disagreement among economists as to what constitutes secondary benefits. Thus, research has to be undertaken to determine which items can legitimately be classified as secondary benefits and how they can properly be accounted for.

Recommendations

A major problem in the estimation of flood control benefits is lack of flood damage data. This study recognized that annual appraisal of property liable to flood damages in a flood plain is expensive. However, if present planning is to provide feedback for future planning, periodic appraisal of property liable to flood damage is essential. Such periodic appraisal of property in the flood plain will also enhnace assessment of the economic performance of flood control projects.

Another problem why the estimation of benefits is so difficult is because the different disciplines have their spheres of study and the areas that are at the peripheral of each of the disciplines receive little attention. To overcome such shortcomings the different disciplines should synthesize thier efforts to produce better socioeconomic tools.

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